From semantic distance to creative text: Rare word pairings shape creativity judgments

Illia Kuznietsov [a, b, *], Tetiana Masytska [a], Larysa Kuznietsova [c], Oleksandr Zhuravlov [a], Stanislav Revko [a], Oleksandr Kazmirchuk [a], Nataliia Kozachuk [a]

[a] *Lesya Ukrainka Volyn National University, Ukraine*
[b] *Purdue University, USA,*
[c] *Independent Researcher, USA*

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Abstract. While individual semantic map structure has been proposed as a foundation for creative text generation, conventional group-aggregated network metrics obscure the idiosyncratic features that may drive creative output. The main objective of current study was to test whether the specific features of individual semantic structure may impact the subjective perception of text creativity level. To test our hypotheses, we used the following methods: text generation (essays), natural language processing, behavioral experiment. During the first stage of the study, we collected essays on a free topic from 41 participants (35 females, M age = 18.2 years, SD = .19, range = 18-20). All texts were processed, and the 15 most frequent and 15 most rare noun pairs used within the same sentence were selected, along with the corresponding sentences. During the second stage, the selected word pairs and sentences were presented to another 71 participants (60 females, M age =18.93 years, SD = .36, range = 18-38). Participants rated the semantic distance between the words in each word pair and the level of creativity of the presented sentences. Our results showed that rare word pairs were perceived as being significantly more semantically distant, while sentences containing rare word pairs were perceived as significantly more creative. We conclude that nodes of semantic map, which show person-specific features significantly impact creative text generation. We further discuss how these individual differences can be used in the design of behavioral and neuroimaging experiments on creativity.

Keywords*: text creativity, semantic maps, semantic distance, cognitive inhibition, brain, age-related changes, event-related potentials.*

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Анотація. Хоча структура індивідуальних семантичних мап була запропонована як основа для створення креативних текстів, традиційні агреговані за групами показники

* Corresponding author: Illia Kuznietsov, 0000-0002-6113-0322, kuznetsov.illya@vnu.edu.ua
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мережі приховують індивідуальні особливості, які можуть бути рушійною силою творчого результату. Головною метою нашого дослідження було визначити, чи можуть специфічні особливості індивідуальної семантичної структури впливати на суб'єктивне сприйняття креативності тексту. З метою перевірки наших гіпотез, ми використали наступні методи: написання тексту (есеїв), методи аналізу природньої мови, поведінковий експеримент. На першому етапі дослідження ми зібрали есе на вільну тему від 41 учасника. Після обробки текстів було відібрано 15 найчастотніших і 15 найрідкісніших пар іменників, ужитих у межах одного речення, а також були відіпрані відповідні речення. На другому етапі відібрані пари слів і речення за допомогою протоколу, реалізованого на платформі PsychoPy, були представлені групі з 71 інших учасників. Учасники оцінювали семантичну відстань між словами в кожній парі та рівень креативності представлених речень. Наші результати демонструють, що рідкісні пари слів сприймалися як достовірно більш семантично віддалені, тоді як речення, що містили рідкісні пари слів, сприймалися як достовірно більш креативні. У кінцевому підсумку, ми припускаємо, що структура індивідуальної семантичної мапи визначає креативність генерації тексту, а також обговорюємо дизайн поведінкових і нейрофізіологічних експериментів із вивчення креативності, які б враховували індивідуальні відмінності семантичних мап.

Ключові слова: *креативний текст, семантичні мапи, семантична відстань, когнітивне гальмування, мозок, вікові зміни, пов'язані з подією потенціали*.

Introduction

Human creativity is a multifaceted phenomenon, which reflects a wide spectrum of applied and abstract areas covered by human cognition (Dietrich, 2019; Khalil et al., 2019). Thus, definition of creativity and its cognitive mechanisms may differ depending on specific tasks which one should implement (Green et al., 2024; Runco & Jaeger, 2012). One of these specific tasks is creative text generation. It is a rich approach in studying creativity, which provides efficient performance metrics and may be constrained to limit or to emphasize factors, impacting creative process (Green et al., 2024; Shah et al., 2011). However, text creativity itself is rarely treated as a single construct. Most studies split it into a few dimensions, which may be separated into a) originality or divergence; b) appropriateness, coherence, or rationality (Bellemare-Pepin et al., 2026; Bos et al., 2015; Green et al., 2024; Sun et al., 2013)

In creative writing specifically, semantic distance captures originality while semantic cohesion captures appropriateness (Fan et al., 2023). Global and local semantic distance tracked originality ratings, while cohesion tracked rationality. Similar results were shown at a more general level of creative cognition: people appear to assign subjective value to ideas by weighing originality against adequacy rather than maximizing novelty alone (Moreno-Rodriguez et al., 2025). The same trade-off was found in spontaneous discourse, where higher divergent semantic integration tended to come at the cost of global coherence (Patel et al., 2024). It is important to note that contemporary dual-process accounts of creativity treat associative (spontaneous, generative) and controlled (evaluative,

retrieval-directed) mechanisms as complementary contributors operating across distinct phases of idea production (Beaty et al., 2016; Benedek & Neubauer, 2013). Controlled tasks dominate in creative text generation because they make originality easier to measure and easier to interpret contrasts, especially in neurocognitive studies. Creative text generation is supported by a dynamic interaction of neurocognitive systems, including semantic memory, executive control, and associative processing, whereby divergent and convergent thinking processes jointly enable the generation and evaluation of novel ideas within goal-directed cognition (Beaty et al., 2016; Dietrich, 2019; Mohamed & Saleh, 2025). Naturalistic writing adds ecological value but also brings ambiguity. In particular, longer texts recruit revision, genre knowledge, self-presentation, and stylistic habit more heavily (Liu et al., 2015; Patel et al., 2024; Shah et al., 2011).

The core associative claim is that more creative people have semantic memory structures that are less rigid and more traversable. Studies which used network approach associated higher creativity with semantic networks that are more flexible and less segregated (Kenett et al., 2014). Later work confirmed this pattern for verbal creativity and showed that associative ability plays an important role in mediating the link between semantic network structure and creative performance (He et al., 2020). In a metaphor production study higher metaphor creativity was associated with semantic networks that were more clustered, less rigid, and more flexible (Li et al., 2021). This evidence is important for understanding creative text generation because writing is a sustained act of semantic retrieval and combination. In story continuation tasks, stronger creative writing performance was associated with texts where keywords spanned more semantic categories and formed more interconnected, efficient semantic structures (Gu et al., 2025).

