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Interaction of Semantic Contexts in Problem Solving: Congruence and Dissociation Effects

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Abstract

Introduction. Many cognitive phenomena can be justifiably interpreted as manifestations of contextual mediation: word superiority effects, priming effects, attitudinal effects, contextual memory effects, and so on. A separate area of research is the study of contextual interactions. In the present work, the aim was to identify congruence and dissociation effects in the interaction of short-term and ultra-short-term semantic contexts. **Methods.** The sample (121 subjects) was divided into four experimental and one control group. The procedure included five blocks of tasks. Participants were required to solve 15 anagrams (three tasks in each block). The short-term context was given by a sequence of words, which were the solutions to the anagrams. After the third anagram in each block, a prime - a word that either semantically matched the short-term context (congruence condition) or did not match it (dissociation condition) - was presented for 40 msec. After the mask, a target task was demonstrated - "complementing the base of the word to the whole". Conditions differed between groups according to congruence/dissociation of contexts and relevance/irrelevance to the solution. **Results.** Relevance and congruence conditions significantly reduced target task completion time. The effect was also evident in the reduced time of contextually related responses compared to the solution alternatives. In context dissociation conditions, there was a reduction in the strength of the effect of contextual interaction. **Discussion.** Contextual interactions have two main types: co-operation, and rivalry. Based on temporal stability, we can differentiate ultra-short-term, short-term, and long-term contexts. Their co-operation or competition defines the longitudinal type of interaction. The transversal type should include the interaction of simultaneously given contexts. The study took into account the types of interaction of the longitudinal type, as well as semantic "relevance/irrelevance" to the task solution.

The main result of the experiment can be considered the establishment of the effect of contextual additivity. The prospect of research may be the study of contextual interaction of different kinds and types.

Keywords

cognitive activity, context, types of context, contextual interactions, congruence and dissociation effects

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Introduction

The concept of "context" is actively used not only in linguistics, but also in scientific and psychological literature. In cognitive psychology, the context effect (CE) is understood as the result of the influence of psychological and situational factors that condition cognitive activity on problem solving (perceptual, attentional, mnemic, thinking, etc.). In other words, contextual mediation is referred to when some organised information, which precedes the process of problem solving, determines the productivity of its performance (Baars, 1989).

According to A. A. Verbitsky (2005), context is "a system of internal and external factors and conditions of human behaviour and activity that influence the features of perception, understanding and transformation of a particular situation" (pp. 137-138). In turn, P. Lindsay and D. Norman (1974) believe that context is a certain set of rules according to which a person constructs the perceptual world. Contexts define our expectations and ensure the meaningfulness of perception.

The idea that stimulus influences of the environment are not isolated is suggested by R. Solso (2006). On the one hand, any object is an element or part of the entire perceptual field, or, in other words, it is embedded in the situational context. On the other hand, the internal, psychological context proper, previously formed in perceptual experience, creates expectations that guide the top-down processes involved in the act of perception. It is known that the role of readiness for perception was particularly emphasised in his

concept by J. Bruner (1977). The opinion that subjective experience can act as a context of perception is shared by E. E. Bechtel and A. E. Bechtel (2005). "Context," these authors note, "is a mental construct that is used to recognise perceived objects, informationally enrich them and optimise perception" (p. 191).

The concept of "context" is one of the key concepts in B. Baars' (1989) theory of global workspace. Currently, it is one of the most popular cognitive theories of consciousness. To the main types B. Baars refers: contexts of perception and mental images, contexts of conceptual thinking, goal contexts and communication contexts (Baars, 1989, pp. 177). Baars (1989) pays special attention to the implicit nature of contextual influences: although a context can be formed as a result of previously realised influences, its influence is beyond conscious control at the moment of a cognitive act. V. M. Allakhverdov (2021) takes a similar position regarding the implicit nature of contextual influences. In his concept he distinguishes between positive and negative choice effects. The positive choice effect, in the broad sense of the word, is the information that is realised by the subject at a given moment of time. At the same time, the actual perceived but unconscious information is chosen negatively. Thus, the author specifies: "...negative choice determines what is usually called context, but without special efforts this context is usually not realised" (Allakhverdov, 2015, p. 1).

