PSIHOLOGIJA, 2011, Vol. 44 (1), 39–60

UDC 159.937.52.072:159.955
DOI: 10.2298/PSI1101039C

Verbal vs. visual coding in modified mental imagery map exploration task

Ivana Ćirović[1] and Sunčica Zdravković[1, 2]

[1] Laboratory for Experimental Psychology, Faculty of Philosophy, University of Belgrade, Serbia
[2] Department of Psychology, Faculty of Philosophy, University of Novi Sad, Serbia

We modified classical mental exploration task introducing verbal modality. Consequently, we could test robust effects from lexical processing in an attempt to understand whether the underlying mental representation is strictly propositional.

In our three experiments, in addition to map modality (visual or verbal), lexical frequency, concreteness and visual frequency were also varied. The symbolic distance effect was replicated, regardless of map modality. Exploration of distances was regularly faster on pictorial maps. Effects of lexical frequency and concreteness were not significant for verbal maps. However, when visual frequency was introduced on pictorial maps both type of frequencies generated measurable effects.

Our findings directly contradict the assumptions of propositional theories (1) subjects were faster in the visual modality, which would be difficult to explain if the perceptual code had to be transformed into propositional, (2) word frequency and concreteness did not contribute as would be expected if propositional code were a default.

Key words: *symbolic distance effect, imagery debate, lexical frequency, concrete concepts, propositional code*

Visual mental imagery is a mental event, which occurs when a "visual short term memory representation of the stimulus is present, but the stimulus is not actually being viewed" (Kosslyn & Thompson, 2003, p. 723). Mental imagery is also referred to as "visualizing", "seeing in the mind's eye", "hearing in the head" or "imagining the feel of" (Kosslyn & Thompson, 2003; Thomas, 1999b). Although theoretically each sensory modality would generate a specific form of mental representation (visual, olfactory, haptic, auditory, kinesthetic and gustative), visual mental representation are mostly studied and discussed.

Corresponding author: cirovicivana@gmail.com

* This work was supported by the Ministry of Science and Technological Development of Serbia, grant number 179033.

Experimental studies of the nature and mechanisms of mental imagery triggered one of the most notable debates in cognitive science – imagery debate (Pylyshin, 1981). The debate revolves around the question of modality of our mental representations. The competing solutions included a universal propositional code and sensory determined analog representations.

Theoretical predecessor of the imagery debate was Dual Coding Theory (DCT), proposed by Alan Paivio. This theory nicely elaborated a group of findings demonstrating a significant gain obtained in reproduction of concrete versus abstract words (Paivio, 1969, 1971; Paivio & Csapo, 1969, 1973). According to Paivio's theory, cognitive system operates two distinct classes of mental representation (or "codes"): verbal representations (symbolic code) and mental images (analog code). Information obtained through language would be stored in verbal code, while information obtained through various sensory modalities would use visual or analog code. This implies that concrete concepts could be coded in both analogue and verbal code, whereas abstract concepts could only be represented in verbal code. As a result a concrete word presented in a free recall task, would evoke both analog concept and associated image, i.e. the two separate, but linked memory traces, one in each memory stores (verbal and visual). Such dual storing would clearly enhance a chance of recognition and retrieval for concrete words (Paivio, 1986). Subsequent experiments also showed that there are significant differences in cognitive processing of verbal and visual representations, particularly in storing and evoking, repeatedly confirming positive bias for visual material (Beg & Paivio, 1969; Paivio, 1975; Paivio & Lambert, 1981).

While Dual Coding Theory was mostly consumed with functional role of the mental imagery in memory and cognition, question of the nature of imagery itself resulted in a new experimental paradigm. These experiments investigated different metric characteristics of the mental images, size above all (Kosslyn, 1975, 1980, 1981, 1994; Kosslyn, Ball, & Reiser, 1978; Shepard & Metzler, 1971; Shepard & Cooper, 1982; Moyer, 1973).

Classical experimental stimulus in this paradigm was a map of an island with unequally spaced objects, so called landmarks (Kosslyn, Ball, & Reiser, 1978). The observers' task was to memorise the map layout as well as a position of each landmark. After five minutes, map was removed and the participants were invited to generate visual images of the displayed map, in order to scan the distances between pairs of landmarks. Observers were advised to imagine a black dot floating above map, travelling from one landmark to another. Reaction time, needed to mentally traverse from one landmark to another, increased linearly with physical distance among the landmarks. This effect was named symbolic distance effect (SDE) (Kosslyn, Ball, & Reiser, 1978).

Kosslyn interpreted obtained findings in terms of analog theory of mental imagery, strongly advocating correspondence between mental imagery and visual perception. Mental images are stored in analog code (also referred to as depictive or pictorial representation), which preserves most of the represented objects' features, including the general structure, and the spatial relations. Accordingly, in analog spatial code larger physical distances would be represented with larger mental images yielding longer exploration time, a result reconfirmed in a number of clever experimental scenarios (Kosslyn, 1980; Kosslyn, 1994; Borst & Kosslyn, 2008; Pylyshin, 2002).

