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Research Article

Perceptual richness of words and its role in free and cued recall

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ABSTRACT

This research aimed to clarify the role of the perceptual richness of words (PR) in the recall tasks. PR was operationalized as the number of sensory modalities through which an object can be perceived. Previously, we found that concepts experienced with many modalities (*dog*) were recalled more accurately in cued recall than those perceived with few modalities (*rainbow*) and abstract words. This finding fitted the Perceptual symbol system theory (PSST) and the Dual coding theory (DCT) predictions. We tested the PR effect in both cued (experiment 1- E1) and free recall tasks (experiment 2 – E2) in the present study. With careful stimuli manipulation of context availability and emotional valence and statistical control of arousal and relatedness, made to exclude their influence on recall, we tested alternative explanations of the concreteness effect offered by the relational-distinctiveness hypothesis. The additional perceptual codes improved recall accuracy in the cued recall task (E1), which was in line with the PSST and the DCT. This conclusion is straightforward: two critical groups of concrete words were matched for concreteness and visual perceptual strength. Thus, more accurate recall of concepts experienced with many modalities can be attributed to richer perceptual experience. However, the relational information was essential for recall accuracy in

the free recall task (E2), as hypothesized by the relational-distinctiveness hypothesis.

Keywords: free recall, cued recall, dual coding theory, perceptual richness, perceptual symbol systems theory

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Introduction

In this paper, we shed light on the debate concerning the origin of the concreteness effect in memory tasks (Marschark & Hunt, 1989; Marschark & Surian, 1992; Paivio et al., 1988; 1994; Paivio, 1991; Schwanenflugel et al., 1992). To test this effect, we chose the Paired-Associate Learning paradigm (Begg, 1973; Begg & Robertson, 1973), where participants can perform free or cued recall tasks after learning pairs of words. Out of many proposed explanations, we focus on the most prominent ones: the Dual coding approach (Paivio 1991; Paivio et al., 1988; Paivio et al., 1994), the Context availability theory (Schwanenflugel et al., 1992) and the relational-distinctiveness hypothesis (Marschark & Hunt, 1989; Marschark & Surian, 1992).

Word concreteness

The word concreteness is defined as the degree to which the word's meaning could be perceptually experienced (Brysbaert et al., 2014; Brysbaert et al., 2014; Clark & Paivio, 2004; Paivio et al., 1968; Reilly et al., 2017). Based on concreteness ratings, the word could be predominantly abstract (truth) or concrete (apple), in which case it could be easily perceived. Higher concreteness has often been linked to more accurate recall (Begg & Robertson, 1973; Marschark & Surian, 1992; Nelson & Schreiber, 1992; Paivio, 1965; Paivio, 1969; Paivio et al., 1988; Paivio et al., 1994).

The Dual coding theory (DCT) offered the first account of the concreteness effect (Paivio, 2013; Paivio & Sadoski, 2011; Paivio, 2008; Paivio, 1991; Paivio, 1969; Paivio, 1965). In line with the DCT, abstract words are mainly represented symbolically, whereas concrete words are double coded: symbolically via verbal codes (system of logogens; Morton, 1969) and perceptually via analogue codes (system of imagens). To explain the additive effect of the two independent systems, Paivio proposed the conceptual peg hypothesis (Paivio, 1991). Based on this hypothesis, one can use different mnemonic techniques to remember words, such as using rhymes or associative relations (*gun-fun* or *blood-wound*). With regards to abstract words, remembering is based on the associative level. However, remembering concrete words is enhanced with the analogue code, representing an additional peg for connecting two words. For example, in the example of *blood* and

wound, there are associative and perceptual relations between the words, so one can create a mental image of a bloody wound, which increases the probability of its correct recall.

However, Context availability theory challenged the idea of using imagery as an automated process (Schwanenflugel et al., 1992; Schwanenflugel et al., 1988; Schfanenfluel & Shoben, 1983). For example, Schwanenflugel and her colleagues (1992) observed concreteness effects only with individuals reporting the use of mental imagery and only when participants were explicitly instructed to evoke mental images (in imageability rating task administered during implicit learning phase), but not when they were instructed to evoke the context in which the word is encountered (context availability rating). Based on this they concluded that imagery is not initiated automatically.

