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THE NATURE OF CONCEPTUAL KNOWLEDGE

The Role of Thematic and Taxonomic Knowledge in the Organization of Semantic Memory

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The Nature of Conceptual Knowledge

The Role of Thematic and Taxonomic Knowledge in the Organization of Semantic Memory

Abstract

Grouping similar objects together is one of the most fundamental capabilities of the human brain. It allows for non-identical entities to be treated the same way, enables generalization of knowledge, and thus makes our everyday life much easier. However, there is at least one more principle relevant for the organisation of knowledge about the world. By this principle, objects are grouped based on their interactions in scenarios or events. These objects are typically not similar, but they play complementary roles while frequently co-occurring in time and space. The first type of relation is referred to as taxonomic, while the second is referred to as thematic.

The question of the roles that these different types of information may play in the organisation of semantic memory has been addressed through a series of norming and experimental studies reported in this thesis.

The pattern of results obtained in norming studies suggests that by the time controlled processing takes place, which may be situation or task required, brain will have already computed the degree of the overlap between the objects, and this estimate of the *overall conceptual overlap* heavily influences subsequent intentional processing. Importantly, our results suggest that the *overall conceptual overlap* accounts for both item similarity in terms of shared features and item contiguity, i.e. relatedness based on frequent co-occurrence and complementarity. Furthermore, there is also evidence for contiguity being given more weight than similarity when computing the conceptual relations. These findings received support in experimental studies, showing early competition of thematic and taxonomic information reflected on the measures of visual attention, and, at the same time, conceptual preference for thematically related objects. The second line of experimental evidence came from masked semantic priming studies, in which thematic and taxonomic priming was detected, although participants were not aware of the presence of the related context. Finally, ERP data added to the discourse by providing evidence that thematic information is more easily semantically integrated, while the processing of taxonomic information requires more effort.

In summary, the results of the studies presented in this thesis give strong support to the view of conceptual knowledge being shaped by the two types of information: taxonomic, based on item similarity, and thematic, based on item contiguity.

Key words: *Semantic memory, Thematic relations, Taxonomic relations, Associative relations, Similarity, Eye-tracking, Thematic preference, Semantic priming, Event-related potentials, N400, P600*

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Улога тематског и таксономског знања у организацији семантичке меморије: нормативни, бихејвиорални и неурални показатељи

Резиме

Способност да различите објекте групишемо на основу њихових заједничких својстава једна је од кључних когнитивних способности човека. Категоризација омогућава да неидентичне објекте третирамо на исти начин и градимо очекивања о новим објектима генерализацијом стеченог знања, те тако значајно олакшава наше сналажење у свету. Ипак, груписање објеката на основу заједничких карактеристика није једини начин на који објекти могу бити организовани. Објекти могу бити груписани и на основу њихових интеракција, те сродности засноване на заједничком појављивању у времену и простору. Такви објекти најчешће нису слични, већ им њихове различите карактеристике омогућавају комплементарност улога које могу имати у неком догађају или сценарију. Први облик груписања назива се таксономским, док је други тематски.

У оквиру ове тезе известићемо о низу нормативних и експерименталних студија које су покушале да дају одговор на питање о томе какве улоге ове две врсте повезаности играју у организацији семантичке меморије.

Резултати нормативних студија показали су да се процесирање опште семантичке повезаности међу објектима одвија аутоматски и претходи контролисаном, стратегијском процесирању које налаже задатак или ситуација. Ова примарна, спонтана процена семантичке повезаности значајно утиче на контролисано процесирање. Наши резултати показују да се при процени семантичке повезаности наш когнитивни систем ослања на две врсте информација: сличност базирану на заједничким карактеристикама, и сродност засновану на заједничком појављивању и комплементарности објеката. Осим тога, налази говоре у прилог тези да се тематској повезаности даје предност, односно да она има већи пондер у односу на таксономску повезаност. Дати налаз добио је подршку и у експерименталним студијама које су кроз мере визуелне пажње указале на рану компетицију тематских и таксономских информација, као и на концептуалну преференцу према тематски повезаним објектима. Друга линија експерименталних налаза потиче из студија маскираног примовања у којима су ефекти тематског и таксономског примовања били значајни иако су услови излагања прима били такви да испитаници нису могли проценити повезаност. Коначно, налази студија евоцираних потенцијала показали су већу лакоћу семантичке интеграције тематских информација, као и потребу да се уложи додатни когнитивни напор у обради таксономске повезаности.

Налази изнесених стидија дају снажну подршку хипотези да се организација концептуалног знања заснива на бар две врсте информација: таксономским, занованим на сличности објеката, и тематским, које се темеље на комплементарности ентитета.

Кључне речи: *семантичка меморија, тематска повезаност, таксономска повезаност, асоцијативна повезаност, сличност, праћење очних покрета, тематска преференца, семантичко примовање, евоцирани потенцијали, N400, P600*

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To Mom and Dad,

for always believing in me

Chapter 1

Introduction

The amount of information stored in our brains is truly impressive. Gigabytes of noises, sounds, smells, images, words, labels, propositions, facts, all stored in a lump of flash no bigger than a cereal bowl. But our brains are not simply collecting and storing this vast amount of information. Pieces of our experience are mutually interconnected making it possible for our brain to use the acquired information to construct new meanings, contemplate them, and ask questions about its own potentials and limitations. Brain: the most complex object in the known universe, packed between the two ears of every human being.

However, maybe even more impressive than the capacities of this growing storehouse of knowledge is its efficiency; the remarkable speed and ease of accessing stored information. The quest for understanding the principles underlying the organization that could support such efficient knowledge storage is very old. The first known explicit statement of principles that organize our world knowledge is ascribed to Aristotle. Aristotle formulated four laws that shape our mental world: (1) *The law of contiguity* (objects occurring together in space and time tend to be linked together in mind), (2) *The law of frequency* (the more often two objects are found together, the stronger the links between them will be), (3) *The law of similarity* (similar objects tend to trigger thoughts of one another) and (4) *The law of contrast* (the experience of one object sparks the recollection of its opposite). Although four in number, they can be treated as two fundamental principles of organization of knowledge in humans: one based on the contiguity of objects and the other one based on the comparison of object features. This distinction was first elaborated by Aristotle but was reformulated and extended by a number of ancient philosophers and scholars, and is still present in different forms in contemporary philosophy and cognitive science.

Despite the fact that the idea of the existence of two fundamental principles shaping our mental world is two millennia old, it does not mean that the mystery of how these principles construct meaning has been resolved. Simple observation of their existence was far from finding the way to bring the two together in theories and models of memory organization. It is no wonder that scientists rarely addressed the problem as a whole, but rather studied either the role of similarity or the role of contiguity, for some time even rejecting the idea of their natural complementarity. On the bright side, it seems that our knowledge about the brain and the tools available to study the ways it functions might have reached the point when we are ready to confront some of the most delicate questions which troubled philosophers and scientists for more than two thousand years.

The modern incarnation of the problem of the similarity – contiguity dualism, in contemporary cognitive science took form of the distinction between thematic and taxonomic type of relations in semantic memory. The term semantic memory is used to refer to general knowledge about the world, which includes knowledge we use in everyday situations in order to recognize objects in our environment, generate expectancies about their interactions with other objects and ourselves, and also other types of concepts, facts, and beliefs that are independent of personal experiences, such as how, when, and where the knowledge was originally acquired (Tulving, 1972; Yee, Chrysikou, & Thompson-Schill, 2013[1]).

Based on our semantic memory, we know that apples and pears are fruit, and since they are fruit, they are edible. Furthermore, if we know that cherimoya is a kind of fruit that

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[1] Although semantic memory has traditionally been defined as general knowledge that is free of context in which it is acquired (Tulving, 1972), the degree to which semantic memory is independent of experience is a matter of ongoing debate. Some researchers disagree with Tulving (1972) and suggest that there is no clear cut between episodic (memory about specific personal experience) and semantic memory, but that semantic memory is also grounded in the sensory modalities, entangled in experience, and dependent on the culture (McRea & Jones, 2013; Yee, Chrysikou, & Thompson-Schill, 2013). Although this debate falls outside the scope of this thesis, it is worth noting since the inclusion of thematic relations in semantic memory organization has been, by some authors, seen as one of the arguments that support the blurred line between episodic and semantic knowledge (McRea & Jones, 2013).

tastes like banana – pineapple mix, although we have never experienced cherimoya, we may predict whether it tastes sweet, sour or bitter. This type of knowledge is based on taxonomic relations between concepts in semantic memory, relations that are based on shared features between objects, that is, object similarity. If objects were not taxonomically related, whenever we would come across a new object, we would need to learn about its characteristics and relations with other objects, regardless of its degree of overlap with what we already know, that is, there would be no generalization of knowledge to new instances.

But not only that relations between concepts enable us to form expectations about the characteristics of objects in the world, they also help us predict when we should expect them to appear, where we should go if we want to find them, or how something should be used. These relations are thematic in their nature, and rely on the knowledge of contiguity of objects and events in space and time. Although both thematic and taxonomic relations between concepts are clearly crucial for our survival, thematic information was neglected from theories and research of semantic memory organization for a long time.

This negligence of thematic relations took two forms. The first is reflected in typically viewing semantic memory as a taxonomically organized system, and the second arises from the operationalisation of relations based on contiguity in cognitive psychology. We will discuss these two issues in the following sections.

Traditional view of semantic memory organization

The traditional theories and models of semantic memory have assumed existence of taxonomic structure of knowledge in which concepts are organized according to their membership in a semantic category (Quillian 1968; Collins and Loftus, 1975; Rosch, 1973). Similarly to the scientific classifications in biology, concepts are supposed to be grouped and categorised hierarchically, according to their shared characteristics. Apples and pears are fruit, which belong to the category of plants, which belongs to the category of living things.

Although the early models of semantic memory have been subjected to significant changes and reformulations that led to more cognitively plausible ideas on how objects and their features are represented and linked in memory (McClelland & Rogers, 2003; Barsalou, Simmons, Barbey, & Wilson, 2003; Tyler & Moss, 2001), the organization and brain mechanisms that might support both similarity-based and contextual, thematic knowledge, have not yet been described.

Despite its limitations, feature-based, hierarchical conceptual organization provided a useful foundation to the study and understanding of a broad range of phenomena in semantic processing. Studies of patients with specific semantic deficits (e.g. Warrington & Shallice, 1984; Caramazza & Shelton, 1998), together with the neuroimaging studies of healthy adult participants (e.g. Perani, Cappa, Bettinardi, Bressi, Gorno-Tempini, et al., 1995; Proverbio, Del Zotto, & Zani, 2007) have suggested that distinct semantic categories may be processed differently and activate distinct brain areas. However, research on semantic organization has been, for years, restricted to identifying differences in performance and brain activation of taxonomic categories (e.g. animate vs. inanimate) and the status of other types of knowledge was out of the focus of researchers.

There is a list of possible reasons why semantic memory models and research have stayed free of contextual information for such a long time. We will list some of them. The first one can be found in the fact that much of the research in the area has been inspired by cases of brain-damaged patients who suffered from category-specific semantic memory deficits. This line of research has paved the way for the research on healthy participants, keeping the focus of the researchers on the localisation of different knowledge categories. The limitation to categorical knowledge may also be attributed to the computer metaphor that was influential in this field from the 1950s onwards (e.g. Broadbent, 1958) and later with the rise of the connectionist models – to the models' restrictions to viewing connections between concepts based on shared units.

In the following section, we will explain why we believe that the operationalisation of relations based on contiguity through the association norms may have represented a hindrance to the research on the role of thematic relations.

Semantic vs. associative relations in semantic memory

> "*Having devoted a fair amount of time perusing free-association norms, I challenge anyone to find two highly associated words that are not semantically related in some plausible way. Under this view, the distinction between purely semantically and associatively related words is an artificial categorization of an underlying continuum.*"
>
> (McNamara (2005) p. 86).

Much more often than taxonomic vs. thematic, relations between concepts were described as semantic vs. associative. Although the basic idea of the mechanisms underlying associative relation between concepts closely resembles what was described as relatedness based on contiguity in experience (Deese, 1965; Moss et al., 1995), the associative relations are in cognitive psychology almost invariably defined in terms of word associations (McRea & Jones, 2013). The term associative relation in psychology denotes the probability with which one word will call to mind another word (e.g., Postman & Keppel, 1970).

For a long time, the discrepancy between the theoretical and operational description of associative relations has been neglected, and interpretations of associative relationship were tied for its normative description. The conglomeration of different types of meaning integrated under the one label – associations, gained vast popularity due to the fact that it has proven to be a good predictor of participants' performance in semantic memory experiments (e.g. Nelson, McEvoy, & Dennis, 2000; Roediger, Watson, McDermott, & Gallo, 2001). However, the assimilation of associative relations with word associations has actually stifled the research on the role of contiguity in semantics and has resulted in information learned by association to be viewed as the opposite of semantic. A number of studies we will present and discuss in Chapter 4 have been conducted in order to distinguish between the influences of semantic and associative relations in memory (e.g. Lucas, 2000; Hutchison, 2003). However, if we were to take a perspective from which associative relations could also be semantic, it might be more fruitful to try to disentangle the roles of different types of semantic relations based on associative learning and relations based on similarity in semantic representations formation. This idea motivated the use of terms thematic and taxonomic in this thesis and in general, as they more precisely reflect the nature of relation types under investigation.

Due to the great ambiguity in the terminology used to talk about conceptual relations in semantic memory research, the following sections will be devoted to an attempt to define thematic and taxonomic relations more precisely, in order to clarify the boundaries between thematic and taxonomic concepts and differentiate them from other related constructs.

Taxonomic relations

Objects are taxonomically related if they belong to the same semantic category based on the overlap in features or meaning (Murphy, 2002; Estes, Golonka & Jones, 2011). For example, *cow* and *donkey* share many features (e.g. four legs, two eyes, a hairy body covering, being warm-blooded) and as such they belong to the same category, the category of mammals. Thus, the main principle of organization of entities in taxonomic groups is similarity.

Based on shared features and meaning, concepts may be represented in conceptual hierarchies in which entities are connected by vertical (connecting entities of different level of abstraction: *cow-mammal-animal-living thing*) and horizontal (connecting entities on the same level of hierarchy: *cow-donkey-giraffe-elephant*) taxonomic relations (Rosch, 1978). In seminal work *Principles of categorization* (1978), Rosh made distinction between the three types of taxonomic relations: (a) superordinate: *mammal* - *animal*; (b) basic level: *mammal* - *bird* and (c) subordinate: *mammal* - *cow*. This classification is important because it sheds light on sometimes overlooked difference in matching concepts of different levels of abstraction. For example, matching representations of *cow* and *donkey* may require different processing mechanisms than matching representations of *cow* and *animal*, and so on.

Taxonomic categories entail the conventional view of categories as sets of objects that are similar or akin. In the literature, terms *categorical* or *semantic* are often been used when referring to this type of categories. However, it is worth noting that some authors (e.g. Thompson-Schill et al., 1998; Moss, Ostrin, Tyler, & Marslen-Wilson, 1995) treat all relations based on meaning as semantic, regardless whether their relation is categorical, functional or of other type. In this thesis, we have adopted the terminology that does not deny semantic nature of other types of relations, for example thematic, but also makes distinction between semantic relations based on complementarity and those based on similarity, and thus is in our view, most appropriate.

Thematic relations

> *Contiguity joins together things that are naturally juxtaposed, or that are, by any circumstance, presented to the mind at the same time, as when we associate heat with light, a falling body with a concussion.*
>
> (A. Bain, *Senses and Intellect*, p. 451)

Thematic relatedness is typically defined as relatedness of objects that have complementary roles in the same scenario or event (Murphy, 2002; Estes, Golonka & Jones, 2011). Links between thematically related objects can be temporal (*cloud* - *rain*), spatial (*picture* - *wall*), functional (*chalk* - *blackboard*), and/or causal (*wind* - *wave*). Although authors have made distinction between the four types of thematic relations, basically all forms of thematic relatedness are based on co-occurrence of objects in space and time, and thus, most often, thematically related objects share more than one link (e.g. *chalk* and *blackboard* are both temporally and functionally related).

In order to distinguish thematic relations from other types of relations, two key properties have been recognized. The first one is that thematic relations are external, that is, thematic relatedness exists between objects, which is in contrast with the relations that are based on connections between the features of objects; such is the case with the taxonomic relations. The second property entails the complementary nature of thematic groupings. Thematically related objects have different roles in events or scenarios. For example, *nail* and *hammer* are thematically related, not only because they co-occur, but because they complement each other in the event of putting a picture on a wall.

Thematic and taxonomic relations: differentiation

Bassok and Medin (1997) have argued that thematic relatedness and taxonomic relatedness stem from two different cognitive processes: comparison and integration. While taxonomically relating objects requires comparison, thematic linking requires integration. This might seem obvious, having in mind that the main difference between thematic and taxonomic concepts is that, while taxonomic relations rely on similarity, thematically related objects are typically not similar, but different, in the way that their different characteristics complement one another. As we have already mentioned, the other important difference is that thematic relations are external (between objects) while taxonomic relation are internal (between features).

Although thematic and taxonomic concepts are theoretically orthogonal, real-life objects are usually both thematically and taxonomically related to a varying degree. For example, although *nail* and *hammer* are complementary in their functions and thus thematically related, they can also be grouped under the taxonomic category of tools.