So far, semantic map structure shows strong relation to creativity, measuring individual semantic relatedness between keywords has becomes a common approach in building the connection between creative text generation and individual semantic structure (Kenett et al., 2014; Ovando-Tellez et al., 2022). Use of the individual semantic relatedness judgments showed that lower modularity and shorter paths predicted real life creativity. This evidence supports the idea that semantic memory structure is a mechanistic layer between brain organization and creative behavior (Abraham & Bubic, 2015; Benedek et al., 2017)From this point of view, a creative writer does not merely sample a stored semantic map, but instead dynamically reshapes access to that map, moving from culturally shared and strongly encoded links toward weaker and more task specific ones.

Besides semantic map structure, several other factors may shape creative text generation. Benedek and Fink came to conclusion, that creative text

generation is supported mainly by the following cognitive functions: constructive memory, imagination-related internal attention and executive control implementing goal for memory and attention (Benedek & Fink, 2019a). Episodic retrieval specificity has been shown to increase the number of internal details in creative writing, though it does not reliably improve originality (van Genugten et al., 2022). In line with these results, the study by Mohamed (Mohamed, 2024) showed that frequently repeated words are processed in more automatic manner, suggesting less flexibility of appropriate semantic connections. Narrative memory organization study showed that more original story endings were predicted by better encoding and recalling of noncentral events from a story background (Wang et al., 2025). This result can be interpreted as evidence of memory integration being important for creative narrative development. The idea selection may depend on a value signal integrating originality and adequacy, thus indicating a role of evaluation and reward in creative writing, where text is usually generated and filtered at the same time, not in a purely generative vacuum (Moreno-Rodriguez et al., 2025). The important role of reward in creative thinking was emphasized in the review by Khalil et al. (Khalil et al., 2019). Finally, emotionality may contribute to creativity judgment and production (Chaudhuri & Bhattacharya, 2025; Gutbezahl & Averill, 1996; Mohamed, 2026).

In summary, existing literature data indicate that flexible semantic maps increase performance in creative writing because they support remote combination. Creative text generation depends on the ability to move through semantic space in an unusually flexible way while preserving enough control to keep the text coherent and valuable. Individual differences in semantic memory structure appear to support this capacity. However, from the perspective of cognitive neuroscience studying text creativity as the product of semantic map structure poses two significant challenges.

First, semantic maps are usually represented as graphs (Kenett et al., 2014) and building a comprehensive semantic map for specific individual means taking into account all relations between keywords, which is is extremely time-consuming and resource-intensive. A promising solution is representing a semantic map as a multidimensional vector space (Riesen & Bunke, 2011), where each vector is a distance between two keywords with arbitrary measure like reaction time, subjective semantic distance, etc. This approach allows researchers to effectively manipulate a separate part of semantic space, using a limited number of keywords, related to specific topic, as a reference axis base and a limited set of other keywords for building keyword pairs. This approach allows transitioning from integrated metrics of brain electrical activity during creative text generation to specific reactions to specific words or word pairs in

stimulus-locked paradigms of brain activity recording, like N170, N250r, N400 or P3 (Mohamed, 2018, 2024).

Second, semantic map structure depends on social factors, reflecting societal and cultural specificity (Lewis et al., 2023; Moore et al., 1999; Thompson et al., 2020). Pushing this aspect to the ultimate limits, we may expect that differences in individual semantic map may be the source of creativity that is specific to the individual. This, in turn, suggests that approach for studying creative text generation should focus on how individual differences in semantic map structure interact with common shared knowledge. Existing approach in studying creativity by separating participants into low-creative and high-creative groups was criticized by Benedek et al. (Benedek et al., 2017). In this study researchers tried to shift from group-level to individual-level design, though still having to keep small groups. Following this design, individual differences in semantic map structure should be identified for the experiment participants and compared with common semantic features in a person-wise manner. From this point, semantic features, that are specific for the individual should be subjectively perceived as more creative by others, when expressed in text. This idea is indirectly supported by the suggestion of Bendek and Neubaer (Benedek & Neubauer, 2013) who came to conclusion, that differences between high- and low-creative individuals may be attributed to weakly associated concepts, which, however, is hard to test. Thus, the main goal of our study was to assess how individuals perceive the level of creativity of sentences, depending on whether these sentences contain word pairs, which can be either close or distant semantically. Based on literature review, we suggested the following working hypotheses:

H1. Sentences containing word pairs rated as semantically more distant will be judged as significantly more creative than sentences containing word pairs rated as semantically closer.

H2. Our main expectation is that word pairs rated as semantically more distant will require significantly longer evaluation times for semantic distance judgments compared to word pairs rated as semantically closer. H3. Sentences rated as more creative will require significantly longer evaluation times for creativity judgments compared to sentences rated as less creative.

Methods

Study General Structure Outline

Our study included two stages. During the first stage we collected the generated texts from volunteers, written in the form of essays. Then essays were processed using natural language processing tools. Most frequent and most unique word pairs and sentences, containing these word pairs were selected. Selected

sentences were further analyzed and compared for the average word uniqueness, sentiment level, and average word count. Selected word pairs and sentences were used as stimuli during the second stage of the experiment. During the second stage, participants had to estimate the level of subjective semantic distance in selected word pairs and the level of subjective creativity of selected sentences. Obtained ratings and reaction times were then analyzed to compare the impact of semantically close/distant word pairs on sentence creativity perception. The study was approved by the local Bioethics Committee (Protocol No. 2, 3 November 2025) and was conducted in accordance with the ethical standards of the institutional science council and the Declaration of Helsinki.

Participants

First stage included 41 participants (35 females, M age = 18.2 years, SD = 0.19, range = 18-20), students of Lesya Ukrainka Volyn National University took part in writing essays. All participants gave informed consent for their participation in the experiment. Second stage included 71 participants (60 females, M age =18.93 years, SD = 0.36, range = 18-38), students of Lesya Ukrainka Volyn National University took part in the second stage of the experiment. All participants gave informed consent for their participation in the experiment. None of the participants had taken part in the first stage (essay writing).

Participants were recruited from a single university for reasons of feasibility and to ensure consistent, controlled administration of the essay writing and computerized testing protocol, as well as to obtain a sample with the native Ukrainian-language competence required by the task.

