Sensory Load and Word Recognition

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Abstract

The hallmark of the Perceptual Symbol Systems model is the hypothesized perceptual simulation that is at the core of conceptual representation. The simulation can be boosted if the attention is directed towards a given modality, or prevented if the input information occupies attentional resources within the given modality. Here, we make use of this effect to demonstrate that perceptual simulation occurs not only when explicitly addressing particular sensory feature (as previously demonstrated), but also in word recognition. We hypothesized that working memory load in the given modality would cancel-out the simulation boosting effect that occurs when the presentation modality and the modality of perceptual experience with objects denoted by the given word are the same. Indeed, our results revealed that the simulation boosting effect that had been observed in the control condition was cancelled out under cognitive load condition by the selective interference. In the light of Perceptual Symbol Systems, this is interpreted as a consequence of the preventing of perceptual simulation, thus pointing to the role of perceptual simulation in the process of word recognition.

Keywords: dual tasks; embodied cognition; lexical decision task; semantic memory; working memory

Introduction

According to the Perceptual Symbol Systems model (Barsalou, 1999) the semantic representation of the word is grounded in the perceptual experience with an object that is denoted by that word and is recorded in the neural states that underlie the process of perception. In order to understand the meaning of the word, i.e. in order to activate the semantic representation, one must re-enact the very pattern of neural activation that had been present during the experience with the object denoted by the given word. In other words, the process of semantic activation is coupled with the process of the simulation of the specific perceptual experience.

Previous research has shown that the process of simulation can be both boosted and prevented (Connell & Lynott, 2012). The boosting of simulation occurs if the perceptual stimulation is applied in such a way that it directs attention to the given modality without occupying the resources within that modality, thus leading to easier simulation and facilitated processing. For example, responding to perceptual stimulus (e.g. visual) leads to subsequent shorter property verification time in the same perceptual modality (e.g. *broccoli is green*; van Dantzig, Pecher, Zeelenberg, & Barsalou, 2008). Similarly, tactile stimulation of the hands leads to faster naming of the relevant object (e.g. *which is bigger: wallet or key*; Connell, Lynott, & Dreyer, 2012). In addition to the boosting, the simulation can also be prevented. This happens if perceptual stimulation from the input occupies attention within the modality thus leaving insufficient resources for the process of simulation and leading to interference. For example, attending to auditory illusion which depicts motion leads to slower sensibility judgements of the sentences that describe the same motion (Kaschak, Zwaan, Aveyard, & Yaxley, 2006). Similarly, holding perceptual stimuli in memory (e.g. visual shapes) leads to slower property verification in the same modality (e.g. *lemon can be yellow*; Vermeulen, Corneille, & Niedenthal, 2008).

In the current research, in order to demonstrate that perceptual simulation is present in word recognition, we aim to join the boosting and the preventing of the simulation in a single study. We start by reasoning that if directing of attention boosts the simulation, and occupying of attention prevents it, than occupying of attention should cancel out the boosting effect in a situation where both are present simultaneously. We will take as the starting point the boosting effect that was observed by Živanović and Filipović Đurđević (2011). In that study, two categories of words were selected: nouns that denote objects that can only be experienced visually (e.g. *rainbow*) and nouns that denote objects that can only be experienced auditorily (e.g. *melody*). Both groups of words were presented in both visual and auditory lexical decision task, i.e. through visual and auditory sensory modality. The results revealed that visual lexical decision latencies were shorter for words denoting visual objects, whereas auditory lexical decision latencies were shorter for words denoting auditory objects. In other words, the boosting of simulation within a perceptual modality was observed if the stimuli were presented in that modality. Visual word presentation directed the attention to visual modality thus helping the simulation of words denoting objects that can be experienced visually. Along the same line, auditory word presentation directed the attention to auditory modality thus boosting the simulation of words denoting objects that can be experienced auditorily. Importantly, in neither case the attentional resources were not occupied, only directed towards a modality. In the current research, we attempted to cancel out this boosting effect by preventing simulation. This was to be achieved by occupying attentional resources within a modality, and we attempted to do so by introducing Working Memory (WM) load within the given modality. We taxed Phonological Loop (PhL) by asking participants to perform lexical decision while performing Serial Digit Recall, and Visuospatial Sketchpad (VSSP) by simultaneous lexical decision and memorizing of visual objects. We predicted that VSSP load will cancel out the advantage of words denoting visual objects only in visual lexical decision task, whereas PhL load will cancel out the advantage of words denoting auditory objects only in auditory lexical decision task.

Method

We conducted a dual task experiment. The primary task was lexical decision task, whereas the second task was designed to tax either PhL or VSSP.

Participants

A total of 111 participants took part in the experiment for the fulfillment of partial course credits. They were randomly assigned to one experimental condition (*N1* = 21; *N2* = 18; *N3* = 18; *N4* = 18; *N5* = 18; *N6* = 17). All were native speakers of Serbian with normal, or corrected-to-normal vision, who signed informed consent form prior to participating. The study was approved by Ethical Committee of the Department of Psychology, at Faculty of Philosophy, at University of Novi Sad.