Thematic and associative relations: differentiation

> "*Objects once experienced together tend to become associated in the imagination, so that when any one of them is thought of, the others are likely to be thought of also, in the same order of sequence or coexistence as before. This statement we may name the law of mental association by contiguity."* (William James, 1890, p. 561).

As explained earlier, associative relations in cognitive psychology are intertwined with the way associative strength has been measured. Associative strength is operationalised through the free production task in which participants are asked to come up with the first word that comes to their mind in the presence of the cue word. The probability of one word calling to mind another word is taken as a measure of its associative strength.

Among other ways, concepts may be associated based on their co-occurrence in language, phonetic similarity (e.g. rhyme), being synonyms or antonyms, or belonging to the same category. However, one of the most common reasons for concepts to be strongly associated is thematic relatedness. Therefore, thematic relatedness may be seen as a specific type of associative relatedness, or one of the sources of associative relatedness. On the other hand, for concepts to be thematically related associative relatedness is not necessary.

Words cow and milk are strongly thematically related, and milk is the first associate for the word cow (Nelson et al, 1999). For the word flower, the first associate is rose, but rose and flower are not thematically related. The two words are associated because rose belongs to the category of flowers. Thematic sister of the word flower is vase. The strength of association between flower and vase is only .01 (Nelson et al, 1999), that is, only one percent of participants would come up with word vase when presented with the word flower.

It should be noted that processes underlying associative and thematic relatedness are the same. They both stem from the association of two stimuli based on their co-occurrences in time or space. However, traditionally defined associative relatedness heavily depends on co-occurrences in language, while thematic relatedness should reflect co-occurrence in the real world. Although these two forms of co-occurrences, one of objects in the real world and the other of the words denoting these objects, should be correlated, norms based on co-occurrences in language are also affected by different language related factors (Jones and Golonka, 2012).

In our view, the heterogeneity of relationship types captured by the association norms makes it unjustifiable to treat associative relatedness based on free production norms uniformly. In order to more deeply understand the roles of different relationship types in semantic memory, a new approach in measuring relations based on similarity and contiguity is needed. We further address this question in Chapter 2.

Review of the literature on thematic and taxonomic processing

The story about the beginnings of research on dissociation between thematic and taxonomic goes back to 1970s, to the debates on thematic-to-taxonomic shift in conceptual development (Smiley and Brown, 1979) and cultural differences in preferences for using thematic or taxonomic relations (Chiu, 1972). Both lines of research were based on testing preferences in grouping objects, mainly by using matching tasks in which participants would choose to group the base object with either thematic or taxonomic alternative. The participants' performance on these tasks differed across age groups and across cultures. Younger participants preferred thematic grouping (*cow* - *milk*), while older children and adults typically relied on taxonomic relations (*cow* - *donkey*) between objects (e.g. Smiley and Brown, 1979; Denney, 1974). These results were interpreted in the context of the prominent developmental theories at that time (Inhelder & Piaget, 1964; Bruner, 1964; Vigotsky, 1977), as a support for the qualitative change in conceptual development from simpler (thematic) to more complex (taxonomic) representations. However, this explanation could not account for the cultural differences in conceptual preference, showing that both children and adults from Eastern Asia tend to group objects thematically, contrasting the behavioral patterns of the Western-world participants who preferred taxonomies after the preschool age (Chiu, 1972; Nisbett and Miyamoto, 2005).

Studies on developmental and cultural differences in thematic and taxonomic thinking were important because they questioned some of the believed-to-be axioms in cognitive psychology. Particularly, they questioned the cognitive status of conceptual relations based on complementarity (cow produces milk) as primitive compared to those based on similarity (cow and donkey are animals). Since the relevance of thematic thinking in adulthood was shown, this called upon a reconsideration of the hypothesis of hierarchical, context-free organization of concepts being the final stage in development. Although matching studies indicated that both thematic and taxonomic concepts are salient in adulthood, how these two types of relations help us process meaning remained out of the scope of these studies and remained unaddressed until recently.

While earlier studies on thematic-taxonomic distinction investigated preferences for one of the types of thinking (e.g. Smiley and Brown, 1979; Chiu, 1972), the present-day research focuses on understanding differences in representations of thematic and taxonomic categories in the brain (e.g. Kalénine, Mirman, Middleton, & Buxbaum, 2012; Sachs, Weis, Krings, Huber, & Kircher, 2008; Estes & Jones, 2009). In the following paragraphs, we will offer a brief review of the most prominent findings in this area and try to illustrate a broad diversity of tasks and methods researchers started to use in order to address this question. The research that is particularly relevant for this thesis will be discussed in detail in subsequent chapters.

Semantic priming studies have shown priming effects for both thematically (Chwilla & Kolk, 2005; Sachs et al., 2008; Sass et al., 2009; Estes & Jones, 2009; Estes et al, 2011; Jones & Golonka, 2012) and taxonomically related objects (Lucas's, 2000; Hutchinson's, 2003). However, the size of the effects and the direction of the differences between thematic and taxonomic primes vary across studies. Sachs et al (2008) have reported greater priming effects for thematic pairs, but no taxonomic priming in auditory-to-visual semantic task (Sass et al, 2012). Taxonomic priming was also questioned by Shelton and Martin (1992), who failed to find priming for category co-ordinates. On the other hand, in a meta-analysis of semantic priming, Lucas (2000) has found reliable priming effects based on the feature overlap between the prime and the target. The difference in patterns of results may be explained by a variety in procedures (e.g. prime exposure duration) and stimuli materials (visual vs. auditory; pictorial vs. language) used, as well as by the variations in category definitions and experimental control (e.g. control of associative strength) across the studies. Nevertheless, it seems that processing can be facilitated by both thematic and taxonomic context, but also that the priming effects are sensitive to a set of experimental parameters.

Using a forced-choice task in which participants were instructed to find a semantic match in picture triads consisting of the target and the two options, one unrelated and one related either thematically or taxonomically, Kalénine et al. (2009) have shown that taxonomic relations were identified faster than thematic relations, but that the pattern of results may depend on the category type, with taxonomic relations recognized faster among the natural concepts and thematic relations recognized faster among the pairs of artefacts. Having in mind that they have used visual stimuli, the difference reported here can be attributed to the higher visual similarity between taxonomically related items which is not as salient when language material is used.

In order to investigate the time course of activation of thematic and taxonomic knowledge, several eye tracking studies have been conducted. The results have shown that thematic relations are detected earlier than relations based on category membership (Kalénine, Mirman, Middleton, & Buxbaum, 2012; Pluciennicka, Coello, & Kalénine, 2013). In an eye tracking experiment (Kalénine, Mirman, Middleton and Buxbaum, 2012) in which participants were instructed to find a target object (e.g. *broom*) in a four-picture display, thematically related objects (e.g., *dustpan*) have shown earlier competition effects than objects that shared the function (e.g., *vacuum cleaner*). Investigating temporal dynamics of thematic and taxonomic knowledge using the ERP methodology, Kriukova (2012) has reported that thematic relations have elicited less negativity than categorical pairs during 350-470ms interval after the stimulus presentation. These studies provided the first evidence that the activation of thematic and taxonomic relationships may be characterized by distinct temporal dynamics.

Investigating the neural correlates of the distinction long recognized in the psychological literature, Sachs and associates have conducted a series of fMRI experiments using semantic priming and matching tasks. In the matching task, thematic and taxonomic matching activated similar cortical regions, but choosing taxonomic option in the presence of thematic match required additional activation of the left thalamus, right middle frontal gyrus, and left precuneus (Sachs, Weis, Krings, Huber, & Kircher, 2008). During semantic priming, taxonomic priming, in contrast to thematic priming, was associated with greater activation of the right precuneus (Sachs, Weis, Zellagui et al., 2008) and suppression in left superior temporal sulcus (Sass, Sachs, Krach, & Kircher, 2009). When related priming condition was compared to the unrelated, thematic relations were found to more strongly activate left superior and middle temporal regions, whereas taxonomic relations have shown increased activation in right-lateralized fronto-temporal regions (Sass, Sachs, Krach, & Kircher, 2009). Taken together, fMRI studies have shown that taxonomic and thematic processing may activate distinct cortical networks, but that this difference is rather a matter of degree of recruitment of similar regions than evidence for existence of relationship-specific brain regions. The enhanced activation in right-lateralized fronto-temporal and occipital regions during taxonomic processing was most often interpreted in terms of more effortful processing of taxonomical in comparison to thematic relations or related to the perceptual similarity of taxonomically related objects, while left-lateralized activation in frontal and the middle temporal gyri was hypothesised to reflect the retrieval of semantic information and processing of semantic associations (Sass, Sachs, Krach, & Kircher, 2009).

In line with these findings, other studies have reported differences in processing categorical and associative relations in patients with left and right hemisphere lesions. Schmidt, Cardillo, Kranjec, Lehet, Widick and Chatterjee (2012) have shown that understanding categorical in comparison to associative analogies required additional recruitment of right mid-posterior temporal region, which these authors interpreted as an evidence of categorical relations being more difficult to process, since they are more distant and abstract than associative relations. Furthermore, Haagort et al. (1996) reported difficulties in patients with left hemisphere lesions and aphasia in comprehension of categorical relations with preserved associative relational thinking.

Additional findings for dissociations between taxonomic and thematic knowledge come from a study by Schwartz et al. (2011). The double dissociation between the left temporoparietal junction (TPJ) and the left anterior temporal lobe (ATL) found in the study of naming errors of aphasic patients provided evidence that thematic and taxonomic relations may be generated by fundamentally structurally and functionally different systems in the brain. In this study, patients with lesions in the ATL would typically mistake an apple for a pear, that is, their naming mistakes were taxonomic. In contrast, patients with lesions in the TPJ, tended to confuse thematically related items, naming, for example, an apple a worm. These results were supported by a computational model that accounted for this neuroanatomical double dissociation (Mirman, Walker and Graziano, 2009). Based on the predictions of this model, both thematically and taxonomically related concepts should be automatically activated during language processing.

Although some authors made strong claims about the different localisation of thematic and taxonomic knowledge (Kalénine et al., 2009; Schwartz et al., 2011; Mirman and Graziano, 2012), there is still more data showing that taxonomic and thematic conceptual processing recruit similar neural networks (Sass, Sachs, Krach, & Kircher, 2009; Sachs, Weis, Krings, Huber, & Kircher, 2008), while differences found vary depending on the task and methodology. However, presented research does suggest that both types of relations are important for adult conceptual organization, and that they may have different roles.

Overview of the thesis

This thesis is organized into five chapters. The present introductory chapter is followed by three chapters reporting on the findings of the norming (Chapter 2) and the experimental (Chapter 3 and Chapter 4) studies. In the final, fifth chapter, the implications of the presented studies are discussed.

The issue of measuring relations based on similarity and contiguity is addressed in Chapter 2. A series of norming studies have been conducted aiming to answer the question of how thematic and taxonomic relations differ on a set of dimensions that should more closely capture one or the other relationship type. In order to achieve this goal, for each of the 69 target objects of our stimuli set, we have selected one object that belongs to the same semantic category, one object that has complementary features with the target object, and one object that is not related to the target. Same stimuli material was used across all studies in Chapter 2. We have collected association strength norms in Study 1, while in Study 2 and Study 3, we have collected thematic and taxonomic production norms. In Study 4, participants rated thematic relatedness, and in Study 5, they rated taxonomic relatedness of pairs of items on a seven-point scale. In Study 6, general similarity judgments were collected, and in Study 7, we have collected judgments on the difference between the pairs of objects. Study 8 examined typicality and Study 9 familiarity of the images used in experimental studies. In Study 10, we have analyzed estimates of local co-occurrence of thematic and taxonomic pairs.

The third chapter was inspired by the extensive literature on conceptual preferences in categorization. The goal of the three matching-task experiments presented in this chapter is twofold. First, we wanted to test for the existence of conceptual preference among educated young adults, Serbian native speakers. Second, we tried to untangle whether the preference in matching tasks is due to the participants' strategy or it reflects something about the semantic memory organization. In order to answer these questions, in addition to standard behavioral measures (speed and accuracy) we have also used eye-tracking methodology. Eye-tracking methodology utilizes a system of cameras with the source of infrared light which allows for recording fine-grained spatial and temporal information about the participants eye-movements, by capturing the reflection of infrared light from the eyes. Measuring eye-movement patterns has proven to be a useful technique for understanding conceptual representations, since it allows measuring participants visual attention without disrupting the natural processing (e.g. Huettig and Altmann, 2005; Huettig, Quinlan, McDonald, and Altmann, 2006; Yee, Overton, and Thopmson-Schill, 2009). In the case of our study, it will allow for tracking competition of activation of different relation types during the matching task, providing the information about the conceptual preferences in the time interval before participants make a decision.

In Chapter 4, we have investigated the time course of activation of thematic and taxonomic information. We have measured the speed of recognition of thematically and taxonomically primed words in masked priming experiments and in a verification task. In the last experiment presented in this thesis, the ERP methodology has been employed. Event-related potential (ERP) stands for the non-invasively recorded electric potentials (summed post-synaptic potential of pyramidal cells in the neocortex) that are generated by the brain in response to specific events, and are collected through electrodes placed on the scalp. ERP is a high-temporal resolution technique reflecting on-going brain activation with no delay, and thus is most useful in answering questions about the timing of information processing. Its millisecond-level precision makes it useful for investigating processes that are too fast to be captured by reactions times and hemodynamic-based neuroimaging methods (e.g. PET, fMRI). On the other hand, ERP has relatively low spatial resolution, since the observed scalp distribution is not sufficient to localize neuroanatomical origins of the ERP effects. In our experiment, we will use ERP data to study the temporal dynamics and salience of mental representations of thematic and taxonomic information.

Finally, in Chapter 5, implications of the results of the studies described in Chapters 2-4 are discussed.

Chapter 2

Norming thematic and taxonomic knowledge

Study 1: Associative relatedness

Study 2: Thematic production

Study 3: Taxonomic production

Study 4: Thematic relatedness

Study 5: Taxonomic relatedness

Study 6: Similarity

Study 7: Difference

Study 8: Typicality

Study 9: Familiarity

Study 10: Co-occurrence

In this chapter we will present studies norming different types of information associated with concept meaning that may influence the ease of processing and thus speak of the nature of concept representation. The norming data are clearly important for methodological reasons, but in case of this topic and research they are even more important and interesting from a theoretical perspective. From a methodological point of view, they will help us avoid or control for the effects of the extraneous factors (e.g. typicality) and validate stimuli selection (e.g. strength of relatedness). Theoretically, they will offer valuable insights on the distinction between thematic and taxonomic categories on a set of pair measures reflecting different aspects of semantic relationship, thus addressing the problem of the perplexing variety of ways in which semantic relationship is being defined and measured.

Ten studies will be reported in this chapter. In Study 1, we have collected associative relatedness norms using free production task. Study 2 and Study 3 report on thematic and taxonomic relatedness obtained in the production task, followed by measures of thematic and taxonomic relatedness gathered using rating procedure in Study 4 and Study 5. In Study 6 and Study 7, we have analyzed similarity and difference of the stimuli pairs. In addition to the pair measures, Study 8 and Study 9 examined typicality and familiarity of individual target items. Complementing the set of norming studies, Study 10 will introduce a computational measure of stimuli similarity/relatedness, i.e. a measure of co-occurrence of word pairs in informal written language.

In order to untangle the individual contributions of different aspects of semantic relatedness to the shaping of thematic and taxonomic knowledge, as well as the overlapping of these two types of semantic relatedness, we have examined thematic and taxonomic concept pairs along the same dimensions which are considered to reflect or be closely related to either one or the other relationship type. For example, participants were asked to rate the thematic relatedness of *milk* and *cow* in Study 4, and the taxonomic relatedness of the same pair in Study 5. Although it has long been recognized that thematic and taxonomic relations are not mutually exclusive but rather that concept pairs are more often related on several grounds, previous studies have typically examined only thematic relatedness of thematic and taxonomic relatedness of taxonomic categories (e.g. Sachs, Weis, Krings, Huber, & Kircher, 2008; Sachs, Weis, Zellagui et al., 2008). In addition to the direct comparison of the strength of relatedness of the two relationship types, we will test for the differences between thematic and taxonomic on dimensions that are often believed to correlate more with one of the relationship types or are even used to define them. For example, by definition, taxonomic items should be more similar (*cow-donkey*), while thematic items should more frequently occur together (*cow-milk*). It is important to note here, that the direct comparison of different measures was made possible because all of the studies in this chapter were conducted on the same set of stimuli.

Thus, this chapter takes a new look at the nature of thematic and taxonomic relationships by testing the hypothesized differentiation based on their definitions and pointing at the often overlooked influence of the nature of relationship on participants' judgment of semantic dimensions.

General method

Participants

In all studies reported in this chapter, participants were either third-year high school students or second-year undergraduate psychology students. All high school participants were volunteers. Undergraduates received course credits for participating. All students were native speakers of Serbian.