Procedures

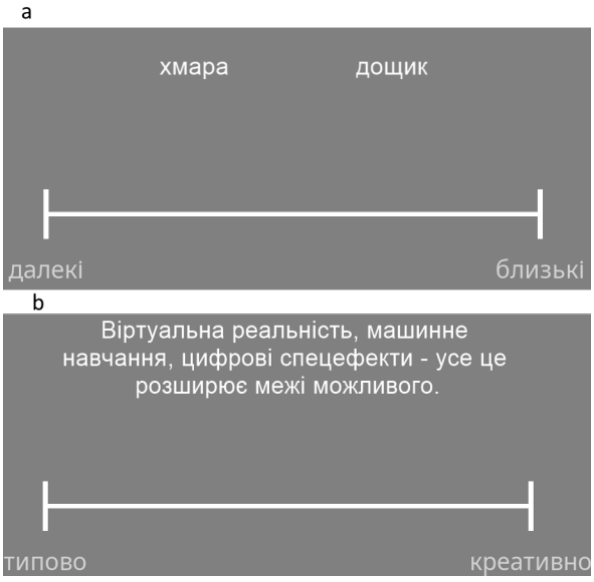
For the first stage, participants were asked to write essays on free topic during 2-week period. Overall, participants wrote 115 essays M = 2.8, SD = 0.22, range = 2-5 essays, with average number of words of M = 335.6, SD = 52.42, range = 174-470. All essays were converted to digital form and processed using natural language processing tools.

Two tasks were administered during the *second stage*. During the first task (Figure 1, a), participants were presented with the pair of words, either from the “rare” or “frequent” group. Stimuli were presented on a 21-inch monitor (resolution 1920×1080) at a viewing distance of approximately 50 cm; all stimuli were displayed centrally and fell within approximately 15° of vertical visual angle around the central fixation point. Words and the response scale were displayed in white on a uniform mid-gray background. A mid-gray field holds the background at a constant, intermediate luminance, keeping participants in a

stable state of light adaptation and providing homogeneous retinal illumination throughout testing; white text preserved high legibility against this background (Rahimi-Nasrabadi et al., 2021). Participants were instructed to assess the semantic distance between words, by clicking on the scale. The left side of the scale indicated “far”, the right side indicated “close” semantic distance. The scale was continuous, and no numerical values were shown to the participants. Selected position on the scale was automatically converted to the continuous value between 0 and 100, such that lower values corresponded to a selection close to “far” end and higher values corresponded to a selection close to “close” end. All word pairs were presented in random order, each pair presented only once. The left-right position of the words in pair and the order of presentation of word pairs was randomized. Each trial began with a central fixation cross of jittered duration (0.5 – 1.5 s). Varying this interval introduced temporal uncertainty about word-pair onset, discouraging anticipatory responses and a fixed response rhythm; such variable foreperiods are an established means of limiting temporal-preparation effects on reaction time (Niemi & Näätänen, 1981). The word pair was then displayed for up to 5 s. As the semantic-distance judgment is a decision task, participants were instructed to respond as quickly as possible while remaining accurate and were informed of the 5-s limit, which standardizes the speed-accuracy regime across participants (Heitz, 2014). This window was generous enough to allow a deliberate decision without truncating responses, yet bounded each trial and defined non-responses as timeouts.

Figure 1

Visual Design of Second Stage Tasks



During Task 1 (a) participants had to estimate how semantically close were presented words by clicking on the scale; during Task 2 (b) participants had to estimate the level of creativity of presented sentence by clicking on the scale.

During the second task (Figure 1, b), participants were presented with the selected sentences of different length, one sentence per trial, either from the "rare" or "frequent" group. Second task used the same visual presentation parameters (monitor, resolution, viewing distance, and background) as first task. Participants were instructed to assess the level of creativity of the presented sentence, by clicking on the scale. The left side of the scale indicated "typical", the right side indicated "creative" level. The scale was continuous, no numerical values were shown to the participants. Selected position on the scale was automatically converted to the continuous value between 0 and 100, such that lower values corresponded to a selection close to the "typical" end and higher values corresponded to a selection close to the "creative" end. The order of presented sentences was randomized, no time limit on sentence presentation was imposed.. Fixation-cross duration before each sentence was again jittered (0.5-1.5 s) on the same rationale as first task; the 5-s response limit was not retained, however, because sentence assessment is a more open-ended judgment than the word-pair task and a fixed deadline would have been inappropriate (Amabile et al., 2002).

Presentations protocols were created and presented using PsychoPy 2023.2.3 v, (Peirce et al., 2019)).

Text Processing

Text processing was implemented only for the essays, collected during *the first stage*, text processing was performed using open-source tools in Python 3.12 (Python Software Foundation, 2024) following a custom analysis pipeline which will be described below. Ukrainian morphological analysis (lemmatization and part-of-speech tagging) was carried out with the pymorphy3 2.0.6 library (pymorphy3 developers, 2023) combined with the Ukrainian dictionary package pymorphy3-dicts-uk 2.4.1.1 (pymorphy3 developers, 2024), which is built on the OpenCorpora morphological dictionary. Tokenisation, sentence segmentation, frequency counting, and statistical calculations were implemented using the Python standard library (modules re, collections.Counter, itertools.combinations, statistics, and math).

Text pre-processing was conducted as follows. All input files were read as UTF-8 plain text. Sentence boundaries were detected with a regular expression splitting on the punctuation characters ".", "!", and "?". Within each sentence, tokens were extracted as maximal contiguous sequences of Cyrillic letters

(including Ukrainian-specific characters “і”, “ї”, “є”, “ґ”) and apostrophes; all tokens were lowercased. Tokens shorter than two characters were discarded.

Each surviving token was lemmatized by selecting the top-ranked parse returned by pymorphy3.MorphAnalyzer(lang=”uk”) and replaced with its normal form. Analysis was restricted to nouns only. Because pymorphy3 occasionally misclassifies common Ukrainian function words as content words (for example, the prepositions “до”, “за”, “про”, “під” may be tagged as noun or adverb), an explicit stopword list of eighty Ukrainian prepositions, conjunctions, particles, and pronouns was applied to both surface tokens and their lemmatized forms.

Word pairs processing. For each input text, unordered word pairs were generated from the filtered lemmas.Words were restricted to nouns because their stable referents elicit consistent and well-defined semantic representations, allowing participants to make reliable pairwise distance judgments and yielding consistency in reaction times needed for an interpretable individual semantic map(McRae et al., 2005; Mitchell et al., 2008). Pairs were formed from all combinations of distinct lemmas occurring together in the same sentence; lemma sets were deduplicated within a sentence before pair enumeration so that repetition of a word in one sentence did not inflate its pair counts.