In addition to behavioural findings, empirical findings from neuroscience research provide a formidable support for analog theory and strengthen the evidence that imagery and perception share common processing mechanisms (O'Craven & Kanwisher, 2000). Several studies showed that mental imagery engages brain mechanisms that are used in perception and that, during mental exploration, visual area V1 is engaged (Kosslyn, Sukel, & Bly, 1999; Kosslyn, Ganis, & Thompson, 2001; Bartolomeo, 2002; Kosslyn, Thompson, & Ganis, 2006; Kosslyn & Thompson, 2003). Activation of visual areas during mental imagery is content specific, i.e. different pictorial contents elicit activation in different regions of extrastriate cortex (Page, Duhamel, & Crognale, 2010). It is even possible to determine the content of single cognitive event from an inspection of the fMRI data from individual imagery trials (O'Craven & Kanwisher, 2000).

However, not all of the authors supported dual treatment of mental representations. Pylyshyn proposed all together different logic of mental codes, suggesting that an impression of creating a mental picture similar to perceptual experience is just an epiphenomenon, a mere accompanying event of a representational process, which is inherently propositional. All stimuli (verbal and pictorial) and all of their characteristics (including metric) are being coded in an unique manner, using separate propositions stored in long-term memory which are being evoked during the formation of mental image. The main disagreement between the two theorists concerned the spatial mechanisms of mental imagery. Unlike Kosslyn, Pylyshyn argued that spatial mechanisms of mental imagery were language related propositional mechanisms, which processed spatial information encoded in the form of discrete propositions (Pylyshyn, 1973).

Pylyshyn explains Kosslyn's imaginary island map findings using the propositional distance mapping mechanisms. Mental distances are always mapped with propositional nodes, which represent symbolic carriers of information of physical characteristics of the perceived objects. Therefore it is no surprise that it takes longer time to mentally scan longer physical distances, as longer distances require more nodes. It is also possible that participants use their tacit knowledge of space relations, and act in accordance with physical reality taking longer time to traverse longer distances (Pylyshin, 1981).

Though the debate continued for several decades, there are still unresolved issues, concerning the very nature of mental representations used in imagery. Our idea was that a certain shift in the imagery island paradigm is needed in order to answer these important questions. Therefore we developed maps, which contained not only images but also words (see Figure 2). We hoped to obtain

SDE even with verbal landmarks. Also, introduction of verbal content enabled testing some additional hypotheses concerning imagery debate. Namely, if mental imagery were propositional in its nature and related to language, than robust factors of language processing would also moderate imagery processes. Hence, we applied two well know lexical processing factors – lexical frequency and concreteness – on the concepts used as landmarks. These two factors were chosen based on numerous previous studies showing that respondents are faster to identify high frequent and concrete words (Howes & Solomon, 1951; Whaley, 1978; Strain, Patterson, & Seidenberg, 1995; Schwanenflugel & Shoben, 1983; Weiss & Rappelsberger, 1996).

Our experimental manipulations should generate opposite predictions from the competing imagery theories. Analog theory (relying on Double Coding mechanism) would not (1) predict the effect of lexical factors and (2) mental exploration of the pictorial material would be all together faster than of verbal material. However, if representational mechanisms are analog to language mechanisms, as propositionalists argue, the maps with verbal landmarks will be explored faster. According to this theory, visual code must be transposed into propositional, and that process would increase the reaction time. Additionally, lexical frequency and concreteness of the displayed content will also affect mental exploration speed.

EXPERIMENT 1

SDE is a robust phenomenon, replicated using different stimuli in numerous previous studies (Kosslyn, 1980). In order to resolve some of the dilemmas of the imagery debate, we modified the imaginary map mental exploration task by varying the properties of landmarks presented on the map. In this experiment, we introduced verbal imagery map, testing weather the SDE could be obtained on such maps as well. Both theories would predict the SDE for verbal material, as both theories presume existence of verbal code. In addition, the concepts used for landmarks were varied by lexical frequency. For this modification two opposing theoretical views predict opposite findings. Within Pylysyn's theory such modification should produce results mimicking those continuously obtained in lingual experiments, a bias for frequent words. However, this is not an expected finding for dual codes theories. In their framework, lexical frequency should only affect verbal maps.

Method

Participants: Nineteen first year students of psychology at the University of Belgrade took part in this experiment in exchange for course credits.

Stimuli: Eight maps were created using Corel Draw graphic design software. Each map consisted of six lines, *paths* (80 mm long) and seven rectangles, *landmarks* (75 mm x 40 mm) and had identical structure of paths and landmark. These maps did not follow island-like structure, used in the classical mental scanning experiments (Kosslyn, Ball & Reiser, 1978). They resembled charts with singular connections between landmarks. Only the content of the landmarks was varied, half of the maps were pictorial (figure 1) and half were verbal (figure 2). Concepts on the landmarks (both verbal and pictorial) were concrete, half of them with high (fr>100) and half with low frequency (fr<3) (Appendix 1) (Kostić, 1999).