Stimuli

The choice of stimuli was based on the previous studies examining differences in thematic and taxonomic processing (Chiu, 1972; Smiley and Brown, 1979; Osborne & Calhoun, 1998; Lin and Murphy, 2001; Unsworth, Sears, & Pexman, 2005; Kalénine & Bonthoux, 2006). Sixty-nine stimuli sets were constructed. Each quadruplet consisted of one target object and three more objects, each representing one type of relation to the target: thematic, taxonomic or unrelated. From the stimuli material of the previous studies, we have selected only concrete, imaginable, and highly familiar objects. All taxonomic option stimuli were related to the target stimuli on the superordinate level (*monkey* - *giraffe*). All thematically related options were chosen based on Estes et al. (2011) definition of thematic relatedness. The thematic pairs in our study excluded closely related schemas, simple linguistic association, and integrative pairs (*high* - *way*). All pairs were selected in a way that they dominantly reflect either thematic *(worm* - *apple*) or taxonomic relationship (*cow* - *donkey*), that is, pairs that are both thematically and taxonomically related (*cat* - *dog*) were avoided. The whole sample of the stimuli is presented in Appendix 1.

Visual stimuli

The visual stimuli were high-quality photographs of real objects chosen mainly from the Hemera image database (Hemera, 2000), The Hatfield Image Test (Adlington, Laws, & Gale, 2008) and some of them were chosen from commercial websites. To facilitate recognition, we chose images in which objects were presented from a canonical (preferred) viewpoint, which for the most of the chosen objects was the profile view. All the images were of the same size and all of them had white background. Images had a maximum size of 200 x 200 pixels and were scaled so that at least one of the two dimensions was 200 pixels. The full set of the selected images is presented in Appendix 3.

All of the selected images were aimed to represent highly typical exemplars of their object categories. Although most of the images were selected from the normed databases, typicality and familiarity ratings were collected, which is described in separate sections.

Study 1: Associative relatedness

As previously discussed in Chapter 1, the term associative relatedness is closely related to thematic relatedness and some authors even use them interchangeably. We have argued that despite the fact that there is a significant overlap, since many thematic concepts are also associatively related and vice versa, they are not synonyms.

Concepts are associatively related if one evokes thoughts of the other. More specifically, the construct is defined in terms of free association probabilities – the strength of association is expressed through the likelihood of producing a word when given a cue word in a free association task. As we have discussed in the previous chapter, it is important to note that the definition of associative relatedness is only operational and conceptually poorly defined since associations may reflect a variety of different relations, and thematic relationship is just one of them.

However, despite the semantic impurity of associative relations assessed in the free production task, this method has been widely used due to the fact it has proven to be a reliable technique for measuring connection strength between concepts and has several advantages in comparison to the rating procedures (e.g. it is independent of relationship type and strength of other stimuli of interest, it gives information about the direction of connection, interconnectivity of the associative neighborhood, etc.), but it also has its weaknesses. One of its biggest shortcomings is the lack of generalizability of association norms. Association strength may depend on the characteristics of the test set (e.g. proportion of nouns, Entwisle et al., 1964), word frequency (Deese, 1962), administration type (Palermo, 1971), and especially the characteristics of the population being tested (e.g. socio-economic status, Entwisle, 1966; Rosenzweig, 1970).

Some of the most interesting factors affecting performance in free association task are age-related factors. Therefore, free association task has been widely used in developmental studies (e.g. Smiley & Brown, 1979) as a measure of preference for different relation types. Differences between children and adult responses were interpreted from different perspectives. While some authors characterized changes, in terms of word class, as heterogeneous to homogeneous (Brown & Berko, 1960), others, taking into account how relationships were learned, saw them as being syntagmatic to paradigmatic (Ervin, 1961), while some authors use these data as evidence for semantic reorganization or additional evidence for the shift in semantic development from thematic to taxonomic concepts (Francis, 1972). Following this line of research, it is reasonable to expect that association norms may be affected by conceptual preference for thematic or taxonomic thinking that is not age related, but culture or language dependent. Although many researchers acknowledged that adult association norms differ across cultures, there are no systematic data explaining the differences.

One of the main problems in investigating effects of preferences on association strength is that there is no clear baseline, so we can only state the difference between the groups, but cannot claim which one of them is biased. To have a baseline would mean to objectively assess association strength, which clashes with the very definition of the concept. However, if we try to tease apart the factors affecting associative strength, we could make a distinction between linguistic and semantic generators (Santos, Chaigneau, Simmons, & Barsalou, 2011). "Pure association" was typically defined as association of words that are not semantically related (see Hutchison, 2003), and thus their relation is based on linguistic similarity and co-occurrence in language. Based on the classification offered by Santos, Chaigneau, Simmons, and Barsalou (2011), pure associations may belong to several categories: compound words (forward and backward continuation responses), words that sound similar (e.g. rhymes) or words that have the same root (e.g. noun produces an adjective: *oil-oily*). Thus, if pairs of words are not linguistically similar (there is no sound similarity) and they do not equally frequently occur together, then they should be equally "purely" associatively related. However, if words that don't sound similar and have the same co-occurrence frequency differ in associative strength, this difference may be attributed to the difference in the nature of the relationship between them.

We will address the question of the effects of the nature of the relationship on associative norms in section Study 10, by comparing association strength estimated in free production task (Study 1) and co-occurrence norms (Study 10) for thematically and taxonomically related word pairs.

Method

Participants

A total of 105 high school students participated in this study. The participants' average age was 17.4 years. 18 of them didn't finish the study.

Stimuli

The list of stimuli included all 69 targets and their thematic and taxonomic pairs from the stimuli sets presented in Appendix 1. The complete set of stimuli resulted in 207 cues to be used in this study.

Task

Participants were instructed to write down the first word that comes to their mind when they think of the target word. No examples were given. They were encouraged to respond as fast as possible.

Procedure

To minimize priming effects, words were presented in random order for each participant. Randomization made the verbal environment of each target for each subject different.

The survey was distributed using Qualtrics online survey software (Qualtrics, Provo, UT). Most of the data was collected under experimenter's supervision in a classroom setting. The rest of the participants answered at home. The dropout rate was 37 percent among students that responded at home and 0 for students in a classroom setting. The average time needed for completing the study was 33 min 40 sec. All responses were used in the analysis, with the corrections for the number of participants.

Results and Discussion

For each thematic and taxonomic pair forward association strength (FAS) and backward association strength (BAS) were calculated. In our study, FAS represents the proportion of participants who produced the thematic or taxonomic word from the pair in the presence of the target word. BAS represents the proportion of participants who produced the target word in the presence of thematic or taxonomic pair as a cue word[2]. For example, for *horse* (target) and *saddle* (thematic pair), FAS is .12 and BAS is .63, which means that 12 percent of participants produced saddle when horse was the cue, and that 63 percent of participants produced horse in response to saddle.

The FAS for thematic pairs ranged from .00 to .84 with a mean of .23 (SD = .23), while FAS for taxonomic pairs ranged only from .00 to .16 with a mean of .01 (SD = .03). The difference in FAS between two relation types was highly significant ($t(68) = 7.57$, $p < .001$). Thematic and taxonomic pairs also differed in BAS ($t(68) = 7.90$, $p < .001$). For thematic pairs BAS ranged from .00 to .77 with a mean of .26 (SD = .23). Taxonomic pairs' BAS ranged from .00 to .30 with a mean of .03 (SD = .06).

Table 2.1. FAS and BAS statistics of thematic and taxonomic pairs

		minimum	maximum	mean	s.e. mean	std. deviation
thematic	FAS	.00	.84	.23	.03	.23
	BAS	.00	.77	.26	.03	.23
taxonomic	FAS	.00	.16	.01	.00	.03
	BAS	.00	.30	.03	.01	.06

[2] It should be noted that the term *target* stimulus or *target* word in our research always refers to the first, base item from the quadruplet sets in Appendix 1. It should not be confused with the use of the term *target* in association norms and priming literature where target refers to words selected to be studied in experiments, and cues are words that are used to prompt recall of *target* words (Nelson et al, 1999).

While mean FAS and BAS for thematic pairs did not differ (t(68) = -.97, p > .05), differences were significant for taxonomic pairs (t(68) = -2.98, p < .01). Looking at the correlations between two measures, FAS and BAS were more strongly related for taxonomic (r = .63, n = 69, p < .001) than for thematic pairs, for which correlation was only marginally significant (r = .23, n = 69, p = .06). The pattern of correlation between the two measures is presented in Figures 2.1.a and 2.1.b.

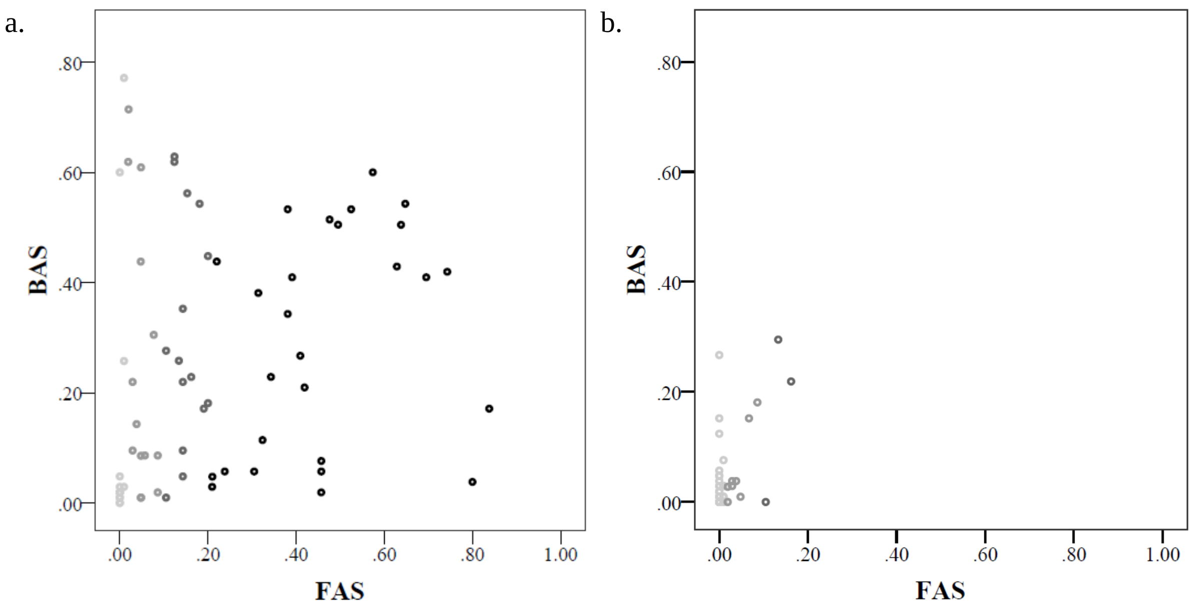

Figure 2.1. FAS and BAS for thematic (left) and taxonomic (right) pairs

Low correlation between forward and backward association strength is not surprising. Nelson and associates (1999) reported correlation of r = .29 for the set of 63,619 responses. Although the correlation for taxonomic pairs is much higher, it should not be taken as a reliable index, having in mind the structure of the data that can be seen in Figure 2.1.b.

Asymmetry in forward and backward association strength is interesting and relevant for dissociation between associative and thematic relations. While this asymmetry is not unexpected for associative relations it should not be found for thematic relations. Some authors believe that this is the key difference between associative and semantic relationships. While *ham* frequently elicits *eggs* as a response (.17), *eggs* as a cue do not often (.01) elicit *ham* (Nelson et al, 1999). On the other hand, for thematically related objects, regardless of which concept is activated first, the relationship should stay comparably strong. In the present study, FAS and BAS of thematic pairs did not differ. This suggests that the association of these pairs does not rely on some extraneous factor (e.g. being compound words) and it is not likely that it is purely linguistic, but that the relationship of this pairs reflects links based on some inherent characteristic of the two objects.

Table 2.2. Percentage of unrelated, weak, moderate, and strong associates among thematic and taxonomic stimuli pairs. Frequencies are given in the parentheses.

		unrelated	weak	moderate	strong
thematic	FAS	18.8 (13)	20.3 (14)	21.7 (15)	39.1 (27)
	BAS	10.1 (7)	30.4 (21)	7.2 (5)	52.2 (36)
taxonomic	FAS	84.1 (58)	11.6 (8)	4.3 (3)	0.0 (0)
	BAS	68.1 (47)	21.7 (15)	5.8 (4)	4.3 (3)

* We adopted here Nelson and colleagues' (1998) categorization of association strengths: strong (>.20), moderate (.10 - .20), weak (.01 - .10), and unassociated (< .01).

As can be seen in Table 2.2. (based on forward association strength), as much as 39% of thematic pairs can be classified as strongly related, while none of the taxonomic pairs satisfy the criteria. On the other hand, as much as 84.1 percent of taxonomic pairs are unrelated, compared to only 10.1 unrelated thematic pairs. This pattern of results in not surprising, having in mind that thematic relationship is often tied with associative relationship. Previous studies demonstrated that for common objects participants frequently produce answers that are either related in terms of function (e.g. *bed* - *sleep*) or thematically related objects (e.g. *bed* - *pillow*) (Palermo and Jenkins, 1964; Markman & Wisniewski, 1997).

We will further address the question of relationship between thematic and associative relations in Study 10.

Relatedness measures: Studies 2-5

In order to measure associative strength, we record what "comes to mind" in presence of the stimuli of interest. Associative strength should reflect accessibility from memory of one concept in presence of the other. As stated in Chapter 1, although this measure can explain a range of phenomena in cognitive psychology, it lacks a theoretical explanation, since there are different factors affecting the likelihood of producing a certain word when encountering other words. On the other hand, one of the main advantages of associative strength measure is that it is operationally well defined.

Trying to understand why some concepts are more easily accessible, or why some concepts have stronger links in memory, we will try to measure specific types of relations between concepts. In contrast to associative relations, thematic and taxonomic relations are theoretical constructs. Their definitions do not offer a straightforward way of measuring relatedness as is the case with associations. For example, the definition of taxonomic relatedness which states that taxonomic objects belong to the same category based on the shared features, clearly distinguishes taxonomic from other concepts, but it does not specify how existence and quantity of taxonomic relatedness can be tested.

The next four studies concern the assessment of strength of thematic and taxonomic relatedness through different measures. The first procedure is motivated by association strength measure, that is, it is based on the production of thematic and taxonomic sisters for target words. The second procedure will employ standard rating of relatedness between the pairs on a number scale. A mutual comparison between the aforementioned measures will be conducted.

Study 2: Thematic production

Participants

Thirty-nine undergraduate students took part in the study.

Stimuli

We have used 69 target stimuli from Appendix 1.

Procedure

Participants read instructions informing/explaining them that objects can be related in a number of different ways and that one common type of relatedness is thematic relatedness. The instruction was based on the definition of thematic categories in Estes et al. (2011): “Thematic relations are temporal, spatial, causal, or functional relations between objects. More specifically, objects are thematically related if they perform complementary roles in the same scenario or event.” Several examples of thematically related objects were given: *cloud* and *rain*, *wind* and *wave*, *picture* and *wall*.

Their task was to write down the first word, denoting thematically related object, they can think of when they read the target word.

All participants gave responses for the whole stimuli set. Target words were presented in a random order for each participant using Qualtrics online survey software (Qualtrics, Provo, UT). Participants gave their responses at home. All of them completed the study.

Results and Discussion

Response coding

All responses for one target word were merged into a single list. Only minor lexical variants of the same word (e.g. singular and plural, different dialects) were joint into a single response. The responses were coded as taxonomic, thematic or none (if response did not fit into one of the two valid response categories) following the criteria described in Schwartz et al. (2011). Responses were first evaluated for being taxonomic. If the response was from the superordinate category (*flower - plant*), the subordinate category (*flower - rose*) or the coordinate category (*flower - tree*), it was coded as taxonomic. If the response did not fall into one of the named taxonomic categories, it was evaluated for thematic relatedness. Any response reflecting relationship based on co-occurrence with the target in the context of an action, event, or sentence was coded as thematic. Although we realize there is no clear cut between thematic and taxonomic categories, and that some of the responses coded as taxonomic also reflect thematic relatedness, we decided to perform hierarchical coding in order to avoid the need for judging which of the relations is stronger when both are present. Being aware of this problem, additional screening of results was carried out.

Results

Nearly all responses fitted into the thematic or taxonomic category. Only 10 responses were coded "none", meaning that they did not fall into either of the categories (e.g. personal associations "*bicycle-Daniela*" or invalid words). Taxonomic responses that were considered errors, were given as the most frequent response for six target words. As can be seen from Table 2.3., four out of six most frequent taxonomic responses also share thematic relations. For the remaining 63 targets, the most frequent response was thematic, and mean proportion of taxonomic responses was .07 (SD = .07). The number of different responses ranged from 2 to 25, with a mean of 14.61 (SD = 5.00).

Looking at the cases of producing taxonomic responses when instructed to produce thematic sisters, we can distinguish several possible sources of these errors. Firstly, as can be seen in Table 2.3., some of the taxonomic answers could also be coded as thematic. For example, dog and cat are both thematically and taxonomically related. This was the case with most of the taxonomic responses in our study. The second reason could be that for some objects the taxonomic relationship is a more natural way of responding. Santos et al. (2011) show that for some words certain conceptual types are more frequent as associates than others. For example, for the word “car” in Nelson et al. (1999) a dominant word associate is a taxonomically related word “vehicle”, while the word “wings” typically provokes associate that represents object that stereotypically contains wings (“bird”). That would mean that different stimuli objects have different potential for being in thematic or taxonomic relation with other objects, and that potential affects performance in a task that can be in line with the stimuli nature or contradicting. On the other hand, taxonomic errors can be interpreted as a tendency of a participant to give a response of specific conceptual type. However, the number of taxonomic mistakes was not large enough to support this possibility. We will discuss this issue further comparing the results from Study 2 to those of Study 3.

