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# CRAT-RUS: A Set of Compound Remote Associates Test Items for Insight Research. Theoretical Foundations and Validation Results

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## Abstract

**Introduction.** Remote associate test is a convenient and widely used tool for studying insight and creative thinking. However, numerous versions of this test exhibit considerable linguistic heterogeneity—both within Russian-language sets and across versions in different languages—which hinders the comparison of research results and further progress in understanding the mechanisms of insightful problem solving. **Methods.** In the present study, a new set of 60 tasks in Russian of two types (semantically convergent and divergent) was developed and tested. The criteria for constructing the task set are described in detail, based on current theoretical conceptions of the cognitive and metacognitive processes involved in insight. Task selection was based on metrics extracted from the Russian National Corpus. The study was validated on a sample of 71 participants (mean age = 23 years). **Results.** Convergent and divergent triads were shown to be balanced in objective difficulty, while an Aha-experience (the affective marker of insight) occurred significantly more often upon finding the correct solution for divergent triads than for convergent ones. The probability of successfully solving a task increased with higher target word frequency and higher strength of target collocations (formed by the triad words with the target word). At the same time, the probability of a correct answer was lower when the frequency of the first triad word was higher. Solution time decreased for triads with higher target word frequency. The probability of an Aha-experience

was related to the metric of semantic distance among triad words—the greater this distance, the more often an Aha-experience occurred upon finding the correct answer. Low target word frequency also increased the probability of an Aha-experience. **Discussion.** Thus, a task set of two types has been created that are equivalent in difficulty but differ in the probability of inducing an Aha-experience. Linguistic predictors of both objective task difficulty and the occurrence of an Aha-experience have also been identified.

### **Keywords**

Compound Remote Associates Test, insight, Aha-experience, semantic coherence, processing fluency, metacognitive prediction error

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## **Introduction**

Research on creative thinking occupies an important place in cognitive science. For over a century, one of the most enigmatic phenomena attracting scientists has been the phenomenon of insight. Insight is generally understood as a subjectively sudden shift from incomprehension to comprehension when solving a creative problem. Insightful problem solving is often contrasted with analytical, step-by-step solving, which uses familiar approaches and procedures and/or involves trying out different options. Insight is also characterised by a specific phenomenology—namely, the occurrence of an Aha-experience—which includes a sense of the sudden emergence of a solution, confidence in its correctness, and positive emotions (Danek et al., 2014; Stuyck et al., 2021).

One of the most widely used methods for studying creative thinking processes in recent years has been the Remote Associates Test, originally developed by S. A. Mednick to assess creativity (Remote Associates Test (RAT), Mednick, 1962) and later adapted by E. M. Bowden

and colleagues to study insight (Compound Remote Associates Test; CRAT, Bowden & Jung-Beeman, 2003; Bowden et al., 2005). Remote associate tasks are used to explore the phenomenology of insight (Stuyck et al., 2021), its neurophysiological mechanisms (Bowden et al., 2005), its influence on long-term memory formation (Kizilirmak, Wiegmann, & Richardson-Klavehn, 2016; Gershkovich, Moroshkina, & Fedosova, 2021), and many other aspects. However, further progress is impeded by the significant diversity of task sets across different languages (Behrens & Oltețeanu, 2020) and the lack of specification regarding the properties of the tasks themselves and the cognitive processes involved in solving them (Wu, Huang, Chen, & Chen, 2020; Afanasieva & Spiridonov, 2024; Lukianova, 2024). Despite isolated attempts to establish the validity of the Remote Associates Test, most task sets are developed without a clear explanation of the criteria for their selection. The theoretical basis for the developed methods remains unclear—what hypothetical mechanisms underpin the solving of problems of this type? What determines whether the solution to a problem will be accompanied by an Aha-experience?

The aim of this study was to develop and validate a new set of remote associate tasks in Russian for use in research on creative thinking and the phenomenon of insight. To achieve this aim, the following objectives were set—

- to establish the key criteria for task selection, based on existing theoretical concepts regarding the cognitive and metacognitive processes that underpin insightful problem solving in remote associate tasks;
- to select and empirically validate a set of tasks of two types (potentially insightful and potentially non-insightful) with the participation of native Russian speakers;
- to describe the linguistic properties of the tasks that determine their difficulty and the likelihood of inducing an Aha-experience during the solution process.

In this work, we develop an approach based on Mednick's methodology and its later version (Bowden & Jung-Beeman, 2003). Mednick originally proposed that creative thinking is based on the ability to find new combinations of distant elements of experience. As a method for assessing creativity, Mednick developed a test consisting of 30 tasks in which participants were presented with a triad of words and asked to find a fourth target word that linked them all (Mednick, 1962). The RAT has demonstrated fairly high validity and reliability. However, it was subsequently shown that scores on this test correlate positively with scores on standard intelligence tests—particularly verbal intelligence tests (for further details, see Valueva & Belova, 2011).

In recent years, the RAT and its variants have come to be used not only to assess associative thinking abilities but also to study the phenomenon of insight experimentally. It has been shown that these tasks are very likely to trigger an Aha-experience in the solver. It has also been shown that even a simple demonstration of the tasks together with the answer can induce hindsight (the “I knew it all along” effect) (Kizilirmak et al., 2016; Moroshkina et al., 2020). However, the original version of the test contained a small number of tasks, and the tasks themselves were quite heterogeneous from a linguistic point of view. Consequently, a new version—the CRAT—was developed, comprising 144 tasks in English (Bowden &

Jung-Beeman, 2003). All tasks in the CRAT set consist of triads of words that always form a compound word or phrase with a target word (for example, for the triad *age / mile / sand*, the answer is *stone*—*Stone Age, milestone, sandstone*). Another key feature of these tasks is that each has only one correct answer, which distinguishes them from divergent thinking tests that require multiple answers to a single question (for further details, see Valueva & Belova, 2011).

The creators of the CRAT set point out the following advantages of these tasks compared to the classic puzzles previously used to study insight (Bowden et al., 2005):

- they are relatively easy, take less time to solve, and allow for more data to be collected at a time;
- they are sufficiently homogeneous, allowing researchers to study insight by comparing not solutions to different task types but different types of solutions to similar tasks;
- they allow for more experimental manipulations within a single research design;
- they are easy to display, and responses can be entered easily using a computer;
- they are adaptable to physiological methods (e.g., EEG, fMRI).

## Russian-language versions of the Remote Associates Test

To date, several attempts have been made to develop a set of remote associate tasks in Russian. The first version of the Remote Associates Test was developed by A. N. Voronin and T. V. Galkina (Voronin & Galkina, 1994). However, this version differs significantly from Mednick's original test, as the tasks do not require finding a single correct answer; and the test is designed to assess divergent associative thinking by analysing the frequency of proposed response associations. Nevertheless, tasks from this test have been used in cross-cultural studies of the Remote Associates Test (Toivainen et al., 2019).

Later, D. V. Ushakov and E. A. Valueva developed an adaptation of Mednick's original test, which was validated on a sample of 357 participants; the internal consistency of the test items, as measured by Cronbach's alpha, was 0.87 (Valueva & Belova, 2011). The test items were based on idiomatic expressions and collocations in Russian (for example, for the triad *кожа / слоновый / лечь* (*skin / elephant / to lie down*); the answer is *кость* (*bone*)—*кожа да кости, слоновая кость, лечь костью* (*skin and bones —very thin, elephant bone—ivory, to lie down with bones—to do the impossible*)). Based on this test, N. V. Moroshkina and colleagues (Moroshkina et al., 2022) developed an expanded set of tasks for studying insight, comprising 100 items (RAT-RUS). The tasks were tested on a sample of 120 participants; data were collected on both task difficulty (mean solution rate = 0.52) and their ability to induce an Aha-experience during problem solving and upon presentation of the correct answer (the probability of inducing an Aha-experience during problem solving is comparable to that reported for similar task sets in other languages, at approximately 0.5).

Another version of a set of remote associate tasks was developed by a team from the Russian Presidential Academy of National Economy and Public Administration under the leadership of V. F. Spiridonov (Spiridonov, Loginov, & Ardislamov, 2021). The authors do not report any validity or reliability testing, as the task set was originally created not as a

psychodiagnostic test but as a set of tasks for experimental research. Perhaps partly for this reason, the majority of the tasks in the set turned out to be highly difficult (with a mean solution probability of about 0.20). The set contains 40 tasks based on Russian word combinations (for example, for the triad *палитра / яркость / оттенок* (*palette, brightness, hue*), the answer is *цвет* (*colour*)—*цветовая палитра, яркий цвет, оттенок цвета* (*colour palette, bright colour, colour hue*)). However, the title of the set uses the abbreviation CRA (Compound Remote Associates), although the target word typically does not form compound words, terms, or fixed expressions with the words of the triad, unlike in the original English-language CRAT set (Bowden & Jung-Beeman, 2003).

Finally, another version of a remote associate task set—the Russian Language Compound Remote Associates Test (RLCRAT)—was proposed in M. S. Vlasov’s master’s thesis (Vlasov, 2021). The test includes 20 tasks constructed according to a single principle based on compound words in Russian (for example, for the triad *колоть / резать / ходить* (*to break, to cut, to drift*) answer is *лед* (*ice*)—*ледокол, ледорез, ледоход* (*icebreaker, ice cutter, ice drift*)). The average solution rate is 0.63, and the internal consistency (Cronbach’s alpha) is 0.88; no information is provided regarding the probability of inducing an Aha-experience. Since compound words are not very widespread in Russian, it is unlikely that the task set for this version of the test can be substantially expanded, which poses a problem for experimental and especially psychophysiological studies.