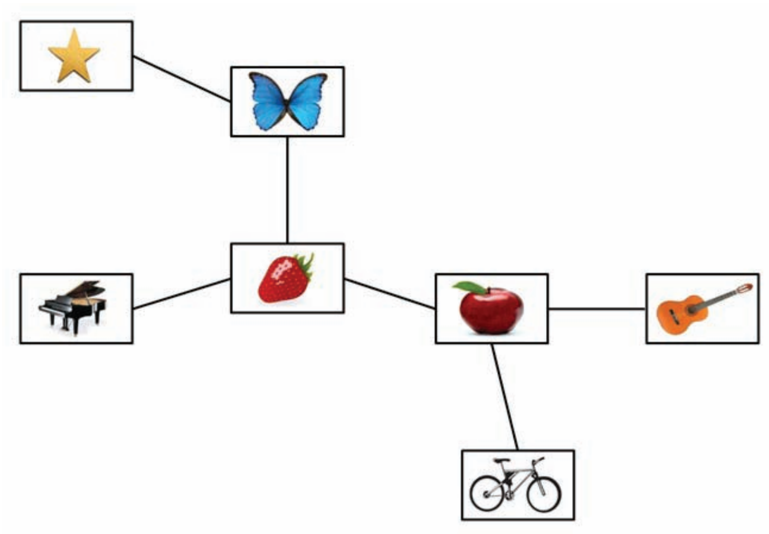

Figure 1. Example of a map with pictorial landmarks

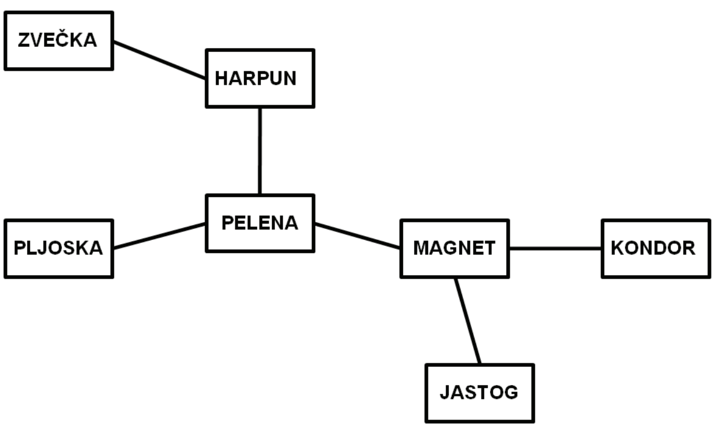

Figure 2. Example of a map with verbal landmarks

Lexical frequencies for the presented concepts were extracted from the Serbian Language Corpus (Kostić, 1999). Only those concepts with obvious visual representation were selected, i.e. chosen concepts had to refer to objects that all participants would imagine in a similar manner. This was tested in a pilot study. A separate group of thirty participants was shown cards with pictures of the selected concepts (occupying a central position on a white background, without any textual or pictorial distracters) and invited to name the presented objects. Only those pictures that shown no variation between the participants were chosen. For this reason only a portion of characteristics usually controlled for in psycholinguistic studies (word length and structure) was applied here. Similarly, the visual characteristics usually controlled for in perception experiments (color, shape and contrast) were also not fully controlled. The control from the pilot study was restricted to cognitive factors of interest (mental representations in the function of imagery). Four maps were used as control, to test if the participants were able to fully memorize presented map and its content. Another four maps – parallel forms – were used in experimental trials.

Procedure: Participants were tested individually in a dark room in the presence of an experimenter. They were seated 150 cm from the computer monitor with their head in a fixed position.

Experiment consisted of four separate experimental sessions. Participants had three minutes to memorise the presented map after which map was removed, and the participants were required to generate a mental image of the memorised map. Then, they would begin mental scanning task. There were eight scanning trials, a pair for each test distance (between the two three, four and five landmarks), presented in the randomised order. First participants were instructed to locate a landmark on their mental map (instruction appeared on the screen: “Find the BALL on the map”). Three seconds later, another landmark would appear on the screen (“Find the PENCIL on the map”) followed by a message which would instruct participant to perform mental scanning between the two landmarks (“Scan from the BALL to the PENCIL”). When ready, participant would press button START to begin mental scanning, while pressing button STOP marked the end of mental scanning task, the moment when they have mentally arrived to the second landmark. The scanning was accomplished by imagining a little black dot flying above shortest path between the two landmarks, as instructed before the beginning of the task.

While experimental maps required only mental scanning, control maps involved an additional task. After participants finished scanning and pressed STOP button, they had to answer questions about the structure of the map. This served as a control whether participants memorised maps accurately. However these results were contaminated for the visual scanning purposes (as the maps were not only memorised but also rehearsed) and therefore not analysed with the rest of the experimental data. In each session, both control and experimental maps were presented, in counter-balanced order.

First experimental session was preceded by 4 practise trials (with another set of comparable maps) aimed to familiarise participants with the procedure. All participants successively took part in all sixteen experimental situations divided in four sessions. The first session lasted twenty minutes, while other sessions lasted about fifteen minutes.

