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ACQUISITION OF NOVEL CONCRETE AND ABSTRACT WORDS THROUGH THE TEXTUAL AND GRAPHICAL CONTEXT

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Усвоение новых конкретных и абстрактных слов через текстовый и графический контекст

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Abstract

Abstract words, due to the absence of material referents, are more difficult to learn and process than concrete ones (the concreteness effect). Here, we have investigated this effect by assessing the outcomes of concrete and abstract word learning provided by meaningful textual or graphical contexts. Five tasks including Free recall, Recognition, Lexical decision, Definition, and multiple-choice Semantic judgment tasks were used to assess the success of the acquisition of newly learnt words at lexical and semantic levels. Within-group analysis revealed the concreteness effect in both experimental groups. However, it was more pronounced after a graphical than a textual presentation (in three tasks vs one) supporting the crucial role of the non-verbal

Резюме

Абстрактные слова из-за отсутствия материальных референтов сложнее запоминать и обрабатывать, чем конкретные (эффект конкретности). В настоящей работе мы исследовали данный эффект, оценивая результаты усвоения конкретных и абстрактных слов, значение которых передано через текстовый или графический контекст. Пять заданий, включая Свободное воспроизведение, Узнавание, Лексическое решение, Формулировку и Выбор определений, были использованы для оценки успешности усвоения как словоформ, так и семантики. Внутригрупповой анализ выявил эффект конкретности в обеих экспериментальных группах. Однако он был более выражен после графического, чем текстового предъявления (в трех заданиях против одного), поддерживая

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(imagery) system in learning of concrete words. Between-group analysis showed more accurate Recall and Definition of concrete nouns as well as better performance of both types of words in terms of Definition quality in the graphical group in comparison with the textual one. However, participants from the textual group recognised novel abstract words better than the other learners. Interestingly, only one between-group difference that was found for abstract words in the Definition task (definition quality) reached significance after the Bonferroni corrections for multiple comparisons. The results show that (1) concrete and abstract word processing may have partly distinct cognitive mechanisms, and (2) visual associations may play a crucial role in the semantic acquisition, especially for concrete words.

Keywords: concrete words, abstract words, concreteness effect, word learning, semantic acquisition, picture superiority effect.

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ключевую роль невербальной (образной) системы в изучении конкретных слов. Межгрупповой анализ выявил более точное Воспроизведение и Определение конкретных существительных, а также лучшую производительность обоих типов слов с точки зрения качества Определения в графической группе по сравнению с текстовой. Однако участники из текстовой группы распознавали новые абстрактные слова лучше, чем участники из графической. Более того, после поправок Бонферрони межгрупповые различия остались значимыми только по отношению к качеству Определения абстрактных слов. Результаты показали, что (1) обработка конкретных и абстрактных слов может иметь частично различающиеся когнитивные механизмы и (2) зрительные ассоциации могут играть решающую роль в усвоении семантики, особенно в случае конкретных слов.

Ключевые слова: конкретные слова, абстрактные слова, эффект конкретности, усвоение слов, усвоение семантики, эффект превосходства изображения.

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Concreteness is a property of nouns; it is — a degree to which their referents are related to real (or at least possible) objects in the material world. Concrete words have an advantage over abstract ones in speed and efficiency of their processing as demonstrated in different behavioural tasks (Fliessbach et al., 2006; Schwanenflugel et al., 1992). This phenomenon is known as the 'concreteness effect'.

Investigating the concreteness effect is widely used to explore the nature and mechanisms of cognitive processing and storage of semantic information (Wei & Gillon-Dowens, 2018). As a result, it was suggested that the efficiency of semantic processing depends on context availability (Schwanenflugel & Shoben, 1983), social context (Barsalou et al., 2005), and conceptual metaphor (Lakoff & Johnson, 2013), involving linguistic and non-verbal systems (the dual-coding theory) (Paivio, 2008), etc. (Mkrtychian et al., 2019). Moreover, an explanation of differences between concrete and abstract words was proposed in embodied and grounded cognition theories: concrete words are most commonly associated with sensorimotor interactions, while abstract concepts, due to the lack of such, are grounded in linguistic, social, and inner experiences (Borghi, 2020).