Recently, both the DCT and the context availability theory were confronted with the affective embodiment perspective, oriented toward investigating the role of emotions in conceptual representations (Kousta et al., 2011; Kousta et al., 2009). This approach attributes differences in word processing to differences in emotional experience, operationalized as the emotional valence (e.g., whether words provoke positive, negative, or neutral feelings). Their experiments recorded differences in lexical processing of concrete and abstract words that were matched for imageability and context availability but not for emotional valence. In other words, they did not exclude the relevance of the DCT; instead, they added the emotional experience as a factor in the abstract knowledge representation.

Paired-Associate Learning - PAL

The concreteness effect was thoroughly tested in the Paired-Associate Learning paradigm, in which participants read the pairs of words, and subsequently engage in either free or cued recall task (Begg, 1973; Begg & Robertson, 1973; Marschark & Hunt, 1989; Marschark & Surian, 1992; Paivio, 1969; Paivio, 1965; Paivio et al. 1994). In the free recall task, the cue-target are fully recalled by the participant, whereas in the cued recall task, they are given the first word from the previously presented pair (i.e., cue), and recall the second word (i.e., target). The concreteness effect in PAL is predicted by several models. However, the description of the precise conditions in which the concreteness effect is expected has been the ground of the

debate between the DCT (Pavio et al., 1994; Paivio, 1991) and the relational-distinctiveness hypothesis (Marschark & Surian, 1992; Marschark & Hunt, 1989).

According to the DCT and peg hypothesis, the advantage of the concrete words in PAL is a consequence of the additional memory code (supplementary analogue representation), which serves as an extra mnemonic peg later in the recall phase (Paivio, 1965; Paivio et al., 1994). For example, when learning the pair *swing-tree*, one can easily create the mental image of the swing hanging on the tree. Later, during recall, the participants could effortlessly reconstruct this image (Paivio used the term *redintegration* for this process; Horowitz & Prytulak, 1969) and accurately recall the stimuli. Accordingly, the concreteness effect should be expected regardless of the presence of the cue and irrespective of the cue-target relatedness (Paivio et al., 1994).

According to the relational-distinctiveness hypothesis, recall relies on relational and distinctiveness processing rather than imagery (Marschark & Hunt, 1989; Marschark & Surian, 1992). The advantage of concrete words is attributed to their better organization in memory and their higher discriminability (distinctiveness) compared to abstract words. However, this discriminative advantage of the concrete word pairs could be evident only after the relational information has been provided by presenting the related cue. Consequently, the concreteness effect is either attenuated or eliminated in the free recall and when participants learn the unrelated word pairs (no relational information is present). Therefore, interaction is expected among concreteness, recall type, and cue-target relatedness, as Marschark and Hunt (1989) observed. They found the concreteness effect in the cued recall of associatively or semantically related targets. There was no concreteness effect in the cued recall of the unrelated targets, nor in the free recall, regardless of the relatedness.

Perceptual richness

In the past decades, within the Embodiment approach (Barsalou, 1999; 2007; 2010; Glenberg & Robertson, 2000; Meteyard et al., 2012; Pecher & Zeelenberg, 2015), researchers were looking for a measure that captures perceptual information more accurately than concreteness. The critical point of the Embodiment theories is that conceptual processing relies on the sensory-motor system (Meteyard et al, 2012;

Pecher et al., 2003). For example, according to Perceptual symbol systems theory (PSST; Barsalou, 1999; Barsalou, 2007; Pecher & Zeelenberg, 2015), the mental representations of concepts are grounded in the sensory-motor experience with their external referents. Accordingly, concept representations are considered simulations of the previous perceptual experience. In other words, when evoking a concept, all sensory-motor pathways, which have been aroused during perception, are reactivated (i.e., the system is performing a simulation of perceptual experience; Barsalou, 1999). As an operationalization of this modality-specific perceptual experience, some authors proposed the measures of per-modality perceptual strength (Connell & Lynott, 2012; Filipović Đurđević et al., 2016; Lynott et al., 2019; Lynott & Connell, 2013; Speed & Majid, 2017; Vergallito et al., 2020). These measures represent the extent to which a concept could be experienced with a specific perceptual modality: visually, tactually, auditorily, gustatorily, and olfactorily. Based on modality-specific perceptual strengths, several measures of perceptual richness have been derived to better articulate the word concreteness (Lynott & Connell, 2013; Filipović Đurđević et al., 2016). Multiple studies have demonstrated the relevance of these measures for cognitive processing (Connell and Lynott, 2012; Filipović Đurđević et al., 2016; Lynott & Connell, 2013; Pecher et al., 2003; Živanović & Filipović Đurđević, 2011).