It is not the aim of this article to provide a detailed comparison of all the mentioned versions of the RAT; we merely note that their existence indicates a high demand for this methodology in psychological research on insight and creativity. At the same time, researchers are constantly striving to improve the proposed versions of the task sets. One of the main problems is the linguistic heterogeneity of the tasks, which introduces various sources of difficulty—including non-semantic ones—and complicates the interpretation of the obtained results. A second difficulty is that, currently, the properties of tasks that facilitate an Aha-experience upon solution discovery remain largely unexplored. When using existing versions of the test, one must rely on solvers’ self-reports regarding the presence or absence of an Aha-experience in order to distinguish between insightful and non-insightful trials post hoc, which leads to a quasi-experimental research design. This approach raises a number of methodological issues in studying the mechanisms of insight, as well as limitations in the interpretation and generalisability of the results obtained.

## **Mechanisms of solving remote associates tasks**

### ***Factors contributing to task difficulty***

The solving process for remote associate tasks can be viewed as comprising two stages: an initial idea-generation stage, followed by a stage of comparison and evaluation of the solution (Smith, Huber, & Vul, 2013). In the first stage, when the participant is presented with the triad words,

close associations are activated in semantic memory according to network models (Collins & Loftus, 1975). These activation processes spread in parallel across the semantic network and at some point converge on the target word, which, due to the summation of activation, becomes accessible for retrieval (Bowers et al., 1990; Bolte & Goschke, 2005; Topolinski & Strack, 2008). However, the retrieved word is merely a guess, which may not be the correct answer to the task. Since the instructions typically require finding a word that forms a specific type of connection with the three words (for example, one that forms fixed expressions or common combinations/strong collocations) an explicit check is needed to ensure that the guessed word meets the task's requirements. At this stage, the solver may attempt to assess the "stability" of the resulting expressions with the target word, which, according to some hypotheses, is associated with backward spread of activation from the target word to the triad words (Moroshkina et al., 2022).

According to the approach proposed by K. S. Bowers and colleagues (Bowers et al., 1990), the idea-generation stage is driven by intuitive processes that sequentially perform the functions of search navigation (guiding stage) and integration of accumulated evidence (integrative stage). At the same time, even in the early stages of search, the solver experiences an intuitive sense of coherence (perception of coherence), which reflects patterns of activation in semantic memory and can serve as an indirect signal of a task's potential solvability. Thus, in Bowers and colleagues' experiments (Bowers et al., 1990) and in a series of subsequent studies (Bolte & Goschke, 2005; Topolinski & Strack, 2010), it was shown that when participants were presented with triads from the RAT, they were able to distinguish between solvable and unsolvable tasks (i.e., triads with a common target word and those without one) with a probability higher than chance after just 1.5—2 seconds.

Later, M. Öllinger and A. von Müller (Öllinger & von Müller, 2017) expanded on Bowers' ideas by proposing a four-stage model in which they explicitly describe the stage of insightful problem solving (restructuring). According to their model, in the first stage (just as in Bowers's model) activation spreads through semantic memory. However, they note that, to prevent the search from becoming endless, it must be constrained in advance by a hypothesis or prior knowledge. In the second stage, activation accumulates, and the system transits to a state of balance (coherence), characterised by increased processing fluency; at this stage, a specific intuitive guess about the solution emerges. The third stage involves the evaluation of this intuitive guess; if the evaluation is successful, a solution is produced. In the case of an unsuccessful evaluation, the system moves to the fourth stage (restructuring), triggering a change in the problem representation and a return to the first stage, but with different constraints on the spread of activation. The system cycles through these four stages until a solution is found.

In his work, E. J. Davelaar (Davelaar, 2015) attempted to model the processes of semantic search when solving RAT tasks. The results of the study showed that the problem solving process in tasks of this type is non-linear in nature. As a rule, the connection between the target word and the triad words is too weak for the summed activation from the triad to lead directly to its conscious retrieval. Reading cue words leads to the activation of their strong

associates, which must be rejected (suppressed) during the search process. As a result, participants demonstrate what the author calls a superadditive search model; they explore the associative fields of each word in the triad, including both elements at the intersection of these fields and the strongest associates outside the intersection. In doing so, they do not explore the associative fields through a sequential exhaustive search, but rather switch between them, which allows them to enhance the activation of the target word (weakly associated with all words in the triad) and weaken the activation of distracting associations (strongly associated with one of the triad words and almost unrelated to the others), thereby maximising the difference between them and ultimately leading to the retrieval of the target word.

What factors contribute to the difficulty of RAT tasks, based on the proposed models of the processes involved in solving them? According to Bowers' model, finding the answer and the time required to do so depend on how strongly the words in the triad are linked to the target word (so-called semantic coherence). The stronger the link, the faster the activation of the target word accumulates, reaching a level sufficient to overcome the threshold of awareness. Davelaar's model points to a second important factor—the presence of strong but irrelevant associates for cue words, as they are activated quickly and distract the search process, increasing the time needed to solve the task. It can also be assumed that, in general, the higher the frequency of cue words, the more associates they have and, consequently, the larger the search space.

In a study by Sio, Kotovsky, and Cagan (Sio, Kotovsky, & Cagan 2021), the stronger the semantic coherence between triad words and the target word—calculated based on association norms—the faster participants solved the task. Furthermore, as the number of strong irrelevant associates to the triad words increased, search times slowed down. Similar results were obtained in another study (Becker, Davis, & Cabeza, 2022)—the authors showed that the higher the semantic coherence between triad words and the target word (cue-solution similarity), the faster participants found the target word. In addition, the researchers hypothesised that semantic coherence among the triad words themselves (cue-cue similarity) would also affect the search for the answer. Triads with strong semantic coherence activate many closely related common associates, leading participants to expect the solution word to also be located nearby. Thus, the higher the semantic coherence, the narrower the constraints participants impose on the search space—a finding consistent with the Öllinger-Müller model. On this basis, the authors predicted that strong semantic coherence among triad words would facilitate solution finding when semantic coherence with the target word is also strong, but impede it when semantic coherence with the target word is weak. Both predictions were confirmed.

In a study by Bowers and colleagues (Bowers et al., 1990), another factor presumably influencing the search processes in RAT tasks was identified—the type of triad itself. The authors observed that in some triads, the words are associated with the target word through its different meanings (e.g., in the triad *strike / same / tennis*, the words relate to different senses of the target word *match*). The authors termed these triads semantically divergent. In other triads, all words are associated with the target word through a single shared meaning (e.g., the triad *goat / pass / green* and the target word *mountain*); such triads were

termed semantically convergent. Since most of the triads were originally taken by Bowers and colleagues from Mednick's set, the classification of triads into types was post hoc. The authors found that semantically divergent tasks had a lower solution rate, and participants were less likely to rate them as coherent—that is, as potentially solvable. Bowers concluded that divergent triads appear to induce only a weak sense of coherence, or perhaps none at all. However, in subsequent studies using the RAT and CRAT, the distinction between semantically convergent and divergent triads has not been discussed or taken into account—which, in our view, is a serious gap. We will return to this distinction in more detail below when discussing the criteria for creating a new set of tasks.

In addition to semantic factors, other task features may influence the difficulty of RAT tasks, including the syntactic relations between the target word and the triad words within the resulting word combinations (Afanasieva, Spiridonov, 2024). Furthermore, a number of studies have shown that the strategy used by the participant can affect both solution accuracy and solution time (Smith, Huber, & Vul, 2013). For example, a common strategy involves beginning the search by generating associations to the first word in the triad. As a result, the frequency of the first word itself becomes one of the factors contributing to task difficulty (Moroshkina et al., 2020).

### ***Factors underlying Aha-experience during problem solving***

When examining the mechanisms of solving remote associate tasks, another important question arises—what determines whether a solution will be reached through insight or through analytical processes? What factors influence the likelihood of an Aha-experience occurring during problem solving? In most insight studies using RAT tasks, researchers ask participants to provide subjective reports of whether they experienced an Aha-experience at the moment of solving. Typically, the proportion of solutions accompanied by an Aha-experience averages about 50% of all correct answers; however, for some tasks this percentage may be higher, while for others it may be lower. The question of which task properties this might depend on has received virtually no discussion in the literature.

According to the Öllinger-Müller model (Öllinger & von Müller, 2017), the defining feature of engaging insight mechanisms in problem solving is the solver's transition to the fourth stage—restructuring—following unsuccessful validation of a prior guess. If the solution is found within the first three stages, it will be non-insightful. However, existing evidence suggests that this is not the case, at least when insight is defined by its affective component—the Aha-experience. E.A. Cranford and J. Moss (Cranford & Moss, 2012) used a verbal protocol analysis, asking participants in their study to solve compound remote associate tasks (CRAT), to verbalise any guesses that occurred to them, and to report whether they experienced an Aha-experience upon finding the solution. Data analysis showed that participants reported Aha-experiences both when their very first guess was correct and when the process was characterised by prolonged search with impasse and a subsequent representational change—the latter corresponding more closely to the Öllinger-Müller model.

