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What is left and what is right? Spatial position as a context for conceptual processing

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Abstract concepts are often described in terms of spatial dimensions. For example, time is represented on a horizontal line with past on the left, and future on the right. Mental number line goes form left to the right. Some studies indicate that a horizontal axis is also used to describe power and affect. Theories of grounded cognition assume that metaphors describe the way in which concepts are represented in memory. In the first experiment we explored influence of spatial position of different word categories on speed in semantic decision task. Pairs of words were presented on a horizontal line one next to the other. Participants were faster to respond to pairs of words related to quantities when small quantities were presented on the left and large on the right. Second experiment examined influence of spatial position on speed of detection of a neutral object after presentation of words from different categories. Participants were slower to identify an object that appeared in the position congruent with the metaphorical representation of previously presented word from categories of time and quantities. Results support the idea of perceptual processes being active during processing of concepts related to time and quantities.

Key words: mental representations, spatial positions, grounded cognition, abstract concepts

Human language is rich in metaphors. Role of the metaphors in language is to help us understand and communicate about concepts that are out of the reach of our senses, like love, fear, freedom, or importance. For example, we use spatial dimensions, in particular vertical dimension, when describing affect or power. When somebody is in a bad mood we say that person is *down*, or we say that some *music lifts us up*, we give *thumbs up* or *down*, we have *friends in high places* or sometimes *we touched the bottom*, etc. Relationship between vertical position and affect, as well as relationship between vertical position and power has been well documented in research. The results from Meier and Robinson (2004) suggest that, when making evaluations, people automatically assume that objects that are high in visual space are positive in meaning, whereas objects that are low in visual space are negative in meaning. Similarly, the results from Schubert (2005) suggest that people automatically assume that objects that are high in visual space are powerful, whereas objects that are low in visual space are powerless. Meier and Robinson (2004) also demonstrated that evaluation task has an influence on spatial attention. After evaluating a word as positive participants were faster to identify neutral letter that appeared on the screen top, while after evaluating a word as negative were faster to identify a letter on a screen bottom.

Apart from vertical dimension, positive and negative affect can be associated with horizontal dimension too. For a person who is very important to us, helps us, or we can rely on, we say that she or he is *out right hand*, for a clumsy person we say she or he *has two left feet*, good and correct answer we call *right*. In Islam doctrine left hand is used for dirty jobs, while right hand is used for feeding, with left foot we enter bathroom and with right we enter mosque. Research supports this idea of left side association with negative affect and right side association with positive affect. Right side body movement (like right hand muscle contraction, right side of face muscle contraction, or stimulus presentation in right visual field) correlate with positive affect (Davidson, 1992; Natale, Gur, & Gur, 1983). In five experiments Casasanto (2009a) showed that subjects with right dominant hand associate right side with positive ideas and concepts (like hero, intelligence, etc.), and left side with negative ideas and concepts (like sorrow). Left handed participants have the opposite tendency. With majority of population being right-handed it is no surprise that we use language expressions that associate left with negative and right with positive, although it may not be true for left-handed people. These findings are in line with assumptions of grounded cognition theories (Barsalou, 2008). These theories suggest that thoughts are made of mental simulations of bodily experiences. From that it can be hypothesized that

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people with different body characteristics have different relations to environment which in turn results in different mental representations. Casasanto (2009a) refers to that idea as body specificity hypothesis. Considering the fact that no linguistic or cultural context can account for body specific metaphor of positive being on the left side, results of Casasanto's research are considered as proofs of embodied nature of (at least some) abstract concepts.

There are only few studies from which we can draw hypothesis of representation of power on horizontal dimension. For example, one investigated relationship between writing habit (from left to right or vice versa) and interpretation of movement (Maass, Pagani, & Berta, 2007). Same movement (scoring a goal in a football game) was perceived as stronger, faster, and more beautiful when showed in space as an action happening from left to right (which was the direction of writing in culture where the research was carried out) then when it was showed mirrored as an action happening form right to left. Aggressive behavior in movie scenes was also perceived as more violent if action was happening from left to right than if it was happening from right to left. Participants who write from right to left showed opposite results which are considered as a proof that this bias in action interpretation is a result of writing habit (Maass et al., 2007). Spatial representation can also be related to stereotype believes in a way that more powerful groups are positioned on the left side while less powerful groups are positioned on the right (Maass, Suitner, Favaretto, & Cignacchi, 2009). Content analysis of more than 200 pictures (paintings, photographs, and comics) with man-woman couples showed that men more often appeared on the left side. Besides that, research showed that people who believe in male superiority more often draw men on the left side and women on the right. That effect is also the result of writing habit. Italian speaking participants placed more powerful groups (men and young people) on the left while less powerful (women and older people) were put on the right. Arabic speaking participants did the opposite (Maass et al., 2009). From all the above we can assume that power might be represented on the left and lack of power on the right, at least for people who write from left to right.