For every word pair the following metrics were recorded across the whole corpus of N author files: the total count (sum of pair occurrences over all files), the average count per file (total count divided by N), and the sentence co-occurrence count (number of distinct sentences in the corpus that contained both members of the pair). 15 most common, frequent and 15 most rare word pairs and corresponding 15 sentences with most frequent word pairs and 15 sentences with most rare word pairs were selected for the second stage. Illustrative examples of both categories, together with the source sentences from which they were drawn, are presented in the Appendix (Table A1). The following criteria were used during selection: all words in word pairs should be different, sentences should be of moderate length (between 10 to 21 words) and be context-independent, not referring directly to other sentences in the text, each sentence within frequent and rare word pairs selections should be generated by different participant. This approach allows to exclude person-related bias and address creativity as a product of individual semantic map organization, rather than a group-level feature. After application of the criteria, only 20 sentences with “rare” noun pairs and 28 sentences with “frequent” noun pairs passed the selection procedure. Each sentence was then assigned a random number, and 15 sentences with the lowest random number values were selected for “rare” and “frequent” noun pair type. Most frequent word pairs and sentences with these word pairs further referred as “frequent” group and most rare word pairs and sentences containing these word pairs further referred as “rare” group.

To control the impact of other rare, uncommon words in sentences and emotionality of sentences, the assessment of lexical uniqueness and their sentiment level was conducted. The reference corpus and the target sentences were preprocessed using the same tokenisation, lemmatisation, POS-filtering, and stopword-filtering pipeline described above. A frequency table F was constructed from the reference corpus by counting the occurrences of each retained lemma. For each target sentence s, the lemma list was extracted, and the corpus frequency of every lemma was retrieved (lemmas absent from the reference corpus were assigned a frequency of zero). Two descriptive statistics were computed per sentence: the arithmetic mean ($\mu(s)$) and the sample standard deviation $\sigma(s)$. From these, a uniqueness coefficient U(s) was derived as $U(s) = 1 / (\mu(s) + 1)$ bounded in the interval (0, 1] and stimuli (word pairs and sentences) were compared using U(s).

The sentiment analysis of selected sentences was based on negative/positive words detection. To assign an emotional value to specific word, we used a freely available online corpus for sentiment analysis (https://github.com/skupriienko/Ukrainian-Sentiment-Analysis), which includes 5747 words in total with the emotional valence assigned. The sentiment lexicon comprised 5747 entries (1883 positive, 3864 negative), of which 5471 were single words and 276 were multi-word expressions. Mean word length was 9.4 characters (SD = 3.0, range 2-29) and 3.8 syllables (SD = 1.3, range 1-12). Part-of-speech composition was 35.2% nouns, 32.9% adjectives, 22.0% verbs, and 7.6% adverbs, with the remaining ~2% comprising gerunds, pronouns, particles, and function words. All the sentences were processed separately, using Python 3.12 (Python Software Foundation, 2024) and NLTK 3.9.4 library for natural language processing (Bird et al., 2009). The sentences were lemmatized; prepositions were excluded. To examine the differences between sentence groups, the separate percentage of negative and positive words per sentence was calculated. For each comparison, descriptive statistics were calculated for both conditions, including sample size, mean, and standard deviation. Independent-samples Welch's t tests were conducted to compare sentences from the "frequent" and "rare" groups on word count, percentage of negative words, percentage of positive words, and uniqueness. As a robustness check, two-tailed Mann-Whitney U tests were also computed for each comparison. Effect sizes were summarized using Cohen's d.

The Python code used for the text and sentiment analyses is available in a public GitLab repository: https://gitlab.com/neuroinformatics-vnu/uniq_creative.

Data Processing and Statistical Analysis

The datasets with reaction times and ratings obtained from the second stage, were screened prior to analysis. Task 1 trials (total 2130 trials, 30 per participant)

with missing values were excluded from analysis. After excluding missing values, the final sample comprised 2,039 observations from 71 participants.

The analysis comprised one independent variable – condition ("frequent" vs. "rare" noun pair) – and two dependent variables, namely the rating (semantic distance in Task 1, sentence creativity in Task 2) and the reaction time. Sentence word count, percentages of negative and positive words, and the lexical uniqueness coefficient U(s) were treated as control variables and were tested before the main analysis to verify that the "frequent" and "rare" sentence groups did not differ on any dimension other than the rarity of the embedded noun pair. Group differences between the "frequent" and "rare" conditions were tested separately for each controls variable for the essay text data. The primary inferential tests were independent-samples Welch's t tests, which were chosen because they do not assume equal variances across groups. For each comparison, descriptive statistics were calculated for both conditions, including sample size, mean, standard deviation and standard error. Degrees of freedom were estimated using the Welch-Satterthwaite approximation. Two-tailed Mann-Whitney U tests were also computed for each comparison to improve robustness. Effect sizes were summarized using Cohen's d.

To account for the repeated-measures structure of the data, obtained during the second stage, trial-level responses were first averaged within each participant and condition, separately for each task and dependent variable. Statistical tests were then conducted on these participant-level condition means rather than on individual trials, because treating trials from the same participant as independent observations would violate the independence assumption and artificially inflate the degrees of freedom.Because each participant contributed observations to both the frequent and rare conditions, condition differences were tested using paired-samples t tests on participant-level condition means. Wilcoxon signed-rank tests were also conducted as non-parametric robustness checks. This approach treats participant as the unit of analysis and avoids violating the independence assumption by treating repeated trials from the same participant as independent observations. All preprocessing, statistical analyses, and visualizations were conducted in Python 3.12 (Python Software Foundation, 2024) using pandas 2.2.3 (McKinney, 2010) for data handling, SciPy 1.17.1 (Virtanen et al., 2020) for inferential testing, and seaborn (Waskom, 2021) and matplotlib (Hunter, 2007) for figure generation.

