Motor Simulation and Verbal Association in Idiom-Idiom Verification: Effects of Imageability

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Abstract

Two experiments were conducted to test the hypothesis that motor simulation contributes to the processing of idioms. A semantic interference paradigm was applied. Critically, imageability of idioms was manipulated. Results of the experiments suggested that processing of highly imageable idioms involved motor simulation in both meaning and familiarity verification tasks. However, low-imageable idioms showed indifference in semantic verification task and a verbal associative facilitation in a familiarity verification task.

Keywords: motor simulation; embodiment; language understanding; imageability; idioms; RT.

Introduction

According to the embodiment paradigm higher-level cognitive processing is based in people's interaction with the environment and is grounded in lower-level sensory-motor processes. From this perspective, language is of great interest since it has traditionally been viewed as a highly symbolic and abstract system. The embodiment paradigm predicts that language should also be grounded in sensory-motor experience and therefore interactions with the lower-level perceptual and motor systems should occur. A variety of experiments have been devoted to looking into this hypothesis. For example, Glenberg and Kaschak (2002) demonstrated the so called "action-sentence compatibility effect". Sentences were presented describing movement to or away from the body and the participants had to respond by actually performing a movement to or away from the body. People were faster if the direction of movement implied by the sentence matched the direction of their actual movement, as opposed to when the two directions did not match. Thus, sentence comprehension and motor processes were found to interact. Moreover, this effect was also present when the sentences described transfer of abstract entities (e.g. *You told Liz the story*) which means that the effect is not restrained to highly literal language describing strictly physical experience, but is also observed at different levels of abstraction. Richardson, Spivey, Barsalou and McRae (2003) also showed that both concrete (e.g. *push, lift*) and abstract (e.g. *respect, own*) verbs tend to invoke a particular horizontal or vertical image schema, and that this image schema interacted with people's performance on both an unrelated object categorization task and a related picture recognition task. Scorolli and Borghi (2007) presented participants with phrases that contained verbs referring to actions with different effectors (HAND, FOOT, MOUTH) and they were asked to make a sensibility judgment by either speaking into a microphone or pressing a pedal. A facilitation effect was observed when the effector involved in the motor response and the one implied by the phrase matched. Thus, the modulation of the motor system appears to be effector-specific. In a study by Bergen, Narayan and Feldman (2003) participants were presented with pictures representing actions performed by the hand, leg, or mouth. After that they saw a verb and were asked to indicate whether the verb described the picture they had just seen. On the critical trials the verbs did not match the actions on the pictures, but they either referred to actions preformed by the same effector or to actions performed by a different effector. If linguistic input triggers activation in a specific motor circuit then it can be expected that a person will need more time to respond if overlapping motor circuits are activated (i.e. responsible for actions with the same effector) rather than non-overlapping ones (responsible for actions with different effectors). Indeed, Bergen et al. (2003) demonstrated a semantic interference effect - participants in their study were slower when both the picture and the verb referred to actions with the same effector rather than to actions with different effectors. Brain imaging also provides evidence for effector-specific motor activation during comprehension of verbs (e.g. Pulvermüller, Haerle & Hummel, 2001) and idioms (Boulenger, Hauk and Pulvermüller, 2009). The results above are at odds with the traditional view on language as highly abstract and operating on amodal symbolic structures.

An alternative to the traditional approach on symbolic systems was proposed by Barsalou (Barsalou, 1999; Barsalou, Solomon, &Wu, 1999). According to the theory of perceptual symbol systems (PSS) schematic representations are derived from actual sensory-motor activations, these representations are stored in memory and function as symbols for certain referents. That is, knowledge representation is not abstract and amodal, but grounded and multimodal (based in different modalities). Perceptual systems are organized in frames called simulators that allow entities, states and events to be simulated in the absence of perceptual input. Simulation is defined as "reenactment of perceptual, motor and introspective states acquired during