Horizontal dimension is also used when talking about concepts related to time. Dominant metaphor places past behind us and future ahead of us. We *turn our back to past*, and we see some *future event as many miles ahead of us*. Time is also often described as movement. Although horizontal dimension is rarely used in verbal expressions related to time, we use it when we are forced to show time in two-dimensional space, for example in graphs or pictures (e.g., comics). Fuhrman and Boroditsky (2007) showed that time needed to evaluate an event described in a picture as one that precedes target picture is faster when answer is given with left hand than with right hand. Similarly, time needed to evaluate picture as one that follows target picture is faster when answer is given with right hand than with left hand. Opposite pattern of results was found when participants came from Hebrew speaking (and writing) region. Sign language uses left-right dimension to describe time (Emmorey, 2001). English speakers use left to right horizontal dimension in gestures that accompany talk about time (Casasanto, 2009b). Arab speakers use right to left gestures when talking about time, placing past on the right side and future on the left (Casasanto & Bottini, 2010). It can be concluded that direction of time flow depends on writing direction. Casasanto and Bottini (2010) asked participants to judge verbal phrases as past or future oriented by pressing key on the left or right side. Reaction time was slower when keys were placed in positions non-congruent with expected time-space relations (past on the left and future on the right). Santiago, Lupianez, Perez, and Jesus Funes (2007) tested the hypothesis of automatic activation of horizontal dimension while processing concepts related to time. Participants categorized words as referring to the past or to the future. Words appeared on the left or right side of the screen, and responses were given with left or right hand. Words referring to the past were judged faster when appeared on the left side while words referring to the future were judged faster when appeared on the right side.

Spatial position is also relevant for concepts related to numbers and quantities. It is well known and documented that mental number line is represented on horizontal spatial dimension going from left to right (Dehaene, Bossini, & Giraux, 1993). That in turn results in faster responses to small numbers with left hand than with right hand, and faster responses to big numbers with right hand than with left hand. This effect is known as spatial numerical association of response codes effect or SNARC effect. Similar effect was obtained with other ordinal arrangements such as months in a year and alphabet (Gevers, Reynvoet, & Fias, 2003) or days in a week (Gevers, Reynvoet, & Fias, 2004). Direction of mental number line is related to writing and reading habit (Dehaene at al., 1993; Zebian, 2005). Nicholls, Loftus, and Gevers (2008) showed that perceptual task induced shift of attention related to number magnitude. Small numbers induced shift of attention to the left side and bigger numbers induced shift of attention to the right side. Same result was obtained by Fischer, Castel, Dodd, and Pratt (2003). Numbers appeared in a screen center followed by target object on the left or right side of the screen. Participants were faster to respond to target object if it appeared left after presentation of a small number or if it appeared right after presentation of a big number. That is considered as a proof of attention shift after presentation of number of different magnitude. It is important to mention that effect was present only under condition that neutral object was presented 400 ms or more after presentation of the number. For intervals shorter than 300 ms there was no difference in speed of the object detection on the left and right side.

Grounded cognition

Traditional theories of cognition assume knowledge is represented in semantic memory, a system separated from modal system for perception and action. Representations from modal systems are transformed to amodal symbols that represent knowledge. Amodal symbols are connected with associations to other symbols, and that is the way they acquire meaning. Theories of grounded cognition, on the other hand, assume that thoughts are not composed of symbols but of visual and motor pictures. Conceptual processes are grounded in activation of perceptual-motor systems. Some theories of grounded cognition focus on the role of bodily states in cognition and are based on research showing that bodily states can be both cause and consequence of cognition (e.g., conceptual metaphor theory; Lakoff and Johnson, 1980). Most of them are oriented on role of simulation in cognition (e.g., perceptual symbol systems; Barsalou, 1999). Simulation is the re-enactment of perceptual, motor, and introspective states acquired during experience with the world, body, and mind. Theories of grounded cognition gained most support through research dealing with representation of concrete concepts. They are often criticized as being unable to explain how abstract concepts are grounded in perceptual and motor systems. Of course, with abstract concepts like freedom, love, or democracy we do not have direct perceptual experiences and therefore we cannot represent them through perceptual or motor simulations.