Results

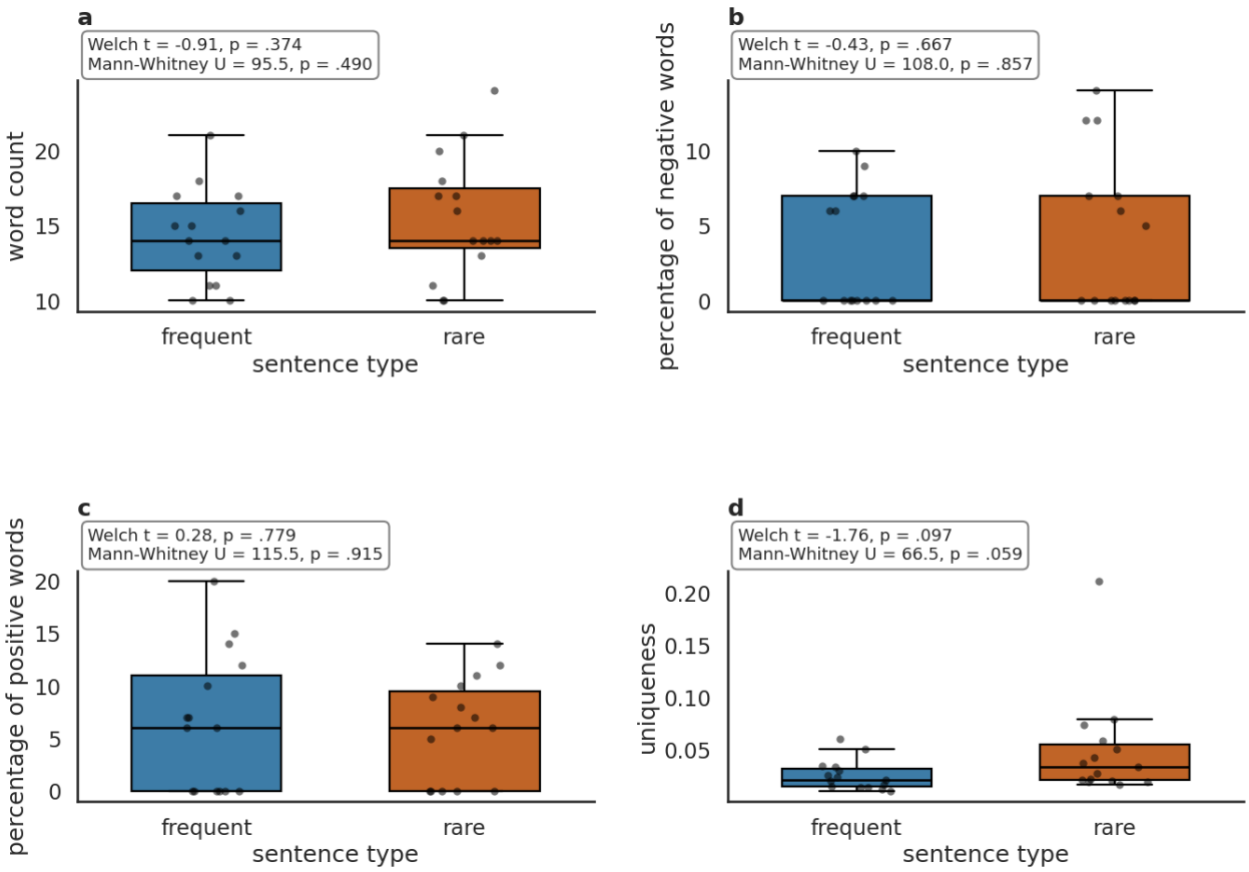
Comparison of Two Groups of Sentences, Selected During the First Stage

There was no statistically significant difference between frequent sentences (M = 14.33, SD = 3.16, Mdn = 14.00) and rare sentences (M = 15.53, SD = 4.05,

Mdn = 14.00)in word count, Welch's t(26.42) = -.91, p = .374 (Figure 2, a). The Mann–Whitney test confirmed this result, U = 95.50, p = .490.The groups did not differ significantly in the percentage of negative words, with frequent sentences (M = 3.47, SD = 3.96, Mdn = .00) and rare sentences (M = 4.20, SD = 5.20, Mdn = 0.00) showing comparable values, Welch's t(26.16) = -.44, p = .667 (Figure 2, b). The Mann–Whitney test was also non-significant, U = 108.00, p = .857. Similarly, no significant group difference was found for the percentage of positive words. Frequent sentences (M = 6.47, SD = 6.59, Mdn = 6.00) and rare sentences (M = 5.87, SD = 4.90, Mdn = 6.00) had similar percentages of positive words, Welch's t(25.85) = .28, p = .779 (Figure 2, c). Finally, the difference in uniqueness was not statistically significant, although rare sentences showed numerically higher uniqueness (M = .049, SD = .049, Mdn = .034) than frequent sentences (M = .026, SD = .015, Mdn = .021), Welch's t(16.44) = -1.76, p = .097. The Mann–Whitney test showed a similar trend but also did not reach conventional significance, U = 66.50, p = .059. (Figure 2, d).

Figure 2

Distribution of and Statistical Differences Between Sentence Types by Word Count (A), Percentage of Emotionally Negative Words(B), Percentage of Emotionally Positive Words (C), Average Semantic Uniqueness (U(S)) Coefficient (D)



"Rare" type represents a group of sentences, which contain noun pairs, rare in essays collected during stage 1; "frequent" type represents a group of sentences, which contain noun pairs, frequent in essays collected during stage 1.

Group Comparisons Within Second Stage Tasks

For Task 1, ratings were significantly lower in the "rare" condition (M = 49.49, SD = 15.03, N = 71, throughout, uppercase N refers to the number of participants) than in the "frequent" condition (M = 75.03, SD = 12.52, N = 71), t(70) = -18.62, $p < .001$, $d_z = -2.21$. The Wilcoxon signed-rank test also indicated a significant difference, W = .00, $p < .001$, indicating that all nonzero participant-level differences were in the same direction. Data showed a shift to lower values in the distribution for the "rare" condition, with substantial separation in central tendency (Figure 3, a). Group ratings are consistent with the direction of semantic distance between words, showing that participants selected lower ratings for "rare" word pairs, which correspond to more "far" semantic distance between words and more "close" semantic distance between "frequent" word pairs.

For Task 1 reaction times, responses were significantly slower in the "rare" condition (M = 2.79, SD = .46, N = 71) and the "frequent" condition (M = 2.68, SD = .46, N = 71), t(70) = 3.52, p = .001, $d_я = .42$. The Wilcoxon signed-rank test also supported this difference, W = 651.00, $p < .001$. These result support the H1. Though the difference is significant, it is consistent with a small effect (Figure 3, b).