Relevant to this paper is the number of sensory modalities (NoM) through which the concept could be experienced, representing the diversity of perceptual experience (Filipović Đurđević et al., 2016; Popović Stijačić & Filipović Đurđević, 2015).

Current goals

To the best of our knowledge, the only study so far that has dealt with the NoM effect on recall is the study in the Serbian language (Popović Stijačić & Filipović Đurđević, 2015). In this study, the participants recalled the concepts that could be experienced with many modalities more accurately than abstract concepts. Although the effect was present in the cued recall, the emotional valence and the context availability was not controlled for. Therefore, the main goal of this study was to explore the unique contribution of the perceptual richness as described by the NoM on memory performance.

To explore the unique contribution of this novel variable, we needed to control for the effects of other known variables that affect memory performance. Firstly, to make sure that the observed effects could only be attributed to perceptual information, we matched abstract and concrete words for the context availability (Schwanenflugel et al., 1992), emotional valence and arousal (Kousta et al., 2009; Kousta et al., 2011). Secondly, we divided concrete words into two groups. The first group contained concepts that could be experienced with a few perceptual modalities, and the second group enclosed concepts that could be experienced with many perceptual modalities. Two groups of concrete words were averaged for concreteness and imageability, thus approximated by the visual strength. Finally, to fine-tune our understanding of the NoM effect, we contrasted the predictions of the two hypotheses accounting for the concreteness effects in PAL, DCT and Peg hypothesis (Paivio et al., 1994) and relational-distinctiveness hypothesis (Marschark & Hunt, 1989). We did so by presenting our target words in the related and unrelated cue context and by testing memory performance in free and cued recall.

Following the DCT (Paivio, 1991) and the Perceptual symbols theory (Barsalou, 1999), we predicted that the recall accuracy would be a function of the NoM. It was expected that the highest recall accuracy would be recorded for the words which denoted objects experienced with a higher number of sensory modalities. Given the strict control that we imposed on our stimuli, it was essential to note that any observed difference between the two groups of concrete words would point to the unique contribution of the perceptual richness as expressed by the NoM. Finally, based on the inconsistent findings concerning the effect of the task and cue-target relatedness, we could not make precise predictions. However, we will be able to contrast the two accounts. According to the peg hypothesis, if the NoM reflects the perceptual richness, a larger number of modalities represents a larger number of pegs available during recall and will enhance retrieval both in free and cued recall tasks.

Additionally, according to the DCT, additional perceptual codes are available regardless of the cue-target relatedness. Therefore, the NoM effect is expected for related and unrelated cue-target words. In contrast, the relational-distinctiveness hypothesis (Marschark & Hunt, 1989) would indicate the NoM effect

only in the cued recall of related cue-target words as more relevant for retrieval is relational information (which is absent in free recall and when cue-target pairs are unrelated).

Considering these goals, we conducted two experiments: in Experiment 1, the participants took part in a cued recall task, and in Experiment 2, another group of participants performed a free recall task.

Experiment 1

Method

Participants

A total of 72 undergraduate students from the University of Novi Sad, native Serbian speakers, took part in this experiment to partially fulfill course requirements. Participants were randomly assigned either to related or unrelated word pairs presentation condition (thirty-six in each condition). All participants signed informed consent after the researcher explained the experimental task and its purpose. The research was approved by The Ethics Committee of the Department of Psychology, Faculty of Philosophy Novi Sad (No. 201610101138_sYfu).

Stimuli

We selected concrete nouns described by Filipović Đurđević et al. (2016) and abstract nouns from study by Popović Stijačić and Filipović Đurđević (2015). There were three groups of nouns regarding the number of sensory modalities through which a concept could be experienced (NoM): 1) abstract nouns ("zero modalities group"; things that cannot be perceptually experienced; e.g., *science*, *freedom*), 2) perceivable with a few sensory modalities ("few modalities group"; objects experienced by one or two sensory modalities; e.g., *moon*, *window*), and 3) perceivable by many modalities ("many modalities group"; objects that could be experienced by three, four, or five modalities; e.g., *apple*, *bee*). Within each NoM groups, targets were paired with related and unrelated cues.