In a number of recent studies, it has been proposed that the Aha-experience is not necessarily associated with a change in problem representation, but may instead reflect a positive metacognitive prediction error regarding task difficulty—that is, the probability and/or time required to find a solution (Dubey et al., 2021; Becker, Wang, & Cabeza, 2024; Moroshkina, 2024). Consequently, the probability of an Aha-experience and its intensity in RAT-type tasks will depend on the combination of two groups of factors: (1) task characteristics that influence the formation of an intuitive sense of coherence in the early stages of problem solving—since these largely determine the metacognitive prediction of solution probability; and (2) characteristics of the target word that determine the actual fluency of its retrieval from memory and/or are associated with backward spread of activation from the target word to the triad words — since these characteristics will influence retrospective assessments of task difficulty.

However, until recently, no attempts have been made to link the probability of inducing an Aha-experience to the linguistic properties of RAT/CRAT tasks. Building on Bowers' distinction between semantically convergent and divergent triads, we hypothesised in our previous study (Savina, Moroshkina, & Oshkanova, 2021) that divergent triads should lead participants to lower their expectations regarding the potential solvability of a given task—due to the weak coherence of divergent triads—and that precisely in divergent triads, finding a solution would be more likely to trigger an Aha-experience. We selected triads of three types—solvable convergent triads, solvable divergent triads, and unsolvable triads. Participants were first asked to intuitively judge within seconds whether each triad had a solution. After making all predictions, participants were asked either to find solutions for all triads or to indicate that a triad had no solution. Analysis of the results showed that the probability of an Aha-experience upon finding a solution was higher for tasks that participants had judged as unsolvable (incoherent) during the intuitive judgment stage. This finding supports the hypothesis linking the Aha-experience to a metacognitive prediction error. However, no relationship was found between Bowers' triad type (convergent vs. divergent) and the probability of an Aha-experience. It is possible that participants' predictions of task solvability were influenced not only by triad type but also by other task characteristics. For example, in the aforementioned study by Becker and colleagues (Becker, Davis, & Cabeza, 2022), it was shown that the Aha-experience may be associated with measures of semantic coherence among words within a triad and semantic coherence between the target word and the triad.

Thus, it can be argued that RAT-type tasks allow for a deeper understanding of the associative search processes in human semantic memory during problem solving. Drawing on advances in computational linguistics, the tasks included in the test can be described in terms of their various linguistic properties and, in turn, be linked to participants' solution success and the probability of an Aha-experience—shedding light on the nature of both the cognitive and affective components of insight.

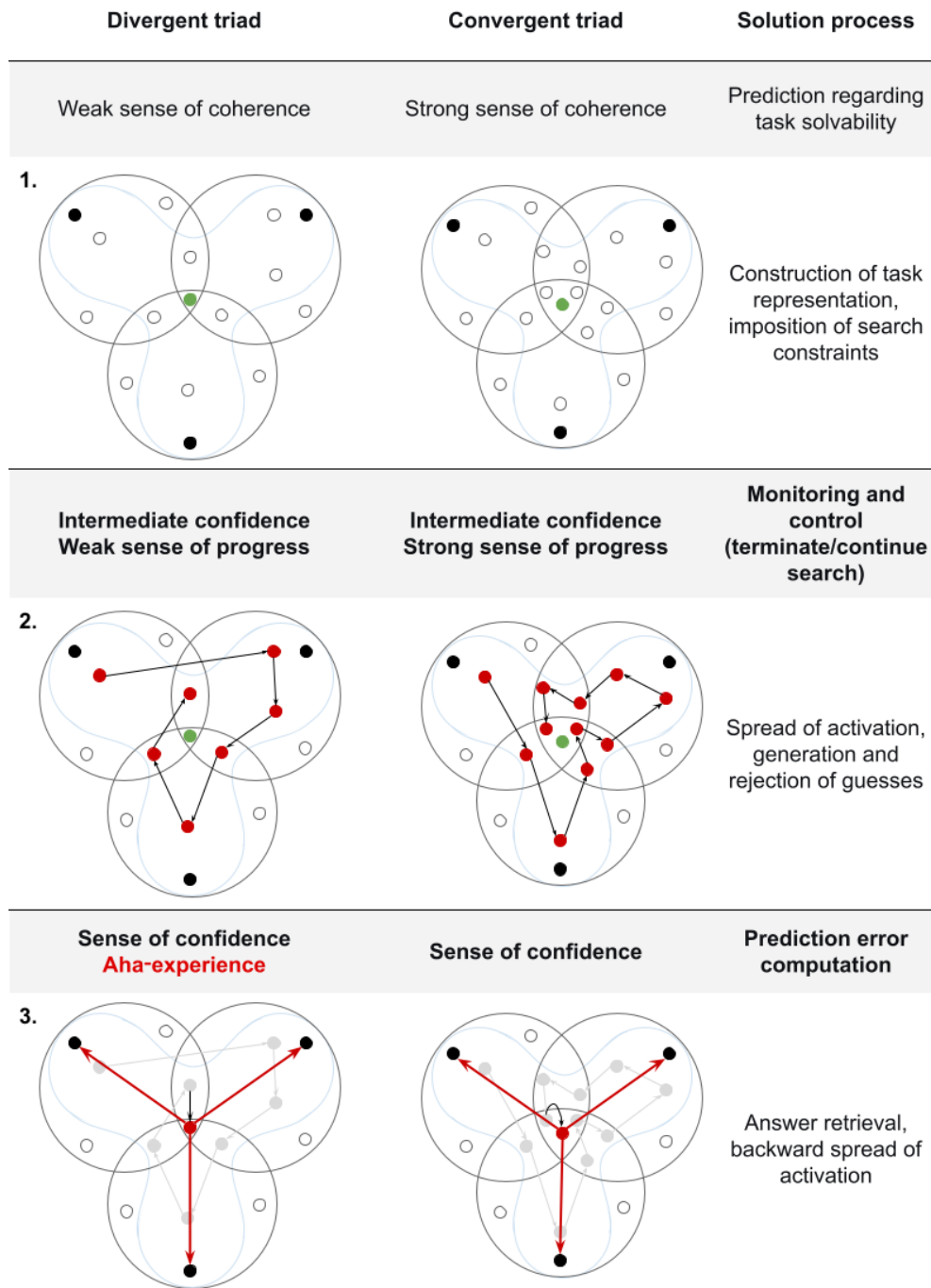
## The present study

The main aim of the present study was to create potentially insightful and non-insightful remote associate tasks. Building on Bowers' approach (Bowers et al., 1990), which we previously implemented (Savina, Moroshkina, & Oshkanova, 2021) but which did not reveal the expected relationship between task type and Aha-experience, we sought to develop a new set of triads of two types (semantically divergent and convergent), while additionally identifying their linguistic properties associated with objective task difficulty and the probability of inducing an Aha-experience.

Our hypothesis is that the Aha-experience, being a metacognitive phenomenon, arises from a metacognitive prediction error regarding task difficulty (the probability and/or time required to solve it). When a task is presented, the metacognitive system generates a prediction about how the solution process will unfold, based on a sense of coherence reflecting one's unique semantic network activation pattern—its structural and dynamic characteristics. The intensity of the sense of coherence changes during the solution process (alongside the dynamics of activation spread across the network) and can increase sharply when the answer is discovered, at the stage of backward spread of activation from the found solution to the task elements. An especially pronounced shift may occur when the speed of activation spread from the task elements to the answer is slower than the backward—from the answer to the task elements (backward activation spread serves to evaluate whether the answer fits the task requirements). In this situation, a positive metacognitive prediction error occurs—the answer is retrospectively judged as more obvious than initially predicted—and the Aha-experience arises. According to our approach, the process of solving remote associate tasks and the accompanying metacognitive experiences are illustrated in Figure 1.

**Figure 1.**

*Solution process for two types of remote associate tasks*



**Note:** *The figure illustrates the solution process for semantically divergent and convergent types of remote associate tasks. It is based on Davelaar's model of superadditive associative search (Davelaar, 2015), extended with a metacognitive level of regulation to account for insightful problem solving. On a white background, from top to bottom, the processes occurring at the cognitive level are shown; on a grey background, the corresponding metacognitive processes and experiences are displayed. The three triad words are indicated by black dots, and their associative fields by large black circles; the solution—represented by a green dot—lies at the intersection of these fields. White dots represent associates of the triad words. The search space, formed in response to task presentation, is outlined in blue. In the central part of the figure, black arrows represent the sequence of generated solution candidates (shown as red dots) produced during the solution process. In the lower part of the figure, red arrows depict the process of backward spread of activation from the solution (red dot) to the triad words, which serves as a mechanism for verifying the solution's consistency with the task requirements.*

Based on the above, potentially insightful tasks should induce a weak sense of coherence in the early stages of the solution process and a stronger sense upon discovery of the answer. With respect to remote associate tasks, this can be achieved by creating triads in which semantic coherence *among* the triad words is weak—specifically, weaker than the semantic coherence between the triad words and the answer. Bowers' criterion of triad divergence, which implies multiple meanings for the target word, ensures weaker coherence among the triad words. However, our previous experience (Savina, Moroshkina, & Oshkanova, 2021) showed that this may not be sufficient. Therefore, when creating the set of triads of two types, we additionally took into account semantic coherence metrics (based on corpus data). For divergent (insightful) triads, semantic coherence *among the words* was required to be weaker than for convergent triads. Semantic coherence between the triad words and the answer was required to be approximately equal for convergent and divergent triads.