experience with the world, body, and mind" (Barsalou, 2008, p.618). Barsalou and colleagues emphasized that simulation does not have to be a conscious process and happens automatically. Barsalou, Solomon and Wu (1999) compared people's performance on a feature listing and feature verification task when half of the participants in each study were given an explicit imagery instruction and the other half were not (neutral instruction). The results supported the hypothesis that both instructions were equivalent (that is, there was no difference in performance) in triggering simulation. However, Solomon and Barsalou (2004), point out that in the imagery condition simulations seem to be richer in detail. It seemed that two mechanisms were at work when people had to verify whether a certain property was related to a particular category, one being deep conceptual processing and the other one activation of lexical associations. Words referring to properties of a particular category are usually also highly associated on a lexical level with the word standing for the category (e.g. a TREE has *leaves*, but these words are also highly associated on the lexical level). If in the experiment the properties that were not associated with the category were also not lexically associated (e.g. TREE and *bricks*), then people would adopt a word-association strategy and simulation effects seemed to be overridden. If on the other hand, the non-related properties were lexically related (for example CRAB is associated with *fin* but *fin* is not a property of CRAB), this strategy was blocked and simulation effects were found. This data is also in keeping with Paivio's (1991) Dual Coding Theory which states that there are two systems, a verbal and a sensorimotor one, responsible for performing manipulations on information, and that these systems are richly interconnected. Different linguistic stimuli can be coded not only as *logogens* in the verbal system, but also to a different extent as *imagens* in the non-verbal system. Thus, imagery can be automatically activated and closely connected with simulation, as shown in other studies, as for example that of Zwaan and Madden (2005). Participants were presented with sentences such as *The ranger saw the eagle in the sky* followed by a picture-naming task. People responded faster if the visual properties of the picture corresponded to the ones implied by the sentence, which suggests that visual imagery must have been automatically employed and is closely linked with the process of simulation.

In research on idiom processing, Janyan and Andonova (2000) received a facilitation effect of an explicit imagery instruction on the comprehension of unfamiliar transparent idioms (semantically transparent idioms are those meaning of which can be guessed from the meaning of the individual words forming the phrases). These results emphasize the importance of two factors in the processing of idioms: imagery on the one hand, and transparency on the other. The effect of transparency, especially in unfamiliar idioms, demonstrates an important point, namely that individual words in an idiomatic phrase do contribute to the overall processing and comprehension of the idiom which contradicts the traditional view, in which idioms have been viewed as separate lexical units that function as a whole, rather than having a compositional nature. According to the Idiom Decomposition Hypothesis by Gibbs and Nayak (1989), individual words actively contribute to the processing of the whole idiom. If this is so, it could be expected that if a simulation process occurs during idiom processing, then it would be at least partly due to the simulation triggered by the individual words. Furthermore, if an idiomatic expression contains verbs referring to actions with a particular effector, this would cause effector-specific motor simulation despite the fact that the overall figurative meaning of the idiom might have nothing to do with actual movement.

The present study steps on the above assumption, while at the same time it is expected that imagery unconsciously evoked by the idiomatic phrase as a whole would also play a most important role due to its connection to simulation processes. In our previous series of experiments (Gradinarova & Janyan, submitted) the possible effects were studied of idioms' imageability (i.e. the ease with which an idiom evokes a mental image) and transparency (i.e. the extent to which the idiomatic meaning can be guessed from the individual meaning of the constituent words). Some evidence was found for effector-specific motor simulation in highly imageable idioms, while transparency did not seem to be as important for triggering a simulation process. However, in the experiments mentioned participants were given a task requiring fairly superficial processing on the lexical level. They were presented with idiomatic expressions followed by a single verb and had to indicate whether the verb contained in the idiom and the one presented afterwards were the same word or not. The critical trials required a NO response – to the verbs referring to either an action performed with the same effector or a different effector as the action referred to by the verb in the idiom (a procedure adopted and modified from Bergen et al., 2003). In the following two experiments, a different task was implemented requiring a deeper level of conceptual processing. Also, only idiomatic expressions were used as stimuli, creating a focus on processes characteristic purely of comprehension of idiomatic language. In the first experiment, pairs of idioms were presented and participants had to indicate whether the two idioms in each pair had approximately the same meaning. In the second experiment, a more superficial task was implemented, requiring subjects to indicate whether they are familiar with (have ever heard) the idioms presented. In both experiments, imageability of the target idioms was varied, while familiarity (the extent to which a person has had experience with a particular expression) and transparency were kept comparatively high and controlled. We expected to find a semantic interference effect/evidence of motor simulation in highly imageable idiom processing and not in low-imageable one.