To evaluate these theories, neuroimaging and neurostimulation approaches were used in numerous studies (Holcomb et al., 1999; Kurmakaeva et al., 2021; Moseley & Pulvermüller, 2014; Rosa et al., 2018). They have shown that cognitive processing of concrete and abstract words is based on partly different neuronal mechanisms, which is reflected in a greater involvement of specific sensory-motor or linguistic areas in the case of concrete or abstract word processing, respectively (Binder et al., 2005; Pexman et al., 2007). For instance, abstract word processing was mainly associated with the involvement of the left temporo-parietal lobe and the left inferior frontal gyrus, whereas concrete words activated both hemispheres equally (Fliessbach et al., 2006; Sabsevitz et al., 2005).

Many studies showed that this advantage was found in newly acquired words as well: concrete words were performed better than abstract ones in lexical tasks (Ding et al., 2017; Kaushanskaya & Rechtzigel, 2012; Martin & Tokowicz, 2020). Moreover, it was also found in semantic tasks: the meanings of concrete words were faster comprehended and acquired in comparison with abstract words (Mestres-Missé et al., 2014).

However, such studies did not estimate acquisition per se, since only novel word forms were used. At the same time, in most of the experimental paradigms, the meanings of the novel words were previously familiar to participants. This could lead to misinterpretation of the learning outcomes caused by personal associations, individual experience of operating these meanings or word forms corresponding to them. Just a few studies used both new word forms and novel semantics. For instance, in the research implemented by Palmer and colleagues (Palmer et al., 2013), low frequent words, unfamiliar to the participants, were presented with their definitions and had to be learnt. In other studies, novel concrete and abstract words were acquired through the demonstration of their 3D Lego models (Borghi et al., 2011; Granito et al., 2015). The described studies revealed the concreteness effect. However, there is still a lack of research related to novel semantics.

New meanings could be acquired either by direct definitions or through meaningful contexts. The second way is more common in the first language (L1) learning (Mestres-Missé et al., 2007). This context may be verbal or non-verbal and involve different modalities, including visual, auditory, tactile, and others. In educational studies, it was shown that acquisition of novel semantics was more efficient when it was accompanied by illustrations (Farinella, 2018; Guo et al., 2020). Moreover, multiple studies showed that pictures are better remembered (recognized and recalled) than words (Paivio, 2008; Shepard, 1967; Whitehouse et al., 2006). One possible explanation of this picture-superiority effect is that image processing leads to the automatic retrieval of multiple semantic associations and representations from the long-term memory, which contributes to a deeper cognitive processing of images in comparison with words (Craik & Lockhart, 1972; Craik & Tulving, 1975; Grady et al., 1998; Nelson & McEvoy, 1979; Paivio, 2008). Furthermore, it was suggested that a faster and more automatic semantic access is provided by pictures, while a faster and more automatic lexical access, on the contrary, is provided by words (Carr et al., 1982). Therefore, we can assume that verbal and non-verbal ways of language learning may differentially influence effectiveness and speed of lexical and semantic acquisition.

However, no direct comparison between these two ways of semantic learning of concrete and abstract words has been implemented yet. The current study aims to investigate the concreteness effect of newly learnt words using two different ways of their presentation — through textual or graphical materials. We suppose that due to the picture-superiority effect, a graphical context acquisition would lead to a better performance of novel words in assessment tasks, in comparison with a textual context presentation. Moreover, we expect that these differences would be less manifested for abstract words, since their processing, in contrast with concrete ones, is based more on verbal than sensorimotor information. Therefore, abstract words would be less sensitive to sensory information provided by images.

Methods

Participants

46 right-handed healthy adults, all monolingual Russian speakers, were divided into two groups that did not differ statistically on their age and handedness (23 people, seven males in each, age (mean±standard error (SE), years) 26.4 ± 1.15 and 23.5 ± 1.13, handedness (mean±SE, %) 80.4 ± 4.34 and 82.5 ± 3.59). One group was exposed to the visual presentation of novel words in a textual context, while another one — in a graphical context. All participants signed informed consent forms and filled in handedness (based on the Edinburgh Inventory (Oldfield, 1971)) and socio-demographic questionnaires. The procedure was approved by the Ethics Committee of St. Petersburg Psychological Society.

Materials

To mimic the naturalistic process of L1 word acquisition, the learning materials contained both new word forms (resembling Russian words) and novel meanings.