In summary, our aim was to create insightful and non-insightful tasks, with a particular focus on linguistic properties associated with the probability of an Aha-experience. Therefore, we sought to ensure that the sets of divergent and convergent triads were approximately balanced in terms of difficulty (i.e., that the mean solution rate did not differ significantly between them). To this end, we controlled for the strength of collocations between each triad word and the answer, as well as the frequency of the first triad word and the target word, so that these were similar for convergent and divergent triads. Thus, our research hypotheses were as follows:

1. The linguistic predictors of difficulty of remote associate tasks are the frequency of the first word in the triad and the frequency of the target word—the proportion of correct answers for a triad will be negatively related to the frequency of the first triad word and positively related to the frequency of the target word. The time required to find the correct answer will increase with higher frequency of the first triad word and lower frequency of the target word.

2. When solving convergent triads, intrusions (incorrect answers) will be more frequent due to higher semantic coherence among the words of convergent triads compared to divergent triads. Accordingly, when solving divergent triads, omission errors will be more frequent.

3. Discovery of the correct answer for divergent triads will be more often accompanied by an Aha-experience compared to convergent triads. Moreover, the probability of an Aha-experience will be negatively related to semantic coherence among the triad words.

## Methods

### Task bank development criteria

In accordance with the aims of the present study, 60 remote associate tasks were created. Each task consists of three nouns for which a common adjective must be found such that the nouns and the adjective form strong (*stable*) collocations in Russian. As a metric of collocation strength when creating the triads, we used the LogDice, extracted from the Russian National Corpus (RNC, Main Corpus (<https://ruscorpora.ru/en/>)), which reflects the strength of the syntagmatic relationship between two words (see Table 1). This metric is calculated based on the co-occurrence of words in a text corpus, taking into account their individual frequencies. The triads were constructed so that each had only one correct answer.

Based on the distinction proposed by Bowers and colleagues (Bowers et al., 1990) and on our previous study (Savina et al., 2021), we selected 30 semantically convergent (potentially non-insightful) and 30 semantically divergent (potentially insightful) triads. In convergent tasks, the target adjective was required to have a single meaning. For example, for the triad *приз / козырь / герой* (*prize / trump card / hero*), the target adjective *главный* (*main*) has one meaning—most important, primary, central. In divergent triads, the adjective was required to have different meanings (at least two) when combined with the nouns. For example, for the triad *дата / печать / сирота* (*date / seal / orphan*), the adjective *круглый* (*round*) has three meanings— (1) calculated without smaller units of counting (*a round date*—an anniversary measured in decades or centuries); (2) having the shape of a circle (*a round seal*); (3) complete, utter (*a round orphan*—a child with neither father nor mother). The number of meanings for each adjective was verified using The Large Explanatory Dictionary of the Russian Language edited by S. A. Kuznetsov (Kuznetsov et al., 1998).

Additionally, convergent and divergent triads were selected based on a metric of semantic coherence among the triad words. This metric was extracted from the RusVectors distributional semantic model (Kutuzov & Kuzmenko, 2017), which is based on the Russian National Corpus (RNC, 2018 version). It reflects the degree of similarity between the contexts in which words appear in the text corpus and is calculated as the cosine similarity between the vectors of two words in the model. Triads were selected so that semantic coherence among the words of convergent triads was higher ( $M = 0.196$ ,  $SD = 0.111$ ) than in divergent triads ( $M = 0.044$ ,  $SD = 0.065$ ). For each task, three semantic coherence metrics were extracted for

the three possible pairwise combinations of triad words. At the same time, the strength of semantic coherence between the target word and the triad (*Collocation strength of target word combinations*) was balanced across the two triad types. As a metric of this strength, we used the LogDice mentioned above (see Table 1).

For the purposes of further analysis, we needed to create a single unified metric of semantic coherence among the words within a triad. We termed this metric *semantic distance among triad words* (*SemDist among triad words*). It was calculated as the cluster density of the three vectors corresponding to the three triad words. The higher the value of this measure, the farther apart the vectors are located in the model space. A comparison of convergent and divergent triads on this metric confirmed that divergent triads have greater semantic distance among words within the triad compared to convergent triads—that is, the words within divergent triads have weaker semantic coherence (see Table 1).

Additionally, to balance task difficulty between the two triad types, we sought to equate the frequency of the first word of the triad and the frequency of the target word across the sets of convergent and divergent triads. Statistical analysis revealed no significant differences between the triad types on these metrics. Mean values for all metrics, independent-samples t-test and Welch's t-test values, and corresponding significance levels are presented in Table 1. A complete list of all tasks and their corresponding linguistic properties is provided in Appendix 1.

**Table 1**

*Linguistic properties of the CRAT-RUS tasks*

Triad type	Convergent		Divergent		t-test, df	Effect size	p-value
	Mean	SD	Mean	SD			
First triad word frequency	48413	53495	37854	61872	t = 1.14, df = 58	0.294	p = 0.259
Target word frequency	31494	33444	32957	36750	t = -0.204, df = 58	-0.0527	p = 0.839
Collocation strength of target word combinations (LogDice)	9.01	0.398	9.00	0.736	t = 0.0812, df = 159	0.0121	p = 0.935
SemDist among triad words	22.9	2.38	24.6	2.10	t = -2.92, df = 58	-0.754	p = 0.005

**Note:** Mean values are presented for the final set of tasks (30 divergent and 30 convergent triads).

## Sample

Seventy-one volunteers (35 women) aged 18 to 35 years ( $M = 23.1$ ,  $SD = 4.2$ ) took part in the present study. All participants were native speakers of Russian. Participants were recruited through online advertisements. The study was approved by the local ethics committee of the N.P. Bekhtereva Institute of the Human Brain, Russian Academy of Sciences.

The sample was collected in two stages. First, a pilot study was conducted with 18 participants (11 women), mean age 26.9 years. The main data collection stage followed later. The procedure did not differ between the pilot and the main stages; however, in the pilot, participants were asked to solve 70 tasks (35 convergent, 35 divergent), whereas the remaining participants solved 59 tasks from the original set plus one new task (60 tasks in total: 30 convergent, 30 divergent). From the initial set of 70 tasks, 11 tasks that were either too easy or too difficult according to the pilot results were excluded, and one new task was created. Due to technical reasons, data from two participants were preserved for only 45 and 43 tasks, respectively.

## Procedure

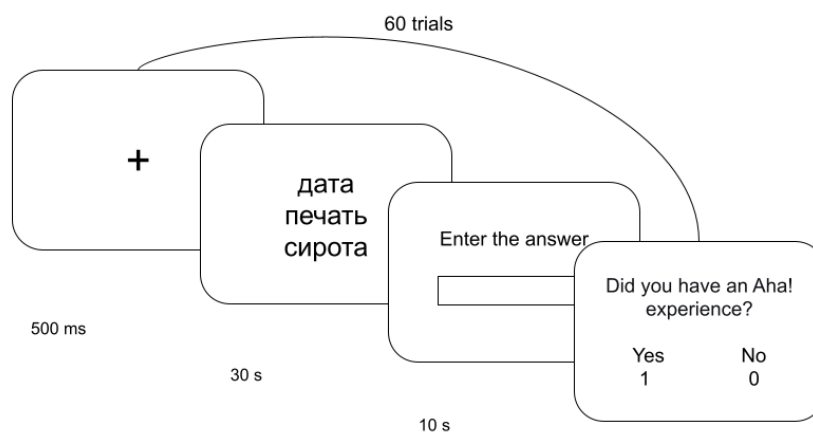
The study procedure was created using the online builder lab.js (Henninger, Shevchenko, Mertens, Kieslich, & Hilbig, 2021). The OpenLab platform (<https://open-lab.online/>) was used to implement the procedure online. Participants used their personal computers to complete the study. Audio communication between the participant and the researcher was maintained throughout the session.

First, participants read the instructions for completing the remote associate tasks and a description of what the researchers mean by an Aha-experience. Participants then completed a practice session consisting of three tasks to familiarise themselves with the experimental interface. After this, participants were given the opportunity to ask the researcher questions about the procedure. The main session, comprising 60 tasks, then began.

Each new trial began with the presentation of a fixation cross for 500 ms. Following this, the triad appeared—three nouns were displayed one below the other in the centre of the screen. Participants had a maximum of 30 seconds to solve each task. At any point when they identified a common adjective, they could move to answer input with the spacebar. Additionally, after 30 seconds, the answer input field appeared automatically. Participants were required to type the adjective into the answer input field using the keyboard. If a participant could not find a common word, they were required to type “no” into the answer input field. After entering their answer, participants pressed the “Enter” key. The time allowed for answer entry was limited to 10 seconds. After that, participants were asked to indicate whether they had an Aha-experience (“Yes”—press “1”, “No”—press “0”).

## Figure 2.

### *Study procedure*



## Data analysis

The data were processed using the Python programming language (version 3.9). At the first stage, descriptive statistics were calculated, and the balance between convergent and divergent triads was assessed on metrics of objective task difficulty (proportion of correct solutions and mean solution time for correct answers). Additionally, the two triad types were compared on the probability of inducing an Aha-experience and on the distribution of error types (proportion of intrusions relative to the total number of errors). Independent-samples t-tests were used to assess differences between the two triad types.