The related and unrelated lists consisted of 33 cue-target pairs: 11 cue-target pairs from the "zero modalities" group (e.g., *theory-science* for the related list,

and *equality-science* for the unrelated list), 11 pairs from the few modalities group (e.g., *chimney – roof* for the related list and *radiator-roof* for unrelated list) and 11 from the many modalities group of the cue-target pairs (e.g., *honey-bee* for the related list and *keyboard-bee* for unrelated list). Finally, to control for primacy and recency effects (Glanzer, 1972; Murdock, 1962), we introduced four filler pairs at the beginning and four filler pairs at the end of each list.

Cue-target relatedness[1] was different for the list of related and the list of unrelated pairs: $F(1,64) = 404.10$, $p < .00$ ($M_{related} = 6.04 \pm 0.70$, $M_{unrelated} = 2.04 \pm 0.90$). The relatedness rating was identical for related pairs of zero, few, and many modalities word groups. However, the unrelated pairs of abstract words were more related than unrelated pairs of concrete words: $F(2,30) = 16.30$, $p < .001$ ($M_{zero} = 2.95 \pm 0.60$; $M_{few} = 1.7 \pm 0.90$; $M_{many} = 1.38 \pm 0.30$). Groups of zero, few, and many modalities were matched for word length, (log) lemma frequency (Kostić, 1999), context availability[2] (Schfanenflugel et al., 1988), and emotional valence[3] (Bradley & Lang, 1999). However, the abstract cues ($F(2,30) = 6.21$, $p < .01$; $M_{zero} = 5.65 \pm 1.50$; $M_{few} = 4.31 \pm 0.90$; $M_{many} = 4.14 \pm 0.60$), and targets ($F(2,30)=6.04$, $p<.01$; $M_{zero}=5.67\pm0.8$; $M_{few}=4.21\pm1.2$; $M_{many}=4.55\pm1.1$) had higher values of arousal than the concrete words. Therefore, both arousal and relatedness were introduced as the covariate variables. Two groups of concrete words were additionally matched for concreteness and visual perceptual strength (taken from Filipović Đurđević et al., 2016, but also described in Connell & Lynott, 2012). The lists of words with the corresponding values on the relatedness are given in Appendix 1.

Design

We manipulated relatedness of cue-target pairs (related vs. unrelated) between subjects and within items, and the NoM (zero, few, many) between items

[1] as rated on a seven-point scale by novel sample of 20 native Serbian speakers.

[2] Ratings for the context availability were collected from 15 Serbian native speakers who did not participate in the experiments. Participants rated how easily the presented word evokes the context on the seventh point Likert scale.

[3] A novel sample of 15 Serbian native speakers estimated the emotional valence and arousal.

and within subject. The dependent variable was recall accuracy (coded 0 for incorrect and 1 for the correct recall).

Procedure

Using Open Sesame software (Mathôt et al., 2012), word pairs were presented with the overhead projector on the classroom wall. The trial consisted of the fixation cross (1000ms) followed by a word pair (8000ms). There were 41 trials: eight fillers (four at the beginning and four at the end of the list), and 33 target trials, randomly sequenced. Since this experiment was a group study, we divided each condition (related and unrelated) into two testing sessions to have at least two orders of stimuli presentation. Accordingly, the participants were assigned to one of the four lists (two unrelated and two related, which had the same stimuli with different presentation orders). Without mentioning the recall test, participants were instructed to read word pairs carefully and in silence. After the stimuli presentation, participants were engaged in the cued recall task: they received a response sheet, with the table containing cues in one column and blank cells in the second column for the participant's answers. They were instructed to write down the matching target of the cues listed in the paper. There were three versions of the response sheets with three different random orders of the cues. Reproduction was limited to five minutes. After this time, the experimenter collected the response sheets.

Data analysis

The data were analyzed in the R statistical software (R Core Team, 2018). We used the lme4 package (Bates et al., 2015) as a more powerful binary data analysis tool than traditional ANOVA over percentages of correct responses (Popović Stijačić et al., 2018). The R code of the analyses, together with the data set, is available on the OSF platform: OSF page link. Based on Barr's recommendation (2013), we started with the model with the most saturated random structure justified by design. However, we kept the model with the best-fit indices, as proposed by Matuschek and colleagues (Matuschek et al., 2018).

Results and discussion

Accuracy observed in six conditions is presented in Figure 1.