Experiment 1: Meaning Verification

Method

Participants 26 native Bulgarian speakers participated in the experiment. 21 were female and 5 were male (mean age=20.5 and SD=11.38).

Stimuli and Design A 2 (Effector Matching: Same Effector vs. Different Effector) x 2 (Imageability: High vs. Low) factorial design was implemented. All target idioms contained verbs that referred to movement with a particular effector: HAND (e.g. *hvashtam mu kraya*, literally *catch its end,* meaning *manage to understand,* where the verb *hvashtam/catch* refers to an action performed with the hand); FOOT (e.g. *klatya si krakata*, literally *dangle one's legs,* meaning *not do anything*) or MOUTH (e.g., *glatvam si gramatikata,* literally *swallow your grammar*, meaning *not be able to say anything)*. 16 high-imageability idioms were paired with 16 high- imageable idioms with same effector or with 16 high-imageability idioms with a different effector. Similarly, 16 low-imageability idioms were paired with 16 low-imageability idioms with same effector or 16 low-imageability idioms with different effector. All 32 idioms that appeared in the first position in a pair contained a verb referring to a HAND motion. In the Same Effector condition the second member of the pair also contained a HAND motion verb, while in the Different Effector condition the second idiom contained a verb referring to an action with the FOOT or MOUTH effector. Table 1 shows examples of idiom pairs in the different conditions.

Table 1: Examples of target idiom pairs

High Imageability	
Idiom1	*hvashtam bika za rogata* (literally: *catch the bull by the horns;* meaning: *act with confidence and determination*)
Idiom 2 Same Effector	*nosya nyakogo na ratse* (literally: *carry someone on your hands;* meaning: *to surround somebody with a lot of care and attention*)
Idiom 2 Different Effector	*uhilvam se do ushi* (literally: *grin to the ears;* meaning: *grin very broadly*)
Low Imageability	
Idiom1	*hvashtam se za dumite* (literally: *hold on to the words;* meaning: *pay too much attention to something said incidentally or without a specific intention)*
Idiom 2 Same Effector	*nalivam um v glavata* (literally: *pour brains into the head;* meaning: *teach or advise someone*)
Idiom 2 Different Effector	*otritvam kasmeta si* (literally: *kick one's luck aside;* meaning: *not to take advantage of a good situation*)

The idioms in the target pairs were controlled for their familiarity, transparency and length (measured in numbers of words and number of characters including spaces). Table 2 shows idiom characteristics collapsed over effector matching conditions, and Table 3 shows idiom characteristics separately for each Effector Matching condition for the second idiom in a presentation row. Low and high imageable items were significantly different in their imageability ratings (p<0.001). T-test showed no significant differences between conditions in idioms' characteristics: familiarity, transparency, number of characters, and number of words in the phrases (all p_s>0.1).

Table 2: Means and standard deviations (in parenthesis) for characteristics of target idiom pairs.

	High Imageability		Low Imageability	
	idiom 1	idiom 2	idiom 1	idiom 2
Imag.	5.7 (0.5)	5.4 (0.27)	3.6 (0.4)	3. 6 (0.3)
Famil.	6.1 (0.3)	6.2 (0.40)	6.1 (0.5)	6.0 (0.7)
Transp.	5.0 (0.6)	5.0 (0.61)	4.9 (0.7)	4.9(0.8)
N.char.	17.4(4.0)	18.0 (3.7)	18.4 (4.6)	18.3 (4.8)
N.word	3.1 (0.9)	3.0 (1.0)	3.1 (1.1)	3.1 (1.0)

Table 3: Means and standard deviations (in parenthesis) for characteristics of second idiom in a presentation row.