For novel word form creation, 30 8-lettered Russian words with the same structure (consonant-vowel-consonant-consonant-vowel-consonant-vowel-consonant) and frequency of more than one per million (according to the Russian National Corpus database) were chosen. Then, these words were divided into three sets that did not differ statistically by their lemma and ultimate trigram frequency. Novel word forms were created by rotating the ultimate syllables within each word set (e.g. mandarin → mandanal* (the last trigram was taken from the word cardinal)).

For novel concrete semantics, rare or obsolete objects were used as referents, whereas new abstract meanings were either borrowed or modified from the foreign languages. Thus, ten novel concrete and ten novel abstract nouns with unfamiliar word forms and semantics were created.

The meaning of new words had to be retrieved from the context of five sentences (textual context) or five pictures (graphical context). For all participants, the same word form corresponded to the same meaning, and new words were always presented in the persistent order.

Novel word forms that were not associated with new concrete or abstract semantics were used as fillers in Recognition and Lexical decision assessment tasks (see the full description below).

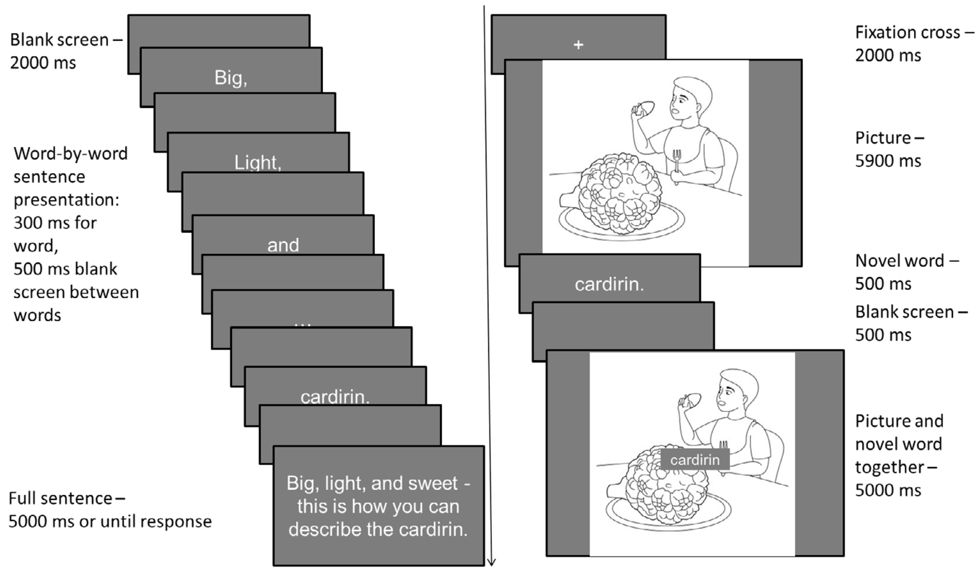
Learning Procedure

The learning procedure differed for two groups of participants (Figure 1).

Stimuli were presented visually on the computer screen using Neurobureau (Neuroiconica) or PsychoPy v1.85.1 (Jonathan Peirce) software for providing a graphical or textual context, respectively. Before the learning part of the experiment, a short training session was provided.

Figure 1

Contextual Learning Procedure for Textual (on the Left) and Graphical (on the Right) Groups



Note. Translation of stimulus material in English is approximate.

Textual Context

Each sentence was presented twice — word-by-word (300 ms for each word with 500-ms interval) and entirely (5000 ms or until response by pressing the ‘Space’ button) with the following parameters: background colour — grey [0,0,0], font Arial (colour — white [1,1,1], size 28 pt).

Graphical Context

Participants were presented with 1) a picture describing a novel concept for 5900 ms (background colour — grey [0,0,0], the picture drawn with black lines on a white background), 2) a word for 500 ms, 3) a blank screen for 500 ms, 4) the picture and a word simultaneously for 5000 ms. Due to the technical restriction, the opportunity to press the button on the keyboard was not provided.

Assessment Tasks

To evaluate the success of the acquisition, participants from both groups performed the same five behavioural tasks immediately after learning: Free recall, Recognition, Lexical decision, Definition, and multiple-choice Semantic judgment tasks.

In the Free recall and Definition tasks, participants were asked to type into spreadsheets novel word forms (without any clue) or definitions (word forms provided), respectively.

Other tasks were programmed in PsychoPy Builder and presented by PsychoPy v1.85.1 (Jonathan Peirce): background colour — grey [0,0,0], font Arial (colour — white [1,1,1], size 28 pt).