At the second stage, we analysed the contribution of linguistic predictors to the probability of a correct solution, the time to discover the correct answer, and the probability of an Aha-experience. To this end, Bayesian hierarchical models were constructed. The advantages of Bayesian methods include greater flexibility in modelling the dependent variable (e.g., using censored distributions and the exponentially modified Gaussian distribution for response times), as well as the ability to quantify evidence in favour of the proposed hypotheses and to use the resulting posterior distributions as prior knowledge in subsequent studies employing the developed stimulus material (Whelan, 2008; Wagenmakers et al., 2018). The hierarchical approach allows for the identification of general patterns in the data while accounting for individual differences (in the present study, a participant-level hierarchical structure was

used—specifically, a model with random intercepts capturing variability between participants) (Casella, Fienberg & Olkin, 2006). The structure of the constructed models is briefly described below.

Before model construction, data from three participants who never reported an Aha-experience during the study were excluded from the full dataset. The following predictors were included in all three models—triad type (convergent vs. divergent), frequency of the first triad word, frequency of the target word, semantic distance among triad words, and the highest collocation strength between the target word and the triad words ( $\text{LogDice}_{\text{max}}$ ). Initially, triads were selected such that  $\text{LogDice}$  was high on average (approximately 9 for both triad types); however, in some cases it varied over a fairly wide range, so it was decided to include it in the model. Moreover, we decided to use the highest collocation strength between the target word and any word within a triad, as we hypothesised that this metric would most strongly influence the speed with which a correct guess occurs. Visual inspection of the distributions of the linguistic predictors revealed extremely high variability in the frequency metrics, with values spanning several orders of magnitude. Consequently, the frequency of the first triad word and the frequency of the target word were log-transformed, and all linguistic predictors were scaled to a common scale through standardisation.

To assess the relationship between the linguistic properties of the tasks and the probability of finding the correct answer and the probability of an Aha-experience, we constructed Bayesian regression models with a binomial likelihood function and a participant-level hierarchy. To assess the relationship between the linguistic predictors and the time to find the correct answer, we constructed a Bayesian hierarchical regression with an exponentially modified Gaussian (ExGaussian) likelihood function. The ExGaussian distribution is defined by three parameters:  $\mu$ —the mean of the Gaussian component,  $\sigma$ —its standard deviation, and  $\nu$ —the rate of the exponential component. The first two parameters reflect the main fast and relatively symmetric part of the response time distribution, while the latter reflects longer responses (it forms the “tail” of the distribution). The response time distribution was right-censored by the study design (maximum 30 seconds), which was also accounted for in the model using a censoring procedure. The models for response time and Aha-experience probability were built only for trials in which the correct answer was found.

Because the Bayesian approach does not rely on classical significance tests, inferences about model parameters were made based on Bayesian credible intervals (HDI, highest density intervals). A parameter was considered significant if its 94% credible interval (3%–97% HDI) lay entirely on one side of zero (if it did not contain zero).

To ensure that the estimates of all models were primarily determined by the data, weakly informative priors were used. Modelling was performed using the PyMC library (version 5.3) in Python. Convergence of the models was assessed using the R-hat and the effective sample size (ESS) statistics. All models showed good convergence (*see more details in the online repository, <https://osf.io/6afmw>*).

## Results

### Comparison of convergent and divergent triads on objective difficulty, probability of an Aha-experience, and error type distribution

To test whether convergent and divergent triads were balanced on objective difficulty metrics (proportion of correct answers and mean solution time for correct answers), and to compare the two triad types on the probability of an Aha-experience and on error type distribution, the data were averaged by triad. The probability of an Aha-experience was calculated as the proportion of Aha! reports out of the total number of trials in which a correct answer was given. The proportion of intrusions was calculated as the number of intrusions divided by the total number of errors (for each triad). The results of the mean comparisons using independent-samples t-tests are presented in Table 2; a full table with data for each triad is provided in Appendix 2.

According to the analysis, the resulting sets of convergent and divergent triads showed no significant differences in either the probability or the mean solution time for correct answers, so they were approximately balanced in difficulty. At the same time, the probability of a correct solution accompanied by an Aha-experience was significantly higher for divergent triads compared to convergent triads, which corresponds to our expectations. Another significant difference was found when analysing errors. For convergent triads, intrusions predominated (participants frequently provided incorrect alternative answers). In contrast, for divergent triads, omission errors predominated (when unable to find the correct answer, participants more often left the answer field blank rather than providing an incorrect alternative).

**Table 2**

*Comparison of convergent and divergent triads on objective difficulty, probability of an Aha-experience, and error type distribution*

Triad type	Convergent		Divergent		Effect size	t-test, df	p-value
	Mean	SD	Mean	SD			
Proportion of correct answers (solvability)	0.46	0.25	0.50	0.20	-0.192	t = -0.745, df = 58	p = 0.459
Time to find the correct answer (in seconds)	10,75	2,68	11,09	2,75	-0.124	t = -0.480, df = 58	p = 0.633

Triad type	Convergent		Divergent		Effect size	t-test, df	p-value
	Mean	SD	Mean	SD			
Proportion of Aha-reports for correct-answer trials	0.42	0.11	0.57	0.12	-1.321	t = - 5.115, df = 58	p < 0.001
Proportion of intrusions out of total errors	0.67	0.13	0.42	0.15	1.734	t = 6.717, df = 58	p < 0.001

### Analysis of the relationship between the probability of finding the correct answer and the linguistic properties of triads

In the model constructed to analyse the relationship between the probability of a correct answer and triad linguistic properties, the binary dependent variable was answer correctness (correct/incorrect). The fixed factors were—triad type (convergent vs. divergent), semantic distance among triad words, maximum collocation strength of target word combinations ( $\text{LogDice}_{\text{max}}$ ), frequency of the first triad word, and frequency of the target word. The random factor was participant.

It was found that target word frequency and  $\text{LogDice}_{\text{max}}$  were significant positive predictors of the probability of finding the correct answer. Thus, the higher the target word frequency and the stronger the collocations formed by the triad words with the target word, the higher the probability of finding the correct answer for a given triad. First-word frequency, in contrast, turned out to be a negative predictor of correct answer probability—the higher the frequency of the first triad word, the lower the probability of finding the correct answer. No evidence was found for an effect of triad type or semantic distance among triad words on correct answer probability.

Table 3 presents the posterior means (mean), standard deviations (sd), and 94% Bayesian credible intervals (HDI 3%–97%) for the key model parameters. For visualisation, partial dependence plots were constructed showing the average predicted probability of finding the correct answer at different values of each linguistic predictor (all other predictors held at their means), separately for convergent and divergent triads. These are presented in Figure 3.

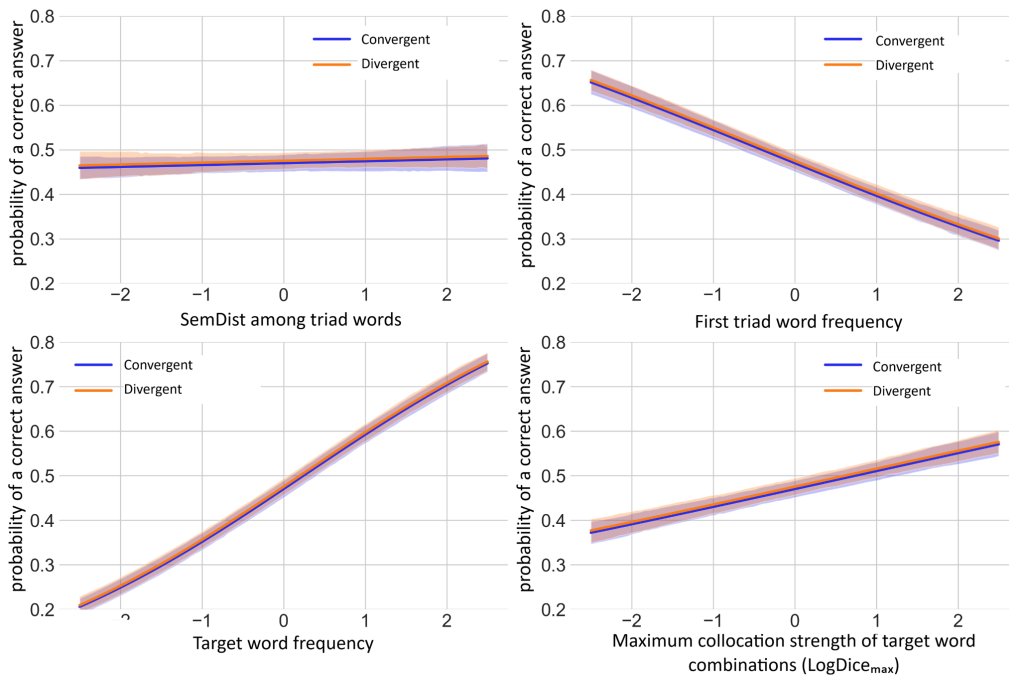
**Table 3**

*Model parameters and posterior distribution metrics for the probability of a correct answer*

<i>a</i>	mean	sd	hdi 3%	hdi 97%
<i>Group-level intercept</i>	-0.120	0.079	-0.266	0.032
Triad type	0.020	0.073	-0.113	0.156
SemDist among triad words	0.017	0.037	-0.049	0.092
Maximum collocation strength of target word combinations ( $\text{LogDice}_{\max}$ )	0.161	0.034	0.097	0.224
First triad word frequency	-0.298	0.036	-0.364	-0.228
Target word frequency	0.492	0.036	0.426	0.562
Participant-level standard deviation	0.517	0.061	0.406	0.633

**Figure 3**

*Partial dependence plots for the probability of a correct answer as a function of the linguistic properties of triads*



## Analysis of the relationship between time to find the correct answer and the linguistic properties of triads

To analyse the relationship between time to find the correct answer and the linguistic properties of triads, a series of models was constructed incorporating individual and linguistic predictors into the Gaussian, exponential, and both components of the response time distribution. Model evaluation and comparison (*see the online repository*, <https://osf.io/6afmw>) revealed that participant effects and the effects of linguistic predictors were captured by the exponential part of the distribution (they were associated with the  $\nu$  parameter). In the final model, the dependent variable was time to find the correct answer. The fixed factors were—triad type (convergent vs. divergent), semantic distance among triad words, maximum collocation strength of target word combinations ( $\text{LogDice}_{\max}$ ), frequency of the first triad word, and frequency of the target word. The random factor was participant.