Zwaan and Yaxley (2003) showed that speed of categorization of two words as semantically related or unrelated is under influence of their position in space. Pairs of words were presented one above the other. Semantically related words were presented in two arrangements, once their position was congruent with their position in a real world (e.g., roof above the basement), and once they were in non-congruent position (basement above the roof). Participants were faster when words were in congruent arrangement. Results can be explained by activation of relevant perceptual simulations in order to understand presented words. In case of non-congruent arrangements reaction is slower due to conflicting perceptual input. Šetić and Domijan (2007) also showed that word position has an influence on speed in semantic decision task. Participants were faster to categorize animal as flying or non-flaying (or object as living or non-living) when their position on screen correspond to their position in a real world.

If perceptual simulation is needed to comprehend a concept, and it activates perceptual mechanisms, than simultaneous perception of an object that requires same mechanisms will be hindered. Perceptual mechanisms needed for identification of an object are already engaged in simulation. Estes, Verges, and Barsalou (2008) confirmed that assumption. Results of their research indicate that after a presentation of a word typically found up (or down) in space, participants need more time to identify target letter presented up (or down) on a screen, if it is presented immediately after the word. Authors assume that delay in reaction time could be a result of attention orientation and active perceptive simulation.

Abstract concepts can be represented through perceptual-motor representations in many different ways. Of special interest for this study is the idea that mechanism which is included in grounding of abstract concepts in experience is described by metaphors, e.g., positive affect is described in light and not dark colors. Processes of perceptual simulation are explained through metaphors which give us clearer picture of how we store knowledge about concepts (e.g., which modalities are included in representation; Lakoff & Johnson, 1999).

Aim of this study was to test assumptions of grounded cognition theories for abstract concepts, and to explore their representation on horizontal line as implied by metaphors. In other words, we investigated the influence of word spatial position on processing speed of abstract concepts. In first experiment we used Zwaan and Yaxley (2003) paradigm to explore changes in processing speed of abstract concepts depending on their position on horizontal axis – congruent or incongruent with their position implied by the metaphor. In second experiment we investigated whether perceptual simulation takes place while we are processing abstract concepts. We used paradigm by Meier and Robinson (2004) and Estes et al. (2008) to explore changes in speed of neutral object identification after presentation of abstract concepts. While Meier and Robinson (2004) showed shift of attention in direction implied by the metaphor right after word presentation, Estes et al. (2008) showed hindered identification due to perceptual simulation in position where concept is usually found. Possible explanation of this difference in effect could be in duration of the interval between word presentation and neutral object. It could be that when the interval is very short (cca. 50 ms) simulation is still active, and perception is slower due to mechanisms occupied with simulation. When the interval is longer (longer than 500 ms as implied by the research of Fischer et al., 2003) shift of attention will occur. In second experiment we explored the effects of short and long interval between word presentation and neutral object presentation on speed of detection of that object.

EXPERIMENT 1

We hypothesised that in semantic decision task participants will be faster to categorize pair of words as semantically related if their position on horizontal axis corresponds with their metaphorical representation (positive words on the right, negative on the left; positive emotions on the right, negative left; less powerful groups right, more powerful left; large amounts right, small left; and future oriented words right, past oriented left).

Method

Participants. Sixty-two undergraduates from University of Zagreb were recruited from several psychology classes in exchange for academic course credit. All of them were native Croatian speakers with normal or corrected-to-normal vision.

Design. Experiment design was within subjects factorial (5x2) with two independent variables, category of word pairs (words with positive/negative valence, emotions, power, time and quantities) and spatial position (congruent vs. incongruent to position implied by the relevant metaphor). Dependent variables were reaction time and response accuracy in semantic decision task.

