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Processing of stimuli with hidden semantics by the cognitive unconscious

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Abstract: The debate about the capabilities and limitations of the cognitive unconscious continues since the term first appeared in scientific discourse. Researchers pay special attention to the processes of reading and related semantic processing, since it is typically believed that they occur exclusively consciously. Cognitive psychology has accumulated impressive empirical material that questions the current state of affairs. Studies in the paradigms of artificial grammar learning, word superiority effect, subliminal priming provide sufficient grounds to assume the ability of the cognitive unconscious to process semantic material. In the present experimental study, the author clarify the forms of manifestation of the cognitive unconscious when processing text material, namely, words written from right to left (inversions) and meaningless letter combinations. The participants perform a mnemonic task to recognize previously presented stimuli in a series of fillers. It is supposed that stimuli with a hidden semantic component – inverted words – will have an advantage in the speed and frequency of recognition, compared to meaningless letter combinations, and fillers will be recognized more slowly and less often than previously presented relevant stimuli. The desired effects were not detected, but a classic result for cognitive psychology is observed – correct answers are given faster than erroneous ones, and correct recognition of inverted stimuli occurs faster than all, which, albeit indirectly, indicates unconscious semantic processing. There are reasons to believe that the hypothesis could not be experimentally confirmed due to the use of the original research paradigm. The author plans a study using the classic subliminal priming paradigm to re-test the hypotheses put forward.

Keywords: cognitive unconscious; priming; word superiority effect; implicit learning.

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INTRODUCTION

The debate about the capabilities and limitations of the cognitive unconscious continues since the term was introduced into psychological science [1–3]. Some scientists reasonably believe that the capabilities of the cognitive unconscious are very limited, if not "primitive", and that the incredible results of unconscious processing of information are merely the result of poor experimental design or incorrect mathematical processing [4; 5]. J. Bargh, on the contrary, argues that many mental processes that we traditionally associate with consciousness occur much faster unconsciously, and that unconscious mental processes are the foundation of our everyday social life [6–8]. However, can opponents of the "intelligent unconscious" be accused of excessive skepticism? After all, if we agree that the unconscious works better and faster than consciousness, then it becomes unclear why we need consciousness in that case.

Phenomena and effects indicating the "intelligence" of the cognitive unconscious have been empirically recorded. A. Reber experimentally demonstrated that test participants can significantly distinguish between letter rows composed according to some pattern and random letter rows, even if they are unable to formulate verbally the rule by which the row is composed [9; 10]. The experimental paradigm he used was called Artificial Grammar Learning (AGL). This paradigm has been repeatedly tested experimentally, and in most studies, the effect has been successfully reproduced: depending on the complexity of the stimulus material, the probability of distinguishing "correct" rows varied from 47 to 75 % [11].

Note that the grammar of everyday language also represents a certain pattern: a grammatically ordered group of letters forms a word that is quickly and easily read by cognitive mechanisms, even when it is written with an error. J. Cattell studied this fact first and called it the word superiority effect (WSE) [12]. The effect is that people recognize letters faster and more accurately when they are presented in words, and not in meaningless sets of letters. Moreover, the effect extends further: words that are not connected are read twice as slowly as words that form sentences. When reading a coherent text, the entire process of perception occurs more effectively. What is surprising is that the fact of putting words together into sentences is

always given a posteriori; therefore, it is unclear how the described acceleration works.

There are a number of competing hypotheses claiming to explain the emergence of the word superiority effect; however, there is no doubt about the reality of the discovered phenomenon [13; 14].

It is interesting, but for a word to be processed by the cognitive system, it is not necessary to be aware of the fact of its presentation. A. Marcel demonstrated this convincingly in a series of sophisticated experiments that gave rise to the experimental paradigm of subliminal priming [15; 16]. It was shown that test subjects, as a rule, did not make mistakes when recognizing a word in a lexical decision task if this word was preceded (even if presented for only 10 ms!) by a semantically related prime. The developed experimental paradigm is considered classical and is actively used in research [17; 18]. Despite the fact that both the research procedure itself and the methods of mathematical analysis are subject to criticism, the priming paradigm remains one of the most frequently used [19–21].