Table 2.3. The most frequent taxonomic responses in the thematic production task

target	proportion of taxonomic responses	most frequent response	most frequent response code	most frequent response proportion
dog	.26	cat	taxonomic	26.5
brooch	.30	jewelry	taxonomic	22.4
moon	.38	stars	taxonomic	22.4
purse	.38	bag	taxonomic	18.4
mouse	.44	cat	taxonomic	38.8
coat	.58	suit	taxonomic	34.7

For each thematic pair, the strength of thematic relatedness was calculated as a proportion of participants who produced the thematic pair from the stimuli set (Appendix 1) in the presence of the target word. Mean thematic relatedness of 69 pairs was .29 (SD = .27) and ranged from .00 to .94. Based on these norms, half (52.2%) of the thematic pairs can be classified as strong (> .20), 11.6 as moderate (.10 - .20), 24.6 as weak (.01 - .10), and 11.6 as unassociated (< .01). The strength of thematic relation obtained in this study will be compared with the strength of taxonomic relation for the stimuli set from Appendix 1, and with measures of rated thematic relatedness in Study 4.

Study 3: Taxonomic production

Participants

Thirty-seven undergraduate students that did not take part in Study 2, participated in this study.

Stimuli

We have used the same set of 69 target stimuli that was used in Study 2.

Procedure

Procedure was the same as in Study 2. The only difference was in participants' task. They were instructed to produce taxonomic sisters for target stimuli, that is, to write down the name of the first taxonomically related object they can think of in response to each target word. We defined taxonomically related objects as objects belonging to the same category (Estes et al, 2011). The definition was followed by an example: "two objects are both animals", thus guiding participants to give taxonomic items of the same level of taxonomy. Although this kind of instruction may make task more difficult than an instruction that is less restrictive, it also prevents participants from making it too easy by simply producing a few labels of broad superordinate categories (e.g. categorizing all stimuli as animals, plants and artefacts). However, all types of taxonomic answers (superordinate, basic level, and subordinate) were accepted as satisfying the criteria.

Results and Discussion

Data preparation followed the principles described in Study 2.

Only 23 responses fitted into neither taxonomic nor thematic category. On the other hand, thematic responses were surprisingly frequent, although the task was to produce taxonomic answers. Four targets with the highest percentage of thematic answers are given in Table 2.4. Even when these four extremes were excluded, the mean of thematic answers for the remaining 65 targets was very high, reaching the proportion of .42 (SD = .14). The proportion of thematic responses ranged from .16 to .89. The number of different responses ranged from 5 to 26, with a mean of 14.36 (SD = 4.23).

Table 2.4. The most frequent thematic responses in the taxonomic production task

target	proportion of thematic responses	most frequent response	most frequent response code	most frequent response proportion
pearl	.76	shell	thematic	54.1
well	.78	water	thematic	37.8
chalk	.84	blackboard	thematic	56.8
key	.89	lock	thematic	59.5

We have calculated the strength of taxonomic relatedness for all 69 taxonomic pairs from Appendix 1. The strength of relatedness shows the proportion of participants who have produced a taxonomic pair from Appendix 1 in response to the target word. The strength of taxonomic relatedness ranged from .00 to .70 with a mean of .10 (SD = .16). Classified into categories of strength of relatedness (Nelson et al, 1999), 42.0 targets were normed as unrelated, 27.5 as reflecting weak, 11.6 moderate and 18.8 reflecting strong taxonomic relationship.

Comparing thematic and taxonomic norms

Based on the production norms, thematic sisters were significantly more strongly related to targets than their taxonomic sisters ($t(68) = -4.58$, $p < .001$). We will reevaluate the strength of the relationship between the pairs in rating studies (Study 4 and Study 5).

The difference in the number of cross category errors between the thematic and the taxonomic task was large and statistically significant ($t(68) = -11.88$ $p < .001$). While there was less than 10% of taxonomic response errors in the thematic production task, participants were more prone to giving a thematic answer when taxonomic one was required. As much as 44% of responses in the taxonomic production task were thematic responses. This kind of errors - having trouble giving a taxonomic answer - is expected when participants are young children (see Lin, 1996, for review), but our participants were undergraduate students. There is no doubt that students are capable of taxonomic thinking. Furthermore, the common view is that taxonomic thinking is the preferred way of reasoning for educated young adults. That is why this result is even more striking. If the lack of attention was the main cause, the number of errors in the thematic task would also be large. However, that is not the case.

In Study 2, we named three possible reasons for cross-category errors: coding (although responses may be thematic and taxonomic at the same time, they could only get one label), stimuli potential for a certain type of relationship, and participant's conceptual preference. While in Study 2 most of the errors could be attributed to the first source – coding, that was not the case in Study 3. In order to test for the second possibility - stimuli potential for being in thematic or taxonomic relation with other objects – we analyzed correlations between thematic and taxonomic mistakes. If for some concepts one type of relationship is more adequate, it should be reflected in higher proportion of mistakes in the task requesting different kind of processing and smaller number of errors in the task that requires a more preferable relationship type.

The correlation between the proportion of thematic answers in the taxonomic task and taxonomic answers in the thematic task is moderate ($r = -.50$, $n = 69$, $p < .001$). Items with higher proportion of taxonomic errors elicited smaller number of thematic errors. That means that the number of cross-category errors can partially be explained by the characteristics of the stimuli. As we have stated before, it is possible that for some items relations by similarity are more appropriate than others, and vice versa. For example, since the defining characteristic of a key is its function, objects complementing its function may be more easily accessed than objects which are similar and thus taxonomically related.

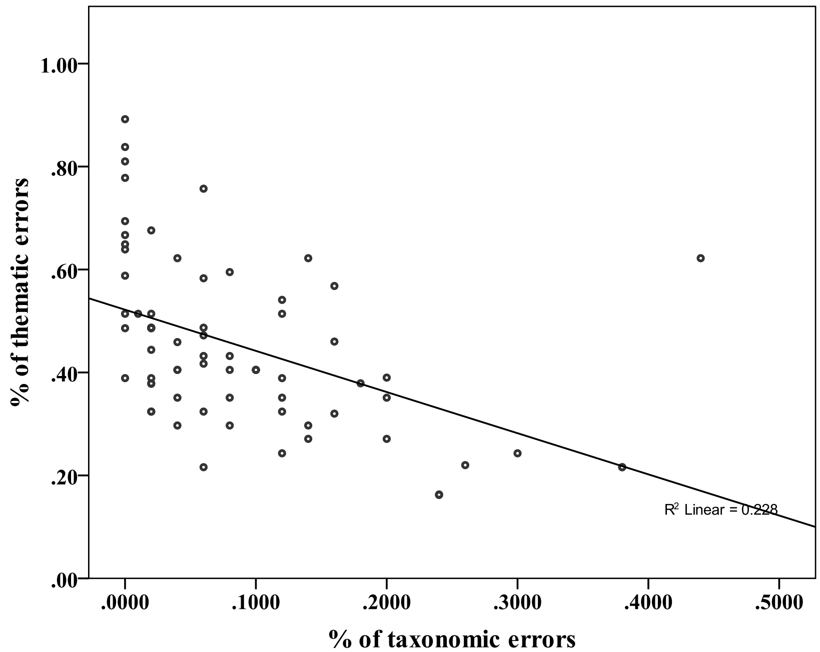

Figure 2.2. Correlation of thematic and taxonomic cross-category errors in the production tasks

However, the proportion of thematic responses in the taxonomic task is still unexpectedly high for adult educated population. Even if stimuli characteristics affect processing, it is surprising that in our study participants were distracted to that extent that they could not focus on the task. We believe that the third named reason, conceptual preference, influenced task performance as well. If the dominant way of grouping objects is based on integration, this preference may interfere with the task that requires comparison processing (for review, Estes et al, 2011). The implications of this can be twofold. Firstly, that our participants show thematic preference usually reported for Eastern cultures in triad task studies (Nisbett & Masuda, 2003; Varnum et al, 2008), or that thematic relations are automatically activated and influence cognition even when they are not relevant for the task. We will discuss this issue further later.

Study 4: Thematic relatedness

Participants

Sixteen high school students volunteered in this study.

Stimuli

A total of 138 word pairs were presented. There were two critical types of pairings from the quadruplets in Appendix 1: target - thematic option (69) and target - taxonomic option (69). Both pair types were presented for thematic relatedness rating.

Procedure

Participants were asked to judge the extent to which the items in each pair were thematically related, using a 7-point scale that was anchored with ‘‘thematically unrelated’’ under 1 and ‘‘highly thematically related’’ under 7. The instruction was based on the definition of thematic categories in Estes et al. (2011): “Thematic relation is temporal, spatial, causal, or functional relation between things. More specifically, objects are thematically related if they perform complementary roles in the same scenario or event.” In addition, several examples of thematic relations were described.

The instruction was given before participants started the task and it was printed on a card that was in front of the participants during the task.

The stimuli pairs were presented in random order. We have used SuperLab 4 for the presentation of the stimuli and data collection.

Results

Thematic pairs were rated as strongly thematically related with an average of 6.19 (SD = .59). The mean judgments ranged from 3.4 to 7, with 96 % of pairs rated over 5. The only three pairs rated less than 5 were: *frying pan* - *onion*, *ball* - *beach* and *brooch* - *lapel*.

Interestingly, taxonomic pairs were also judged as strongly thematically related. Mean rates ranged from 2.44 to 6.41, with a mean of 4.29 ($SD = .88$).

The strength of thematic relatedness was significantly larger for thematic in comparison to taxonomic pairs ($t(68) = 13.72$, $p < .001$) but there was no difference in the time participants needed to evaluate pairs ($p < .05$).

Thematic pairs' relationship strength was in moderate ($r = .46$, $N = 69$, $p < .001$) but significant correlation with relationship strength measure obtained in production task (Study 2).

Study 5: Taxonomic relatedness

Participants

Nineteen high school students took part in this study.

Stimuli

We have used the same stimuli set described in Study 4.

Procedure

We followed the procedure from Study 4. The main difference was that participants rated the taxonomic relatedness of the presented pairs of words. Taxonomic relatedness was defined as relatedness between objects that belong to the same category, and complemented by examples (e.g. "beaver and chinchilla are animals", "apple and pear are fruit").

Results

The average ratings for taxonomic pairs on the taxonomic dimension ranged from 4.2 to 6.3 with a mean value of 5.6 ($SD = .55$). The taxonomic relationship of thematic pairs was judged as significantly lower ($t(68) = -11.43$, $p < .001$). However, the mean rating for thematic pairs was quite high ($M = 4.42$, $SD = .70$), with a range from 2 to 5.79. There was no difference in the speed of judging taxonomic relatedness of thematic and taxonomic pairs ($p < .05$).

Ratings were moderately correlated with the taxonomic strength measure from Study 3 ($r = .38$, $N = 69$, $p < .001$).

Comparing measures of thematic and taxonomic relatedness: Results and Discussion

Targets were judged to be in strong relationship with their thematic and taxonomic sisters. Not only that average ratings for the two categories were above 5, but 98% of all stimuli pairs were judged above 4.5. Still, thematic relationship (target - thematic pair, M = 6.19, SD = 0.59) was judged to be stronger ($t(68) = 5.79$, $p < .001$) than taxonomic relationship (target - taxonomic pair, M = 5.6, SD = .55). Both thematic and taxonomic relationship judgments were in moderate correlation with production norms from Study 2 and Study 3.

Although thematic and taxonomic pairs differed significantly on both the thematic and the taxonomic dimension, it is interesting that they were rated high on both dimensions. Average ratings for taxonomic pairs on the thematic dimension were above 4 (4.29). The same is true for ratings of thematic pairs on the taxonomic dimension (4.42). This shows that relatedness between the pairs is not easily limited to one type of relationship. We will compare these results with the results of two other recent studies[3] (Schwartz et al, 2011; Mirman & Graziano, 2012).

We can notice several similarities between results presented in Table 2.5. The rates are fairly high and comparable across all three studies. Unexpectedly, differences between the conceptual types on two dimensions are small and in some cases even not significant. In all three studies, the results revealed asymmetry in thematic - taxonomic distinction.

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[3] In both studies we report below, stimuli triads were selected according to the same principles we have used in our study. All stimuli were highly familiar, concrete, imaginable objects, either sharing the same semantic category (taxonomic option) or not belonging to the same category but frequently participating in the same event or scenario (thematic option).

Table 2.5. Summary of the results of norming thematic and taxonomic pairs for thematic and taxonomic relatedness

dimension	pair	Schwartz et al. (2011)	Mirman & Graziano (2012)	Ilić (2014)[4]
thematic	thematic	4.1	4.4	4.4 (6.2)
	taxonomic	3.5	4.3	3.1 (4.3)
taxonomic	thematic	3.2	3.4	3.1 (4.4)
	taxonomic	3.5	4.1	4.0 (5.6)

In Mirman and Graziano (2012) norming study, average ratings on the thematic dimension were just slightly higher for thematic (4.4) than for taxonomic (4.3) pairs, while on the taxonomic dimension, participants judged taxonomic pairs significantly higher (4.1) than thematic (3.4) pairs. In the norming study done by Schwartz et al. (2011) participants judged thematic pairs (4.1) as more thematically related than taxonomic pairs (3.5) ($p < .001$), and taxonomic (3.5) pairs as more taxonomically related than thematic pairs (3.2) ($p < .001$). In contrast to Mirman and Graziano (2012) and similarly to Schwartz et al. (2011), in our study, the difference between relation types was larger ($t(68) = -3.44$, $p < .001$) on the thematic ($M = 1.90$, $SD = 1.15$) than on the taxonomic dimension ($M = 1.19$, $SD = .87$).

Thematic pairs were judged higher on the thematic, and received lower relatedness ratings on the taxonomic dimension in all three studies ($t(68) = -20.83$, $p < .001$, in our study). Interestingly, taxonomic pairs were judged equally high on both dimensions in Schwartz et al. (2011) study, and even slightly higher (4.3 on thematic and 4.1 on taxonomic) on the thematic dimension in Mirman and Graziano's (2012) study. In our study, taxonomic pairs were rated significantly higher on the taxonomic dimension ($t(68) = 14.72$, $p < .001$). However, the differences between rates on the two dimensions were larger for thematic ($M = 1.77$, $SD = .70$) than for taxonomic ($M = 1.32$, $SD = .75$) pairs ($t(68) = 3.95$, $p < .001$).

[4] Note that Mirman and Graziano (2012) and Schwartz et al. (2011) used 5-point scale, while in our study 7-point scale was used. For the purpose of comparison with the other two studies, we rescaled ratings from our study to range from 1 to 5.

Part of the explanation for the observed pattern of results can be found in the interplay of processes of comparison and integration in cognitive tasks. Wisniewski & Bassok (1999) report several experiments that provide evidence that people tend to compare taxonomically related items and integrate thematically related items. Furthermore, their study shows that stimulus compatibility with process can override task requirements, but that task instructions have modest effects on overriding stimulus compatibility. These conclusions are illustrated by examples of participants' justification of responses in similarity and integration tasks. For example, judging overall similarity between *man* and *tie*, participant elaborated that *man* is similar to *tie* because a man might wear a tie, while when judging thematic relatedness, the explanation read that *milk* is thematically related to *lemonade* because both are beverages. However, while comparison mediated thematic relatedness ratings only for taxonomically related objects that are not thematically related, integration intruded on comparison (taxonomic) task on all levels of taxonomic relatedness with the larger effect for taxonomically unrelated stimuli. This explains high rates for both thematic and taxonomic pairs on both dimensions. If there is no thematic relationship between objects, participants will rely on taxonomic relatedness in judging their thematic relationship. The same applies for judging taxonomic relatedness of thematic pairs. Although some authors would rather categorize thematic influence in a taxonomic task (or taxonomic influence in a thematic task) as judgment error, same patterns of data collected on different participants speak in favor of the former counterintuitive explanation.

The other part of the explanation on asymmetry in thematic - taxonomic distinction, comes from the data on individual differences in activation of taxonomic relations compared to thematic relations and accompanying tendency to favor one type of relation over the other in a judgment task (Mirman and Graziano, 2012). If participants had conceptual preference for taxonomic categories, it would be manifested in magnified thematic similarity for taxonomic items, which could result in small differences between conceptual types on the thematic dimension. Thematic preference would mirror this pattern, showing smaller differences on the taxonomic dimension in comparison to the differences on the thematic dimension, as a result of higher taxonomic relatedness rates for thematic pairs. The case of conceptual preference for taxonomic categories matches data from Mirman and Graziano's (2012) study, while the case of conceptual preference for thematic categories matches our data.

We will continue this discussion in the following sections and complement it with similarity and difference judgment data.

Studies 6 and 7: Similarity and Difference

> *"For surely there is nothing more basic to thought and language than our sense of similarity; our sorting of things into kinds."*
>
> (Quine, 1969; p. 116)

Judgment of similarity is crucial for cognition. Categorization of novel objects and inferences about the characteristics of those objects are based on the judgment of similarity between common and novel objects.