Materials. Pairs of words were selected in the pre-test. In every word category there were eight pairs of nouns. They were selected based on several criteria: every word was estimated as clear representative of category (e.g., every positive word was estimated as very positive); every word was a member of only one category (for example, positive word was estimated as neutral on dimension of power); there was a significant difference between positive and negative words on dimension of valence; there was a significant difference between power estimation of words in category more and less powerful groups; for categories of quantities and time, every word was estimated by majority of subjects as member of that category. Additionally, 48 pairs of neutral words were selected. None of them was estimated as possible member of relevant categories and none of them was related to spatial dimensions. Examples of word pairs from each category are shown in Appendix.

Procedure. Words appeared in black 18-point Arial letters on a white background. The study was run on desktops with 17'' displays (resolution 1024 × 768) and programmed in E-Prime ver. 2.0 beta (Schneider, Eschman, & Zuccolotto, 2002). Pairs of words were presented one next to each other, left and right from the screen centre. Participants' task was to give answers with only one hand, and press number 1 if two words were semantically related or press 2 if they were not. Prior to each trial, there was a fixation cross presented in the middle of the screen. Duration of the fixation randomly varied from 800 ms to 1200 ms. Every participant started with a practice block of 10 trials, five semantically related and five semantically unrelated pairs. Practice block was followed by two blocks. In each one there was 96 pairs presented, 48 semantically related and 48 unrelated. Neutral word pairs were mostly semantically unrelated and pairs coming from relevant word categories were semantically related. For each word category there were four pairs presented in congruent position and four in incongruent position. Trials in the block were completely randomised. After first block participant was encouraged to take a break as long as she or he needed. When participant was ready, second block of trial begun. In second block 96 pairs were presented again, but pairs in congruent position from the first block were now in incongruent position and vice versa. Position of the words in neutral pairs was also changed. Block order was rotated from subject to subject. Duration of the experiment depended on the pause duration, and was approximately 15 minutes.

Results

Latencies longer than 5000 ms and shorter than 300 ms were excluded from the analysis. Participant's results in each experimental situation were represented by median latencies of accurate trials and error rates. A 5 (word category: words with positive/negative valence, emotions, power, time, and quantities) X 2 (spatial position: congruent vs. incongruent with the metaphor) within subjects ANOVA was performed on the latencies. The main effect of word category was significant, $F(4, 244) = 27.48$, $p < .001$, $\eta_P^2 = .311$, indicating that participants were faster to respond to some word categories than the other. Main effect of spatial position was significant, $F(1, 61) = 7.27$, $p < .01$, $\eta_P^2 = .106$, indicating that responses were faster to congruent ($M = 834.6$ ms) than incongruent trials ($M = 852.2$ ms). Word category X Spatial position interaction was also significant, $F(4, 244) = 2.56$, $p < .05$, $\eta_P^2 = .040$, indicating that effect of spatial position is not equally emphasized in all word categories.

As shown in Figure 1 reaction times appear to be slower in incongruent trials for all word categories except emo-

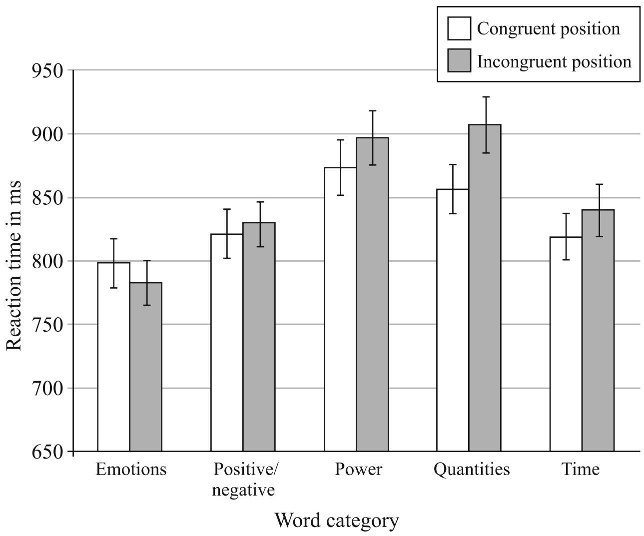

Figure 1. Average latencies for five word categories in congruent and incongruent spatial position. Error bars denote the standard error of the mean.