Data analysis: Three subjects with reaction time beyond 3 standard deviations (in any of the experimental situations) were excluded from the analyses. One participant could not complete control task (i.e. memorizing of control map) and was also excluded from the experiment.

The data were analyzed using repeated measure analysis of variance with 3 factors (distance, frequency and modality). First factor, the distance, had four levels (distance between 2, 3, 4 or 5 landmarks), the lexical frequency had two levels (concepts expressed with high– or low-frequent words), and the factor modality had two levels (verbal or pictorial).

Reaction time was measured as an interval between the participants’ pressing of buttons START and STOP.

Results and discussion

The main finding on our modified stimuli material is a significant SDE for both types of maps, visual as well as verbal (F(3,18)=37,395, p=.000) (Figure 1). Consistent with previous research, time required to perform scanning of imagery distance increased with an increase of distance on a real map. This finding proved that both types of maps could be equally used in imagery tasks and enabled us to generalize the rest of our findings to imagery debate. However expected, this finding alone does not distinguish between the two theories, and even the opposite result (lack of SDE) would generate equally substantial problem for both models.

Though both theories would expect the obtained finding, their explanations are very different. Analog theory suggests that SDE happens due to assumed analog nature of mental image. Namely, mental image preserves physical distances (Kosslyn, 1994). Contrary to that, propositionalists argue that mental distances are mapped with propositional nodes, symbolic carriers of spatial information. Since longer distances are mapped with more nodes, mental scanning of the longer distance will require more time (Pylyshyn, 1981).

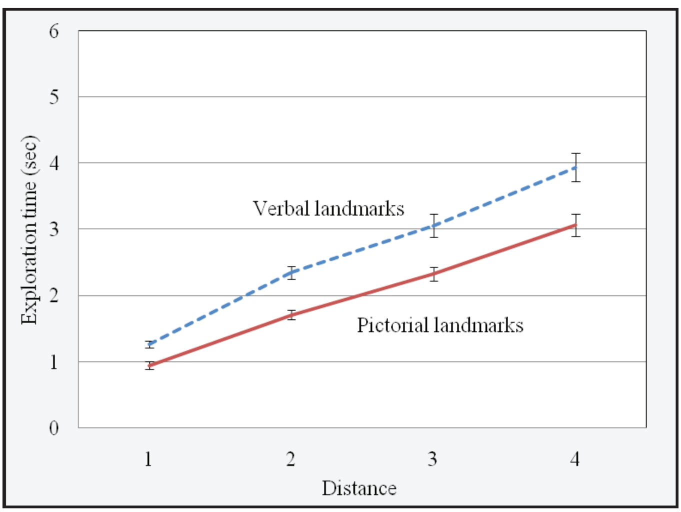

Figure 3. Averaged reaction times of mental exploration of the maps with verbal and pictorial landmarks

However, further scrutiny of the obtained data does facilities opposing predictions from the opposing theories. According to propositional theory, pictorial material must be transposed into propositional code, which is not the case when verbal maps are mentally represented. Therefore, propositionalists would argue that verbal maps would be scanned faster. Analog theory, if anything, would favour analog code, a natural environment for testing spatial relations.

In our experiment main effect of modality was obtained ($F(1,18)=43,931$, $p=.000$). Subjects were significantly faster to explore the distances on the maps with pictorial landmarks. This finding contradicts predictions from propositional theory. Bias for visual material in mental exploration task is yet another confirmation of the existence of different codes engaged in representational processes.

Lexical frequency was also introduced aiming to discriminate between the two theories. Within propositional framework it would be expected that lexical frequency, robust factor of verbal processing, would moderate processes that are language like, i.e. propositional process. Hence lexical frequency should affect both scanning of verbal and pictorial maps, since both of them would eventually relay on propositional code. Analog theory would assume absence of lexical frequency effect, since mental imagery task is inherently visual.

Our finding showed that lexical frequency did not reach statistical significance. There was no difference in time required to perform mental exploration of the maps with high and low frequent words, nor between maps with pictorial landmarks, which could also be denoted as high or low frequent words.

Interaction between distance and modality was registered ($F(3,18)=3.559$, $p=.020$) (could be observed on Figure 3). Increase of the exploration time was significantly faster for maps with verbal content. That is, not only that our subjects needed more time to scan maps with verbal landmarks, but their exploration time was increasing more rapidly when more words were included in scanning task. On the maps with pictorial landmarks this enhancement was significantly slower.

None of the presumed predictions from propositional theory was confirmed, except for the finding of SDE for verbal maps. If mental imagery and exploration of images are representational in its nature, than pictorial code must be transformed into propositional code, and such process would increase amount of time needed to explore maps with pictorial content. But not only that maps with verbal landmarks were slower to process, lexical frequency also didn’t moderate exploration process on any map modality. Findings of the first experiment clearly support the analog theory of mental representations, which predicts faster cognitive processing of the pictorial material.