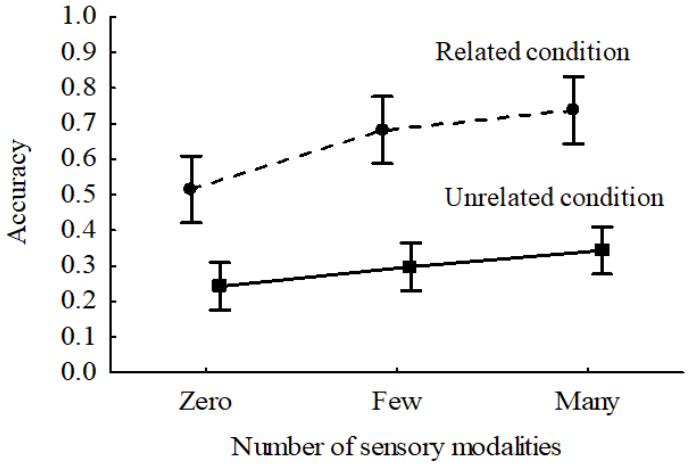

Figure 1. Accuracy in the cued recall of the related and the unrelated noun pairs

Generalized mixed-effects regression revealed that recall was more accurate for the targets in the related condition across the NoM groups. Additionally, we observed NoM by relatedness interaction, which revealed that the advantage of related pairs was less pronounced for abstract words. Finally, the effect of NoM was significant between zero and many modalities condition of both related and unrelated word pairs.

The observed differences could not be explained neither with context availability theory (because the stimuli were matched for context availability; Schwanenflugel et al., 1992), nor with the theoretical account that proposed the affective experience as relevant for the representation of abstract words (Kousta et al., 2011). The observed pattern of the NoM and relatedness effects is more in accordance with the DCT and the conceptual Peg hypothesis (Paivio, 1971; Paivio et al., 1994). Namely, the difference between concrete and abstract targets was observed in related and unrelated conditions, which was not predicted by the relational-distinctiveness hypothesis (Marschark & Hunt, 1989).

Table 1

The estimates of the coefficients of the fixed effects and the fit indices for the first model

Predictors	Estimate	*SE*	*z*	*p*	Fit indices
Intercept: NoM = few; Relatedness = unrelated	-1.17	.30	-3.90	.00	
NoM: zero	- .37	.31	- 1.21	.22	*AIC*: 2512.70
NoM: many	.32	.30	1.07	.28	*BIC*: 2558.90
					logLik: -
Relatedness: related	2.21	.35	6.35	.00	1248.40
NoM: zero/relatedness: related	- .58	.25	-2.27	.02	
NoM: many/relatedness: related	.01	.25	0.07	.95	
Intercept: NoM = zero; Relatedness = unrelated	-1.54	.30	-5.08	.00	
NoM: few	.37	.31	1.21	.23	
NoM: many	.69	.30	2.28	.02	
Relatedness: related	1.63	.35	4.72	.00	
NoM: few/relatedness: related	.58	.25	2.27	.02	
NoM: many/relatedness: related	.59	.25	2.34	.02	
Random effects					
σ^2 participant (intercept)	1.55				
σ^2 item (intercept)	0.32				

Notes. Both sets of coefficients belong to the same model. In the upper part of the table, the intercept was set to few numbers of modalities, and the unrelated condition; in the lower part of the table, the intercept was set to zero number of modalities. SE – standard error of an estimate; *z* – z test; *p* – p-value; σ^2 - variance.

Considering that concrete cues and targets (both in few and many condition) were less related than abstract cue-target pairs, we also conducted the analysis with relatedness as the continuous predictor (Table 2). As expected, an increase in relatedness was followed by an increase in accuracy of cued recall. However, when controlling for relatedness in such way, we also observed a more robust effect of NoM. Targets denoting objects that could be perceived with many

modalities were recalled more accurately than those from the few modalities group, and targets from the few modalities group were recalled more accurately compared to the abstract words. Thus, there was a weak but statistically significant effect of the NoM, regardless of the relatedness. This finding is in accordance with the Perceptual symbol systems theory (Barsalou, 2010; 2007), the DTC (Paivio, 1991; Paivio et al., 1994) and conceptual peg hypothesis (Paivio et al., 1994). Other theoretical explanations (context availability and influence of emotions and arousal; Schwanenflugel et al., 1992; Kousta et al., 2009; Kousta et al., 2011) could be excluded, at least in a cued recall condition, since the relevant groups of words were matched by the listed variables.