	High Imageability		Low Imageability	
	Same effector	Different effector	Same effector	Different effector
Imag.	5.4 (0.3)	5.4 (0.3)	3.6 (0.3)	3.6 (0.3)
Famil.	6.2 (0.5)	6.2 (0.3)	6.1 (0.7)	6.0 (0.7)
Transp.	5.1 (0.5)	5.0 (0.7)	4.9 (0.8)	5.0 (0.8)
N.char.	19.0 (3.3)	16.9 (3.9)	17.6 (5.9)	18.9 (3.4)
N.word	3.3 (1.2)	2.8 (0.8)	2.9 (1.1)	3.2 (0.9)

Note. Imageability, familiarity, and transparency represent a 7-point subjective rating (7 – the most imageable, familiar, and transparent) based on a number of pretests conducted with native Bulgarian speakers; N. char. and N. word refer to idiom length measured in number of characters and number of words, respectively.

In addition to 32 target idioms (requiring a NO response), 18 pairs of filler idioms containing verbs with different effectors requiring a NO response, and 50 synonymous pairs of idiomatic expressions (requiring a YES response) were constructed.

Procedure A phrase verification task was used. Participants saw two idioms presented on a screen one after the other and had to press a YES button if the phrases had (approximately) the same meaning, or press a NO button if the meaning of the idioms was different. Examples of

idioms requiring a YES and a NO responses were given in the instruction text.

Effector matching condition was counterbalanced across idioms. For that two lists were devised so that each initial idiom in a pair appeared in one Effector Matching condition in the first list and in the other Effector Matching condition in the second list. Each participant saw every target idiom only once. At the beginning of the experiment, participants were randomly assigned to one of the two lists, presented with a written and oral instruction, and were then run through a short practice session. After that the experiment started and participants were presented with the respective list in a unique for each participant pseudorandomized order so that the same condition did not appear on more than 3 consecutive trials. Every trial started with a fixation cross ("+") for 1000 ms followed by an idiom that stayed on the screen for 1500 ms, and then a blank screen for 500 ms. After that a second idiom was presented and stayed on the screen for 4000 ms or until the participant's response. The intertrial interval was 1500 ms.

E-prime software (Schneider, Eschman, & Zuccolotto, 2002) was used to present the stimuli and record the RTs. Participants had to press a YES or NO button on a serial response box with a 1 ms time resolution. The experiment was run in a sound-proof booth and took about 12 minutes. Participants took a short break in the middle of the experiment.

Results and Discussion

Prior to the analysis, erroneous responses (5.4%) and response times lying more than ±2 standard deviations from the RT mean per condition were excluded (3.5%).

A 2 (Imageability: Low vs. High) x 2 (Effector Matching: Same vs. Different) repeated measures ANOVA was performed for item means, with effector type as a within-group variable and imageability a between-group variable, and for subject means, with effector type and imageability as within-group variables. Table 4 shows mean response times and standard deviations per condition for each mean type.

Table 4: Mean response times (in ms) and standard deviations (in parenthesis) for the experimental conditions, item (*i*) and subject (*s*) means, Experiment 1.

	Low Image	High Image
Different Effector, *i*	1597 (150)	1442 (164)
Same Effector, *i*	1578 (239)	1575 (124)
Different Effector, *s*	1597 (215)	1443 (256)
Same Effector, *s*	1580 (282)	1590 (257)

Predictably, repeated measures ANOVA revealed a main effect of imageability in subject means though not in item means ($F_s(1, 25)=5.51$, $p<.05$, $\eta_p^2=.18$; $F_i(1, 30)=2.81$, $p>.1$, $\eta_p^2=.09$). The significant main effect suggested that response times were faster for processing of a high-imageability idiom (1517 ms) than for one with low imageability (1589 ms; cf. Table 4). This effect is in accordance with studies showing advantage of concrete words over abstract ones in a variety of linguistic and memory tasks (e.g., Schwanenflugel, Harnishfeger & Stowe, 1988; Hamilton & Rajaram, 2001; Allen & Hulme, 2006). Dual Coding Theory (Paivio, 1991) posits that imageable concrete entities have both verbal and non-verbal representations which 'ensure' their advantage over abstract entities that have a representation in the verbal modality only.