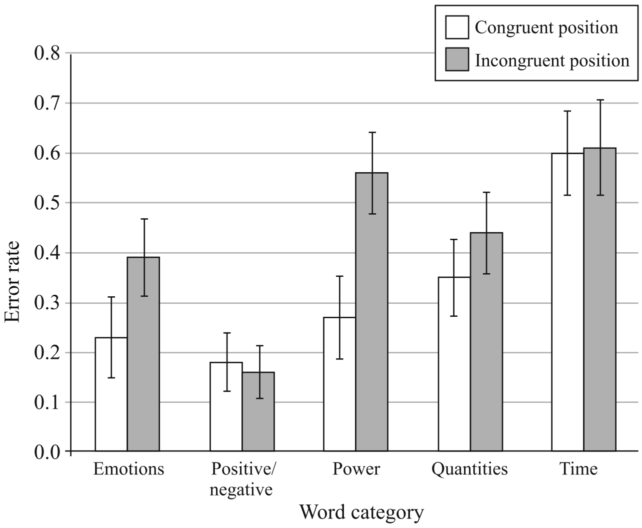

Figure 2. Average error rates for five word categories in congruent and incongruent spatial position. Error bars denote the standard error of the mean.

tions. However, Bonferroni post-hoc tests revealed significant difference between congruent and incongruent situation only in category of words related to quantities (M_{cong} = 858 ms; M_{incong} = 908 ms, $p < .01$).

Identical analysis was conducted on accuracy rates. The main effect of word category was significant, $F(4, 244) = 9.11$, $p < .001$, $\eta_p^2 = .130$, indicating that participants made different number of errors in different categories of words. Main effect of spatial position was significant, $F(1, 61) = 6.11$, $p < .05$, $\eta_p^2 = .091$, indicating that more errors were made in incongruent (M = 0.43) than congruent trials (M = 0.33). Word category X Spatial position interaction was marginally significant, $F(4, 244) = 2.28$, $p = .06$, $\eta_p^2 = .036$, indicating that effect of spatial position on error rates is not equally emphasized in all word categories.

As shown in Figure 2 number of errors appears to be higher for incongruent word pairs in categories of emotions, power, and quantities. These results are not in contradiction to results obtained by analysis of latencies, so we can assume that speed-accuracy trade off did not happen. However, Bonferroni post-hoc test revealed significant difference between congruent and incongruent situation only in category of words related to power (M_{cong} = 0.27, M_{incong} = 0.57, $p < .01$).

Taken all together, analyses showed that speed of processing concepts related to quantities is under the influence of spatial position of words presented. When concepts are presented from small to larger quantities going from left to right, processing is faster comparing to situation where concepts are presented the other way around. In other word categories similar trend is noticeable.

EXPERIMENT 2

In second experiment we explored the effects that metaphorically implied position on horizontal line of different word categories have on perception. We measured reaction times needed to identify neutral object positioned on the left or right side after the presentation of word in the middle of the screen. We tested the hypothesis of different effect that longer or shorter intervals between word and neutral object have on attention and perception. Perceptual simulation should interfere with perceptual processes in the same area of visual field. That is, when the interval between word and object presentation is short (50 ms), perception of an object appearing in the position congruent with the metaphorical representation of word previously presented should be hindered. On the other hand, when the interval is longer (500 ms) we expect shift of attention (faster identification of neutral object) in direction suggested by metaphorical representation of word. Results in line with these assumptions could be interpreted as a support of theories of grounded cognition, e.g., perceptual symbols system theory (Barsalou, 1999).

Method

Participants. Seventy-one undergraduates from University of Zagreb were recruited from several psychology classes in exchange for academic course credit. All of them were native Croatian speakers with normal or corrected-to-normal vision. None of them participated in Experiment 1.

Design. Experiment design was mixed factorial (5x2x2) with three independent variables, category of words (words with positive/negative valence, emotions, power, time and quantities), spatial position of neutral object (congruent vs. incongruent to position implied by the relevant metaphor) and interval between presentation of the word and neutral object (50 ms short or 500 ms long). Interval between a word and a neutral object was between subject's variable and participants were randomly assigned to one condition. Dependent variables were reaction time and response accuracy.

Materials. Eighty words from Experiment 1 were used (in Experiment 1 there were 40 pairs from five word categories). Letters X and O served as neutral objects.