Table 2

The estimates of the coefficients of the fixed effects and the fit indices for the second model

Model 2	Estimate	*SE*	*z*	*p*	Fit indices
Intercept: NoM = few	-1.35	.31	-4.36	.00	*AIC:* 2497.50
Relatedness (continuous)	0.44	.06	7.70	.00	*BIC:* 2532.10
NoM: many	0.49	.25	1.96	.05	*logLik*: -1242.70
NoM: zero	-0.76	.25	-3.07	.00	
Random effects					
σ^2 participant (intercept)	1.57				
σ^2 item (intercept)	0.25				

Note. SE – standard error of an estimate; z – z test; p – p-value; σ^2 - variance.

Experiment 2

Method

Participants

A novel sample of 78 students from the Department of Psychology, Faculty of Philosophy, University of Novi Sad, all native Serbian speakers, participated fulfilling the course credit. Participants were randomly assigned to either the unrelated condition, or to the related condition (thirty-nine participants in both of the conditions).

Stimuli and design

The stimuli and design were identical to those in Experiment 1.

Procedure

The procedure was the same as in Experiment 1, with one difference: participants were performing a free recall task instead of a cued recall. They were given a blank sheet of paper to recall as many as possible word pairs in five minutes.

Results and discussion

Recall accuracy was low overall, as presented in Table 3. The observed tendency of higher accuracy for related word pairs was confirmed for relatedness both as categorical variable (Table 4a) and a continuous predictor (Table 4b). We did not observe significant effect of number of modalities, nor the interaction of relatedness and the number of modalities.

Table 3

Percent of recall accuracy by NoM and by Relatedness condition in the free recall task

		Number of Modalities		
		Zero	Few	Many
Relatedness	Unrelated	19.6% (16.1; 23.6)	20.1% (16.5; 24.1)	20.8% (17.2; 24.8)
	Related	22.4% (18.7; 26.6)	29.4% (25.3; 33.9)	30% (25.9; 34.6)

Note. 95% confidence intervals are given in the brackets below the percent.

Table 4a

The estimates of the coefficients of the fixed effects and the fit indices for the first model

Predictors	Estimate	SE	*z*	*p*	Fit indices
(Intercept)	-1.53	.14	-1.80	.00	*AIC:* 2718.8
Relatedness: related	0.44	.19	2.34	.02	*BIC:* 2759.8
					logLik: -1352.4
Random effects					
σ^2 participant (intercept)	0.29				
σ^2 item (intercept)	0.18				
σ^2 item x relatedness (intercept)	0.06				
σ^2 relatedness, related (slope)	0.30				
Correlation (intercept & slope)	-0.69				

Note. SE – standard error of an estimate; *z* – z test; *p* – p-value; σ^2 - variance.

Table 4b

The estimates of the coefficients of the fixed effects and the fit indices for the second model

Predictors	Estimate	SE	*z*	*p*	Fit indices
(Intercept)	-1.71	.18	-9.50	.00	*AIC:* 2716.8
Relatedness continuous	0.10	.04	2.70	.01	*BIC:* 2746.1
					logLik: -1353.4
Random effects					
σ^2 participant (intercept)	.29				
σ^2 item (intercept)	.20				
σ^2 item: relatedness (slope)	.00				

Note. SE – standard error of an estimate; *z* – z test; *p* – p-value; σ^2 - variance.

The results from the free recall experiment are in accordance with the Marschark and Hunt relational-distinctiveness hypothesis (1989). As predicted, the NoM was attenuated in the free recall since relational information during the recall phase was absent. Generally, the recall accuracy was low in both related and unrelated conditions. However, in the related condition, the recall accuracy was enhanced by relational information and not by the additional sensory modality-specific memory codes. The recall was statistically equal for all three groups of words, regardless of the number of sensory modalities.