Note that in the previously mentioned studies [9–12; 15–18], semantically loaded material was presented in accordance with the rules and norms of language, albeit with some noise that interfered with conscious processing. However, will the semantic material be read if these rules are violated? Note: not in the absence of any rules, but with an atypical presentation of words.

It was found that when presented with levidrome words – words that, when read backwards, form other meaningful words (for example, FLOW, WOLF; DEW, WED), test participants tend to read from right to left if the word is more frequent when spelled backwards [22]. Results indicating the unconscious reading of levidrome words from right to left were obtained by V.M. Allakhverdov together with L.E. Osipov: test participants read levidrome words significantly more slowly if they had previously encountered their reverse version [23].

However, will the cognitive unconscious process stimuli, which are assessed subjectively as meaningless, as meaningful words? It would seem that an insatiable urge to search for patterns and a special sensitivity to verbal stimuli should push towards such a result.

The present study is based on the theory of consciousness of V.M. Allakhverdov [24] as one of the most, in author's opinion, original and carrying heuristic potential. The derived by V.M. Allakhverdov's laws of the work of consciousness have both theoretical and empirical bases, which allowed including them in the psychological laws section as a very stable part of psychological reality[1]. It is these psychological laws that served as the basis for predicting the results of the work of the cognitive unconscious when processing stimuli with hidden semantics. Let us list some of them. James's law – unchangeable information is displaced from consciousness; Hume's law – random events are attributed to non-random causes; Freud – Festinger law – contradictory information is either displaced from consciousness or distorted, eliminating the contradiction.

To recognize a stimulus as previously presented, a standard must be stored in consciousness, with which the currently presented stimulus is compared. In order to store a stimulus as a standard, according to James's law, the stimulus must be modified, transformed. If a stimulus subjectively evaluated by the test participant as meaningless is presented, then, according to the Freud – Festinger law, this stimulus must either be changed or repressed from consciousness. But the presented stimulus must be stored, which means that work must be done to transform it. Consequently, the task of memorizing the stimulus becomes equivalent to the task of transforming it. This transformation will be aimed at giving the stimulus meaningful content, since, according to Hume's law, randomness is unthinkable by consciousness, therefore, the presented set of letters will be evaluated a priori as regular. V.M. Allakhverdov asserts that consciousness cannot stand nonsense, that is why it independently introduces regularity into the presented images [24]. It seems that this will be equally true for a row of letters, since the processing of text material begins with its visual perception, and in this, letters are no different from other images[2]. It turns out that the most available for search pattern in a letter row is grammatical ordering, and along with it, semantic loading.

The latter position is especially important, because it is well known, and in some ways even self-evident, that meaningful information is remembered better than meaningless information. A number of authors believe that memorization occurs due to the provision of a stimulus with semantic content[3]. Even the phenomenal memory of S.V. Shereshevsky is explained through the somatisation of the memorized, sometimes meaningless, material. It can be assumed that memorization and comprehension are identical phenomena.

Meaningful words are remembered better and recognized faster, which is obvious in itself, but if these effects are noticed on subjectively meaningless stimuli with hidden semantics, it can be argued that through the change that is necessary to store the stimulus, its semantic interpretation was found. If the hidden semantic component of the stimuli was not discovered during their transformation, then they will not have any advantage.

The purpose of the study is to clarify the forms of manifestation of the cognitive unconscious when processing text material.

[1] *Balin V.D. Introduction to theoretical psychology. Sankt Petersburg, St. Petersburg State University Publ., 2012. 231 p.;*

Yurevich A.V. Psychology and methodology. Moscow, Institute of Psychology Publ., 2005. 310 p.

[2] *Hoffmann J. Active memory: experiment, experimental studies and theories of human memory. Moscow, Progress Publ., 1986. 308 p.*

[3] *Lindsay P., Norman D.A. Human information processing. Moscow, Mir Publ., 1974. 550 p.;*

Hoffmann J. Active memory: experiment, experimental studies and theories of human memory. Moscow, Progress Publ., 1986. 308 p.;

Norman D. Learning and memory. Moscow, Mir Publ., 1985. 159 p.;

Agafonov A.Yu. Man as a semantic model of the world. Samara, BAHRAH. M Publ., 2000. 336 p.