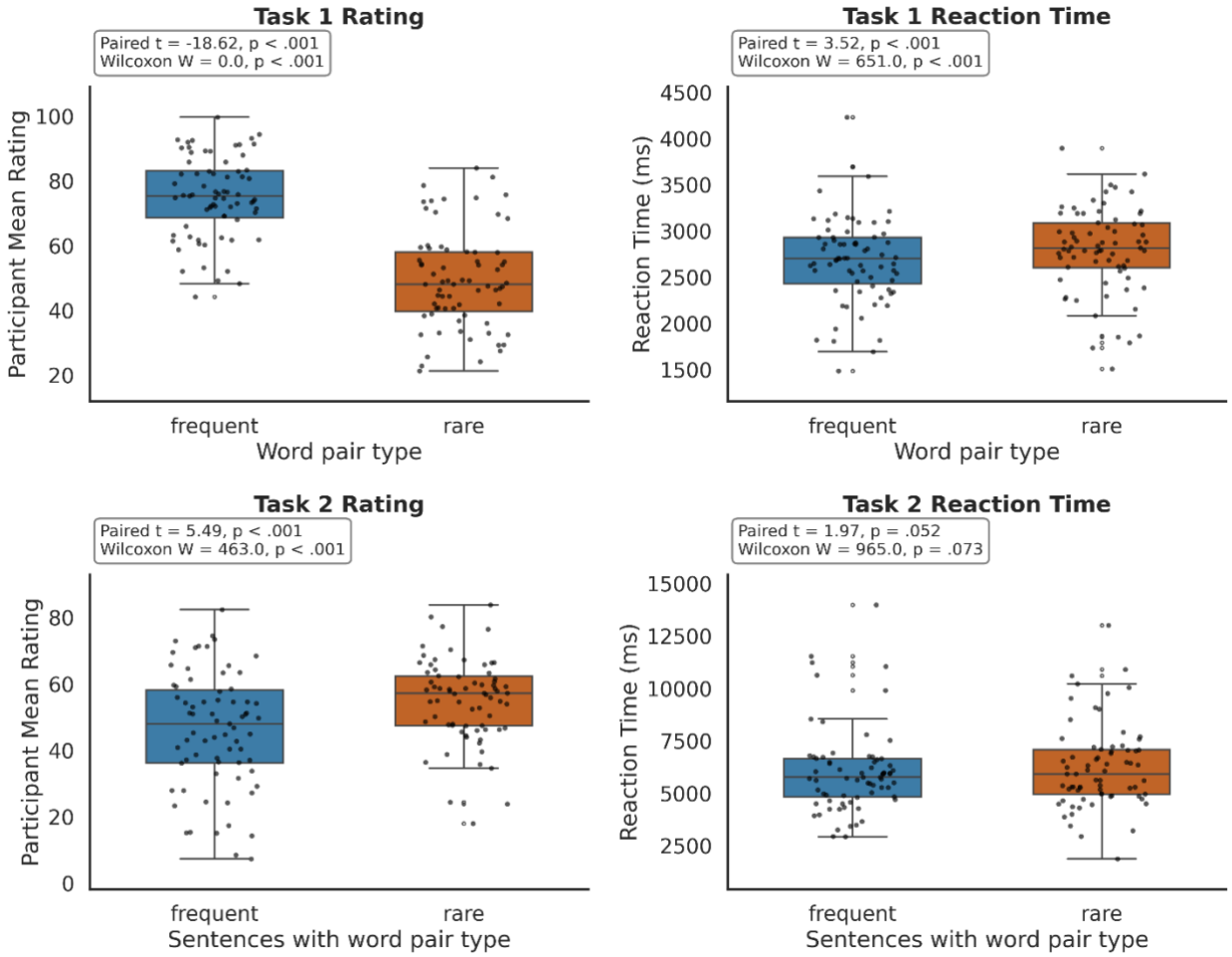
For Task 2 ratings, ratings were significantly higher in the "rare" condition (M = 54.96, SD = 12.48, N = 71) than in the "frequent" condition (M = 46.08, SD = 17.53, N = 71), t(70) = 5.49, $p < .001$, $d_я = .65$. The Wilcoxon signed-rank test supported the same conclusion, W = 463.00, $p < .001$. (Figure 3, c). This means that the sentences, which contain "rare", more semantically distant word pairs are subjectively perceived as more creative, which confirms our working hypothesis H2.

"Rare" type represents word pairs, rare in essays collected during stage 1; "frequent" type represents word pairs, frequent in essays collected during stage 1.

For Task 2 reaction times, the difference between the sentences with "rare" word pairs (M = 6.25, SD = 2.00, N = 71) and the sentences with "frequent" word pairs (M = 6.02, SD = 2.05, N = 71) was not statistically significant, t(70) = 1.97, p = .052, $d_я = .23$. The Wilcoxon signed-rank test was also not significant, W = 965.00, p = .073. Though the general trend is consistent with the prediction of working hypothesis H3, the significance level rejects H3. The absence of difference in reaction time between groups is due to high variability in this parameter, which was not limited during the task.

Figure 3

Ratings and reaction times on "rare" and "frequent" word pairs and sentences, containing "rare" and "frequent" word pairs



Discussion

Obtained results support the main hypothesis H2 that presence of semantically distant noun pairs in the sentence results in higher creativity ranking of this sentence. This conclusion overlaps with the results of Rossman & Fink, who reported, that more creative individuals perceive semantic distances between unrelated word pairs being smaller, in comparison with less creative individuals (Rossmann & Fink, 2010). Within the originality-effectiveness (or novelty-appropriateness) definition of creativity (Runco & Jaeger, 2012), our study primarily targets the novelty component: semantically distant word pairs increase the rated novelty of a sentence, while appropriateness is held implicitly constant. Recent work has emphasized that creativity judgments depend on both these dimensions (Moreno-Rodriguez et al., 2025). The present results should therefore be interpreted as evidence for the novelty aspect of creativity.

Creativity in text generation is usually related to the ability of cognitive processes to link low-related concepts (Kenett et al., 2014; Mohamed & Saleh, 2025; Olson et al., 2021). This association is discussed mainly in terms of subjectively reported closeness ratings or indices based on structural analysis of produced text (Fan et al., 2023; Kenett et al., 2014; Lewis et al., 2023; Li et al., 2021).

However, reaction time values add an additional dimension for understanding the cognitive mechanisms underlying creative associative processing (Mohamed, 2026). Supporting our working hypothesis H1, "rare", more semantically distant word pairs required more time for estimating this distance. In neurocognitive terms, a longer time taken to evaluate the association between two words indicates that semantic retrieval and integration require greater processing resources; this can reflect either weaker pre-activation (reduced spreading-activation facilitation) between the words (Gu et al., 2025; He et al., 2020) or more active inhibition of competing close associates (Green et al., 2010). The reduced-facilitation account is supported by neurophysiological response (N400) which varies in relation to semantic relatedness, with weakly related pairs eliciting larger responses interpreted as harder lexico-semantic pre-activation rather than active suppression (Kutas & Federmeier, 2011). So far the lower reaction times were observed for words pairs out of context, and this effect is common throughout the sample, lower facilitation is a more feasible explanation for longer "rare" word pairs processing.