There are different models of similarity. The most intuitive one is Tversky's (1977; Tversky & Gati, 1978) *contrast model* which defines similarity judgment as a feature-matching process. Similarity between two objects increases as the number of the common features increases and/or the number of distinctive features decreases. In addition to feature-matching, *the structural alignment model* also takes into account the relationship between objects' features (Markman & Gentner, 1993). The main difference between these two models is that the first one sees the object's representation as a list of features, while the key assumption of the second model is that the representation is a structure, a structure that captures relations between the features in the list. What both models agree on is that the similarity judgment is basically a comparison process. Following the logic of these two models, a *cow* and a *donkey* are similar because: (a) they have more common than distinctive features and (b) because these common features are related in the same way in both objects. This is typical of the members of the same category. On the other hand, the similarity between *cow* and *milk* is low since they don't share features. In other words, similarity is expected to be high for taxonomically related, and to be low for thematically related objects.

In contrast to the predictions of the presented models, it has been reported that thematically related objects are judged to be more similar than thematically unrelated objects (Wisniewski and Bassok, 1999; Estes, 2003). This research demonstrates that not only similarity and relations between objects' features, but also the quality of relations between objects may affect perceived similarity. These data motivated formulating *the dual process model of similarity* (Wisniewski & Bassok, 1999; Estes, 2003; Simmons & Estes, 2008), which improves upon the comparison-only models by taking into account the influence of integration process on perceived similarity. Wisniewski and Bassok (1999) offered an explanation for the unexpected effect of thematic relations on similarity judgments. They suggest that different types of stimuli are compatible with different types of processing. Taxonomically related concepts are compatible with the process of comparison, while thematically related concepts are compatible with the process of integration. On the other hand, different tasks are compatible with different processing modes. While comparison should be dominant for similarity judgments, it is expected that thematic integration dominates relational judgments. Along these lines, *the dual process model of similarity* predicts that the relative dominance of the comparison and integration processes depends on the interaction of these two factors: (a) the nature of relationship between the objects and (b) the task requirements. High similarity ratings for thematically related objects, imply that stimulus compatibility with comparison or integration can even override the demands of the task, that is, stimulus compatible process can interfere with the process required or appropriate in a specific context. It is clear that the measure of similarity based on the objectively defined principles (e.g. Cree & McRae, 2003) and the similarity judged by participants do not rely on the same processes as it was assumed.

The *dual process model of similarity* (Wisniewski & Bassok, 1999) assumes that whenever one judges the similarity of two objects, this judgment is going to be affected by the strength of thematic relatedness between the objects of interest. In other words, the model accounts for differences between stimuli, but it does not account for individual differences between subjects. If participants differ in conceptual preference for thematic or taxonomic thinking, this preference should mediate thematic effect on similarity judgment. Simmons and Estes (2008) reported five studies supporting this hypothesis. Presented with the triads (base - thematic - taxonomic), some participants consistently judged thematic pairs as more similar to base, while some consistently judged taxonomic match as more similar. Similarly, some participants rated thematic pairs as more similar than taxonomic pairs, while others showed the opposite preference. For a small proportion of participants no preference was found. Taken altogether, the dynamics of the processes underlying similarity judgment appears to be surprisingly complex, mediated by individual differences in stimuli compatibility and participants' conceptual preference.

According to the comparison models, difference should mirror similarity, that is, they should be in perfect negative correlation. However, contrary to the comparison models and common sense, perceived similarity is not always inversely related to perceived difference. In the study of Medin and associates (1999), participants were presented with geometric objects' groupings, and asked to judge which of the two optional groupings is more similar to the base stimuli. For example, the base item was a black square above a white circle and the participants needed to judge whether it is more similar to a white square above a white circle (elements differ, relation maintained) or a black square next to a white circle (same elements, relation changed). Surprisingly, participants tended to chose the same items as both more similar and more different. In both cases, relation match was selected. Building on these results, several other studies have shown non-inversion in similarity and difference judgments (Estes & Hasson, 2004; Simmons & Estes, 2008; Golonka & Estes, 2009). Estes and associates (Estes & Hasson, 2004; Simmons & Estes, 2008; Golonka & Estes, 2009) demonstrated that non-inversion of similarity and difference can be caused by preexisting thematic relations between the items and that the strength of thematic effect varies across participants. This non-inversion is manifested in thematic matches judged to be both more similar and more different. In their view, the non-inversion is caused by thematic relations being more heavily weighed in similarity than in difference judgments and affecting judgment of similarity by increasing the contribution of commonalities.

Our study followed up the questions on the effects of relation type on similarity and difference judgments posed by Estes and associates (Simmons & Estes, 2008; Golonka & Estes, 2009), but differed in several important ways. Instead of using triads task, we asked participants to judge similarity and difference by rating thematic, taxonomic and unrelated pairs of items. Same participants judged similarity and difference of all stimuli in two sessions (three weeks apart)[5].

Method

Participants

The same 36 undergraduate psychology students participated in Study 6 and Study 7. Half of the participants first participated in Study 6 and afterwards in Study 7, while for the other half, the order of the studies they took part in was reversed.

Stimuli

There were 171 word pairs of thematically related (57), taxonomically related (57) and unrelated (57) stimuli from Appendix 1. Two versions of the stimuli list were formed. The lists differed in the order in which words in pairs were given. For example, in the version A participants would judge the similarity of *cow-milk* pair (target - thematic pair), while in the version B *milk-cow* (thematic pair - target) pair would be judged. Each list contained all stimuli pairs, and both A and B versions, but only version A or version B of one stimuli pair.

[5] Although some studies (e.g., Simmons and Estes, 2008; Wisniewski and Bassok, 1999) also used rating procedure, they tested only item similarity.

Task

In Study 6, participants were instructed to rate the degree of similarity between pairs of objects on a 7-point scale. If items were very similar, the pair should have got a high score (7). Items that were not similar should have got a low score (1). In Study 7, participants judged the difference of pairs of items on a 7-point scale, where higher numbers denoted higher dissimilarity. No definitions or examples were given.

Procedure

The surveys were distributed using Qualtrics online survey software (Qualtrics, Provo, UT), and participants gave their responses at home. Stimuli pairs were presented in random order for each participant.

Results and discussion: Similarity and Difference

Prior to analysis, ratings were transformed to standard (z) scores, in order to control for the possible differences between the similarity and difference scales. The z scores were calculated separately for similarity and difference judgments. In all graphs and tables, we will report the raw scores in order to facilitate interpretation.

Unrelated pairs

Since unrelated pairs were used as fillers, that is, to disguise the nature of the tasks, we will shortly present data collected on this type of items, but they will not be used in the main analysis. We will examine differences between judgments on thematic and taxonomic pairs more closely.

The average similarity and difference ratings for the three types of pairs are shown in Table 2.6. We analyzed the effects of relationship type (thematic, taxonomic, unrelated) on mean similarity and difference judgments. The relationship type had a significant effect on similarity judgments ($F(2, 166) = 209.75$, $p < .001$, $\eta = .728$). As one would expect, similarity ratings for unrelated pairs were lower than for taxonomically related items ($p < .001$), but unrelated pairs were also judged to be significantly less similar than thematically related items ($p < .001$). There was no difference between thematic and taxonomic items ($p > .05$). The relationship type also affected difference judgments ($F(1, 166) = 213.38$ $p < .001$). All three relationship types differed in perceived difference.

Table 2.6. The average similarity and difference ratings

relationship type	Mean	SD	S. E. Mean	Minimum	Maximum
similarity					
thematic	4.00	.53	.07	2.42	5.17
taxonomic	4.32	.99	.13	2.36	6.28
unrelated	1.53	.58	.09	1.06	4.11
difference					
thematic	4.06	.38	.05	3.44	5.28
taxonomic	3.66	.63	.08	2.56	5.03
unrelated	5.55	.37	.05	3.94	5.94

Similarity and difference judgments were strongly correlated $r = -.716$, $N = 57$, $p < .001$. One outlier was excluded.

Thematic vs. Taxonomic

We will test for the effects of relationship type on judgment ratings in analysis across items. Individual differences, that is, agreement in judgments, will be tested across participants.

In order to test for an effect of stimuli order (target - match, match - target) we conducted repeated measures ANOVA (2 (order) x 2 (judgment) x 2 (relationship type)) on standardized ratings. Neither the main effect of stimuli order nor the interactions with other two fixed effects were significant ($p > 0.1$).

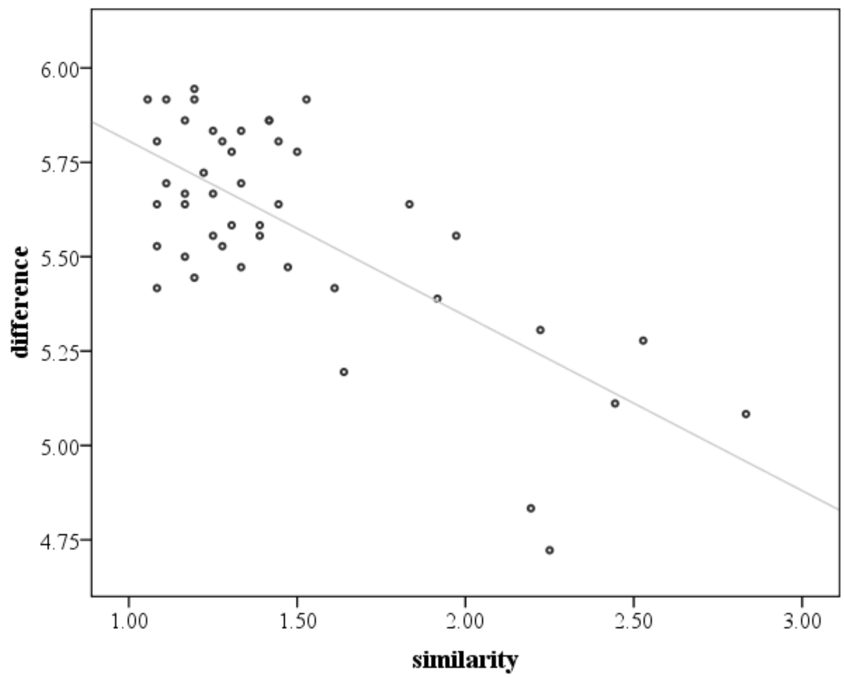

Figure 2.3. Similarity vs. difference for unrelated pairs

Effects of relationship type on judgment ratings

As can be seen in Table 2.6., similarity and difference ratings for thematic and taxonomic pairs are moderate and comparable not only in terms of average values, but also in range.

Correlation between similarity and difference ratings was strong for both thematic ($r = -.81$, $N = 56$ $p < .001$) and taxonomic pairs ($r = -.94$, $N = 57$ $p < .001$).

A repeated measures ANOVA with judgment (similarity, difference) and relationship type (thematic, taxonomic) as within-subjects factors revealed significant effect of judgment ($F(1, 56) = 111.15$, $p < .001$, $\eta = .67$) and significant judgment by relationship type interaction ($F(1, 56) = 8.84$, $p < .01$, $\eta = .14$). Paired samples t-tests revealed that there was no difference in similarity ratings between thematic and taxonomic pairs ($t(56) = -2.20$, $p > .05$[6]), but there was a significant difference in difference ratings ($t(56) = 3.98$, $p < .001$).

Although we have found the non-inversion of similarity and difference in our study, it was much more subtle than in the studies reported by Estes and colleagues (Estes & Hasson, 2004; Simmons & Estes, 2008; Golonka & Estes, 2009). The correlation between the similarity and difference ratings was also much higher in our study. It is possible that the size of thematic effect in previous studies was boosted by the task in which participants were forced to choose between thematic and taxonomic options. In our study, we avoided directly pitting thematic versus taxonomic option. Additionally, the type of the task allowed us to account for the possible differences between the similarity and difference scales (that is, similarity and difference question) by transforming raw rates to standard (z) scores.

Still, the influence of thematic relationship on similarity and difference judgments was evident. Although thematically related objects by definition share only few, if any, features, they were judged on average as equally similar as objects that belong to the same taxonomic category. For example, an *elephant* was judged to be more similar to *peanuts*, than to a *camel*. Our data could not be explained by comparison models of similarity and they give support to the *dual process model of similarity*, which suggests that thematic relations influence performance even in the tasks for which they are irrelevant or might be counterproductive.

Individual differences in perceived similarity and difference

For each participant, we calculated the differences in judged similarity and judged difference for thematic and taxonomic pairs, using standardized values (thematic pair similarity – taxonomic pair similarity, that is, taxonomic pair difference – thematic pair difference). Participants that scored above zero on difference measures were treated as showing preference for thematic pairs.

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[6] The p value was corrected for the number of tests run (.05/2 = .25).

As expected, participants were not uniform in their judgments of similarity and difference. While some participants (45%) tended to assign higher similarity and lower difference rates to taxonomic pairs (taxonomic group), as much as 33% of participants judged thematic pairs as more similar and less different (thematic group). Some participants (11%) judged thematic pairs as both more similar and more different (mixed group), while others judged taxonomic pairs as more similar and more different (11%) than thematic pairs (mixed group). Mean judgment differences for four groups are shown in Figure 2.4.

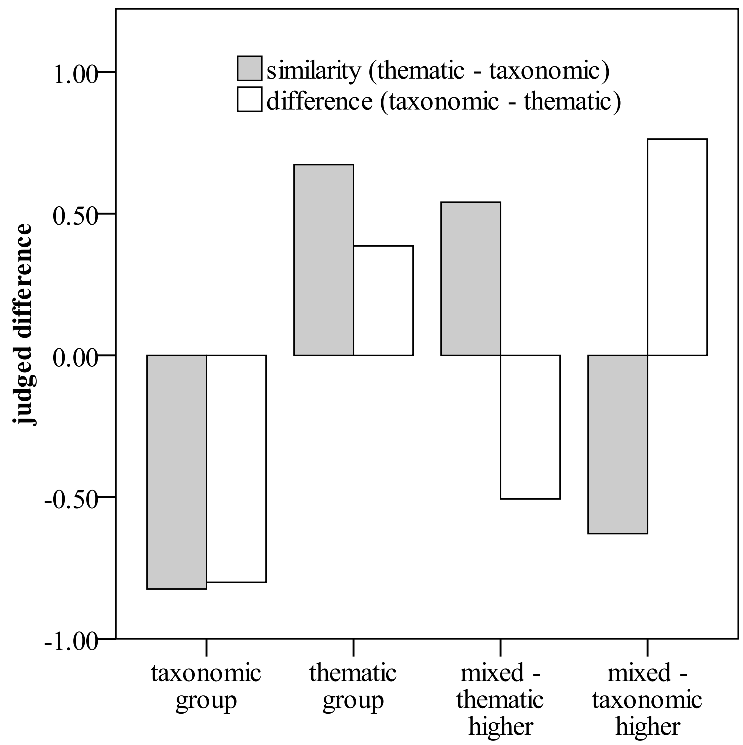

Figure 2.4. Mean difference in similarity and difference ratings as a function of response group

Our results support the hypothesis that thematic influence in similarity judgments is mediated by participant’s conceptual preference. It is interesting to note that the thematic and the taxonomic participant group judged thematic pairs differently (similarity: t(26) =

5.31, $p < .001$; difference: $t(26) = -8.68$, $p < .001$), but they did not show differences in taxonomic pairs' ratings ($p < .05$). That is, while thematic conceptual preference increases perceived similarity between thematic pairs, it does not affect the perceived similarity of taxonomic pairs.

Following the classification principles Simmons and Estes (2008)[7] used in their study, based on similarity ratings, only 5 (14%) of our participants would be classified as thematic respondents, half of them (18, 50%) would belong to the taxonomic category, and 13 (36%) gave mixed responses. Similar pattern was recorded for difference ratings: 3 (8%) thematic, 17 (47%) taxonomic, and 16 (44%) mixed.

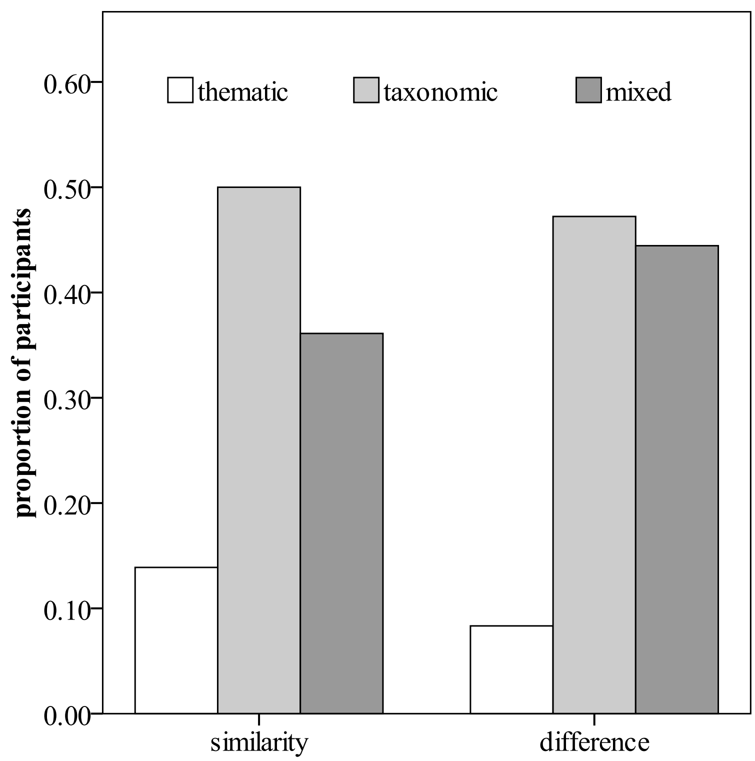

Figure 2.5. Distribution of participants showing thematic, mixed or taxonomic preference in the similarity and difference tasks

[7] Based on thematic proportion values, participants were classified into three groups: taxonomic (thematic proportion < .31), mixed (.31 > thematic proportion < .69), and thematic (thematic proportion >.69) (Simmons & Estes, 2008).