EXPERIMENT 2

One of the most important findings that had inspired Paivio to postulate two inherently different cods for mental representations was the idea of concreteness of concepts (Paivio, 2006). Concrete concepts (such as “butterfly” or “arrow”) would be represented both as an image and as a word, whereas abstract concepts (such as “beauty” or “wisdom”) could only be represented verbally. Paivio found empirical confirmation for two codes both on level of isolated words (Paivio, 1971) and on the level of sentence (Begg & Paivio, 1969). The difference between the two types of concepts seems to be deeply rooted even in development, and the two types of concepts appear to have different developmental trajectories (Vygotsky, 1986).

Our newly developed paradigm offered a convenient setting for testing the concreteness for both modalities and to question the depth of the differences between the two codes. Therefore, in the Experiment 2 we manipulated modality of the maps (pictorial and verbal) and the concreteness of the concepts presented on the landmarks (concrete and abstract). Analog theory would predict the positive bias for concrete pictorial material, which is double coded in the system. Propositional theory would stress the effect of concreteness in the verbal domain, where this factor has been clearly demonstrated.

Method

Participants: Twenty-three high school students from Petnica Science center took part in the experiment.

Stimuli: Four experimental and four control maps, equally structured as in Experiment 1 (figures 1 and 2), contained landmarks presented with one of the following: (1) concrete words (2) abstract words (3) pictures of the concrete concepts (4) abstract pictorial material (Appendix 2).

Concepts were extracted from the Serbian Language Corpus (Kostić, 1999). Both concrete and abstract concepts had uniform word length and lexical frequency. Additional pilot study (with 20 participants) was used to ensure the adequacy of the selected concepts.

Abstract pictorial landmarks contained less familiar abstract textures from the paintings of the eminent abstract painters.

Procedure: The experimental procedure was the same as in the first experiment.

Data analysis: Four subjects with reaction time beyond 3 standard deviations (in any of the experimental situations) were excluded from the analyses. All participants completed control task.

The data were analysed using repeated measure analysis of variance with 3 factors (distance, modality and concreteness). First factor, distance, had four levels (distance between 2, 3, 4 or 5 landmarks), factor modality had two levels (verbal or pictorial), and concreteness also had two levels (abstract or concrete).

Results and discussion

SDE was again obtained on all of the maps used in the second experiment ($F(3, 22)=67.169$, $p=.000$) (Figure 4).

The effect of modality, observed in the first experiment, was replicated only on the concrete level ($F(1,22)=13{,}99$; $p=0.001$) (could be also observed on Figure 4). Consequently, interaction between the two factors, modality and concreteness, was also significant ($F(1,22)=9{,}05$; $p=0.006$) (figure 5).

In this experiment we observe a positive bias for pictorial representation only on concrete level ($F(1,22)=64{,}68$; $p=0.000$). Interestingly enough, abstract pictorial representation behaved in a very much the same manner as verbal material. Another somewhat unexpected finding was the lack of influence of concreteness on verbal maps.

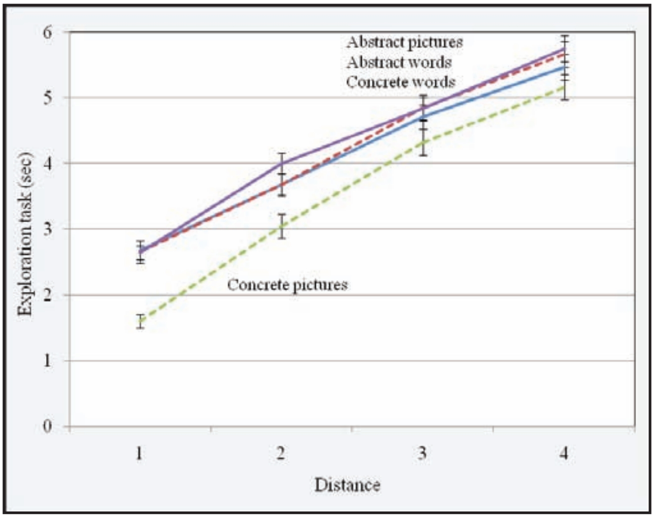

Figure 4. Averaged reaction times of mental exploration of the maps with landmarks of different modality and concreteness

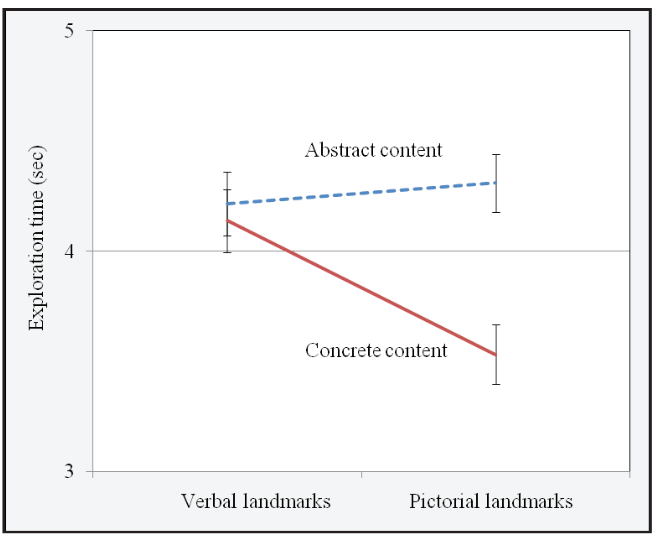

Figure 5. Interaction between the modality and concreteness.