The following experimental hypotheses are put forward: 1) the cognitive unconscious significantly distinguishes relevant stimuli from irrelevant ones (fillers), which is expressed in the fact that relevant stimuli are (a) more often and (b) faster recognized than irrelevant ones; 2) the cognitive unconscious significantly distinguishes inverted words from a meaningless set of letters, which is expressed in the fact that inverted words will be (a) more often and (b) faster recognized compared to meaningless sets of letters.

METHODS

Sample

The study involved 112 people aged from 17 to 49 years (average age 24.65 years), including 49 men and 63 women. All participants had normal or corrected-to-normal vision and were native Russian speakers. Each participant was familiarized with the informed consent and gave voluntary consent to participate in the study with subsequent data processing. The proposed research hypotheses do not imply a more detailed collection of demographic data. Neither social status nor educational level are independent variables, since their significant influence on the obtained results is not initially assumed. General characteristics of mental processes are studied, which makes it appropriate to abstract from private and individual characteristics of the participants, moreover, these differences are taken into account in the mathematical model.

Stimulus material

Inverted words, i. e. words spelled backwards (for example, "privet" – "tevirp" (hello – olleh)), were chosen as stimulus material. The stimulus material was based on words of the Russian language included in the frequency dictionary[4], and was selected according to the following rules: 5 letters, 2 syllables, a consonant is always capitalized, letters in a word are not repeated.

Further, stimuli that in their inverted form resembled existing words were filtered. For example, the inversion of the word "zakon" – "nokaz" (law – wal) resembles the existing word "nakaz" (mandate), the inversion of the word "nomer" – "remon" (number – rebmun) resembles the existing word "remont" (repair, remount). It is known that words with a missing or one extra letter are highly likely to be read as a normal word due to the word superiority effect.

The phonetic complexity of the syllable makes it difficult to pronounce and perceive the stimulus[5]; therefore, stimuli forming in their inverted form phonemes that are atypical for the Russian language were selected. For example, the word "muzey" (museum) in its inverted form forms the unreadable "yesum".

Due to the presence of very strict parameters for selecting the stimulus material, it was not possible to match the selected words by frequency (ipm), but this parameter was taken into account in the mathematical model.

As a result, 12 nouns that underwent inversion were selected as target stimuli. 12 relevant – meaningless letter combinations were formed based on the selected nouns: the words were divided into syllables and mixed to form a meaningless letter combination corresponding to the previously specified parameters. 24 meaningless filler stimuli were created in the same way. Forming stimuli from the same syllables in different sequences was supposed to prevent their recognition by isolating smaller structural units (chunks), since for correct recognition it is necessary to preserve the entire stimulus.

Procedure

The study was conducted in person, in three stages, using a specially developed program based on LabJS.

The first stage is a demonstration of the stimulus series. In the experimental task, participants are asked to remember the presented letter rows (24 pcs., 12 – inverted words, 12 – meaningless letter combinations). The stimulus material is presented once, one after another, the demonstration time of each stimulus is 380 ms. There is a 36 ms break between stimuli so that the stimuli do not overlap. In this experiment, we refused to use a mask, since it additionally noisily interferes with the stimulus, and we assume that inversion is an analogue of noise that complicates the recognition of the stimulus as a meaningful word.

The second stage is a recognition task. 48 single stimuli, among which there are both relevant stimuli (inversion or nonsense) and fillers, are sequentially shown to participants. The participants are asked to decide whether they saw this stimulus at the demonstration stage or not.

The third stage is checking the awareness of the stimuli. After completing all the experimental tasks, the participants are informed that words were encrypted among the stimuli shown, and are asked whether they noticed this, and if so, they are asked to write down the words that were detected.

The presentation format is on the monitor screen, the decision on recognition of the stimulus is recorded by pressing the button for the corresponding answer. The time for making a decision is not limited, but the instructions ask to answer as soon as possible.