Compared to the results collected by Simmons and Estes (2008), the proportion of thematic respondents is much lower in our study. Again, it should be noted that differences may arise from dissimilarities in procedures and materials in the two studies, and not necessarily participants' preference. Nonetheless, taken together with previous analysis, we find more similarities than differences in patterns of results obtained in the two studies, despite the evident methodological dissimilarities.

Regarding the categorization shown in Figure 2.5., we believe that, having in mind that task instruction was explicit in requirements, and that the population tested is adult and educated, the criteria proposed by Simmons and Estes (2008) seem task biased. Simmons and Estes (2008) considered as thematic respondents only the participants who judged more than .69% of thematic pairs as more similar than taxonomic. However, it is clear that the participants in the mixed group were also strongly affected by thematic relations between the items. Participants in the mixed group judged more that 31% of thematic pairs as more similar (or less different). We believe that if an educated young adult was seduced by thematic relations in more than one third of the questions asking to simply judge items' similarity, it strongly speaks in favor of the hypothesis that thematic concepts and relations are apprehended involuntarily and that thematic thinking influences our performance even in the tasks which require different modes of processing.

Study 8: Typicality

Typicality differences influence performance in a wide variety of cognitive tasks, from identification (Murphy and Brownell, 1985) to production (Mervis, Catlin and Rosch, 1976), in learning (Rosch, Simpson, and Miller 1976) and in language, when making inferences (Rips, 1975) and so on. The effect of typicality is among the strongest and most reliable effects whenever the task requires relating an object to its category (Murphy, 2001).

We will focus here on the typicality effect literature of direct interest to the studies reported in the following chapters. In the study of Rips, Shoben, and Smith (1973), participants were faster to verify category membership of more typical items. In other words, it was easier for them to affirm that *robin* belongs to the category of birds, than a less typical example – a *chicken*. The same was found for identifying visual stimuli. Murphy and Brownell (1985) showed that images of more typical items were identified faster than less typical examples of the category.

Being familiar with the typicality effects, in the process of item selection, we have strived to include only those items which can be considered as highly typical examples/representatives of their categories. In order to test for typicality differences and prevent a potential impact of item's typicality on object recognition, a group of participants was recruited to rate the typicality of the visual stimuli used in experimental studies.

Method

Participants

Twenty-three high school students volunteered in the study.

Stimuli

Materials included 69 images selected for the experimental studies.

Procedure

Each image was presented individually, accompanied by the object's label written below the image, on the same screen. Participants were asked to judge how typical an example was as a member of the category indicated by the label.

The typical examples were described as those they would normally think of when thinking about their categories, while atypical items would be those that can still be classified as members of their categories but are unusual in some way.

Participants gave their answers on a scale ranging from 1 (*less typical items*) to 7 *(very typical items*), using a computer keyboard.

For the presentation of the stimuli and data collection we have used SuperLab 4.

Results

The mean typicality ratings were above 5 (on the scale 1-7) for 90 percent of rated items, with the overall typicality of 5.82 (SD = .63). The item typicality ranged from 3.87 (SD = 2.03) for *hat* to 6.74 (SD = .62) for *sheep*. The average time needed to judge item typicality was 2563.20 ms (SD = 595). The speed of judgment was moderately correlated with the ratings ($r = -.42$, $N = 69$, $p < .001$). Items judged to be more typical were evaluated more quickly.

Study 9: Familiarity

Method

Participants

Seventeen undergraduate students volunteered in the study.

Stimuli

We have used the same stimuli material that was tested for typicality in Study 8 - 69 images selected for the experimental studies.

Procedure

The procedure was identical in all details to the procedure of Study 8, with the exception of the task requirement. Participants were instructed to judge the familiarity of the objects in the images. Familiarity was defined as “the degree to which you come into contact with or think about the concept.” in accordance with the definition given by Snodgrass & Vanderwart (1980).

Results

The mean item familiarity ranged from 2.65 (SD = 1.94) for *king* to 6.88 for *bed* (SD = .49) and *door* (SD = 0.33). The overall mean for 69 items was 4.92 (SD = 1.23). For 48% of items, average familiarity rates were above 5. Participants needed 2381.90 milliseconds (SD = 497) on average to respond and the speed of judgment was moderately correlated with the rates ($r = -.39$, $N = 69$, $p < .001$).

Although average familiarity of images was fairly high, the variance of the familiarity estimates across images was unexpectedly large. Part of the explanation can be found in how this measure is typically operationalised. Although participants must be highly familiar with the concept of the king, they do not come into contact or think about kings very often, and thus king was judged low on the scale of familiarity.

Study 10: Co-occurrence

There are various measures of word co-occurrence. The broad distinction can be made based on the level of analysis, differentiating between local and global co-occurrence (Jones &Golonka, 2012). Local co-occurrence refers to the frequency of the exact word pair in a given corpus, while global co-occurrence computes the number of times two words occur in a document, sentence or window of *n* words[8], not necessarily next to each other, not even necessarily at the same time[9]. Although corpus based measures offer promising alternative for assessing word meaning and relations, showing that they are good

[8]Window-based co-occurrence measures may be classified in both local and global co-occurrences, depending on the model design.

[9]Some of the co-occurrence measures (e.g. LSA or BEAGLE) simply count the frequency of the terms surrounding target words, building a high *(e.g. 50-1500)* dimensional "semantic space" in which the representation of each word is determined by a vector of context words. The similarity between two words is given by the correlation (that is, cosine) of their vector representations. In such a model, for two words to be recognized as similar, it is not necessary for them to co-occur, but they need to show similar patterns of co-occurrence with other words.

predictors of semantic priming effects (Landauer and Dumais, 1997), typical vocabulary growth rate of school children (Landauer and Dumais, 1997), and eye-movement patterns (Huettig, Quinlan, McDonald, and Altmann, 2006), as well as that they correlate with participants' similarity judgments (Landauer and Dumais, 1994; Simmons and Estes, 2006), what remains unclear is the nature of the information they capture.

Word co-occurrence measures are typically used as measures of semantic (taxonomic) similarity, building on the assumption that similar words tend to occur in similar contexts (Landauer & Dumais, 1997; Huettig, Quinlan, McDonald, and Altmann, 2006). However, little is known about the sensitivity of co-occurrence measures, since it may vary depending on the level of analysis, that is, the narrowness of the context unit. Evidence from a study examining psychological validity of corpus-based semantic similarity measures (Huettig, Quinlan, McDonald, and Altmann, 2006) has shown that measures using smaller units of analysis (typically strings of 5 -12 words) may be more sensitive to semantic similarity than measures reflecting global co-occurrences (using whole documents as units).

Furthermore, it is possible that different co-occurrence measures catch different types of semantic dimensions. Frequent co-occurrence of thematically related items is expected since joint occurrence in real world should be reflected in co-occurrence in language. On the other hand, the main assumption of the corpus based co-occurrence measures predicts high co-occurrence of taxonomically related objects. Thus, both thematic and taxonomic concepts may frequently co-occur in language, and consequently, it may be impossible to untangle the two types of semantic information based on the global co-occurrence measures. However, based on the definitions of thematic and taxonomic relations, it would be reasonable to expect that objects that are parts of the same event, and related by temporal and spatial proximity (thematic pairs) have higher local co-occurrence than objects that are related by the membership in the same category (taxonomic pairs). Therefore, while global co-occurrence measures may be a good approximation of taxonomic similarity of concepts, local co-occurrence may more adequately reflect relations based on temporal and spatial proximity, since co-occurrences of objects in the real world may be reflected in language.

In a recent study, Jones and Golonka (2012) focused on how global (LSA) and local (Google hits) co-occurrences vary among integrative (phrasal associates), thematic, and taxonomic pairs that are not associatively related. Unsurprisingly, local co-occurrence was higher for integrative pairs in comparison to taxonomic pairs, but comparison with thematic pairs revealed no difference. Lower global co-occurrence of integrative pairs compared to thematic and taxonomic pairs could be interpreted as reflecting lower semantic similarity of these items. More relevant for our work is the finding that no difference between thematic and taxonomic relations was discovered on either of the two measures.

As we have discussed earlier, the type of relation that heavily depends on co-occurrences in language is associative relationship. Therefore, it is reasonable to expect high correlation between associative strength and word pair co-occurrences. This assumption was tested by Wettler and Rapp (1993), whose model successfully predicted the strength of the word associations based on free association norms from the word co-occurrence in large text corpora. An interesting finding from this study was that, although the model fairly correctly predicted paradigmatic associations, it was biased towards syntagmatic associations. Taken from the reverse perspective, even for the words which more frequently jointly occur with their syntagmatic pairs, participants' responses in free association task were paradigmatic, showing that associative strength is not completely based on simple co-occurrence, but it is also influenced by the nature of the relation between the two words.

In Study 1 of this chapter, we have reported on higher associative strength between thematically related in comparison to taxonomically related words. Since it has been well documented that answers in free production task may be influenced by participants' conceptual preferences, we have posed the question whether the stronger association between thematic associates reflects thematic preference of our participants. We have also proposed a way of testing this hypothesis, which will be carried out in this study – we will test how the type of relationship two words share may affect the relation between language co-occurrences and association strength.

Merely co-occurring in the same sentence or text, or occurring in similar contexts, is not likely to produce association between two words. Since in associative learning proximity plays an important role, the relevant co-occurrence measures are measures of local co-occurrence. In order to assess local co-occurrence, Jones and Golonka (2012) have used Google hits. Google hits estimate the frequency of joint occurrence of a pair of words in informal written language. In contrast to other measures of co-occurrence, Google hits take into account the word order (when the pair is entered in quotes), making it suitable for comparison with forward and backward association strengths separately.

One of the advantages of using Google hits is that the measure satisfies some of the important criteria in obtaining reliable estimates of the word co-occurrences. Firstly, it is based on large text corpora. Secondly, the body of text reflects different texts types (examples), that is, it is not restricted to a certain domain. Consequently, it may be a better approximation of the use of language in everyday life in comparison to corpora based on literary texts or journal articles. Finally, the materials are machine readable and freely available. The biggest disadvantage of Google hits is the variation of the estimates. In order to encompass this problem, researchers have typically transformed raw scores by logarithm function (Jones and Golonka, 2012). The second issue with Google hits is that this measure gives an estimate of the frequency of the two words being immediate collocates. In natural language, words that co-occur do not necessarily occur in each other's immediate lexical environment, that is, with no lexical items in between the two words. This is one of the important limitations of Google hits as a measure of local co-occurrence that needs to be taken into account when comparing it with the estimates of the related measures.

The specific problem of using corpus based measures in Serbian language is that Serbian language belongs to the group of languages with rich inflectional morphology. That means that the estimate of co-occurrence of one pair of nouns would need to take into account up to fifteen variations of this pair. Although Google engine recognizes different forms of the same lexeme, it is only the case when the word is not put in quotes. However, without using quotes, the engine will not estimate local co-occurrence (the level of analysis would vary) and word order wouldn't be taken into account. Unfortunately, this problem cannot be easily resolved. In an ideal case, lemmatized corpus of the given language could be used, but the corpus of contemporary Serbian language is still not available in a lemmatized form.

Thus, we have decided to follow the methodology of the previous studies (Jones and Golonka, 2012), that is, to use Google hits of exact word pairs as an estimate of local co-occurrence.

Method

Stimuli

We have used 69 thematic and 69 taxonomic pairs used in the previous sections of this chapter.

Although target words were the same in both thematic and taxonomic condition, the co-occurrence estimates could have been influenced by the frequency of the pair words. However, the two lists of words - the thematic and taxonomic alternatives - did not differ on word frequency (based on Vasic & Vasic, 2004).

Measurements

Google hits represent the number of hits obtained in a search on google.com, retrieved on October 27, 2014. Stimuli pairs were entered in quotes in forward (‘‘target pair_item”) and backward (‘‘pair_item target”) version.

FAS and BAS measures were taken from Study 1, and similarity and difference measures from Study 6 and Study 7, from this chapter.

Results and Discussion

Prior to analyses, data were scanned for extreme values. After excluding the data exceeding 2 standard deviations (6%), the distribution of logGoogle (raw Google hits scores transformed by logarithm function) did not significantly deviate from a normal distribution ($p > .01$).

We have first compared logGoogle hits among the thematic and taxonomic relations, taking into account the word order. One-way analysis of variance (Relationship Type (thematic, taxonomic) x Relationship Direction (forward, backward)) revealed significant differences between word pair frequencies of thematic and taxonomic pairs ($F(1, 255) = 5.60$, $p < .02$, $\eta = .02$). Taxonomic pairs ($M = 7.11$, $SD = 2.12$) were found to co-occur more often that thematic pairs ($M = 6.50$ $SD = 2.07$). Relationship Direction and interaction between the factors did not affect pair frequencies.

Table 2.7. Thematically related items: Google hits and association strength

	forward				backward			
	M	SD	min	Max	M	SD	min	Max
hits (in thousands)	3.04	5.01	0.015	23	3.24	11.12	0.003	89
Loghits	6.49	2.18	1.61	10.04	6.05	2.39	1.10	11.40
association strength	.23	.23	.00	.84	.26	.23	.00	.77

Table 2.8. Taxonomically related items: Google hits and association strength

	forward				backward			
	M	SD	min	max	M	SD	min	Max
hits(in thousands)	5.46	11.44	0.001	61.90	7.37	14.94	0.004	63.2
loghits	6.88	2.35	.00	11.03	11.03	6.81	2.51	1.39
association strength	.01	.03	.00	.16	.03	.06	.00	.30

In the next step, we examined whether the pattern of differences between thematic and taxonomic relations depended on the strength of association between the pairs. The strength of association measure from Study 1 was treated as 4-level categorical variable. Analysis of variances with factors Relationship Type (thematic, taxonomic) and Association strength (unrelated, weak, moderate, strong), and logGoogle hits as dependent variable indicated differences among the relationship types ($F(1, 251) = 8.83$, $p < .01$, $\eta = .03$) and between levels of association strength ($F(3, 251) = 5.57$, $p < .01$, $\eta = .06$). Additionally, the two factors interacted significantly ($F(3, 251) = 6.71$, $p < .01$, $\eta = .07$). The pattern of results can be seen in Figure 2.6.

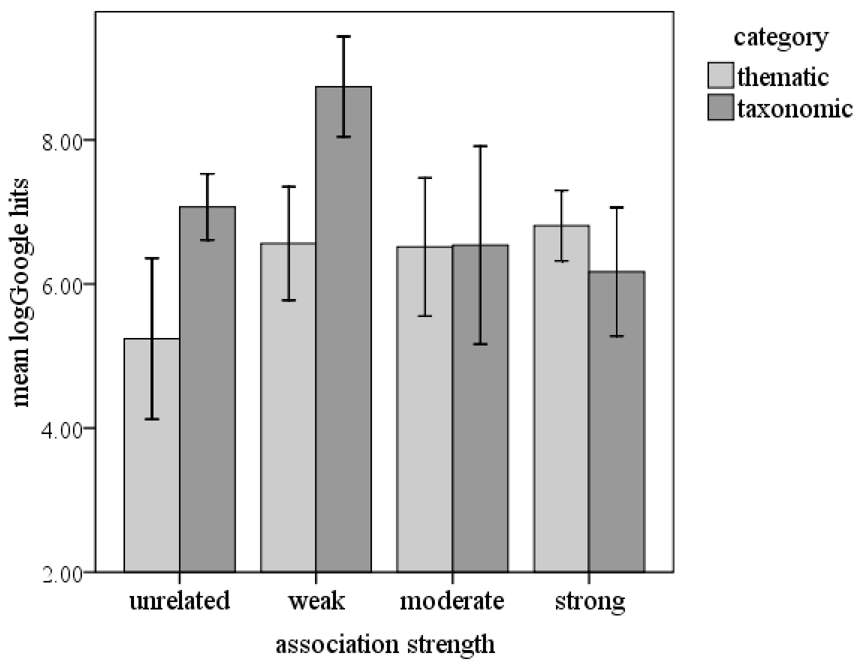

Figure 2.6. Co-occurrences of thematic and taxonomic pairs across levels of association strength.

Additional analyses have shown that thematic and taxonomic pairs differed only in the group of unrelated and weakly associatively related items ($p < .01$), while there was no difference for moderate and strongly related items ($p < .05$). Among unrelated and weakly related items, taxonomic items were more frequently found together than thematic ones.

In order to test simple correlation between the associative strength and Google hits, it was necessary to rank both variables (as the distribution of association strength significantly differed from the normal distribution). Although the correlation was significant ($\rho(275) = .20$, $p < .001$) it was weak and heavily influenced by extreme values.