In the Recognition and Lexical decision tasks participants were supposed to press the 'X' key with their left index finger ('yes' answer) or the 'Z' key with their left middle finger ('no' answer) on the keyboard as soon as possible. The tasks were provided with the following questions: 'Have you seen these words in sentences/pictures?' and 'Is it a meaningful word?'. Stimuli (novel and control words and pseudowords, competitor words and pseudowords) were shown for 600 ms with a 3200 ms blank screen between them.

In the multiple-choice Semantic judgment task, novel word forms were provided with four possible answers: correct definition, two definitions of other novel words, and 'none of the above' options. The response time was not limited.

Before the Recognition and Semantic judgment tasks, training sessions were implemented to adopt for the procedure (and keys).

Statistical Analysis

In the Free recall task, participants could receive from 0 to 5 scores for each novel word depending on the amount of correctly typed letters (word forms with less than four correct letters were assessed as 0 scores). Then, the sum of the scores was calculated for each word type (concrete and abstract) and converted to the percentage. Accuracy of the Recognition, Lexical decision, and Semantic judgment tasks was calculated as a percent of correct answers. The Definition task was assessed in terms of accuracy (percent of definitions correctly corresponded to the word forms) and quality, which was evaluated by four experts.

Within-group analysis (abstract vs concrete concepts) was implemented using a non-parametric Wilcoxon signed-rank test, while between-group analysis (textual vs graphical context acquisition) — using a Mann-Whitney U test. Then, p-values were adjusted with the Bonferroni corrections for multiple comparisons. All the analyses were done using IBM SPSS Statistics 26 software.

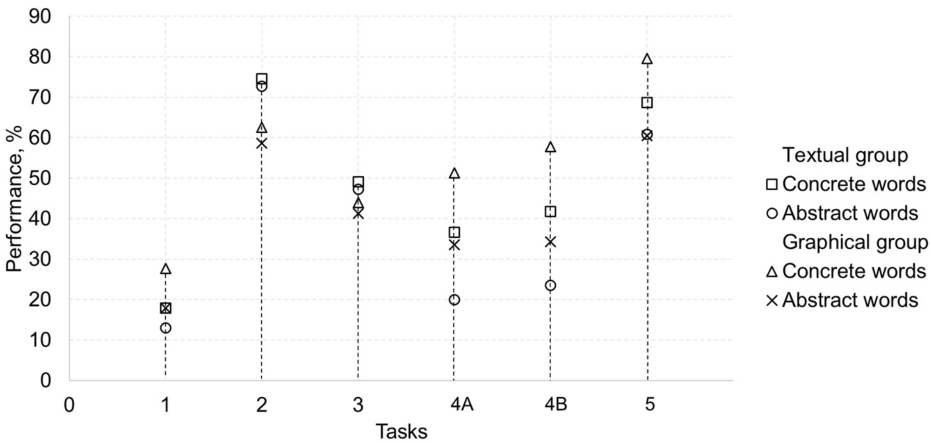
Results

By the serial-position effect, a word, which was presented at the end of the learning session, was recalled significantly better than others (accuracy was more than mean plus three standard deviations) and, therefore, was excluded from the calculation of Free recall task accuracy. Mean values for all task performance are shown in Figure 2.

Within-group analysis revealed the concreteness effect in the both groups (with textual and graphical contexts of acquisition). However, this effect varied between groups (Table 1): concrete words were performed with significantly higher scores for definition quality and accuracy in both groups, while in Free recall and Semantic judgment tasks — in the graphical group only. The adjusted p-value (the Bonferroni correction) in all cases is less than $0.05/12 = 0.0042$.

Figure 2

Performance for Textual and Graphical Groups (Mean Values, %)



Note. 1 — Free recall accuracy; 2 — Recognition accuracy; 3 — Lexical decision accuracy; 4A — Definition quality; 4B — Definition accuracy; 5 — Semantic judgment accuracy.