Statistical data processing

The jamovi program (version 2.5.3) was used for statistical analysis. The answer frequency analysis was performed in the program using a Generalized Mixed Model. The dependent variable was the participant's response (recognized – did not recognize), the factor was the stimulus type (inversion, nonsense or filler), the categorical dependent variable was logistic, and the cluster variables were individual differences in stimuli and test participants.

[4] *Lyashevskaya O.N., Sharov S.A. Frequency dictionary of the modern Russian language (based on the materials of Russian National Corpus). Moscow, Azbukovnik Publ., 2009. URL: http://dict.ruslang.ru/freq.php.*

[5] *Sarris M.E., Panagiotakopoulos C.T. Linguistic Effects on Anagram Solution: The Case of a Transparent Language. World Journal of Education, 2013, vol. 3, no. 4, pp. 41–51. DOI: 10.5430/wje.v3n4p41.*

The results for the time of making a decision on recognition were analyzed using a Mixed Model. Numerical values of time in milliseconds were subjected to logarithmation, and only logarithmic values were used in the model. Such a transformation makes the distribution closer to normal, softens the influence of extreme values and outliers, and helps to analyze relative changes in response time.

The selected statistical models are a more reliable analogue of ANOVA, which has proven its effectiveness in cognitive studies. It is assumed that the mixed model works primarily with normally distributed data, however, it is noted that violation of this rule does not usually lead to significant problems [25].

To minimize type I errors, the results were adjusted according to family-wise error control using the Holm multiple comparison method.

RESULTS

At the final stage of the experiment, the participants were informed that there were inverted words among the presented stimuli and were asked whether they noticed this. Only 7 of the 112 respondents were able to name meaningful words that were inverted, and they usually named no more than 2 out of 12 such words. It turns out that for the majority of respondents (94 %), inverted words were subjectively no different from a meaningless set of letters, and those respondents (6 %) who noticed the inversions were able to report no more than 2 words out of 12. The identified inversions were excluded from further analysis.

Statistically significant differences were found in the frequency of recognition of relevant stimuli and fillers (Fig. 1): relevant stimuli (63 %) are recognized significantly more often than false recognition of the filler (52.6 %) (p_{Holm}=0.009) occurs. The absolute difference in frequency appears to be insignificant, yet the participants show a consistent tendency to recognize relevant stimuli, which is consistent with the proposed hypothesis (1a).

Statistically significant differences were found in the frequency of recognition of inversions and fillers (Fig. 2): inversions (65.8 %) are recognized significantly more often than fillers (52.6 %) (p_{Holm}=0.022). However, no significant differences were found in the frequency of recognition of inversions and meaningless sets of letters (60.2 %) (p_{Holm}=0.335), as well as meaningless sets of letters and fillers (p_{Holm}=0.231), which contradicts the hypothesis (2a).

No statistically significant differences in response time were found for previously presented (relevant) stimuli and filler stimuli (Table 1): decisions on recognition of both types of stimuli were made at approximately the same rate (p_{Holm}=0.45). No significant differences in response time were found among inverted words and meaningless sets of letters (p_{Holm}=0.3), which contradicts the experimental hypotheses (1b and 2b).

At the same time, a result classical for experimental psychology was obtained: correct answers are given significantly faster than erroneous ones (Table 2). It means that respondents recognize relevant stimuli significantly faster than make an omission error (p_{Holm}<0.001); respondents erroneously recognize fillers significantly slower than make decisions about their correct non-recognition (p_{Holm}<0.001); respondents recognize inverted words significantly faster than make an omission error (p_{Holm}<0.001); respondents recognize meaningless sets of letters significantly faster than make an omission error (p_{Holm}<0.001). Moreover, statistically significantly less time is required to make the correct answer about recognizing an inverted word compared to a meaningless set of letters (p_{Holm}=0.003) and correct non-recognition of the filler (p_{Holm}<0.001). Apparently, inversions do have some advantage, albeit a very limited one.