No single code model could account for the obtained results (figure 5), as it would be impossible to explain the shorter reaction times for concrete pictures (and none of the other three types of materials) in a single code modality. Therefore the explanation must be found in the models, such as Paivio's, proposing two separate modalities. However within original theory (Paivio, 1986) certain equality was drown between concrete and pictorial on one side and abstract and propositional on the other. Our results do not support this categorization. Modality and concreteness appear to be separate factors.

Abstract pictorial material was probably the most advanced step away from the classical experimental paradigms. Even in the everyday communication mentioning something analog (i.e. picture-like) but abstract is an oxymoron. Keeping all this in mind we wanted to insure that our results were not a consequence of a particular random quality of the chosen stimuli. Therefore, in a separate experiment, we asked another 8 participants to perform the same task but viewing other three types of abstract materials (figure 6). Again we obtained the same results as in Experiment 2.

Figure 6. Three additional types of abstract pictorial stimuli: fractals, Chinese letters and snowflakes.

The fact that abstract pictorial material had a different treatment from the concrete pictorial material does not necessarily contradicts model such as Paivio's. The longer scanning time might as well be a consequence of a single memory trace. Only in this case it is not a verbal material without a pictorial trace but a pictorial material without a verbal trace.

However, the finding that there was no positive bias for concrete words is a problem for the theory postulating two different types of mental traces, which would enhance retrieval. We could conclude that maybe mental scanning, an inherently visual task, is at odds with any kind of verbal representations and the landmarks with concrete words did not produce the expected effect.

EXPERIMENT 3

Both previous experiments suggest that there are separate modalities of mental representation as well as a very articulated interaction between those modalities. In an attempt to understand these interaction we introduced verbal imagery map in the Experiment 1, abstract pictorial landmarks in the Experiment 2 and in Experiment 3 we are introducing frequency in the visual domain.

Word frequency is a widely studied and confirmed factor of verbal processing (Granger, 1990). But just like with words, we are frequently exposed only to a subset of visual objects. Naturally, there is an expected correlation between lexical and visual frequencies: frequently seen objects would be named more often, used more often and therefore talked about more often, etc. Paradoxically, there are certain classes of objects that are frequently represented in our visual field but almost never named or talked about (bellybutton, for example) or even do not have a proper label (tip of the index finger).

In the present experiment we manipulate visual frequency in order to see whether the results would parallel those obtained with lexical frequency. In addition we examined the interaction between the modalities manipulating the visual frequency against lexical frequency.

Method

Participants: A different group of twenty-five first year students of psychology at the University of Belgrade took part in this experiment in exchange for course credits.

Stimuli: Four experimental and four control maps, equally structured as in Experiment 1 (figures 1 and 2), contained landmarks presented with one of the following: (1) pictures of the concepts with high-frequent visual representations, which would be named with high-frequent words (2) pictures of the concepts with high-frequent visual representations, which would be named with low-frequent words, (3) pictures of the concepts with low-frequent visual representations, which would be named with high– frequent words and (4) pictures of the concepts with low-frequent visual representations, which would be named with low-frequent words (Appendix 3).

Concepts were extracted from the Serbian Language Corpus (Kostić, 1999) and word length was controlled. All words in the high frequency condition had frequency value of more than 100 (Kostić, 1999), and all words in the low frequency condition had frequency value of less than 3 (Kostić, 1999). Additional pilot study (with 35 participants) was used to ensure the adequacy of the selected concepts. In order to determine the visual frequency of the concepts pictures of the concepts were shown to the participants, and their task was to rate how often does the object presented on the picture occurs within their visual field. Frequency was graded on Likert scale (0=never, 1=once a year; 2=once a month; 3= several times a week; 4= once a day; 5=several times a day).

Procedure: The experimental procedure was the same as in the previous experiments.

Data analysis: The data were analysed using repeated measure analysis of variance with 3 factors (distance, lexical frequency and visual frequency). First factor, the distance, had four levels (distance between 2, 3, 4 or 5 landmarks), the factor lexical frequency had two levels (concepts expressed with high– or low-frequent words), and visual frequency factor also had two levels (pictures of the concepts with high– or low-frequent frequent visual representations).

Results and discussion

Again SDE was replicated on every map presented in the third experiment ($F(3, 24)=5,10$, $p=.003$) (Figure 7). Both main effects of visual and lexical frequency were insignificant.

Nevertheless, there was an interaction between visual and lexical frequency (F(1,24)=8,23, p=0.008) (Figure 7). Subject were significantly slower only with map made of landmarks of low visual and low lexical frequency.