Table 1

Within-Group Analysis — Concrete vs Abstract Words

Variable	**Wilcoxon test**		**Mean±SE (%)**	
	Textual group	Graphical group	Textual group	Graphical group
1. Free recall accuracy	n/s	p = 0.002* z = −3.057	17.87 ± 4.44 vs 13.04 ± 3.24	27.63 ± 3.55 vs 17.91 ± 2.97
2. Recognition accuracy	n/s	n/s	74.55 ± 3.27 vs 72.73 ± 4.42	62.61 ± 4.76 vs 58.70 ± 4.41
3. Lexical decision accuracy	n/s	n/s	49.09 ± 7.84 vs 47.27 ± 7.71	43.91 ± 5.29 vs 41.30 ± 5.77
4. Definition quality	p < 0.001* z = −3.848	p < 0.001* z = −4.061	36.65 ± 3.93 vs 20.02 ± 3.60	51.35 ± 2.72 vs 33.54 ± 3.16
5. Definition accuracy	p = 0.001* z = −3.312	p < 0.001* z = −3.934	41.74 ± 5.09 vs 23.48 ± 4.77	57.83 ± 4.22 vs 34.35 ± 5.37
6. Semantic judgment accuracy	n/s	p = 0.001* z = −3.432	68.70 ± 4.32 vs 60.87 ± 5.18	79.57 ± 3.47 vs 60.43 ± 5.01

Note. * indicate p-values less than 0.05 after Bonferroni correction for multiple comparisons.

Between-group analysis. The between-group comparison using the Mann-Whitney U test (Table 2) revealed significantly better recognition of abstract words in the textual group in comparison with the graphical one (p = 0.032, Z = −2.144, mean(textual) = 72.73 ± 4.42, mean(graphical) = 58.70 ± 4.41).

Table 2

Between-Group Analysis

Task and variable	Stimulus type	Mann-Whitney		Mean±SE (%)	
		p	Z	Textual group	Graphical group
1. Free recall accuracy	Concrete words	0.018	−2.356	17.87 ± 4.44	27.63 ± 3.55
	Abstract words	n/s		13.04 ± 3.24	17.91 ± 2.97
2. Recognition accuracy	Concrete words	n/s		74.55 ± 3.27	62.61 ± 4.76
	Abstract words	0.032	−2.144	72.73 ± 4.42	58.70 ± 4.41
3. Lexical decision accuracy	Concrete words	n/s		49.09 ± 7.84	43.91 ± 5.29
	Abstract words	n/s		47.27 ± 7.71	41.30 ± 5.77
4. Definition quality	Concrete words	0.011	−2.549	36.65 ± 3.93	51.35 ± 2.72
	Abstract words	0.003*	−2.978	20.02 ± 3.60	33.54 ± 3.16
5. Definition accuracy	Concrete words	0.032	−2.150	41.74 ± 5.09	57.83 ± 4.22
	Abstract words	n/s		23.48 ± 4.77	34.35 ± 5.37
6. Semantic judgment accuracy	Concrete words	n/s		68.70 ± 4.32	79.57 ± 3.47
	Abstract words	n/s		60.87 ± 5.18	60.43 ± 5.01

Note. * indicate *p*-values less than 0.05 after Bonferroni correction for multiple comparisons.

However, the Definition quality test showed the opposite results: a significantly lower performance after the verbal versus graphical context acquisition for both concrete and abstract words ($p = 0.011$, Z = −2.549, mean(textual) = 36.65 ± 3.93, mean(graphical) = 51.35 ± 2.72 for concrete words; $p = 0.003$, Z = −2.978, mean(textual) = 20.02 ± 3.60, mean(graphical) = 33.54 ± 3.16 for abstract words).

Moreover, in the graphic group concrete words showed higher accuracy than in the textual one in Free recall ($p = 0.018$, Z = −2.356, mean(textual) = 17.87 ± 4.44, mean(graphical) = 27.63 ± 3.55) and Definition ($p = 0.032$, Z = −2.150, mean(textual) = 41.74 ± 5.09, mean(graphical) = 57.83 ± 4.22) tasks. Yet, only one *p*-value remained significant after Bonferroni correction for multiple comparisons: *p*-value for abstract word definition quality was less than 0.05/12 = 0.0042.

Discussion

The current study was aimed to investigate the concreteness and the picture-superiority effects within one experimental paradigm. The within-group differences, in general, confirmed the concreteness effect (Borghi et al., 2011; Granito et al., 2015; Wei & Gillon-Dowens, 2018) regardless of the way of learning (verbal or non-verbal). However, this effect was observed mainly in the group, in which novel words were acquired through illustrations, which supports our hypothesis about the role of the non-verbal (imagery) system in learning of concrete words. Three of the five assessment tasks showed an advantage of concrete words in the graphical group, where concrete words were acquired better than abstract ones at both lexical (Free recall task) and semantic (Definition and Semantic judgment task) levels. Whereas after verbal contextual learning, the concreteness effect was observed only in one semantic (Definition) task.