Procedure. Words and neutral objects appeared in black 18-point Arial letters on a white background. The study was run on desktops with 17" displays (resolution 1024 x 768) and programmed in E-Prime ver. 2.0 beta (Schneider et al., 2002). Every trial began with a fixation cross in the middle of the screen with duration of 1500 ms, followed by the word with duration of 250 ms. After a short break (that lasted 50 ms or 500 ms depending of the experimental situation), letter X or O appeared left or right from the screen centre with duration of 70 ms. Participants had a task to carefully read presented word and than as quickly as possible identify object that follows. Letters X and O appeared equal number of times in both locations. Participants answered with keys 1 and 4 on numerical part of the keyboard (to avoid Simon effect; Simon, 1969), and meaning of the answer keys was rotated from subject to subject. To ensure reading of the words (instead of skipping that part of the task) we told participants that there will be a short recognition test of the presented words at the end of the experiment. Every session began with a practice block of 20 trials and ended with a short recognition test. Main part was divided in two blocks. In first, 80 words were presented, followed by neutral object in position congruent (in half of the cases) or incongruent (in other half of the cases) with metaphorical representation of presented word. After a pause, in a second block, 80 words were presented again, but followed with a neutral object in different position than in the first block. Block order was rotated from participant to participant. Session finished with a short recognition test of 20 words, half presented previously in experiment. Duration of the experiment depended on the pause duration, and was approximately 20 minutes.

Results

Latencies longer than 3000 ms and shorter than 150 ms were dropped from the analysis. Participant's results in each experimental situation were represented by median latencies of accurate trials and error rates. A 5 (word category: words with positive/negative valence, emotions, power, time, and quantities) X 2 (spatial position: congruent vs. incongruent with the metaphor) X 2 (interval between presentation of the word and neutral object: 50 ms short vs. 500 ms long) mixed ANOVA was performed on the latencies. The main effect of word category was significant, $F(4, 276) = 2.98$, $p < .05$, $\eta_P^2 = .041$, indicating that participants were faster to identify neutral object after some word categories than after the other. Interaction of word category and spatial position was significant, $F(4, 276) = 2.38$, $p = .05$, $\eta_P^2 = .033$, as well as triple interaction of word category, spatial position, and interval length, $F(4, 276) = 2.71$, $p < .05$, $\eta_P^2 = .038$. All other main effects and interactions were not significant. Identical analyses were conducted on accuracy rates. All effects were nonsignificant. Recognition test at the end of experiment showed that subjects followed the instructions and read the presented words; average accuracy rate was 83%.

As shown in Figure 3 interaction of spatial positions of neutral objects and word category depends on interval length. When the interval between word presentation and neutral object presentation was 50 ms short participants needed more time to identify object if it appeared in position congruent to metaphorical representation of words in category quantities and time. That was confirmed by Bonferroni post-hoc test (for category of time: $M_{cong} = 474$ ms, $M_{incong} = 452$ ms, $p < .05$, and for category of quantities: $M_{cong} = 465$ ms, $M_{incong} = 442$ ms, $p = .065$).

When the interval between word and object was longer (500 ms) these differences disappeared. In case of other word categories, no differences in latencies between congruent and incongruent position of neutral object were found, in both situation of short and long interval. Exception is the category of emotions where Bonferroni post-hoc test in situation of long interval showed significant difference ($M_{cong} = 422$ ms, $M_{incong} = 442$ ms, $p < .01$) in expected direction (shorter reaction times to object appearing in congruent than incongruent position).