General discussion

Our results are partially in accordance with the DTC and the peg hypothesis (Paivio, 1971; Paivio et al., 1994) and partly in line with the relational-distinctiveness hypothesis (Marschark & Hunt, 1989; Marschark & Surian, 1992). The NoM effect was recorded in cued recall task after controlling for concreteness, context availability, emotional valence, and arousal. The highest accuracy was accomplished for the words denoting concepts that could be experienced with many perceptual modalities (three and more), and the lowest recall was recorded for abstract words. In other words, additional memory codes equally contributed to the recall accuracy in both relatedness conditions, i.e., the relational and perceptual information had an additive effect in the cued recall. These results were predicted entirely by the DCT

and conceptual peg hypothesis (Paivio, 1971; Paivio et al., 1994). It should be emphasized that perceptual information was defined as the number of perceptual modalities and not as word concreteness (two groups of concrete cue-target pairs were matched for concreteness). Thus, our results fit the Perceptual symbol systems theory (Barsalou, 2007; 2010). This finding implies that each additional modality-specific information contributed to the recall accuracy. This conclusion is straightforward: two critical groups of concrete words were matched not only for concreteness but also for visual perceptual strength. Thus, the difference in the recall accuracy between concepts experienced with few modalities and those experienced with many modalities can be attributed to richer perceptual experience. In terms of the conceptual peg hypothesis, a modality-specific perceptual experience related to concepts represents an additional memory peg. The results from the first experiment cannot be attributed to the context availability theory (Schwanenflugel et al., 1992) since the abstract and two groups of concrete terms had an equal degree of context availability. And finally, the NoM effect was not a consequence of the emotional experience (Kousta et al., 2009; Kousta et al., 2011) because the words were matched by emotional valence, and the arousal was statistically controlled in the analysis.

However, the results from the free recall were not in line with the DCT and peg hypothesis assumptions since the NoM did not influence the recall accuracy in either relatedness conditions. The relatedness between word pairs was the only significant predictor of the recall accuracy, where the participants were more accurate in a related condition. Thus, the results from free recall tasks were in accordance with the relational-distinctiveness hypothesis. According to this hypothesis, recall is not enhanced by a perceptual richness of cue-target pairs but only by their relatedness in the free recall. Again, none of the alternative theoretical explanations was eligible since the same lists of words were used in this task as in the cued recall.

Finally, this paper demonstrates that the perceptual richness of the words plays a significant role in the recall and the PAL paradigm. However, this benefit of the perceptual information is conditioned by a recall task. Namely, cued recall is enhanced by a larger number of sensory modalities through which a concept could

be experienced, regardless of the cue-target relatedness. On the other hand, in a free recall task, the benefit of the perceptual information is diminished.

It should be pointed out that the participants did not receive instruction to remember the words in any of the experiments. According to some authors (Barsalou et al., 2003; Pecher et al., 2009), it is essential to demonstrate that perceptual information spontaneously stimulates cognitive processes since such results would indicate that sensory-motor simulations are part of the conceptual knowledge. Moreover, it is essential to distinguish the imagery processes from sensory-motor simulations related to conceptual knowledge. The imagery is considered intentional, and it is related to the ability of individuals to create mental images. On the other hand, conceptual knowledge and retrieval are mostly not under conscious control (Pecher et al., 2009). Therefore, if sensory-motor simulations are part of concept representations, they should be retrieved unconsciously. Since, in our experiments, the participants were not instructed to use imagery as a mnemonic technique, nor were they informed about the later recall task, we could say that the effect of perceptual diversity was a consequence of the modality-specific simulations and not the imagery processes. This conclusion is promoted by the fact that both groups of concrete words were matched for visual strength (the extent to which a concept is experienced visually), the variable that extrapolated imageability. Both experiments could be administered as explicit memory tasks to explore whether such experimental manipulation would advance the influence of the perceptual richness in free recall.

This study has several weak points, which could be advanced in future studies. Firstly, by the recommendation of Brysbaert (2020) and Brysbaert and Stevens (2018) concerning the statistical power in mixed linear models, the number of participants should be enlarged, especially if the interaction is tested (which is the case in this study). Secondly, the low recall rate in free recall suggests that recall of word pairs was demanding for the participants. Thus, in future research, one should reconsider changing the instruction of the free recall task. For instance, participants should be encouraged to recall any words they could come up with (cue or target), not just word pairs. Finally, in an unrelated condition, we sampled different cue words in this study. However, using the same but reorganized cues in

unrelated conditions would be more informative. It would provide more precise insight into the relevance of contextual information for Paired-Associate Learning.

Note

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Conflict of interests

The authors declare no conflict of interest or competing interests.

Ethical approval

This study was performed with the principles of the Declaration of Helsinki. The approval was granted by the Ethics Committee of the Department of psychology, Faculty of Philosophy, University of Novi Sad, Republic of Serbia, License No. 20151025144144_juke. All participants in this study signed the informed consent to participate in the study and consent for data publication.