The between-group differences highlighted the role of the context type (verbal and non-verbal) in the success of new semantic acquisition. It was shown that the advantage of the graphical versus textual context after Bonferroni correction was observed only for abstract words at the semantic level of acquisition. However, this tendency can be observed for both word types (concrete and abstract) in several tasks aimed to assess both lexical and semantic levels of word acquisition. Perhaps, a larger sample is needed to see the significant differences after corrections for multiple comparisons. Our results are matched to the picture-superiority effect (Whitehouse et al., 2006). One possible explanation of this phenomenon is the activation of both hemispheres of the brain and the parallel processing of stimuli by different systems with the simultaneous involvement of different functions (Rogers et al., 2013), including the extraction of semantic associations, actualisation of social experience, and a deeper cognitive processing of stimuli (Paivio, 2008).

Many psychological and educational studies have focused on the effectiveness of learning new information using various visualisation tools (Peters & Webb, 2018; Scicluna & Strapparava, 2019; Valdois et al., 2019). It was found that the advantage of using educational comics in comparison with the text is based on higher semantic integrity, concreteness, and consistency, as well as the possibility to express the emotional and functional aspects of meaning (Kostromina et al., 2018). This makes a better understanding of information and contributes to its better memorization. Figures contain more information that is not expressed in words but supports the understanding of the whole situation (McCloud, 1994). At the same time, textual presentation of information improves the acquisition of abstract concepts (Kostromina et al., 2018). However, the influence of visualisation tools on learning success is ambiguous and depends, among other things, on psychological variables and specialisation of students (Ibid.).

In the current study, textual and graphical ways of information presentation differently affected the performance of novel concrete and abstract words. The direct comparison of the two experimental groups showed better performance of concrete words acquired through the graphical context than through the textual presentation in both (lexical and semantic) types of assessment tasks. These outcomes emphasise the role of the visual system and non-verbal experience in the acquisition of concrete words (Mkrtychian et al., 2019). Abstract words, similarly to concrete words, were better performed in the semantic (Definition) task in the graphical group compared to the textual one. However, the lexical task showed the opposite results: participants in the textual group were more successful in recognising novel abstract words, in comparison with the graphical group. These findings support the idea that concrete and abstract words are processed differently. Since concrete words have referents in the material world, they evoke quick associations with similar and semantically close objects and, therefore, connections with sensorimotor experience. Abstract words, in contrast, do not have such and rely mostly on linguistic experience. The dual-coding theory (Paivio, 2008) describes in detail the relationship between verbal and visual representation systems in the process of word coding. Picture presentation involves the non-verbal imagery system and forces semantic associations. These processes seem to be more essential for concrete concepts (vs abstract ones) improving their processing and acquisition (Mkrtychian et al., 2019). This is in line with the previous neurophysiological studies, which showed that cognitive processing of concrete and abstract words is based on partly different neural mechanisms (Binder et al., 2005; Pexman et al., 2007), particularly, on the involvement of sensorimotor areas at different extent (Fliessbach et al., 2006).

Conclusion

Firstly, our findings demonstrated that the presence of non-verbal context enhances the advantage of concrete words due to their direct relation to sensory and motor representations, on the one hand, and the crucial role of linguistic experience in the acquisition of abstract concepts, on the other hand (Borghi & Binkofski, 2014). Secondly, after the graphical way of presentation, participants showed better performance in the semantic task, in comparison with the textual context. This suggests that the graphical context facilitated understanding of the meaning of both concrete and abstract words by providing coherence, dynamism, and semantic completeness of their representation. In the lexical tasks, the influence of the context type differed between concrete and abstract words: images provided better recall of concrete but less accurate recognition of abstract words. These findings support the assumption of the different grounding of concrete and abstract words. The results of the study may be used to create educational materials that facilitate comprehension and acquisition of new semantic information. However, future studies on expanded numbers of subjects of different age ranges are needed to confirm the advantage of the non-verbal way of contextual word learning. Moreover, it would be useful to conduct a neuroimaging study to find neurophysiological confirmation of differences in the textual and graphical contextual acquisition of concrete and abstract semantics.

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