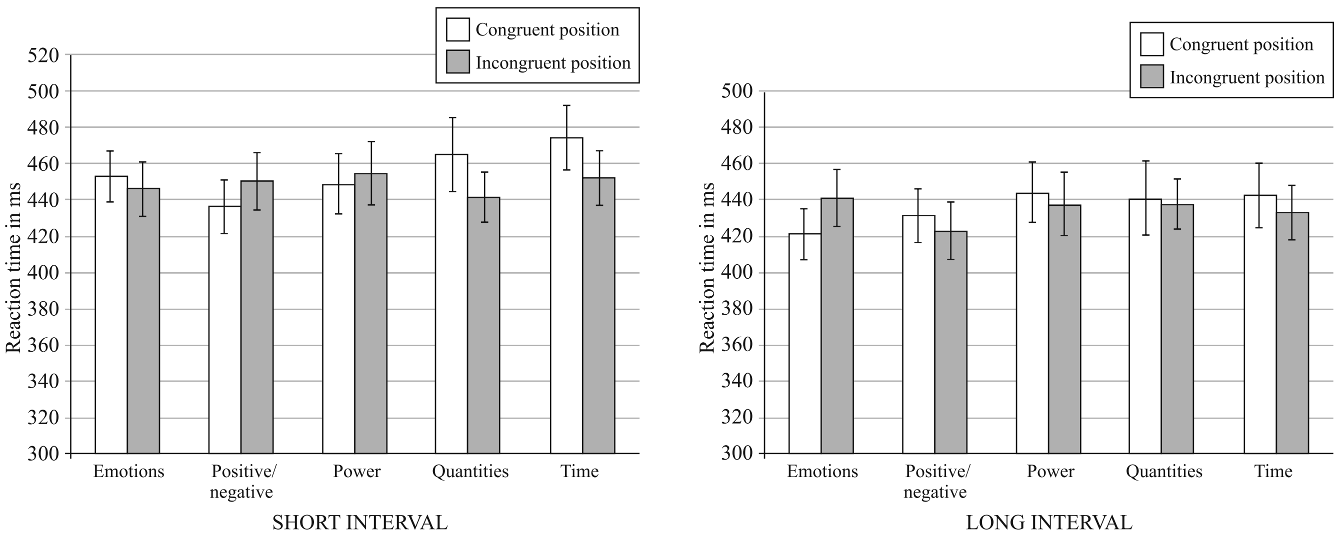

Figure 3. Average latencies of object identification in congruent and incongruent spatial position after presentation of five word categories in situation of short and long interval. Error bars denote the standard error of the mean.

DISCUSSION

In Experiment 1 analysis showed that for category of words related to quantities participants were faster to judge whether two presented words are semantically related when they were presented in the way predicted by metaphorical representation of numbers. That is, small quantities on the left and large quantities on the right. Analysis revealed slower reaction times when words were presented in incongruent position. These results are similar to those obtained in research about SNARC effect. This effect refers to the longer reaction time in cases where small number requires response with the right hand or in cases when big number requires response with left hand, even when task itself does not include processing of the number magnitude (Dehaene et al., 1993). Perceptual symbol system theory (Barsalou, 1999) postulates that mental representations include simulations in sensory as well as in motor systems. It is then possible to expect SNARC-like effect when words or numbers are presented left and right in visual field and not only when they require responses with left and right hands. In this experiment we showed the expected pattern of results using words, and not numbers, which represent quantities (e.g., *singular* and *plural*, *individual* and *group*). Similar results can be observed in category of words related to time, although difference between congruent and incongruent position is smaller. Again, this finding is in line with previous research where participants needed less time to categorize word phrases as future oriented when they appeared on the right side of visual field, and vice versa for the past oriented phrases (Santiago at al., 2007). Although participants in our experiment did not have the task explicitly related to judgment of time, there is visible trend of faster conceptual processing when words are presented in position congruent with the expected time flow, from left to right. Expected trend of results can be seen in category of power, too. We hypothesized faster reaction times when words that denote something powerful are positioned on the left, while words that denote something less powerfully are positioned on the right. This was the first time that representation of power on the horizontal axis was explored in this manner. Although results are not conclusive, they indicate an interesting potential for further research. For concepts related to affect we haven't confirmed our expectations. There are only a few studies about mental representation of affect on horizontal line, and we can say that even if affect has a relation to horizontal axis it is far less pronounced than its representation on vertical axis. Same applies for concept of power.

It is important to mention the main difference between this and previous investigations in the field. Participants in this experiment did not have the task to categorize words directly to categories of power or affect, while, for example, in research from Meier and Robinson (2004) participants had the task to categorize words as positive or negative and in research from Shubert (2005) participants had the task to categorize groups as powerful or powerless. It could be that it was possible to solve the semantic decision task without deeper processing of concepts, simply relying on associative strength between presented words (most of the word pairs were opposites), and valence or power was simply neglected in conceptual processing. Further research should use pairs of words with low associative strength in order to avoid possible use of such strategy.