Open data access

The data of this study, together with the R statistical codes, are placed on the author's OSF page: OSF page link.

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Apendix A

List of word pairs in related and unrelated situations, with value of relatedness for each pair

CUE word	TARGET word	NoM	Relatedness category	Relatedness
Teorija	nauka	ZERO	RELATED	6.6
memorija	znanje	ZERO	RELATED	6.3
Duša	smrt	ZERO	RELATED	4.65
Sreća	bogatstvo	ZERO	RELATED	4.15
ljubomora	zavist	ZERO	RELATED	6.15
Vreme	istorija	ZERO	RELATED	6.1
sloboda	misao	ZERO	RELATED	5.7
San	mašta	ZERO	RELATED	5.85
Mit	religija	ZERO	RELATED	6.4
dogovor	politika	ZERO	RELATED	5.7
osećanje	potreba	ZERO	RELATED	5.2
Plakat	bilbord	FEW	RELATED	6.5
Odžak	krov	FEW	RELATED	6.8
Igla	ubod	FEW	RELATED	6.55
Sijalica	bandera	FEW	RELATED	6.2
sveska	olovka	FEW	RELATED	6.25
Leptir	cvrčak	FEW	RELATED	5.75
Suknja	pantalone	FEW	RELATED	6.5
fotografija	slika	FEW	RELATED	6.7
Nož	kutlača	FEW	RELATED	5.85
Ekran	monitor	FEW	RELATED	7
Cigla	kamen	FEW	RELATED	5.75
Patika	čarapa	MANY	RELATED	6.2
Nokat	aceton	MANY	RELATED	5.8

Vosak	sveća	MANY	RELATED	6.9
deterdžent	sapun	MANY	RELATED	6.25
autobus	automobil	MANY	RELATED	6.55
pepeljara	cigareta	MANY	RELATED	6.9
bosiljak	cimet	MANY	RELATED	5.3
Žaba	kiša	MANY	RELATED	5.05
Lepak	smola	MANY	RELATED	5.85
Voda	vatra	MANY	RELATED	5.55
Cvet	pčela	MANY	RELATED	6.45
jednakost	nauka	ZERO	UNRELATED	3.1
Stil	znanje	ZERO	UNRELATED	2.9
Istina	smrt	ZERO	UNRELATED	3.85
bliskost	bogatstvo	ZERO	UNRELATED	2.45
Dosada	zavist	ZERO	UNRELATED	2.75
Požuda	istorija	ZERO	UNRELATED	1.9
Kriza	misao	ZERO	UNRELATED	2.7
profesija	mašta	ZERO	UNRELATED	4.25
Humor	religija	ZERO	UNRELATED	2.95
sudbina	politika	ZERO	UNRELATED	2.8
Dobrota	potreba	ZERO	UNRELATED	2.85
Lava	bilbord	FEW	UNRELATED	1.1
radijator	krov	FEW	UNRELATED	2.65
reflektor	ubod	FEW	UNRELATED	1.55
Žbun	bandera	FEW	UNRELATED	2.6
vetrenjača	olovka	FEW	UNRELATED	1.5
Varnica	cvrčak	FEW	UNRELATED	1.6
dalekovod	pantalone	FEW	UNRELATED	1.25
putokaz	slika	FEW	UNRELATED	4.05
Planina	kutlača	FEW	UNRELATED	1.1
Ptica	monitor	FEW	UNRELATED	1.3

Šal	kamen	FEW	UNRELATED	1.05
Nafta	čarapa	MANY	UNRELATED	1.35
Seno	aceton	MANY	UNRELATED	1.3
Prašina	sveća	MANY	UNRELATED	2.1
paprikaš	sapun	MANY	UNRELATED	1.25
bajadera	automobil	MANY	UNRELATED	1.3
Prase	cigareta	MANY	UNRELATED	1.1
Testera	cimet	MANY	UNRELATED	1.4
Slag	kiša	MANY	UNRELATED	1.45
Pljesak	smola	MANY	UNRELATED	1.25
Slon	vatra	MANY	UNRELATED	1.55
tastatura	pčela	MANY	UNRELATED	1.15

Notes. Cue – cue word, Target – target word; NoM – number of modalities category; Relatedness category – related and unrelated; Relatedness – mean rating of relatedness for a given word pair