In the psychology of cognition, a large number of experimental effects have been described that can be considered private varieties of EC: priming effects (Marcel, 1981; Marcel, 1983; Falikman & Koifman, 2005; Agafonov, 2010; Gulan & Valerjev, 2010); attitudinal effects (Uznadze, 2004; Arbekova, 2016; Koifman, 2017); multivalence understanding effects (Rayner & Frazier, 1989; Kudelkina, 2008; Mamina, 2012; Filippova, Moroshkina, 2015; Haro, Demestre, Boada & Ferré, 2017; Filippova, Allakhverdov, 2020); context-dependent memory effects (Godden & Baddeley, 1975; Bower, Monteiro & Gilligan, 1978; Parker & Gellarty, 1997; Grant et. al, 1998; Isarida & Isarida, 2006; Isarida & Isarida, 2014); the effect of contextual cues (Chun & Jiang, 1998; Chun, 2000; Jiang & Chun, 2001); the effect of functional fixity in thinking (Dunker, 1965); and so forth. It is no coincidence that B. Baars (1989) believes that "context" is a collective concept for various phenomena of a wide cognitive spectrum; "it is a modern close relative of "attitude," "level of adaptation" in perception, and a variety of proposed knowledge structures and "frames" in cognitive science" (pp. 161).

A promising direction in the study of EC in cognitive activity is the study of contextual interactions. The search in this direction is stimulated by the idea that the subject of cognition can be simultaneously included in different contexts, so it is important to take into account the mediating influence on cognitive activity of intercontextual connections, not only local, isolated contexts. B. Baars (1989) distinguishes two main types of such interaction: competition (rivalry) and co-operation (pp. 392). In the case of competition, contexts are incompatible, i.e. conflicting with each other. In the case of co-operation, we can talk about their unification ("coalition", in B. Baars' terms). An example of co-operation is such interaction when some contexts are embedded in others.

In addition to the types described by B. Baars, we should also distinguish types of contextual interactions. Longitudinal and transversal types can be roughly distinguished. The longitudinal type includes interactions of contexts that have different temporal stability. By analogy with the accepted classification of memory types, contexts can be differentiated on this basis into ultra-short-term, short-term and long-term. Their interaction defines the longitudinal type of interaction. The transverse type includes the interaction of simultaneously given contexts. The same context can be involved in different types of interaction. In other words, intercontextual links can form a network of contextual interactions.

In our study, we took into account the types of contextual interaction of the longitudinal type, as well as such a characteristic of the context as "relevance/irrelevance" to the task solution (in our case - semantic correspondence of a separate context to the solution of the target task). Thus, the experimental plan assumed the variation of the states of two independent variables.

The aim of the study was to establish the influence of contextual interaction on the productivity of cognitive problem solving. The following hypotheses were tested:

- *Hypothesis 1*: The positive effect of the influence of contextual interaction will be most pronounced when the ultra-short-term and short-term contexts relevant to the target task are congruent;
- *Hypothesis 2*: The dissociation of ultra-short-term and short-term contexts will lead to a reduction in the strength of the influence of contextual interaction on problem solving;
- *Hypothesis 3*: The negative effect of contextual interaction will occur when there is congruence between short-term and ultra-short-term contexts irrelevant to the task.

Methods

Sampling

The procedure involved 121 participants (80 females and 41 males) aged 17 to 34 years (M = 22) with normal or corrected-to-normal vision. Four experimental groups (EG1-EG4) of 25 participants each and one control group (CG) of 21 subjects were formed. The experiment was conducted with each subject individually in laboratory conditions.

Study procedure

The experimental design was realized using the PsychoPy software package. A personal computer with a monitor diagonal of 18 inches was used.

The procedure consisted of five blocks of tasks. The subjects were instructed to solve 15 anagrams (three problems in each block). In each separate block, the sequence of

words that were anagram solutions established a short-term context (STC). The CCs for the different task blocks were formed by anagram solutions belonging to the following categories: "winter", "food", "sports", "furniture", "animals". For example, in the first block of tasks, subjects were presented with anagrams in which the following words were encoded: "holod", "sneg", "led". It took no more than 30 seconds to solve the anagram.