As Kenett and colleagues have proposed, creative text generation is supported by greater flexibility in operating with items in semantic memory and by higher interconnectedness of the underlying network (Kenett et al., 2014; Li et al., 2021), suggesting that the facilitation level of the associative process is a major determinant of creative performance. The interconnection of semantically distant words could be achieved either through active controlled search for distant connections (Badre & Wagner, 2002; Davelaar, 2015; Schatz et al., 2022) or through a pre-existing organization of the individual's semantic map that already brings these concepts closer together (Kenett, 2025; Kenett et al., 2014). In the latter case, which is more close to hypothesis H2, individuals would generate more creative sentences simply because they possess stronger semantic links between the words used, whereas the same associations remain loose in others. In the former case, higher cognitive control, including inhibitory processes, should be engaged during text generation (Benedek & Fink, 2019a; Khalil et al., 2019). Ovando-Tellez et al. propose that creative processing involves active reorganization of semantic structure to provide effective access to loosely connected parts of the individual semantic map (Ovando-Tellez et al., 2022). (Beaty et al., 2016; Benedek & Neubauer, 2013)We found that associations

between distant, rare word pairs took significantly more time than associations between close, frequent pairs.

Nevertheless, our results don't support working hypothesis H3, meaning that the estimation time for sentence creativity did not depend on the type of word pair incorporated in the sentence. Within our paradigm, this pattern is consistent with the interpretation that the structural organization of semantic maps contributes more strongly to the rated novelty of sentences than do controlled evaluative mechanisms. This conclusion should, however, be qualified: the broader creativity literature shows that executive functions, controlled retrieval and inhibition contribute substantively to creative production (Benedek & Fink, 2019b; Benedek & Neubauer, 2013; Gerver et al., 2023; Khalil et al., 2019; Nusbaum & Silvia, 2011), and our task assesses judgment of creativity rather than its production. Furthermore, the absence of a reaction-time difference at the sentence level may also result from higher variability in timing, driven by the interplay of multiple factors (e.g., word count, syntactic structure, distribution of verbs, nouns and adjectives) that shape sentence complexity. Further research with explicit control of these linguistic factors, ideally combined with ERP measures such as N400 is needed to disentangle these contributions. Nevertheless, the statistical analysis of sentences, which were generated during stage 1 and used further in stage 2 indicate that the "frequent" and "rare" sentence groups did not statistically differ on any of the four examined attributes: word count, percentage of negative words, percentage of positive words, or uniqueness.

Based on these results, we consider the groups of sentences to be comparable in terms of sentence length, emotional load, and average frequency of words used. Hence, the selected sentences do not show any specific bias that could significantly impact the decision process. A deeper insight into the role of distant semantic associations can be obtained from developmental studies. The semantic networks of children appear to remain in active growth and to support a relatively high proportion of loosely connected concepts, while cognitive control mechanisms continue to mature throughout childhood and adolescence (Crone & Steinbeis, 2017; Denervaud et al., 2021; Marek et al., 2015; Markovits et al., 1998; Yadan et al., 2023). Recent evidence suggests that the combination of these factors contributes to creative thinking in children (Denervaud et al., 2021). At the same time, this developmental account should be advanced with caution. No peer-reviewed study to date has directly compared the modularity and clustering of children's and adults' semantic networks within a single sample, and the existing literature does not unambiguously support the claim that immature cognitive control by itself enhances creativity. This nevertheless suggests that individual-specific features of semantic map structure deserve to be considered a key source of creative text generation, complementing – rather

than replacing – the existing approach of contrasting high- and low-creativity groups based on aggregated performance (Kenett et al., 2014).

Recent studies of semantic networks have shown that group-aggregated networks can systematically misrepresent the structure of individual networks (Cosgrove et al., 2023; Wulff et al., 2022). Combined with our results, this argues for paradigms that estimate how person-specific semantic structure shapes the perceived creativity of generated text.

Conclusion

Cognitive studies of creativity commonly compare individuals grouped by high and low task performance. In the present study, we showed that noun pairs perceived as rare and unique render the sentences containing them as more creative, while other sentence-level features remain comparable. This indicates that creativity is, at least in part, a situational property: a given individual may produce high-originality output depending on the specific concepts available to them. Because creative text generation is closely tied to the structure of individual semantic networks, what one person perceives as a common concept pairing may appear creative to another. Our results therefore support a shift in cognitive and neuroscientific studies of creativity away from between-subjects comparisons of high- and low-performing groups, and toward the comparison of pooled concept-connections that differ in their network features across individuals (Figure 4). They also suggest that measurements of creative text generation will be most appropriate when both the texts and the concepts under study are derived from the study sample itself, rather than from third-party material.

Each graph represents the semantic map of separate individual; different colors of the semantic maps denote different integral features of the maps; protruding regions indicate the individually specific organization of particular semantic concepts within an individual's semantic map. Map colors and edge lengths do not correspond to any empirical values and are shown for illustrative purposes only.

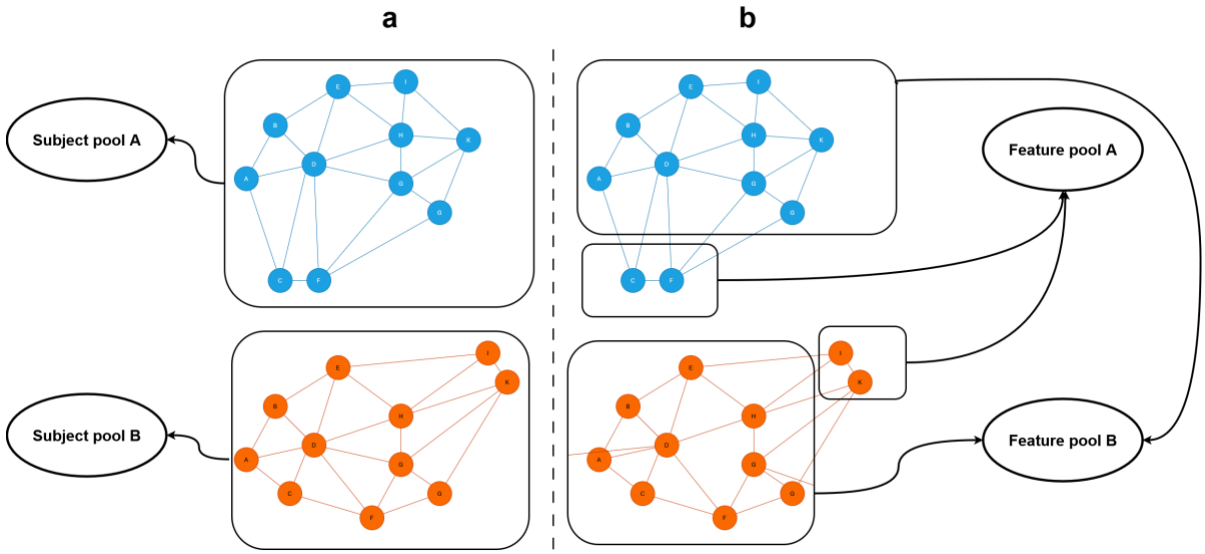
Implications and Future Directions

Current study is an initial step in studying how specific individual differences in semantic map structure relate to creative text generation and what are the brain mechanisms of this process. Our results support the further development of cognitive neuroscience protocols, which will include text generation with limited space of keywords, mapping the semantic distances between the