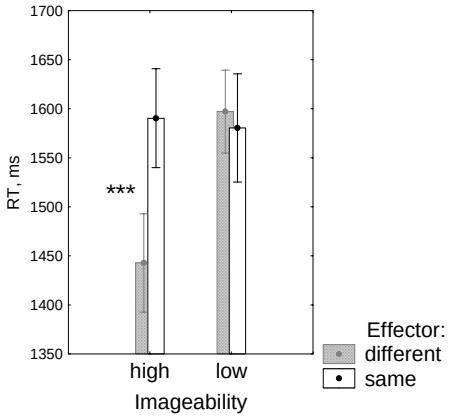

Figure 1: Imageability by Effector Matching, subject means (vertical bars denote standard error).
*** - $p<0.001$.

ANOVA obtained main effect of effector matching again in subject analysis but not in item analysis ($F_s(1, 25)=4.41$, $p<.05$, $\eta_p^2=.15$; $F_i(1, 30)=2.04$, $p>.1$, $\eta_p^2=.06$). Overall, idioms with different effector were processed faster (1520 ms) than idioms with the same effector (1585 ms). Finally, a significant interaction was found in subject means ($F_s(1, 25)=10.37$, $p<.01$, $\eta_p^2=.30$) and a marginal one in item means ($F_i(1, 30)=3.61$, $p<.07$, $\eta_p^2=.11$). The interaction is presented in Figure 1. It is seen that semantic interference effect is present in processing of high-imageability idioms ($p<0.001$) and absent in the processing of low-imageability ones.

Experiment 2: Familiarity Verification

The experiment sought to test if the semantic interference effect would be strong enough and 'survive' a task that does not require explicit semantic processing and meaning activation of idioms and their constituents. A familiarity decision task was used in such a way that target phrases required a NO response, too, as it was in the Experiment 1.

Method

Participants 24 native Bulgarian speakers participated in the experiment. 18 were female and 6 were male (mean age=24.7 and SD=3.46).

Stimuli and Design The same target stimuli and design were used as in Experiment 1. Because of the difference in the task, other 50 pairs of idioms were used as YES fillers. In these pairs either the first or the second idiom (or rarely both) were unfamiliar idioms translated into Bulgarian from other languages. 30 pairs of stimuli were taken from a previous study on processing of unfamiliar/unknown idioms (Janyan & Andonova, 2000). The rest were taken from another (unpublished) study on memorizing unfamiliar idioms.

Procedure A familiarity verification task was used. Participants had to judge whether at least one of the idioms they saw in a pair was unfamiliar by pressing the YES button if there was an unfamiliar idiom and the NO button if there was not. Everything else was the same as in Experiment 1.

Results and Discussion

Errors (5.6%) and response times lying more than ±2 standard deviations from the RT mean per condition were excluded (4.7%) from the analyses. A 2 (Imageability: Low vs. High) x 2 (Effector Matching: Same vs. Different) repeated measures ANOVA was performed for item and subject means with the same within- and between-group variables as in Experiment 1. Table 5 presents mean response times and standard deviations per condition for subject and item means.

Table 5: Mean response times (in ms) and standard deviations (in parenthesis) for the experimental conditions, item (*i*) and subject (*s*) means, Experiment 2.

	Low Image	High Image
Different Effector, *i*	1455 (216)	1277 (115)
Same Effector, *i*	1337 (171)	1370 (108)
Different Effector, *s*	1452 (366)	1293 (311)
Same Effector, *s*	1349 (276)	1394 (328)