Since co-occurrence has been assumed to reflect semantic similarity of objects, we have correlated estimates of similarity and difference obtained in judgment task in Study 6 and Study 7 with co-occurrence norms collected in Study 10. For thematic pairs, co-occurrences correlated with both similarity ($r = .33$, $n = 108$, $p < .001$) and difference ($r = -.29$, $n = 108$, $p < .01$) estimates. Although the correlation found was modest, it was highly significant. On the other hand, co-occurrence of taxonomic pairs, only weakly correlated with similarity ratings ($r = .24$, $n = 105$, $p < .05$), while it did not correlate with participants' estimate of difference ($p > .05$).

The obtained pattern of results was contrary to our predictions. Since thematic relations are based on item co-occurrence, we have expected higher overall frequency of global co-occurrence for thematic pairs. However, the results have shown the opposite pattern. This result is also in contradiction with the results of the previously reported study that has shown no difference between thematic and taxonomic pairs in Google hits in English language (Jones and Golonka, 2012). In the analysis that took association strength into account, result clarified that co-occurrence rates are higher for taxonomic items only in the case of unrelated and weakly related items.

Higher co-occurrence of taxonomic pairs may be explained by the nature of Google hits measure. Since the Google hits capture immediate collocates, it is possible that co-occurrences of taxonomic items were extracted from listings which typically gather members of the same category. On the other hand, the local co-occurrence of thematic pairs may be low since, although they may frequently occur in the same sentence, they are in natural context often linked (in this case separated) by other words. Thus, it would be interesting to compare these estimates with the estimates of local co-occurrence that would use window-based approach which would catch broader context than the context given by the immediately preceding or succeeding word.

Analyzing correlations of co-occurrences and similarity (and difference), we have found modest but significant correlations for thematic pairs, while correlations for taxonomic pairs were less convincing. This difference may be explained by the difference in the basis for estimating similarity of thematic and taxonomic pairs. While the similarity of taxonomic pairs is mostly based on the similarity of their features, for thematic pairs, which typically lack feature similarity, participants are believed to rely on the items contiguity. Thus, it is possible that variation in co-occurrence may be more relevant for predicting variation is similarity judgments of thematic items than for predicting taxonomic items' similarity judgments.

Summary

At the end of this chapter, we would like to list the most important findings obtained in the set of norming studies presented. Table 2.9. gives an overview of the differences found between thematic and taxonomic pairs in this chapter. In summary, we found strong influence of thematic relatedness in production tasks (Studies 1 - 3) and profound effect of thematic relations in tasks that required taxonomic processing, namely taxonomic relatedness study (Study 5) and studies examining similarity (Study 6) and difference (Study 7) judgments. On the other hand, we have also detected the influence of taxonomic relatedness in thematic relatedness task (Study 4) and higher local co-occurrence estimates for taxonomic pairs.

Table 2.9. Comparison table of thematic and taxonomic advantage across studies

			taxonomic > thematic	**thematic** > taxonomic
Study 1	FAS	proportion of answers	×	*
	BAS		×	*
Studies 2 & 3	thematic and taxonomic production	no. of cross-category errors	7%	44%
Study 4	thematic relatedness	mean rates	×	*
Study 5	taxonomic relatedness		*	×
Study 6	similarity	mean rates	no difference	
Study 7	difference		×	*
Study 10	co-occurrence	logGoogle hits	*	×

* An x stands for disadvantage, while an * stands for advantage.

Chapter 3

Thematic thinking in adulthood

Experiment 1: Eye tracking study 1: In pictures

Experiment 2: Eye tracking study 2: In words

Experiment 3: Forced choice matching

When Chiu published his results in 1972, showing that Chinese students differ from their colleagues from the United States in the way they organize knowledge, he wrote that his intention was "furthering our understanding of the forces shaping cognitive development". However, individual and cultural variables (which he particularly had in mind), were not in the centre of attention of cognitive psychologist at that time, and his results remained out of focus until recently. Nevertheless, the study had huge influence on future studies examining cultural influences on categorization.

Chiu (1972) adapted Sigel's Cognitive Style Test (Sigel 1967), the instrument most frequently referred to today as the triads task. Chinese and American children, 9 and 10 years old, were shown a series of cards, each depicting three objects. Their task was to answer which two objects were alike or went together and to state the reason for their choice.

Figure 3.1. Illustration of the triad from Chiu's (1972) test.[10]

American children typically grouped *chicken* and *cow*, explaining that they go together because they are both animals. On the other hand, Chinese children typically reasoned that because cows eat grass, *cow* and *grass* should be put together. Chinese youngsters consistently relied on relationships and objects' interdependence, while young Americans preferred to analyze components of the individual stimuli and detect similarities

[10] Reprinted by kind permission of Nisbett & Masuda (2003).

between them. Chiu (1972) proposed that differences found in categorization styles reflect differences between Eastern and Western social and cultural worlds - one collectivistic and the other one individualistic in its nature.

Over the past two decades, differences in categorization styles of East Asians and European Americans have been repeatedly demonstrated by Nisbett and colleagues (Ji, Zhang, and Nisbett, 2004; Nisbett and Miyamoto, 2005) and other authors (e.g. Unsworth, Sears, & Pexman, 2005). Additionally, the hypothesis of holistic, context-dependent cognitive style of the Eastern world and analytic, individual-centered cognitive style of the Western societies was supported by a variety of findings in perceptual tasks (similarity judgments: Norenzayan et al, 2002; change blindness: Masuda and Nisbett, 2006; context sensitivity: Masuda and Nisbett, 2001; rod and frame test: Ji, Peng, and Nisbett, 2000; framed-line test: Kitayama, Duffy, Kawamura, & Larsen, 2003, patterns of attention: Abel and Hsu, 1949, Chua, Boland, & Nisbett, 2005).

Once striking cultural differences in perception and cognition were demonstrated, broad claims about human behavior based on the understanding of WEIRD (Western, educated, industrialized, rich, and democratic) societies began to be questioned (Henrich, Heine, & Norenzayan, 2010). Due to the oversampling of WEIRD population, reliance on thematic relations was long considered to be a primitive approximation of *real* categorization, categorization based on taxonomic categories (for a review, see Estes, Golonka & Jones, 2011). The widely accepted assumption that thematic relations play little if any role in adults' categorization, originally came from developmental research that established thematic-to-taxonomic shift as a typical course of cognitive development (Inhelder and Piaget, 1964; Denney, 1974; Smiley and Brown, 1979; Nelson, 1977). Thematic thinking had been seen as a basic way of reasoning, rooted in episodic knowledge, which through development becomes upgraded to formal, context-free conceptual organization. In its strong version, thematic-to-taxonomic shift assumed fundamental change in the way semantic knowledge is organized (e.g. Inhelder and Piaget, 1964): thematic thinking dominates in early childhood, until the age of 7, when hierarchical, taxonomic system of categorization takes its primacy. However, it has been shown that children are capable of both thematic and taxonomic thinking long before the age of 7 (Smiley and Brown, 1979, Markman, Cox, & Machida, 1981; Waxman & Gelman, 1986), but they prefer to use thematic concepts in categorization tasks. Therefore, thematic-to-taxonomic shift was reformulated to describe a trend of changing conceptual preference.

While it has been well documented that conceptual preference is not only age-dependent (e.g. Ji, Zhang, and Nisbett, 2004; Nisbett and Miyamoto, 2005; Unsworth, Sears, & Pexman, 2005), factors underlying the variation in preferences are not clearly identified. In addition to explanations coming from social psychology, focusing on the influence of social practices, it has been speculated that preferences may be explained by differences in formal education system or language structures (e.g. Logan, 1986; Ji, Zhang, and Nisbett, 2004). Still, all of the speculations and explanations share the same problem – it is hard to generalize them beyond the distinction between American and East Asian culture, education or language (English vs. Chinese). In other words, in order to be able to make a claim about causes of variations in categorization styles and distinguish between what is regular and what is exceptional, we need to know what is going on in the rest of the world, world between the US and China.

To our knowledge, there are only two studies that examined conceptual preference outside the US and East Asia. In both studies, authors used triads task akin to the one originally used by Chiu (1972). Thematic preference was found among high school students from the south of Italy (Knight & Nisbett, 2007), Croatian university students (Varnum et al, 2008), and a mixed group of Central and Eastern European graduate students (Varnum et al, 2008). Students from all three samples made thematic groupings in three quarters of triads, which was significantly more often in comparison to the proportion of thematic groupings among students from Northern Italy, West Europeans, and American students who took part in these studies. Still, it is interesting to note that none of the groups had shown taxonomic preference. Although not numerous, these studies call into question the oversimplified distinction between Eastern and Western cognition and provide evidence for salience of thematic relations in adulthood.

While studies presented so far focused on identifying “forces shaping cognition”, some authors considered the possibility that differences found could simply be artifacts of methodological inconsistencies. For example, Lin and Murphy (2001) reported a series of experiments showing that adults' preferences for thematic categories in triads task may depend on instructions and stimuli characteristics. It has been demonstrated that instructions to find items that “go together” or the item that "goes best with the target" may bias participants towards thematic choices, whereas choosing “another one” or “the same kind of thing” tends to result in more taxonomic groupings (Waxman & Namy, 1997; Deák & Bauer, 1995; Lin & Murphy, 2001; see also Estes, Golonka & Jones, 2011). Stimuli modality may also bias categorization. While presenting items pictorially may generate more taxonomic groupings by highlighting the physical similarities of taxonomically related items, thematic relations may be more salient when stimuli material is verbal (Lin & Murphy, 2001). Estes, Golonka, and Jones (2011) objected that experiments using triads task often lack the control of salience of thematic and taxonomic relations contrasted and fail to equate the options on relevant factors such as similarity, familiarity, and frequency of co-occurrence. We have discussed these issues in detail in Chapter 2. In the case of cross-cultural studies, salience of thematic and taxonomic relations of stimuli necessarily vary across samples even when the same set of stimuli is used, due to individual and group differences in perceived strength of relations.

Despite some valid criticisms, methodological peculiarities cannot offer a thorough explanation for great variations in performance in triads task, though they can be extremely useful in explaining differences in the effects’ sizes across experiments. Nevertheless, this research provided valuable insights for future research on conceptual preference, shedding light on possible confounds and context dependence of categorization in triads task.

Regardless of its weaknesses, the triads task has been ubiquitously employed for more than 40 years. In order to improve the explanatory power of the task, different variations have been used. One of the most common supplements to the categorization question is the justification of choice. Explanations offered by participants may enrich our understanding of the mechanisms responsible for the differences in performance, and help to at least partially answer the big question behind the triads task: Where does the effect lie? When measuring categorization preference, do we only measure the strategy of our participants that can be a result of different global (school context) and local (understanding of the instruction) contextual differences? Or, does the performance in categorization task tell us something about the genuine conceptual preference, that is, does it speak about how our brains are wired? In short, is it strategy or conceptual organization?

An extraordinary opportunity to come closer to answering this big question is given by the possibility to track the attention of participants. Patching up the insights of the studies on conceptual preference with the experiments investigating hierarchy of relation types in semantic memory, offers unique standpoint for deeper understanding of the dynamics of the process of categorization. In the next few paragraphs we will describe how tracking eye movements can help us in this scenario.

Cooper's work from the seventies (1974) was the first to show that people spontaneously direct their gaze towards the objects in their visual field that are most closely related to the meaning of the words they hear. Among the findings that are frequently cited in the language comprehension literature, the observation of the biggest interest for our study was that participants were more likely to fixate pictures of lion and zebra while hearing the word Africa, than pictures of objects that were not related to this word. Building on the work of Cooper (1974), the visual world paradigm (tracking eye-movements in a multipicture display while verbal information is presented) has been used in many studies as a visual equivalent of semantic priming (e.g. Huettig and Altmann, 2005; Huettig, Quinlan, McDonald, and Altmann, 2006; Yee, Overton, and Thopmson-Schill, 2009).

In order to untangle the role of associative and semantic relations in the organization of semantic memory, Yee, Overton, and Thopmson-Schill (2009) recorded eye fixations while participants were viewing a four-picture display in a search for a target object. The display always contained a target, a related object, and two unrelated objects. The related object was associatively related to the target and it was additionally either semantically related (semantic condition) or unrelated (non-semantic condition). Importantly, related pairs were asymmetrically associated – while *eggs* were frequently elicited in response to *ham*, *ham* was rarely evoked by *eggs* as a cue – which allowed manipulation of associative strength while keeping the semantic relationship constant.

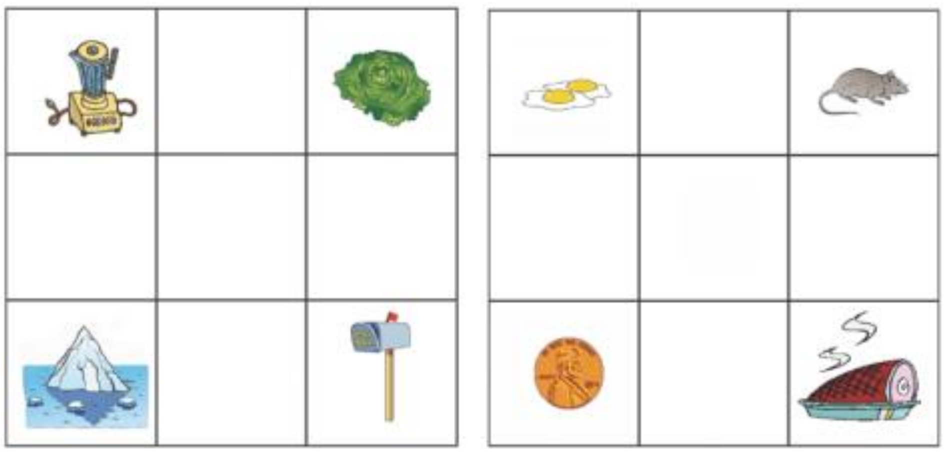

Figure 3.2. Illustration of the stimuli for non-semantic (left panel) and semantic (right panel) conditions used in Yee, Overton and Thopmson-Schill (2009). In the example given, while presented with four images, participants were asked to find *ham* or to find *eggs*.[11]

Results revealed that semantically related concepts activate each other regardless of their associative strength (*ham-eggs* = *eggs-ham*). Interestingly, associative relatedness effect was not found, that is, concepts that were associated but were not semantically related did not activate each other. No difference between forward (e.g., *iceberg-lettuce*) and backward (e.g., *lettuce stick-iceberg*) direction of presentation was found. These results suggest that the role of simple association in the organization of semantic memory is weak at best.

[11] Reprinted by kind permission of Yee, Overton and Thopmson-Schill (2009).

It is interesting to note here that semantic relation between the pairs in the semantic condition had to be based to a large extent on objects' co-occurrences, since they were associatively related. That means that we could say that behind the semantic effect in this study possibly lies a more specific form of relatedness – thematic relatedness. More importantly, when pitted against pure associative relatedness (free of semantic relatedness), this specific type of semantic relatedness has a privileged status.

Investigating which type of relationship drives the "visual semantic priming", Huettig and Altmann (2005) tested whether these effects exist for items that are semantically, but not associatively related. In other words, they chose only items that were taxonomically related, and showed that participants made more fixations towards trumpet when hearing piano, than towards the images of goat or hammer that were not related to the verbal cue. Furthermore, the study had shown that semantic priming effects persist even for the items that are not visually similar. Following this line of research, Huettig, Quinlan, McDonald, and Altmann (2006) correlated eye-movement measures with different corpus-based measures of semantic similarity: LSA and contextual similarity. Critically, they found that each measure separately predicted eye-movement patterns, but when put together in regression equation, only contextual similarity remained a significant predictor.

While Huettig and associates (2006) tried to explain their findings by the increased sensitivity of the semantic store for paradigmatic in comparison to syntagmatic relations, we would like to propose an alternative explanation. The main difference between the LSA and contextual similarity is that the first reflects global co-occurrence (how many times items appear in a particular text) while the second measures local co-occurrence (how frequently items appear together in a thread of n words, where n is usually as small as 7). Since contextual similarity uses much smaller units of analysis compared to LSA, it is more closely related to the concept of thematic relatedness. Thus, this result tells us that probability to fixate unassociated taxonomically related items was boosted by contextual similarity between items, that is, unassociated taxonomic matches attracted more attention if they were thematically related.

In summary, the results of the presented studies have shown that:

1. eye movements are sensitive to relatedness between verbal and visual objects in the environment;
2. pure associative relatedness does not affect eye movement patterns;
3. eye movements are sensitive to the degree of semantic overlap and to the contextual similarity.

Building on the results of the aforementioned studies, we have designed three experiments that will be presented in this chapter. All three experiments were conducted on the population of educated young adults, Serbian native speakers. Based on the results of the norming studies reported in Chapter 2, we hypothesized that thematic relations may be more salient than taxonomic relations among adult Serbian college students. In this chapter, this hypothesis was directly tested in three experiments using standard and modified matching task. We further addressed the question of the dynamics of the categorization process. If the preference does exist, is it only a strategy in response (decision level), or is it the case that preference may be present even before the decision stage and it can be detected on more subtle measures, such as measures of attention?

In Experiment 1 and Experiment 2, we combine the traditional triads task and eye-tracking methodology in order to shed light on the dynamics of the process of categorization in the triads task. The experiments were designed in order to diminish or control for the effects found to influence preferences: the instruction was neutral, stimuli were presented in both modalities (pictorially and verbally) and the option stimuli were normed on variables of interest (for details see Chapter 2).