The linguistic predictor that showed a statistically significant effect on time to find the correct answer was target word frequency—its posterior distribution lay entirely in the negative region (3%–97% HDI < 0), indicating that more frequent words are discovered more quickly. In addition, a significant difference in time to find the correct answer was found between divergent and convergent triads—divergent triads on average required more solution time (96.8% of the posterior distribution of the coefficient lay to the right of zero). These patterns are illustrated in the partial dependence plots showing the relationship between solution time and triad properties in Figure 4. For the remaining linguistic predictors (first word frequency and  $\text{LogDice}_{\max}$ ), the posterior distributions included zero, which does not allow us to confidently infer their contribution to the model. Posterior means, standard deviations, and credible intervals for the model parameters are presented in Table 4.

**Table 4**

*Model parameters and posterior distribution metrics for time to find the correct answer*

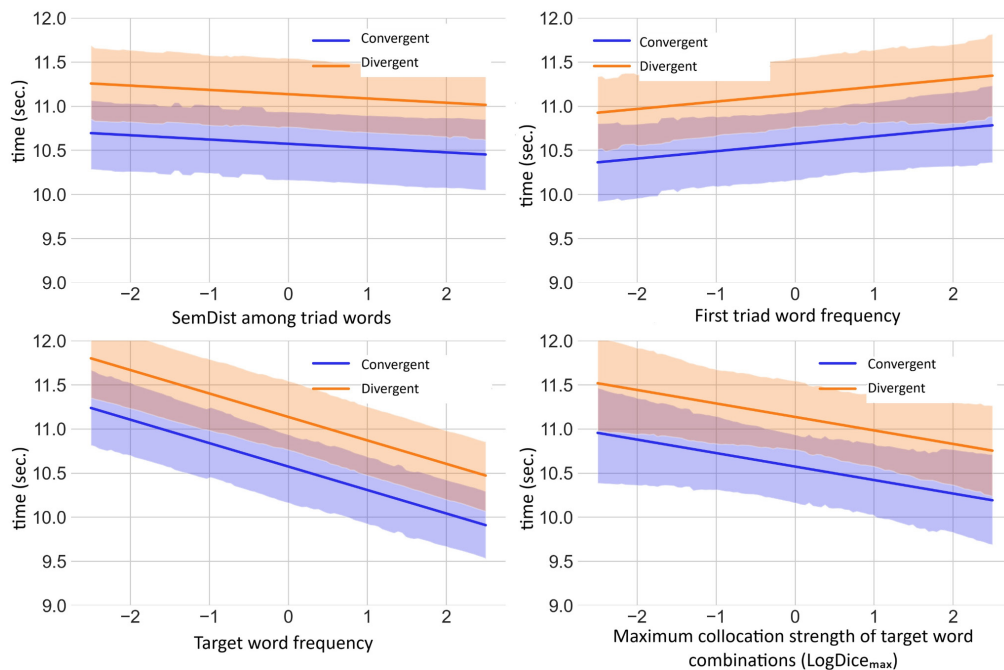
	mean (sec.)	sd	hdi 3%	hdi 97%
Group-level intercept for $\mu$ (Gaussian component)	2.423	0.068	2.293	2.550
Group-level intercept for $\sigma$ (Gaussian component)	0.630	0.059	0.519	0.739
Group-level intercept for $\nu$ (exponential component)	8.161	0.427	7.405	9.016
Triad type	0.560	0.307	-0.015	1.124

	mean (sec.)	sd	hdi 3%	hdi 97%
SemDist among triad words	-0.048	0.039	-0.117	0.029
Maximum collocation strength of target word combinations (LogDice <sub>max</sub> )	-0.152	0.156	-0.432	0.148
First triad word frequency	0.082	0.084	-0.078	0.239
Target word frequency	-0.264	0.056	-0.371	-0.161
Participant-level standard deviation	2.692	0.300	2.137	3.256

Note: All linguistic predictors, as well as the participant effect, load onto the  $v$  parameter (onto the exponential component of the response time distribution).

**Figure 4.**

Partial dependence plots for time to find the correct answer as a function of triad properties



## Analysis of the relationship between the probability of an Aha-experience upon finding the correct answer and the linguistic properties of triads

To analyse the relationship between the probability of an Aha-experience and the linguistic properties of triads, a model was constructed in which the binary dependent variable was the presence of an Aha-experience upon finding the correct answer. The fixed factors were: triad type (convergent vs. divergent), semantic distance among triad words, maximum collocation strength of target word combinations ( $\text{LogDice}_{\text{max}}$ ), frequency of the first triad word, and frequency of the target word. The random factor was participant.

Triad type proved to be a significant predictor of Aha-experience probability. Aha-experience occurred more frequently for divergent triads compared to convergent ones. Semantic distance among triad words was also positively related to Aha-experience probability. The farther apart the triad words are located in semantic space, the more likely an Aha-experience is to occur when the answer is found. No convincing evidence was found for a relationship between first word frequency or  $\text{LogDice}_{\text{max}}$  and Aha-experience probability. Target word frequency was a negative predictor of Aha-experience probability. The more frequent the target word, the lower the probability of an Aha-experience upon its discovery.

Table 5 presents the posterior means, standard deviations, and credible intervals for the parameters of the model described above. Figure 5 shows partial dependence plots of Aha-experience as a function of the linguistic properties of triads, with convergent and divergent triads distinguished by colour.

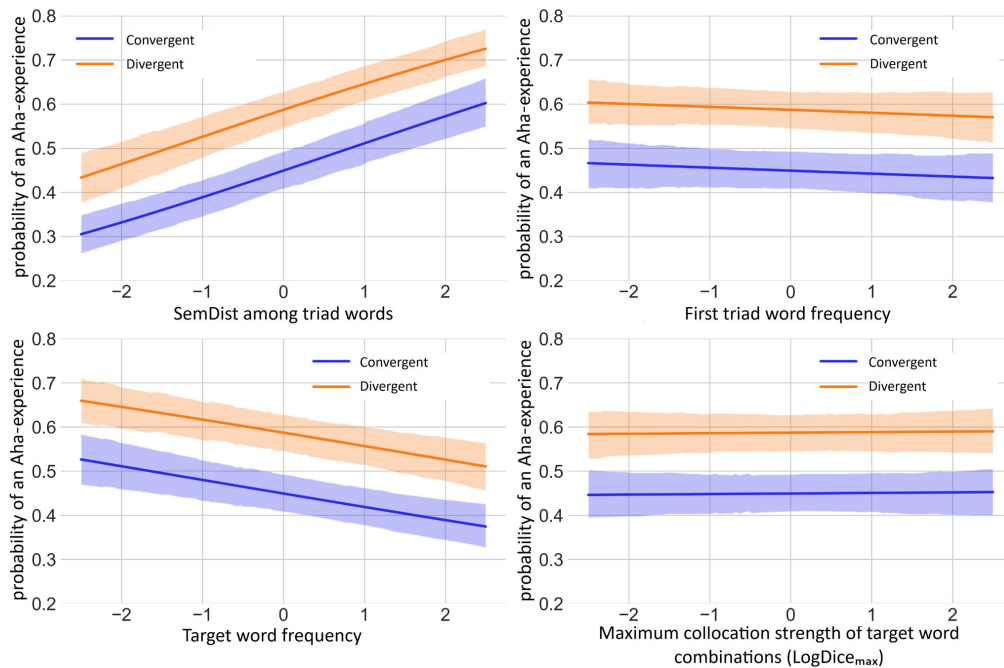
**Table 5**

*Model parameters and posterior distribution metrics for the probability of an Aha-experience upon finding the correct answer*

	mean	sd	hdi 3%	hdi 97%
Group-level intercept	-0.207	0.180	-0.555	0.125
Triad type	0.557	0.117	0.341	0.777
SemDist among triad words	0.248	0.058	0.138	0.354
Maximum collocation strength of target word combinations ( $\text{LogDice}_{\text{max}}$ )	0.006	0.055	-0.098	0.110
First triad word frequency	-0.028	0.061	-0.144	0.086
Target word frequency	-0.125	0.060	-0.233	-0.009
Participant-level standard deviation	1.329	0.143	1.058	1.585

**Figure 5.**

*Partial dependence plots for the probability of an Aha-experience upon finding the correct answer as a function of triad properties*



## Discussion

The aim of the present study was to develop and validate a new set of remote associate tasks in Russian for insight research, as well as to identify and describe the linguistic properties of the tasks that serve as predictors of objective task difficulty (probability and time of solution) and the probability of an Aha-experience during problem solving. In developing the task set, we sought to select semantically divergent and convergent triads (potentially insightful and non-insightful, respectively), while balancing the two task types by difficulty as far as possible.