DISCUSSION

According to the obtained results, our participants do not demonstrate unconscious differentiation between inverted words and meaningless sets of letters:

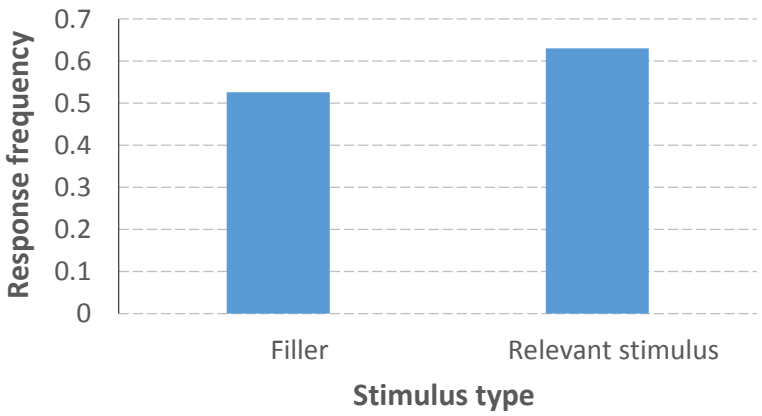

Fig. 1. *Average values of recognition of relevant stimuli and fillers*
Рис. 1. *Средние значения опознания релевантных стимулов и филлеров*

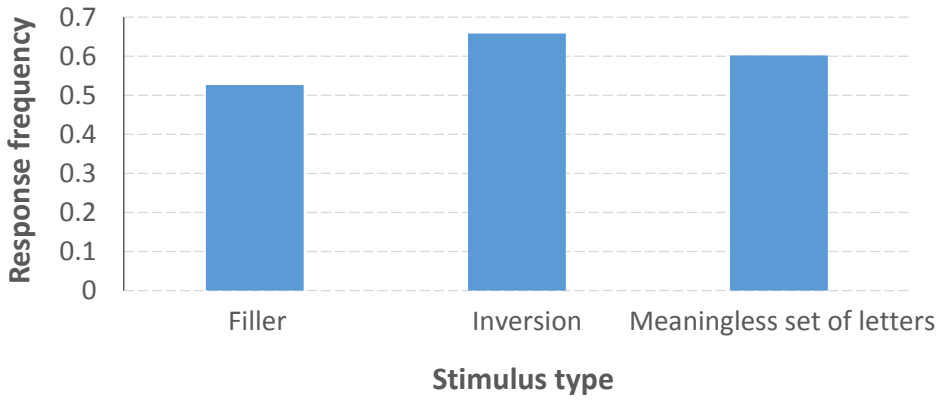

Fig. 2. *Average values of recognition of stimuli – inversions, meaningless sets of letters and fillers*
Рис. 2. *Средние значения опознания стимулов – инверсий, бессмысленных наборов букв и филлеров*

Table 1. *Average time of response to different types of stimuli, ms*
Таблица 1. *Среднее время ответа на разные типы стимулов, мс*

Stimulus type	Arithmetic average	Standard deviation
Relevant stimuli	1,150	838
Inversions	1,104	672
Meaningless sets of letters	1,195	974
Fillers	1,200	935

Table 2. *Average time to make correct and incorrect answers, ms*
Таблица 2. *Среднее время принятия верных и ошибочных ответов, мс*

Stimulus type	Answer type			
	Correct answer	Standard deviation	Erroneous answer	Standard deviation
Relevant stimuli	1,076	706	1,275	1,011
Inversions	1,016	503	1,274	890
Meaningless sets of letters	1,142	872	1,276	1,106
Fillers	1,145	976	1,248	894

no significant differences are observed in either the speed or frequency of recognition, which contradicts the proposed hypotheses (2a and 2b). However, it was found that the test participants significantly more often recognized previously presented stimuli (1a), and a result classical for cognitive psychology was also obtained – correct answers were given significantly faster than erroneous ones. Consequently, the respondents unconsciously distinguished between relevant stimuli and fillers, despite the fact that they subjectively assessed both types of stimuli as meaningless. This is possible only when imprinting and storing what was previously presented.