Repeated measures ANOVA replicated a main effect of imageability in subject means but not in item means ($F_s(1, 23)=4.72$, $p<.05$, $\eta_p^2=.17$; $F_i(1, 30)=2.82$, $p>.1$, $\eta_p^2=.09$). The significant main effect showed that response times on the second phrase were faster for a high-imageability idiom (1344 ms) than for a low-imageability idiom (1401 ms; cf. Table 5). ANOVA obtained no main effect of effector matching ($F_s(1, 23)=0.001$, $p>.9$, $\eta_p^2=.00$; $F_i(1, 30)=0.11$, $p>.7$, $\eta_p^2=.004$) and a significant interaction in subject and item means ($F_s(1, 23)=18.44$, $p<.001$, $\eta_p^2=.44$; $F_i(1, 30)=8.62$, $p<.01$, $\eta_p^2=.22$). The interaction is presented in Figure 2. The interaction showed a surviving semantic interference effect in processing of high-imageability idioms ($p<0.01$). However, processing of low-imageability idioms elicited an opposite pattern: idioms with same effectors facilitated processing in comparison to idioms with different effectors ($p<0.01$). Thus, here a task requiring a more 'superficial' processing probably triggered activation of verbal/lexical associations in low-imageability idioms though still on the level of concrete individual constituents of the idioms (verbs).

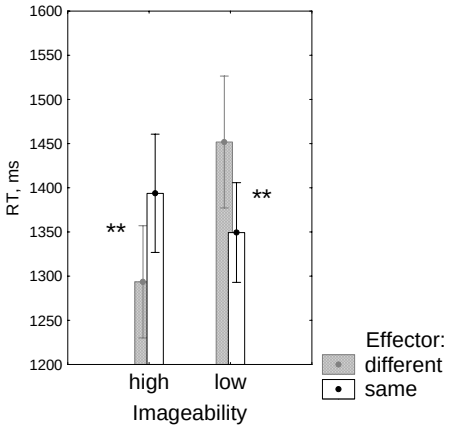

Figure 2: Imageability by Effector Matching, subject means (vertical bars denote standard error). ** - $p<0.01$.

Conclusion

Most previous studies have been trying to find support for links between language/semantic processing and sensory-motor experience by investigating processing of single words/pictures or literal sentences. Very little is done on seeking grounded links in figurative language processing. The present studies aimed at testing whether motor activation is involved in the processing of idioms that contain a verb denoting an action. Based on previous research that suggested imagery as an important part of mental simulation (e.g. Zwaan & Madden, 2005) we reasoned that presentation of highly imageable transparent idioms would evoke a mental image that would trigger the motor simulation. However, idioms with low imageability would not evoke a mental image, hence, would not trigger mental simulation. To test these assumptions, we used a semantic interference paradigm (Bergen et al., 2003) pairing each idiom (that contained a verb denoting an action performed by the hand) with two other idioms. The paired idioms contained a verb denoting an action that is performed with either the same (hand) or a different effector (foot, mouth). The expected indicator of motor simulation during imageable idiom processing would be the semantic interference effect. In the case of a shared effector the activation of corresponding parts of the motor cortex responsible for the actions would overlap and the interference effect would appear. The interference effect should not appear in the case of non-shared/different effectors – the motor circuits would be activated without any overlap (Bergen, 2006). This is exactly what was found for high-imageability idioms in the first experiment which

used a task that required an explicit semantic processing and idiomatic meaning activation of both idioms. Low-imageability idioms remained indifferent to the effector manipulation in meaning verification task. However, while a superficial familiarity task did not change the overall pattern of semantic interference for high-imageability idioms, it did change the pattern of low-imageability idioms dramatically. The results showed a directly opposite pattern to the semantic interference one - facilitation in response times in the case of shared effectors. Following the Dual Coding Theory (Paivio, 1991), we argue that low-imageability idioms may have mostly/predominantly one representation modality, a verbal* one. A superficial idiom familiarity task has, probably, triggered verbal/lexical associations within a logogen system of verbs. Hence, verbs that shared an effector (e.g., *touch* and *knock*) were associatively activated and facilitated overall idiom processing.

In conclusion, the study provided unambiguous evidence that transparent high-imageability idiom processing involves motor simulation during semantic and familiarity tasks. This result is strengthened by the effector-indifference of low-imageability idioms during a semantic task and by the associative facilitation during a familiarity task. Overall, the study showed the differentiation effect of imageability in motor simulation in idiom processing.

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* Note that neuroimaging studies suggest that concrete and abstract words have access to different neural processing structures (Swaab, Bayhes & Knight, 2002; Zhang, Guo, Ding, & Wang, 2006).