Grounded cognition theories assume it is not possible to separate conceptual processing from activation of processes in perceptual and motor systems. To prove this assumption more directly, we conducted the second experiment with the aim of testing hypothesis that representation of some concepts as predicted by metaphors has an influence on perception. In Experiment 2 we examined influence of typical concept location on speed of neutral object identification. Participants first read word presented in the screen center and then were given a task of object identification. Neutral object appeared in location congruent or incongruent with the position according to the metaphorical mappings of previously presented word. Time interval between presentation of the word and neutral object was either short or long. Results showed that after reading words that denote quantities and time participants were slower to identify neutral object if it appeared on spatial position which is consistent with metaphorical mappings of quantities and time (for past time and small quantities on the left and for future time and larger quantities on the right). This effect appeared when interval between word and neutral object was short and not when it was longer. That could be due to perceptual simulation that is active at the same time and in the same position where object appeared, as predicted by perceptual symbols system theory (Barsalou, 1999; Estes et al., 2008). In case of longer interval, we did not confirm expectations about shift of attention in the direction implied by the metaphor. In all word categories except emotions, no difference was found in the speed of object identification in congruent and incongruent position. Our strongest expectation was in category of quantities as shown in experiment by Fischer at al. (2003) with numbers. Only after the words from category of emotions participants were faster to respond to objects appearing in position congruent with metaphor of good being on the right side.

Although our results are not completely in line with the hypothesis, some indication of perceptual processes involved in conceptual processing exists. Spatial position of a word influences speed of processing, at least for concepts related to quantities and time which are represented on a horizontal line. It seems that representation of time and quantities share many common characteristics. Both groups of concepts are dominantly represented on horizontal axis. Direction of time flow and mental number line is dominantly explained by writing and reading habit. Many behavioral and neurophysiological research examined relations of quantity and time with space. That is in accordance with the idea of common cortical metrics of time, space, and quantity (Walsh, 2003). This idea is already supported by experiments of Casasanto and Boroditsky (2008), Weger and Pratt (2008), and previously described Santiago at al. (2007) which all showed interdependence of processing concepts related to time and space. Besides, there is dependence in processing of quantity and perception of time (Xuan, Zhang, He, & Chen, 2007). SNARC effect is an example of relations between number magnitude and space. Our experiments showed same trend in relation between space and time, and space and quantities.

As already described in the introduction, affect and power are dominantly represented on vertical axis. That is also noticeable in language metaphors with more frequent expressions that describe this representation. In case of time, more often we use approach and avoidance metaphor which represents time as something behind or in front of us. It is obvious that abstract concepts can be represented in terms of perceptual processes in many different ways. Which representation will be active at given point in time depends on attention processes (e.g., as shown by Torralbo, Santiago, and Lupiáñez [2006] in case of time).

Further research should include more trials in experimental situations, and preferably splitting one experiment into few shorter and more focused on one or two word categories. This could ensure equal task difficulty for every concept (although in our experiment the task was clearly not difficult, main effect of word category indicates different task difficulties). Furthermore, effects of longer (longer than 500 ms) interval between word and neutral object on attention shift should be explored, because interval we have chosen was minimal in which attention shift can be expected.

We can conclude that processing of concepts related to time and quantities cannot be separated form perceptual and motor processing, although strength of this relationship will remain of interest for further research. We haven't found support for hypothesis of mental representation of other word categories on horizontal dimension. It is possible that power and valence are primarily represented on vertical dimension as other studies suggest. Our results support theories of grounded cognition to some extent. If there is a connection between conceptual processing and perception it provides many opportunities in generating new hypothesis, even for fields of applied psychology. For example, if perceptual-motor processing is inseparable from cognitive processing than results from Stepper and Strack (1993) come as no surprise – people feel more proud when sitting upright. Or even further, maybe it is impossible to feel down if we stand up.

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APPENDIX

Examples of word pairs used in Experiment 1

Emotions: love – hate, happiness – sadness, joy - sorrow

Positive/negative words: justice – crime, health – illness, richness – poverty

Power: master – servant, power – weakness, boss – employee

Quantities: singular – plural, individual – group, few – many

Time: past – future, yesterday – tomorrow, beginning – end

Neutral: apple – car, fire – dimension, telephone - milk