According to the previously introduced theoretical provisions, the storage of presented information is possible only when it is transformed, ordered and endowed with semantic content. Since the relevant stimuli were successfully recognized, these processes occurred.

Some test participants reported in the post-experimental interview that the stimuli presented to them evoked certain

associations that helped them memorize and subsequently recognize the stimulus. It is likely that the desired process of semantisation of meaningless material occurred, but took a different path than expected. This opens up the following possibility for interpretation: participants do not manifest a tendency to read unconsciously from right to left, the hidden semantic component is ignored, and the most adaptive strategy for memorizing meaningless material is to endow the stimulus with personal meaning. At the same time, if the participants could report it to us, then this process occurred consciously, which is contrary to the theory of the “smart” cognitive unconscious.

The results of this study cannot be interpreted either as a refutation of V.M. Allakhverdov’s theory or as evidence of the limited capabilities of the cognitive unconscious. Firstly, the alternative interpretation is argued against by the speed of stimulus material presentation – 380 ms, which is in the critical time window. This time is sufficient to see and read the stimulus, but not enough for a conscious search for an association, given that there are 24 such stimuli. It seems improbable that the obtained results indicate conscious semantisation. Secondly, it is also worth considering that when implementing an experimental study, there is a non-illusory chance to obtain a false negative result both due to the incorrect application of mathematical data processing methods and due to inaccuracies in the experimental design. It is likely that the obtained results may be associated with the original experimental paradigm, the “hidden pitfalls” of which have not yet been “polished” by many years of research experience. Further testing of the formulated hypotheses is planned using already established experimental paradigms.

CONCLUSIONS

1. Relevant stimuli are recognized significantly more often than fillers.

2. Inverted words are recognized significantly more often than fillers.

3. No significant differences were found between the recognition of inversions and meaningless sets of letters, either in speed or in frequency.

4. Correct answers are given significantly faster than incorrect ones.

5. Correct answers about recognizing inversions are given significantly faster than other correct answers.

6. Incorrect answers for all types of stimuli are given in the same time range.

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Обработка когнитивным бессознательным стимулов со скрытой семантикой

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Аннотация: Дискуссии вокруг возможностей и ограничений когнитивного бессознательного не утихают с момента появления этого термина в научном дискурсе. Особое внимание исследователей уделяется процессу чтения и связанной с ним семантической обработке, так как хрестоматийно считается, что они происходят исключительно сознательно. Когнитивная психология накопила внушительный эмпирический материал, ставящий под сомнение сложившееся положение дел. Исследования в парадигмах artificial grammar learning, word superiority effect, subliminal priming (англ. «искусственное изучение грамматики», «эффект превосходства слов», «подпороговый прайминг») дают достаточно оснований предполагать способность когнитивного бессознательного к обработке семантического материала. В настоящем экспериментальном исследовании уточняются формы проявления когнитивного бессознательного при обработке текстового материала, а именно слов, написанных справа налево (инверсии), и бессмысленных буквенных сочетаний. Испытуемые выполняют мнемическую задачу на узнавание ранее предъявленных стимулов в череде филлеров. Предполагается, что стимулы со скрытой семантической составляющей – инвертированные слова – будут обладать преимуществом в скорости и частоте узнавания, по сравнению с бессмысленными буквенными сочетаниями, а филлеры будут узнаваться медленнее и реже, нежели ранее предъявленные, релевантные стимулы. Искомых эффектов обнаружено не было, однако наблюдается классический для когнитивной психологии результат: верные ответы даются быстрее ошибочных, а верные узнавания инвертированных стимулов происходят быстрее всех, что, пускай и косвенно, свидетельствует о бессознательной семантической обработке. Есть основания полагать, что гипотезы не удалось экспериментально подтвердить ввиду использования оригинальной исследовательской парадигмы. Планируется исследование с использованием классической парадигмы subliminal priming (англ. «подпороговый прайминг») для повторной проверки выдвинутых гипотез.

Ключевые слова: когнитивное бессознательное; прайминг; имплицитное научение.

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