We hypothesised that the frequency of the first triad word and the frequency of the target word could serve as sources of difficulty in remote associate tasks. The first word plays an important role because participants' spontaneous strategy typically involves generating associations to the first word and then checking whether the resulting guesses fit the remaining triad words. Our hypothesis was confirmed—first-word frequency was negatively related to the probability of a correct solution. This finding is consistent with the results of our previous study (Moroshkina et al., 2020) and with the study by Sio and colleagues Sio,

Kotovskiy, & Cagan 2021), who showed that as the number of strong irrelevant associates to the triad words increases, solution time slows down. According to corpus data, word frequency is strongly positively correlated with the number of collocates with which the word has high co-occurrence frequency. At the same time, consistent with previous studies (Vlasov, 2021), target word frequency was positively related to the probability of its discovery.

Although we balanced the triads on the collocation strength between the triad words and the target word (LogDice), thereby reducing the variance of this metric, we found that the maximum collocation strength of target word combinations was positively related to the probability of finding the correct answer. This finding is consistent with previous results by M. Marko and colleagues, who showed that syntagmatic distance between triad words and the target word (also calculated using LogDice) was positively related to task difficulty (Marko, Michalko, & Riečanský, 2019). The authors also reported that syntagmatic distance, calculated from a text corpus, and associative distance, obtained from an association experiment, correlated rather strongly positively ( $r = 0.64$ ). This may indicate that corpus-based linguistic metrics and distributional models derived from texts can adequately reflect the solver's mental lexicon.

The analysis also showed that we succeeded in balancing convergent and divergent triads by difficulty. The mean proportion of correct answers was 0.46 for convergent triads and 0.50 for divergent triads (difference not significant). At the same time, as we expected, triad type was strongly associated with the predominant error type. We hypothesised that for convergent triads — in which all three triad words are related to the target word through a single shared meaning — these words might also share many common associates, creating greater competition between the target word and other associations. For example, for the triad **зубы / парус / знамя** (*lips / sail / banner*), the correct answer is **алый** (*scarlet*), while a frequent intrusion is **красный** (*red*). However, the word **красный** (*red*) cannot be considered correct because, according to the instructions, the answer must form a strong/stable collocation; “red sails” is not such a collocation, whereas “scarlet sails” is. In contrast to convergent triads, for divergent triads we expected omission errors to predominate, because the triad words share virtually no common contexts of use and combine with the target word through its different meanings. This hypothesis was confirmed—the proportion of intrusions out of total errors was 0.67 for convergent triads, compared to 0.42 for divergent triads.

Our main hypothesis was that the semantically divergent triads we selected would trigger an Aha-experience upon finding the correct solution more often than convergent triads. This hypothesis was confirmed, although the difference cannot be described as large (mean proportion of Aha-solutions for divergent triads—0.57; for convergent triads—0.42). Nevertheless, the difference is significant, and the effect size is quite high by statistical standards (Cohen's  $d = 1.321$ ). Unlike objective task difficulty, the probability of reporting an Aha-experience is determined to a much greater extent by subjective factors. It is important to note that the study included separate participants who almost always reported an Aha-experience when they found the answer, as well as those who almost never reported an Aha-experience. This depends not only on the properties of the tasks themselves, but also on

how developed participants' reflection is and how they relate their subjective experience in the study to their own lay theories of insight.

Nevertheless, despite the subjectivity of the Aha-experience phenomenon, we also succeeded in confirming the hypothesis that the linguistic properties of the tasks contribute significantly to its probability. As expected, semantic distance among triad words was positively related to reports about Aha-experience. According to our hypothesis, the greater the semantic distance among triad words, the weaker the intuitive sense of coherence in the early stages and the lower the participant's expectations (based on that sense) regarding the ease/fluency of retrieving the solution. This prediction turns out to be erroneous when the participant, upon discovering the solution, retrieves all the collocations embedded in the triad relatively quickly. Consequently, the actual processing fluency of the target word and its associations with the triad significantly exceeds the expected fluency (retrospectively, the solution seems obvious), and an Aha-experience occurs.

Our results are partially consistent with those of Becker and colleagues (Becker et al., 2022), who showed that the subjective suddenness of the solution—a component of the Aha-experience—is higher when semantic coherence among the triad words is weaker. At the same time, the authors also found a positive relationship between subjective suddenness and the semantic coherence between the target word and the triad. In our study, the relationship between the target word and the triad was controlled using a syntagmatic distance metric (LogDice), and we did not find a relationship between this metric and the Aha-experience. This may be due to the fact that this metric was uniformly high for all triads (its variance was severely restricted from the outset).

Furthermore, we found that the probability of an Aha-experience was negatively related to the frequency of the target word. Target word frequency was also negatively related to the time to find the correct answer. Taken together, these findings suggest that for an Aha-experience to occur, the task must not be too easy, and the solver must have time to experience incomprehension before the answer emerges. This result is consistent with previous studies (Ishikawa et al., 2019; Moroshkina et al., 2022).

Overall, the results of the conducted analysis allow us to conclude that the main aim of the study has been achieved. We have developed remote associate tasks of two types (potentially insightful and potentially non-insightful). This does not eliminate the need to use subjective reports of Aha-experiences, but it does allow for better control over the variation/manipulation of factors associated with the potential insightfulness of the solution. Furthermore, the task set we have developed contains a clear specification of the tasks and a description of their linguistic properties related to objective task difficulty; the tasks are balanced on a number of additional parameters (such as the type of word relations in the resulting collocations, the strength of those relations, and grammatical uniformity). The proposed approach can be scaled to create new task sets for specific research purposes.

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## **Supplementary materials**

*Online repository:* <https://osf.io/6afmw>

## Appendix 1

### Complete list of CRAT-RUS tasks and their linguistic properties

№	Answer	Word 1	Word 2	Word 3	Type	Sem-Dist	Freq1	FreqAns	Log-Dice <sub>max</sub>
1	алый	парус	губы	знамя	conv	27,02	8618	5467	10,82
2	божий	дар	суд	промысел	conv	24,05	20182	53122	10,13
3	взаимный	помощь	обязательства	доверие	conv	19,33	100778	14049	10,14
4	военный	госпиталь	училище	отряд	conv	23,91	11532	102056	9,82
5	высший	проба	сорт	пилотаж	conv	21,43	7133	61862	9,20
6	газовый	баллон	котел	колонка	conv	17,15	1899	7176	10,11
7	главный	приз	козырь	герой	conv	21,85	5088	154634	10,26
8	глубокий	колодец	рана	след	conv	22,82	7695	60780	9,16
9	горный	река	тропа	вершина	conv	19,62	101228	22310	10,26
10	детский	страхи	книги	игры	conv	23,77	58080	48209	9,77
11	жирный	крем	свинья	пища	conv	24,41	3511	9676	8,84
12	идеальный	чистота	вариант	форма	conv	22,50	13870	11615	9,25
13	космический	пространство	спутник	пыль	conv	23,10	47473	17916	10,37
14	летний	платье	лагерь	кафе	conv	25,32	39847	21325	9,30
15	личный	пример	разговор	просьба	conv	23,72	68241	59604	8,69
16	массовый	протест	безработица	мероприятие	conv	22,58	11465	19925	8,84
17	мокрый	снег	нос	асфальт	conv	21,64	63519	22723	10,37

№	Answer	Word 1	Word 2	Word 3	Type	Sem-Dist	Freq1	FreqAns	Log-Dice <sub>max</sub>
18	ответный	письмо	реакция	удар	conv	26,88	184226	4611	9,70
19	пламенный	речь	призыв	привет	conv	21,54	107837	4596	9,13
20	преступный	замысел	деятельность	халатность	conv	20,97	10683	7834	9,67
21	пустой	бутылки	карманы	улицы	conv	22,81	33042	51783	10,40
22	рабочий	стол	стаж	кабинет	conv	24,34	154690	46840	9,27
23	семейный	портрет	бюджет	очаг	conv	26,85	34886	24364	10,20
24	стойкий / сильный	ощущение	запах	иммунитет	conv	24,37	32630	2984	9,35
25	стройный	ноги	талиа	кипарис	conv	21,88	189325	11470	9,05
26	тайный	агент	свидание	голосование	conv	23,85	14052	24807	10,14
27	тихий	шорох	шепот	стон	conv	17,54	5071	46347	8,90
28	учебный	центр	план	нагрузка	conv	23,71	68601	21384	9,46
29	шахматный	король	турнир	партия	conv	23,64	45049	3801	10,52
30	экстремальный	туризм	условия	ситуация	conv	23,53	2132	1551	9,71
31	беглый	раб	чтение	взгляд	div	25,61	16315	5579	9,15
32	белый	танец	стих	флаг	div	24,10	6689	149048	8,92
33	верный	слуга	догадка	гибель	div	22,51	19047	54153	10,37
34	горький	пьяница	обида	шоколад	div	20,25	5894	16956	10,09
35	грудной	молоко	клетка	ребенок	div	23,28	23191	4769	11,02
36	деловой	переписка	круги	колбаса	div	23,67	11178	13555	9,12