keywords as a multidimensional embedding vector space, selecting pairs of keywords with distances being different for specific individual, and using these specific pairs of keywords as stimuli material in N400 and P3 event-related potential paradigms on the same sample thus comparing the behavioral and brain responses to word pairs, semantically close for one specific participant and semantically distant for all other participants from the sample. This design will allow to shift away from group-based approach in studies of cognitive creativity mechanisms and use more individual-specific approach, more consistent with the understanding of creativity as an individual-specific phenomenon.

Figure 4

Group-based Versus Concept-based Experimental Designs in Studies of Creative Text Generation



Note. (a) In the group-based design, participants are partitioned into separate subject pools according to integral (global) features of their semantic maps, and group-level differences in creative output are then compared between pools. (b) In the concept-based design, semantic features are aggregated across all participants into two common feature pools – one comprising features that are individually specific to single participants, and the other comprising features that are commonly shared across participants – and text features associated with each pool can subsequently be used as stimulus material in neurocognitive experiments conducted on the same participant sample.

Limitations

The following limitations should be considered. First, despite obtaining significant results, the study operated on a relatively small text corpus, represented by essays,

which significantly limits the options for generating more creative sentences, resulting in low numbers of "frequent" word pairs and making the uniqueness of "rare" word pairs sensitive to randomly occurring infrequent words.

Second, the sample was relatively small and demographically homogeneous, comprising students recruited from a single university. This sampling constraint reflects practical limitations on participant recruitment imposed by the current political and socio-economic conditions in the country in which the study was conducted, and it should be addressed in future work through larger, more demographically and geographically diverse samples.Third, we cannot completely exclude the presence of the bias effect, which may be introduced by the second stage experiment design. Specifically, word pairs, incorporated in the sentences in Task 2 were first presented to participants during Task 1. Paying attention to words in word pairs, processing their meanings to make specific decisions about semantic distance may prime sentences with these word combinations for being later perceived as more or less creative. Though the presentation order of stimuli was randomized, no instructions no instructions to the participants contained explicit mention that presented word pairs could be later found in the presented sentences and assessed features (semantic distance for word pairs vs sentence creativity level) represent different scales, some bias in Task 2 introduced by Task 1 may persist and should be thoroughly tested and considered in future studies.

Fourth, during experiment stage 1 no filtering for word pairs, present in common collocations was applied. To our knowledge, modern language processing tools do not allow such word pairs to be filtered automatically. Such word pairs, being present in well-known common collocations, should be perceived as semantically close, or be primed to be perceived in this way. Furthermore, some word pairs present in sentences as separate entities (i.e. "decision", "making" – "прийняття", "рішення" in Ukrainian) may be a part of a well-established collocation. The existence of common collocations should be taken into account in future studies.

Finally, because subjective familiarity norms are not available for Ukrainian and could not feasibly be collected for the full 5,747-item sentiment analysis lexicon, word familiarity was not assessed; we note this as a limitation, since familiarity can influence processing independently of the lexical properties we report.

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CRediT Author Statement

Illia Kuznetsov: Conceptualization, Methodology, Software, Formal Analysis, Investigation, Data Curation, Writing – Original Draft, Writing – Review & Editing, Visualization, Supervision, Project Administration; **Tetiana Masytska:** Methodology, Validation, Data Curation; Writing – Reviewing & Editing; **Oleksandr Zhuravlov:** Validation, Formal Analysis Data Curation, Writing – Reviewing & Editing; **Oleksandr Kazmirchuk:** Methodology, Software, Data Curation, Visualization; **Stanislav Revko:** Software, Validation, Formal Analysis, Writing – Original Draft, Writing – Review & Editing, Visualization; **Nataliia Kozachuk**: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Resources, Writing – Original Draft, Writing – Review & Editing, Supervision, Project Administration.

Disclosure Statement

The authors reported no potential conflicts of interest.

Generative AI Statement

During the preparation of this work the authors (Illia Kuznietsov, Stanislav Revko, Nataliia Kozachuk) used Claude Opus 4.8 in order to correct spelling and grammar errors in the manuscript text and remove tautologies, Julius 1.2 for initial prototyping of Python code for data and statistical processing, Undermind for literature search. All Python code was tested on sample datasets and was corrected, if necessary. After using these tools and services, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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Appendix A

Sample word pairs and containing sentences

Table A1. *Sample of frequent (n=5) and rare (n=5) word pairs with example source sentences.*

N.	Word 1	Word 2	Sentence	Word pair type
1	*звичка*	*планування*	*Ранкові звички - це фундамент дня: невелика розминка, склянка води, кілька хвилин тиші або планування*	rare
2	*дитин-ство*	*мульт-фільм*	*Музичні теми з улюблених мульт-фільмів часто стають саундтре-ком нашого дитинства.*	rare
3	*енергія*	*подих*	*Спорт - це більше, ніж рух, це спосіб життя, музика тіла і духу, енергія, яка тече в кожному м'язі, в кожному подиху.*	rare
4	*аромат*	*економіка*	*Стоячи на різдвяному ринку серед ароматів кориці та гарячого шоколаду, я вперше замислився, як культура впливає на економіку.*	rare
5	*графіті*	*місто*	*Для мене графіті - це ніби пульс міста, який можна побачити.*	rare
6	*життя*	*людина*	*Мрії змінюють людину і світ навколо неї, роблячи життя більш змістовним та яскравим.*	frequent
7	*мислення*	*спосіб*	*Мова - це не лише інструмент передачі інформації, але й спосіб мислення, спосіб відчуття світу, спосіб існування культури в часі та просторі.*	frequent
8	*страх*	*сумнів*	*Учитель часто стає тією людиною, до якої дитина може прийти зі своїми проблемами, страхами, сумнівами.*	frequent
9	*відчуття*	*тепло*	*Справжнє відчуття літа приходить тоді, коли складаєш останній екзамен і розумієш що попереду три місяці спокою та тепла.*	frequent
10	*відповідь*	*питання*	*Саме тому питання «досвід чи сучасність» не повинно мати категоричної відповіді.*	frequent