Materials and design

We adopted the two groups of Serbian nouns from Filipović Đurđević and Živanović (2011). One group consisted of nouns denoting objects that could only be perceptually experienced in visual modality (*N* = 20), whereas the other group denoted objects that could only be perceptually experienced in auditory modality (*N* = 20). The two groups were matched for word length, orthographic neighborhood, uniqueness point, lemma frequency, and word familiarity (subjective frequency). The forty critical stimuli, along with fillers (*N* = 20) and pseudo-words (*N* = 60) were presented to four groups of participants. Half of the participants were presented with ALD and half of them were presented with VLD. Simultaneously with performing lexical decision, participants were engaged in the second task which incurred additional WM load. Within each presentation modality, half of the participants were performing serial digit recall which was taxing their Phonological Loop (PhL), whereas half of the participants were memorizing visual matrices which taxed their Visuospatial Sketchpad (VSSP). Additionally, the data collected from two groups of participants that were engaged either in VLD or ALD without additional WM load were taken from Filipović Đurđević and Živanović (2011) to serve as the control condition.

The targeted design was 2x3x2 factorial design. We manipulated the presentation modality between participants (VLD, ALD), the modality of WM load between participants (PhL load, VSSP load, no load), and the modality of the experience with an object between stimuli (visual, auditory).

Procedure

The dual-task procedure of Lexical Decision Task coupled with WM load was adopted from Preković et al., (2016). Stimuli were presented in blocks which were preceded by presentation of the material to be maintained in WM during the LD task and recalled at the end of each block.

Results

Linear mixed effects regression model fitted to log transformed processing latencies revealed significant three-way interaction of the presentation modality, modality of WM load and modality of the experience with an object (Table 1 and Figure 1).

Although PhL load incurred the highest processing cost (as expected given the verbal nature of the primary task), this effect was the same across word types and across the presentation modalities. As compared to the no-load (control) condition, VSSP load was also detrimental for processing in general. However, VSSP load was more detrimental for processing words which denoted visual objects, but only when presented in VLD. In other words, VSSP load was more detrimental for processing visually presented words denoting objects that can be experienced visually (e.g. *rainbow*) than to visually presented words denoting objects that can be experienced auditorily (e.g. *melody*).

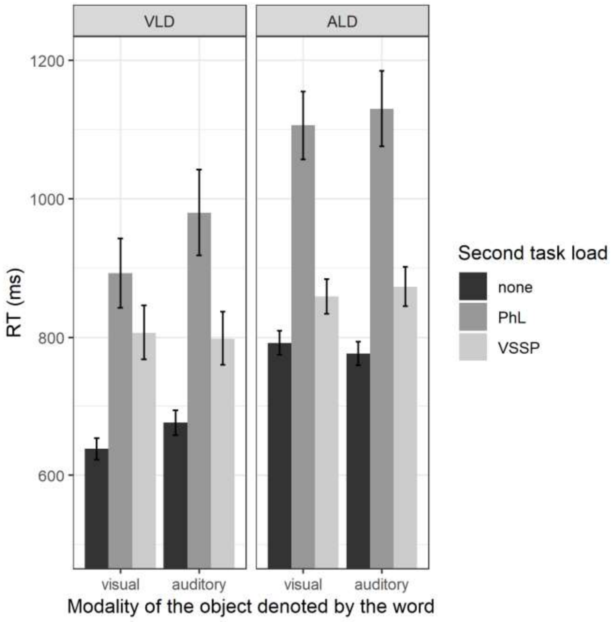

Figure 1: Average reaction time per condition. The left hand side plots data from Visual Lexical Decision task (VLD) and the right hand side plots the data from Auditory Lexical Decision task (ALD). Shades of gray depict the type of processing load: control condition (no load - none), Phonological Loop load (PhL), and Visuospatial Sketchpad (VSSP). Perceptual modality of the objects denoted by the words in question is presented on x axes. Vertical bars denote 95% confidence intervals.

Table 1: Coefficients from the mixed-effects regression model fitted to (log transformed) processing latencies.

Random Effects	Variance	Std.Dev.
Participant (Intercept)	.018	.134
By-participant slope for the order of trial presentation	.002	.040
Word (Intercept)	.007	.086
Residual	.216	

Fixed Effects	Estimate	Std. Error	t value	Pr(>|t|)
Intercept (Perceptual modality: visual; Presentation modality: VLD; Second task load: none)	**6.44**	**.04**	**165.26**	**<.001**
Order of trial presentation	.01	.01	1.33	.187
Perceptual modality: auditory	**.06**	**.03**	**1.97**	**.054**
Presentation modality: ALD	**.22**	**.05**	**4.78**	**<.001**
Second task load: PhL	**.23**	**.05**	**4.74**	**<.001**
Second task load: VSSP	**.18**	**.05**	**3.80**	**<.001**
Perceptual modality: auditory, Presentation modality: ALD	**-.08**	**.02**	**-3.53**	**<.001**
Perceptual modality: auditory, Second task: PhL	-.01	.03	-.34	.735
Perceptual modality: auditory, Second task: VSSP	**-.07**	**.03**	**-2.68**	**.007**
Presentation modality: ALD, Second task: PhL	.05	.07	.69	.494
Presentation modality: ALD, Second task: VSSP	-.12	.07	-1.80	.074
Perceptual modality: auditory, Presentation modality: ALD, Second task: PhL	-.01	.04	-.25	.806
Perceptual modality: auditory, Presentation modality: ALD, Second task: VSSP	**.09**	**.03**	**2.55**	**.011**

Discussion

We have observed that cognitive load could cancel out the simulation boosting effect if presented within the same modality. Such cancelling-out effect is rooted in the preventing of simulation that occurs as a consequence of such load occupying attentional resources (Connell & Lynott, 2012). By doing so, we have demonstrated that perceptual simulation is present in word recognition, as postulated by Perceptual Symbols model (Barsalou, 1999).

However, the predicted effect was observed only in visual domain. Therefore, future research should focus on replicating the effect in a higher-powered study and on manipulating cognitive load in a way that would allow for relating a change in cognitive load with a change in processing latencies.

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