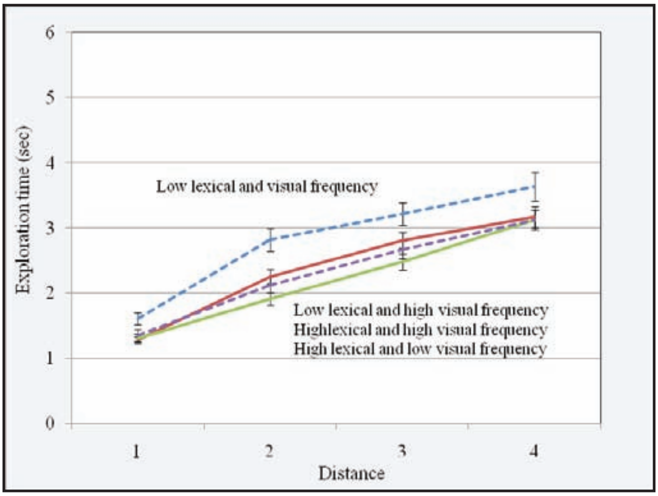

Figure 7. Averaged reaction times of mental exploration of the maps with landmarks of different lexical and visual frequency

It appears that visual frequency affects the outcome in this kind of task in a similar manner that lexical frequency biases lexical tasks. Results reveal shorter exploration time when participants scan maps with frequent visual objects. This was an expected result. Another expected result was that concepts, which are not frequent in both domains, take longest time. Both of these findings could be explained in a manner otherwise used to explain effects of lexical frequency. Due to constant usage, frequent words have a lower threshold, which leads to faster recognition (Whaley, 1978). We would assume that visually frequent objects would also have mental representation with lower thresholds, producing faster recognition in the initial phases of our task. Inspection of our results reveals the difference between the intercepts of the functions but not between the slopes of functions. This would be indicative of the differences in early phases and not the processing itself. The difference in slope, suggesting difference in process of scanning, can be obtained when the material comes from different modalities, which is the case in Experiment 1, for example (see Figure 3).

Although the present task has exclusively pictorial material, lexical frequency seems to play a significant role. This is particularly surprising, as we did not establish the effect of lexical frequency in our first experiment. There is a difference between the two conditions, though. In Experiment 1, maps were in both modalities. However, lexical frequency was not significant in either of the two modalities. The only other difference between the two experiments is that in Experiment 3, there was no mixture of modalities but the whole block consisted of trials within a single modality. This line of reasoning is implying an importance of certain order effects, but the underplaying mechanism remains unclear.

Finally, it seems that infrequent objects with frequent names are still processed fast. This would indicate an extremely efficient functioning of cognitive system, being able to gain from the high frequency regardless of modality. In other words, there is a gain even if the presented picture has a label, which happens to be a frequent word. Recently developed cognitive theories, such as perceptual theory of knowledge could account for the data obtained in this experiment. According to these theories cognitive representations are “inherently perceptual” (Barsalou, 1999, p 577) and even the conceptual symbols retain perceptual qualities (Glaser, 1992).

GENERAL DISCUSSION

The current study was conducted in order to determine the symbolic distance effect during mental exploration of imaginary maps with verbal content. In addition to this, we wanted to investigate whether various perceptual and lexical properties of the contents presented on the map could modify time required to perform mental scanning task.

SDE was obtained in a number of studies (Kosslyn, 1980) and on different types of pictorial material such as maps (Kosslyn, Ball & Reiser, 1978), real geographical maps (Stojanović i Zdravković, 2007), with variable number of items within a given distance (Thorndyke, 1981). In addition it was shown that the effect could also be obtained using objects instead of space (Paivio, 1978; Koslyn, 1973, 1975; Shepard & Metzler, 1971; Cooper & Shepard, 1973). Finally, the effects of individual differences (e.g. Paivio, 1971; Richardson, 1977), developmental stages (Lew, Foster, Bremner, Slavin, & Green, 2005) and training (Blazhenkova & Kozhevnikov, 2009) were also demonstrated. Present research adds verbal maps to this list of different material where SDE can be measured.

Introducing verbal content into imaginary maps enabled us to readdress the question of mental representations modality. Positive bias for pictorial material in mental scanning process indicates existence of different codes involved in mental imagery. In addition to this, visual frequency of the pictorial content moderate exploration of imagery maps. Unique coding models cannot account for these findings.

The fact that verbal material could be mixed with space-like context and produce effects that would hypothetically need analog representation is certainly theoretically interesting. However there is a practical side, too. We can conclude that maps and instructions, which use labels instead of icons, will be processed in a similar way and could be used in everyday situations. Nevertheless, verbal maps should be limited to the situation where time is not of essence (i.e. in a shopping mall but not in traffic) as introduction of verbal material slows processing. Furthermore, according to our results the bigger the verbal map (meaning with more landmarks), the slower the processing.

Otherwise well-established factors of lexical processing (lexical frequency and concreteness) did not affect mental exploration of verbal maps. These results cannot be easily incorporated into propositional theory (Pylyshin, 1981), which claims that representational processes are propositional and related to language.