After solving the third anagram in each block, the ultra-short-term context (USC) was set. For this purpose, an experimental priming technique was used. A masked prime, a word that either semantically matched the CC (congruence condition) or did not match it (dissociation condition), was exposed to the subject in the centre of the screen for 40 ms. After prime stimulation, a grating mask was exposed for 100 ms. Immediately after the visual masking, a target task was demonstrated - "addition of the word base to the whole" (Falikman & Koifman, 2005). For example, the subject had to find as quickly as possible a word that matched the base "_oro_" (potential solutions could be the words: "moroz", "gorod", "korob", "threshold"). The following target tasks were presented: "_oro_", "_ul_a", "_urn_r", "_i_an", "_o_ka". The tasks could have a single solution ("_urn_r" / "turnir"; "_ul_a" / "bulka") or several possible solutions (e.g., "_i_an" / "divan", "tyran"). When finding an answer, the subject had to react as quickly as possible by pressing the "space" key, followed by naming the word aloud. The programme recorded the reaction time (RT) and the experimenter noted the subject's response in the experimental protocol. All stimuli were printed in bold, size 48. Before the main procedure, participants underwent a training phase.

The conditions in the groups differed according to context congruence/dissociation and relevance/irrelevance to the solution of the target problem:

- EG1: CC and USC are congruent and relevant to the solution of the target problem;
- EG2: contexts are congruent and irrelevant to the solution;
- EG3: contexts dissociated; CC was relevant to the decision USC was irrelevant;
- EG4: contexts dissociated; CC was irrelevant to the decision USC was relevant;
- CG: contexts are dissociated and irrelevant.

Results

Only those answers in the task blocks in which all three anagrams were solved were selected for processing. After removing outliers (values that were greater / less than two standard deviations from the mean), the data distributions became normal.

The experimental design is a patchwork design and is not a full factorial design; therefore, a one-factor analysis of variance was used to test the hypotheses. First, the time to solve the target task was analyzed for the factor "relevance / irrelevance of congruent contexts to the solution of the target task" for EG1 and EG2. (The dispersions in the compared groups did not differ significantly by Fisher's criterion, which confirms

the validity of using the analysis of variance: F = 1.781, p = 0.056). The results showed that subjects in EG1 were significantly faster in completing the target task than those in EG2: F (1; 48) = 6.462; p = 0.014.

Next, a one-factor analysis of variance was performed on the factor "context congruence/dissociation" with the results obtained in EG1, EG3 and EG4. Thus, the type of CC and USC interaction served as the independent variable. (The variances were not significantly different: F = 1.939, p = 0.069). Task performance was found to vary significantly across conditions: F(2; 69) = 7.017; p = 0.001. At the same time, CC mismatch with the target task solution (EG4) had a significantly stronger effect on task completion time than USC mismatch (EG3): by Tukey's criterion, p = 0.032. The results on RT for all groups of subjects are given in Table 1.

Table 1
Results of target tasks, in sec.

groups	Average solution time	Standard deviation	95 % confidence intervals	
			From.	Before
EG1	4,689	2,945	3,474	5,905
EG2	8,757	7,416	5,625	11,888
EG3	6,525	3,763	4,936	8,114
EG4	7,689	3,104	6,347	9,032
CG	11,269	7,103	8,019	14,486

Comparison of the experimental groups' indicators with the results of the CG was carried out using Tukey's criterion. It was found that RT in EG1 and EG3 was significantly lower than in CG: EG1 (p < 0.001), EG2 (p = 0.25), EG3 (p = 0.008), EG4 (p = 0.1).

Next, we analyzed the indicators of time spent by subjects on solving only those target tasks that potentially had several answer options. The RT in situations where the answers were words corresponding to the contexts (e.g., "holod", "turnir", "koshka") and the time of alternative answers (e.g., "gorod", "korob", "divan", "tyran", "gorka", "lodka") were compared (Table 2). Processing was performed using Student's t-criterion with Bonferroni correction.

Table 2
Results of solving target tasks with several answer options, in sec.

groups	Average time of contextually related responses, in sec	Average time of alternative answers, in sec
EG1	3,724	8,117
EG2	3,924	8,499
EG3	3,929	6,291
KG	6,07	5,677

It was found that subjects in EG1, EG2 and EG3 were significantly faster in giving the answer corresponding to both contexts (EG1) compared to the alternative choice: EG1 ($t(21) = 2.9$; $p = 0.046$). No significant differences were found in EG2, EG3 and CG: EG2 ($t(29) = 0.8$; $p > 0.05$), EG3 ($t(38) = 0.7$; $p > 0.05$), CG($t(24) = 0.15$; $p > 0.05$). In EG4, the subjects did not give any contextually related answers; therefore, no analyses on this indicator were conducted in this group.