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№	Answer	Word 1	Word 2	Word 3	Type	Sem-Dist	Freq1	FreqAns	Log-Dice <sub>max</sub>
37	домашний	скот	задание	арест	div	25,26	14148	27128	10,22
38	железный	дорога	занавес	логика	div	24,53	172179	48856	12,13
39	звездный	час	карта	болезнь	div	26,56	242654	6999	8,54
40	золотой	молодежь	руки	век	div	30,35	27596	54946	9,63
41	каменный	джунгли	лицо	уголь	div	24,91	1749	33224	10,86
42	крепкий	чай	сон	дружба	div	24,54	63003	32867	9,92
43	круглый	дата	печать	сирота	div	24,01	10836	28389	10,46
44	крутой	нрав	яйцо	поворот	div	24,26	13860	17782	10,97
45	мягкий	обложка	знак	посадка	div	23,40	4822	32978	9,68
46	натуральный	блондинка	логарифм	хозяйство	div	23,12	3297	8136	9,09
47	простой	карандаш	число	предложение	div	24,77	12942	93373	7,76
48	свинцовый	пуля	тяжесть	небо	div	24,54	11917	3522	9,26
49	сердечный	клапан	приступ	благодарность	div	25,20	2798	12309	11,15

№	Answer	Word 1	Word 2	Word 3	Type	Sem-Dist	Freq1	FreqAns	Log-Dice <sub>max</sub>
50	слабый	пол	звено	надежда	div	25,59	69519	45334	9,23
51	сладкий	перец	жизнь	парочка	div	23,48	4584	16983	9,34
52	служебный	долг	роман	вход	div	26,29	39423	11520	9,50
53	собачий	холод	чушь	вальс	div	20,80	21322	7755	9,75
54	сонный	царство	артерия	муха	div	23,69	23457	7330	10,69
55	строгий	костюм	учитель-ница	ошейник	div	21,02	28245	29547	8,48
56	сухой	вино	климат	закон	div	27,23	42805	16983	8,97
57	туалетный	вода	бумага	столик	div	26,89	219771	1664	10,36
58	холодный	закуска	душ	война	div	27,03	6358	54328	9,71
59	цветной	капуста	металл	фото-графия	div	23,11	7969	12393	10,90
60	черный	юмор	список	лестница	div	26,90	8040	140305	8,90

**Note:** Type—triad type; SemDist—semantic distance among triad words; Freq1—frequency of the first triad word; FreqAns—frequency of the target word; LogDice<sub>max</sub>—maximum collocation strength among the three target word combinations.

## Appendix 2

### Complete list of CRAT-RUS tasks and validation data

№	Answer	Word 1	Word 2	Word 3	Type	N	Prop. corr	RT, sec.	Prop. Aha	Prop. Intr
1	алый	парус	губы	знамя	conv	69	0,41	9,37	0,46	0,76
2	божий	дар	суд	промысел	conv	69	0,58	8,63	0,25	0,66
3	взаимный	помощь	обязательства	доверие	conv	71	0,13	10,66	0,22	0,48
4	военный	госпиталь	училище	отряд	conv	71	0,78	10,26	0,42	0,81
5	высший	проба	сорт	пилотаж	conv	71	0,85	5,73	0,48	0,73
6	газовый	баллон	котел	колонка	conv	71	0,54	12,01	0,34	0,64
7	главный	приз	козырь	герой	conv	70	0,66	8,49	0,35	0,67
8	глубокий	колодец	рана	след	conv	70	0,91	7,20	0,45	1,00
9	горный	река	тропа	вершина	conv	70	0,36	9,34	0,48	0,69
10	детский	страхи	книги	игры	conv	70	0,56	12,47	0,39	0,48
11	жирный	крем	свинья	пища	conv	71	0,62	9,72	0,43	0,44
12	идеальный	чистота	вариант	форма	conv	70	0,17	18,92	0,25	0,50
13	космический	пространство	спутник	пыль	conv	70	0,51	11,27	0,36	0,62
14	летний	платье	лагерь	кафе	conv	71	0,61	8,85	0,47	0,79
15	личный	пример	разговор	просьба	conv	53	0,17	11,89	0,44	0,68

№	Answer	Word 1	Word 2	Word 3	Type	N	Prop. corr	RT, sec.	Prop. Aha	Prop. Intr
16	массовый	протест	безработица	мероприятие	conv	70	0,14	13,84	0,30	0,63
17	мокрый	снег	нос	асфальт	conv	71	0,49	10,81	0,49	0,78
18	ответный	письмо	реакция	удар	conv	71	0,16	7,80	0,64	0,70
19	пламенный	речь	призыв	привет	conv	71	0,34	9,07	0,42	0,64
20	преступный	замысел	деятельность	халатность	conv	71	0,18	11,45	0,54	0,59
21	пустой	бутылки	карманы	улицы	conv	71	0,79	11,69	0,32	0,80
22	рабочий	стол	стаж	кабинет	conv	71	0,47	12,43	0,61	0,82
23	семейный	портрет	бюджет	очаг	conv	71	0,54	12,05	0,61	0,55
24	стойкий / сильный	ощущение	запах	иммунитет	conv	70	0,11	14,98	0,50	0,90
25	стройный	ноги	талия	кипарис	conv	70	0,23	13,05	0,31	0,67
26	тайный	агент	свидание	голосование	conv	71	0,66	7,76	0,40	0,63
27	тихий	шорох	шепот	стон	conv	71	0,87	10,69	0,27	0,78
28	учебный	центр	план	нагрузка	conv	70	0,11	7,14	0,25	0,47
29	шахматный	король	турнир	партия	conv	70	0,49	11,60	0,50	0,72
30	экстремальный	туризм	условие	ситуация	conv	71	0,28	13,35	0,55	0,51

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№	Answer	Word 1	Word 2	Word 3	Type	N	Prop. corr	RT, sec.	Prop. Aha	Prop. Intr
31	беглый	раб	чтение	взгляд	div	71	0,17	12,63	0,92	0,53
32	белый	танец	стих	флаг	div	70	0,40	8,22	0,64	0,64
33	верный	слуга	догадка	гибель	div	71	0,49	12,71	0,54	0,36
34	горький	пьяница	обида	шоколад	div	70	0,87	13,40	0,39	0,33
35	грудной	молоко	клетка	ребенок	div	70	0,23	12,67	0,56	0,39
36	деловой	переписка	круги	колбаса	div	70	0,16	19,23	0,82	0,25
37	домашний	скот	задание	арест	div	71	0,69	9,75	0,55	0,14
38	железный	дорога	занавес	логика	div	71	0,39	8,92	0,61	0,40
39	звездный	час	карта	болезнь	div	70	0,26	6,15	0,33	0,52
40	золотой	молодежь	руки	век	div	70	0,63	11,64	0,66	0,35
41	каменный	джунгли	лицо	уголь	div	70	0,33	12,84	0,57	0,51
42	крепкий	чай	сон	дружба	div	70	0,86	7,04	0,45	0,70
43	круглый	дата	печать	сирота	div	71	0,54	10,58	0,63	0,36
44	крутой	нрав	яйцо	поворот	div	71	0,89	8,10	0,49	0,25
45	мягкий	обложка	знак	посадка	div	70	0,39	14,10	0,56	0,47
46	натуральный	блондинка	логарифм	хозяйство	div	71	0,39	14,08	0,46	0,28

№	Answer	Word 1	Word 2	Word 3	Type	N	Prop. corr	RT, sec.	Prop. Aha	Prop. Intr.
47	простой	карандаш	число	предложение	div	71	0,55	8,56	0,59	0,63
48	свинцовый	пуля	тяжесть	небо	div	71	0,49	13,49	0,54	0,14
49	сердечный	клапан	приступ	благодарность	div	71	0,70	11,48	0,64	0,33
50	слабый	пол	звено	надежда	div	70	0,50	11,82	0,43	0,46
51	сладкий	перец	жизнь	парочка	div	70	0,64	9,55	0,51	0,68
52	служебный	долг	роман	вход	div	70	0,39	10,20	0,56	0,42
53	собачий	холод	чушь	вальс	div	71	0,37	10,94	0,58	0,27
54	сонный	царство	артерия	муха	div	70	0,56	7,76	0,67	0,35
55	строгий	костюм	учительница	ошейник	div	70	0,56	15,12	0,49	0,52
56	сухой	вино	климат	закон	div	71	0,49	9,95	0,74	0,44
57	туалетный	вода	бумага	столик	div	70	0,21	12,51	0,53	0,62
58	холодный	закуска	душ	война	div	71	0,78	8,70	0,62	0,63
59	цветной	капуста	металл	фотография	div	70	0,44	10,07	0,58	0,38
60	черный	юмор	список	лестница	div	71	0,65	10,41	0,46	0,36

**Note:** Type—*triad type*; N—*number of participants who solved the triad*; Prop.corr—*proportion of correct answers for the triad out of total trials*; RT—*mean time to find the correct answer in seconds*; Prop.Aha—*proportion of correct-answer trials in which an Aha-experience occurred*; Prop.Intr—*proportion of intrusions out of total errors*.

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**Nadezhda V. Moroshkina** — overall project supervision, conceptualisation, development of stimulus materials and research methodology, analysis and interpretation of results, writing and editing of the manuscript

**Anna V. Kosyakova** — development of stimulus materials and research methodology, data collection, data analysis and interpretation, visualisation, writing and editing of the manuscript

**Alena P. Oshkanova** — development of stimulus materials and research methodology, data collection, editing of the manuscript

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## Conflict of Interest Information

The authors have no conflicts of interest to declare.