Although certain interplay between visual and verbal representational mechanisms is postulated in classical dual coding and hybrid models (Paivio, 2006), there were few empirical and theoretical efforts to clarify the nature of this relation. Introducing the visual frequency factor provided us with a possibility to examine the relation of visual and verbal coding in mental imagery.

Dominance of nonverbal coding in mental imagery was demonstrated through the interaction of lexical and visual frequency. Although lexical frequency had certain moderating effects, visual frequency had superior effect in mental scanning process. These findings are supporting DCT, confirming the existence of interplay between separate codes in general, but also a dominance of analog coding in specific tasks, such as mental imagery.

These findings are yet another confirmation of the analog theory assumptions, based on DCT, which postulates existence of modality specific representational mechanisms, contrary to ideas of common-coding, propositional models. If mental imagery was based on common-coding mechanisms, visual frequency would not show moderating effects, and lexical frequency would be the only factor to affect mental scanning task.

Kosslyn and Thompson (2003) updated different analog code model into a rather influential theory of mental imagery, sometimes called perceptual anticipation theory. The essence remains the same: images within visual imagery are depictive or quasi-pictorial. These depictive representation would require specifically structured brain mechanisms, that is brain areas organised for analysis of analog information. Naturally, visual brain offers this kind of structure, especially primary visual cortex (areas V1/area 17 and V2/area 18). In opposition to perceptual anticipation theory is logically significantly more elegant propositional theory (Pylysyn, 2002). Not only that it requires a single coding mechanism and no translation– or bonding-between-the-codes algorithms, but it does not require described neural infrastructure either. However, data seem to incline to the less elegant solution. Kosslyn and Thompson (2003) analysed about 60 relevant brain-imaging studies and in half of them early visual cortex was activated during visual imagery task. Based on such analysis we could conclude that the discussion on neural foundations of imagery is certainly not yet resolved.

The imagery debate is not the first time general psychology encounters the issue of mental representations in imagery like tasks. Among classical theories of learning a concept of "cognitive map" was offered to explain maze behavior (Tolman, 1948). Cognitive map was very much analog representation without any need for conceptual counterpart and as such could have been found in other species but humans. It would be evolutionary plausible that the first concepts, such as those found in humans, have developed from the perceptual code. The notion of common representations for perception and cognition was dominant before 20th century and has returned in fashion. For Barsalou "conceptual representations are modal, not amodal. The same type of representations underlie perception and conception" (Barsalou, 2003, p. 521). In fact this author of theory of knowledge goes even one step further proposing that these perceptual notions are coming from senso-motor systems.

We would agree with this general framework. Also, our findings directly support the assumptions of analog theory of the mental representation. This theory assumes facilitation of pictorial material cognitive processing, and does not predict the effects of the lexical properties of the contents presented on the maps. On the other hand, obtained results could not be easily incorporated into propositional theory. Cognitive system performs mental scanning faster with pictorial material. These findings are another confirmation of the idea that different codes are engaged in representational processes.

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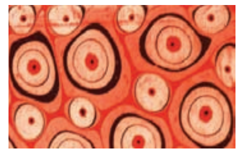
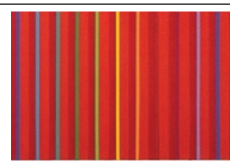
APPENDIX 1

Content of experimental maps in first experiment

	Map 1	Map 2	Map 3	Map 4
Modality	Verbal	Verbal	Visual	Visual
Lexical frequency	Low	High	Low	High
Content presented on the landmarks	RATTLE (ZVEČKA)	CURTAIN (ZAVESA)		
	HARPOON (HARPUN)	WINDOW (PROZOR)		
	DIAPER (PELENA)	BOX (KUTIJA)		
	SCHOONER (KRIGLA)	BED (KREVET)		
	MAGNET (MAGNET)	PILLOW (JASTUK)		
	LOBSTER (JASTOG)	PENCIL (OLOVKA)		
	CONDOR (KONDOR)	BUILDING (ZGRADA)		

APPENDIX 2

Content of experimental maps in second experiment

	Map 1	Map 2	Map 3	Map 4
Modality	Verbal	Verbal	Visual	Visual
Concreteness	Concrete	Abstract	Concrete	Abstract
Content presented on the landmarks	OLIVE (MASLINA)	FREEDOM (SLOBODA)		
	BALL (LOPTA)	THOUGHT (MISAO)		
	WINDOW (PROZOR)	PREMONITION (SLUTNJA)		
	BOAT (ČAMAC)	TIME (VREME)		
	COAT (KAPUT)	LOVE (LJUBAV)		
	LAMP (LAMPA)	IDEA (IDEJA)		
	TRAM (TRAMVAJ)	CULTURE (KULTURA)		

APPENDIX 3

Content of experimental maps in third experiment

	Map 1	Map 2	Map 3	Map 4
Lexical frequency	Low	Low	High	High
Visual frequency	Low	High	Low	High
Content presented on the landmarks