The number of contextually related and alternative responses was compared using the χ^2 -Pearson criterion (Table 3).

Table 3
Number of contextually related and alternative responses

groups	Contextually related responses	Alternative answers
EG1	20	5
EG2	11	21
EG3	20	23
EG4	0	35
CG	6	20

The results showed that in EG1 there were significantly more "contextual" responses than alternative ones. In contrast, the opposite ratio was found in CG: EG1 ($\chi^2 = 7.84$; $p < 0.01$), EG2 ($\chi^2 = 2.532$; $p > 0.05$), EG3 ($\chi^2 = 0.094$; $p > 0.05$), CG ($\chi^2 = 6.5$; $p < 0.05$).

Discussion

The results of the study showed that the strength of the influence of contextual interaction on the solution of the insight-type task, which was the task "addition of the word base to the whole", depends both on the nature of the contexts' interaction and on their relevance to the solution.

When contexts are congruent and, at the same time, semantically relevant to the solution of the target task, the time spent on the task is significantly reduced. Thus, we can say that the cooperation of congruent contexts significantly increases the total power of contextual influence. We propose to understand "power" as a parametric characteristic of a context that reflects the measure of integration of individual, local contexts (e.g., semantic, perceptual, or spatial orientation contexts) into a single context. Such integration can take place in conditions of both longitudinal type of co-operation, as in our case, and transversal.

The cumulative positive effect of context co-operation was also manifested in a greater number of choices of contextually related solutions compared to alternatives. "Contextual" answers were given by the subjects four times more often than alternative answers. In turn, a significant difference was also found between the time of contextually relevant solutions and the time of alternative solutions: contextually related answers were given more than twice as fast.

This study result is consistent with the experimental data obtained by A. Marcel (1981), who used sequential prime stimulation, and with the data of D. Balota & S. Paul (1996). In the latter's experiment, the nature of the interaction between two successive prime stimuli preceding a target task varied. When the primes were semantically close, the severity of the priming effect increased. In our case, under the conditions of co-occurrence of relevant contexts, the expression of the EC increased.

At the same time, a noticeable decrease in the strength of the influence of contextual interaction occurs in conditions of context dissociation, when only one of them is relevant to the task solution. If the relevant USC slightly accelerates the solution (the effect was manifested at the level of tendency), the relevance of the CC has a much more noticeable facilitating effect on the solution. This is quite consistent with the results of an earlier study that assessed the difference in the degree of influence of previously realised and unrealised information on the effects of perception of ambiguous images (Agafonov, 2007).

The data obtained in the experiment also allow us to speak about the detected negative effect of the influence of contextual interaction. It manifested itself in the increase of task performance time in conditions when both contexts were congruent, but at the same time irrelevant to the solution.

Conclusion

The results of the study demonstrated that in conditions of co-operation of relevant semantic contexts, the total power of the context or, in other words, the strength of contextual influence on the solution of the task increases, which was manifested in the

- A meaningful reduction in task completion time;
- b) a greater number of contextually related answers compared to the number of answers semantically irrelevant to contexts;

- c) a meaningful reduction in the time of contextually related decisions compared to alternative choices.

Thus, an experimental fact has been established in the co-occurrence of relevant contexts, which can be tentatively called the *contextual additivity effect*.

In conditions of context dissociation, when only one of them is semantically relevant to the task solution, a decrease in the strength of the influence of contextual interaction was found. In this case, the semantic inconsistency of the short-term context with the solution slows down task performance more compared to the condition when the ultra-short-term context is irrelevant. In turn, a negative context effect was found in conditions where both contexts had no semantic correspondence with the potential solution.

Thus, the experimental results demonstrated both facilitative and inhibitory effects of contextual interaction on cognitive productivity.

The prospect of further research in this area may be the study of the effects of interaction between heterogeneous contexts of different types and kinds, as well as the construction of a model of contextual interactions that would take into account both the parametric characteristics of individual contexts (e.g., "homogeneity", "stability") and the features of the interactions themselves.

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Conflict of Interest Information

The authors have no conflicts of interest to declare.