In Experiment 3 we modified the instruction for triads task, forcing participants to group objects as either thematically related, taxonomically related or unrelated, in order to test the ease of grouping in each of the ways. The main idea of this experiment was to test conceptual preference when strategic responding is put under control.

General Method

Stimuli

The same set of 26 quadruplets was used in all three experiments reported in this chapter (Appendix 2). We had chosen 23 stimuli triads from the previous chapter (sets 1-10, 12-13, 15-25 from Appendix 1), selecting the sets containing items which could be easily recognized in isolation (without the context, i.e. background) when presented pictorially. Thematic and taxonomic relatedness of these items was high (M_{them} = 6.22, SD_{them} = .66; M_{tax} = 5.60, SD_{tax} = .47); and similarity (M_{them} = 4.16, SD_{them} = .41; M_{tax} = 3.79, SD_{tax} = .94) and difference (M_{them} = 3.94, SD_{them} = .27; M_{tax} = 3.95, SD_{tax} = .69) were moderate. Pair measures were based on the studies reported in Chapter 2.

The final choice of the stimuli included additional 3 triads which were selected following the same principles explained in Chapter 2 (TARGET-thematic-taxonomic (unrelated): *DRUM-drumsticks-saxophone* (*closet*); *SHIRT-tie-jacket* (*tambourine*); *TOOTHBRUSH-toothpaste-hairbrush* (*bed*)).

In all three experiments, we presented the target stimuli auditorilly and the option stimuli visually (pictorially in Eye tracking study 1: In pictures and the behavioral study, and verbally in Eye tracking study 2: In words) for the following reasons:

a) if presenting both the target and the option stimuli visually (in pictures), participants' responses and their looking behavior might be predominantly affected by the visual similarity of our stimuli, rather than conceptual relations between them;

b) looking behavior might be affected by the visual salience of the chosen stimuli, therefore, in Eye tracking study 2: In words we presented words denoting option stimuli.

Visual stimuli

The visual stimuli were high-quality photographs of real objects chosen from the Hemera image database (Hemera, 2000), The Hatfield Image Test (Adlington, Laws, & Gale, 2008), and commercial websites. The criteria for the selection of images are described in Chapter 2.

The whole sample of visual stimuli consisted of 78 (26x3) images in total.

Written words, for Eye tracking study 2 were presented in Serbian using the Latin alphabet, with black text (1.5 cm high) on a 5-percent grey background.

Word length

There was no difference in word length of the option stimuli. Thematic options were 5.54 (SD = 1.53) characters long on average, which was not significantly different from 5.62 (SD = 1.34), which was the average length of taxonomic options, or 5.69 (SD = 1.01), the average length of unrelated options. The difference between the taxonomic and the unrelated option was not significant either. For all comparisons, t-tests values were extremely small ($t < 0.5$).

Auditory stimuli

The 26 target object labels (for the auditory cues) were pronounced at a normal speaking rate by an adult male native speaker of Serbian and recorded in the context of a carrier phrase: ‘Say <target>, please.’ This procedure is widely used in studies of auditory lexical decision (see Slowiaczek & Pisoni, 1986), in order to control for abnormal durations and unnatural accentuation when words are produced in isolation.

In the next step, the target word was then taken out from the carrier phrase to be presented as a single word and edited to remove background noise by using Praat software (Boersma i Weenink, 2009). The duration of the target words varied from 365ms to 956ms. In order to uniform the duration of the auditory stimuli, silence sound was added at the end of all sound files, so that they all lasted 1500ms.

Experimental setup for eye-tracking experiments

Participants were tested individually, seated at a comfortable distance of approximately 100cm from the computer display.

Visual stimuli were presented on a CRT monitor screen (ViewSonic G90fB CRT, 19″, 1600 × 1200 pixels, 36.5 × 27.5 cm, subtending a visual angle of 20° × 15°, running at 77 Hz) using the SR Research Eyelink Experiment Builder software (SR Research Ltd., Mississauga, Ontario, Canada). The stimuli were viewed from an approximate viewing distance of 100 cm.

The auditory stimuli were presented via two loudspeakers positioned behind the viewing monitor.

Eye movements were registered using an EyeLink II head-mounted eye-tracker system (SR Research Ltd., Mississauga, Ontario, Canada) sampling at 500 Hz from the right eye. Viewing was binocular.

The experiment began with calibration procedure. In the Eye tracking study 1: In pictures, a standard nine-point fixation stimulus was used, while in the Eye tracking study 2: In words, the system was calibrated using three calibration points (mid left, centre, mid right). After half of the trials, the eye-tracker was recalibrated using the same fixation stimulus, as at the beginning of the experiment. If the validation was poor, the calibration process was repeated. Calibration took typically about 90s in the first and 30s in the second eye-tracking study.

The beginning of each trial was controlled by the experimenter. Before each trial, in order to allow for any drift in the eye-tracker calibration to be corrected, participants were asked to fixate a single centrally-located dot. After a participant has successfully fixated the dot, the experimenter would press a button for the next trial to start. The trial was terminated after participant responded. Eye movements were recorded from the beginning of each trial until the participant pressed the joystick button.

Participants were told that they should look freely when they see the objects or the text, but not to take their eyes off the screen throughout the experiment.

Responses were recorded using a SR Research gamepad. The entire experiment lasted 10 minutes on average.

Areas of interest

Experiment 1: Eye tracking study 1: In pictures

A rectangular interest area was drawn around each object in the display. The three rectangles were of identical size (200 × 200 pixels) within each trial and across the trials.

Fixations were counted for each object type (thematic, taxonomic, and unrelated) when landed within the boundaries of the corresponding AOI. The distance between the three objects was big enough for interest areas not to overlap.

Experiment 2: Eye tracking study 2: In words

In this experiment, interest areas were defined using the automatic word segmentation option in Experiment Builder software (SR Research Ltd., Mississauga, Ontario, Canada) that creates dynamic interest areas based on the space between words. This method creates segments for individual words for each trial separately.

Measurements

In Experiment 1 and Experiment 2, we recorded participants' choice and calculated five measures reflecting eye movement patterns. These were:

1. First fixation position
2. Number of fixations: the total number of times an interest area was fixated during one trial.
3. Percentage of the number of fixations: the number of fixations on a particular area of interest divided by the total number of fixations during a trial.

4. Looking (fixation) time: the total amount of time (in milliseconds) participants spent fixating an interest area.
5. Percentage of looking (fixation) time: the fixation time on a particular interest area divided by the total duration of the trial, that is, total fixation time across all areas of interest.

In Experiment 3, we collected response times and calculated error rates.

Design

All three experiments were run as a within-participant design with Stimuli Type (Task in Experiment 3) and Stimuli Position as fixed factors. Each participant received a random order of 24 experimental trials. For each experiment, three counter-balancing groups were tested in which the assignment of stimuli to the task, or the position, was done by using a Latin Square.

Experiment 1: Eye tracking study 1: In pictures

Method

Participants

We recruited 32 students, all first-year undergraduates, Serbian native speakers with normal hearing and normal or corrected to normal vision. Three of the recruited students were excluded from the analysis due to the failure of calibration.

Stimuli

26 previously described stimuli sets were used in this study. The first two (*flower* and *coconut*) were practice, and the remaining 24 test sets. Cues were presented auditorily, and option objects pictorially.

Procedure

We used the standard matching-to-sample task. Participants were presented with an auditory cue (e.g. "*monkey*"), followed by simultaneous presentation of three visual items, three objects' photographs presented on the same screen in the angles of an imagined triangle (Figure 3.3.). One of the three items was thematically related to the auditory label (e.g. "*banana*"), another one was taxonomically related (e.g. "*giraffe*") and the third item was unrelated to the preceding word (e.g. "*bench*").

The instruction was neutral. The participants were instructed to choose the option that is best related to the base. English translation of the instruction: "Your task is to decide which of the objects in the pictures seems most closely related to the one whose label you've heard." The position of option stimuli was counterbalanced, and the presenting order of stimuli sets was randomized.

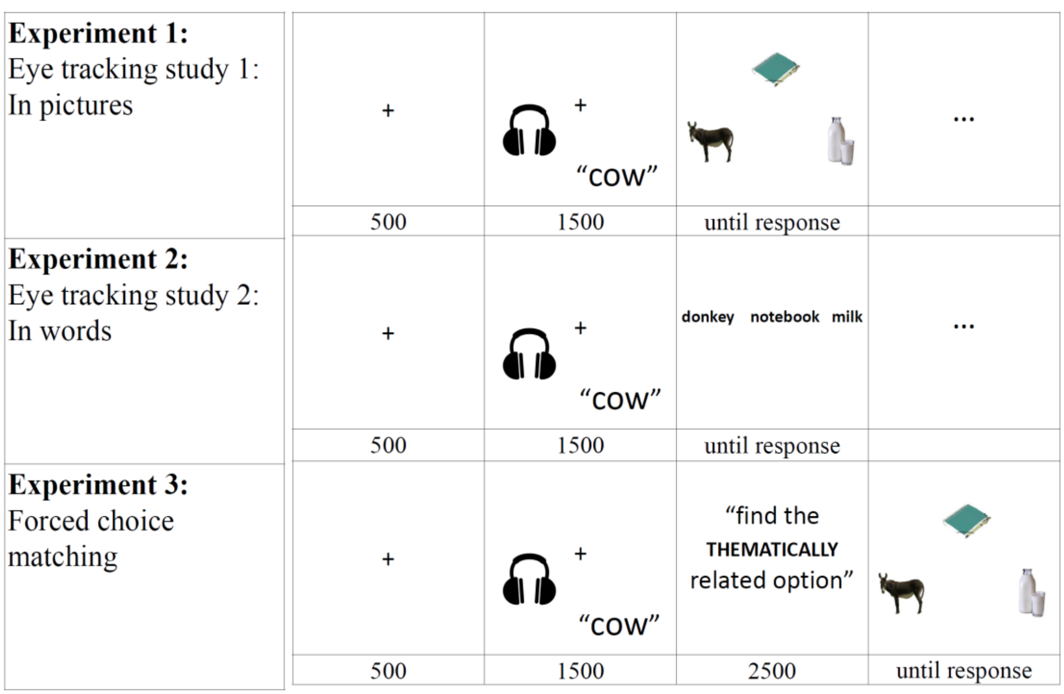

Figure 3.3. The time course of the stimuli presentation

Results

Participants' choice

Participants consistently chose thematic relationship over the taxonomic and unrelated option for 24 out of 24 triads used in the study ($\chi^2(2) = 934.51$, $p < .01$). Even for trials that received most taxonomic responses, the ratio of taxonomic vs. thematic did not exceed 2/3. Only in the cases of three out of 29 participants did thematic choices comprise two thirds or less of all choices.

Before the analysis of the eye movements, data were scanned for missing values. Only three trials were excluded because there were no eye-movement data for these trials. In trials where subjects did not fixate some of the areas, but did fixate the other(s), that was not treated as missing data and these data points were entered in the analysis as 0s. Since approximately 180ms is needed for a saccade to be initiated (see Huetting and Altmann, 2004), all fixations recorded in the first 200ms from the beginning of presentation of the visual stimuli were excluded.

The first look

The first look was affected by the stimuli type $\chi^2(2) = 16.16$, $p < .01$. Interestingly, participants tended to direct the first look more often to the taxonomically related object than to the thematically related one ($\chi^2(1) = 6.09$, $p = .01$).

Data were analyzed in 3x3 repeated measures analyses of variance with Stimuli Type (thematic, taxonomic, and unrelated) and Stimuli Position (left, top, and right) as within-subject factors.

Percentage of looking time and looking time (in ms)

With the percentage of trial time spent looking at the specific interest area as a depended measure, the analysis revealed only the main effect of Stimuli Type $F(1.69, 47.28) = 116.90$, $p < .01$, $\eta^2 = .81$. The analyses of trial time (in ms) has shown the same pattern of results – only the main effect of Stimuli Type $F(1.71, 47.91) = 97.20$, $p < .01$, η^2

= .78. Post-hoc tests for both variables showed that participants preferred the taxonomic over the unrelated option ($p < .01$), but more interestingly, they also preferred the thematic over the taxonomic option ($p < .01$).

Percentage of the number of fixations and the number of fixations

With the percentage of the number of fixations falling on the interest area, analysis revealed the main effect of Stimuli Type ($F(2, 56) = 77.71$, $p < .01$, $\eta^2 = .74$) and the main effect of Stimuli Position ($F(2, 56) = 6.96$, $p <. 01$, $\eta^2 = .20$). The number of fixations was also affected by Stimuli Type ($F(2, 56) = 77.58$, $p < .01$, $\eta^2 = .74$) and the main effect of Stimuli Position ($F(2, 56) = 10.30$, $p < .01$, $\eta^2 = .27$). The number of fixations and the percentage of the number of fixations were significantly greater for taxonomic than unrelated objects ($p < .01$), and also significantly greater for thematic than taxonomic ones ($p < .01$). Fixations were equally distributed across the left and the top position, but the number of fixations and the percentage of the number of fixations were significantly smaller for the right position in comparison to both the left ($p < .05$) and the top position ($p < .01$).

In the following step, data were scanned across trials and across participants in order to check whether the general eye-movement pattern of results is true for individual participants and trials.

Five participants showed taxonomic preference, making more fixations on taxonomic options, but only one of them also tended to spend more time looking at taxonomic options. Looking at their answers, three of them had more than one fifth of taxonomic choices. Three participants spent the same amount of time looking at thematic and taxonomic options, while the other two fixated thematic and taxonomic options equally often.

Three trials received more fixations and more time was spent looking at them, while other two were only fixated more often. There was no difference in the number of fixations and the time spent on two trials. No difference in the number of fixations was found for two more trials, and no difference in looking time was found for one more trial.

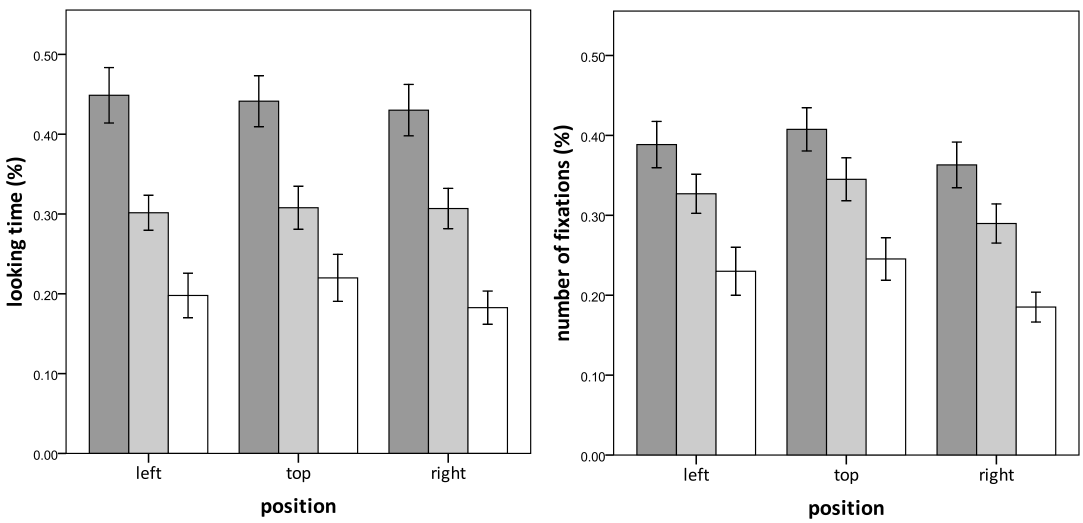

Figure 3.4. Average looking time (left) and average number of fixations (right): position by stimuli type. Dark grey bars represent thematic, light grey taxonomic and white bars represent nonrelated stimuli. Error bars represent confidence intervals.

Experiment 2: Eye tracking study 2: In words

Method

Participants

Twenty-three first-year undergraduate students, Serbian native speakers with normal hearing and normal or corrected to normal vision, who did not participate in the previous study, were recruited for this experiment.

Stimuli

We used the same stimuli sets as in Experiment 1. The only difference between the two studies is the type of option stimuli. Option stimuli in Experiment 2 were nouns denoting objects' names, presented visually, on the same screen, in the same line, positioned 270 pixels from the top of the screen: one on the left, one in the center and one on the right side of the screen.

Procedure

The experimental procedure for Experiment 2 was exactly the same as for Experiment 1. Participants were instructed, same as in Experiment 1, to choose the option that *is best related to the base.* The position of option stimuli was counterbalanced, and the presenting order of the stimuli sets was randomized.

Results

The analyses of the participants' choice have shown strong thematic preference ($\chi^2(2) = 810.57$, $p < .01$). Participant with the highest number of taxonomic choices had 7 out of 24 taxonomic choices. Only two trials had more than 25% taxonomic choices: *drum* (37.5%) and *pearl* (29%).

Trials with no eye movement data were excluded from further analysis (7.2%).

The first look

The first fixation location was completely driven by Stimuli Position ($\chi^2(2) = 406.740$, $p < .01$), with 78% fixations on the central interest area.

Data were analyzed in 3x3 repeated measures analyses of variance with Stimuli Type (thematic, taxonomic, and unrelated) and Stimuli Position (left, central, and right) as within-subject factors.

Percentage of looking time

The analysis revealed the main effect of Stimuli Type $F(1.32, 29.05) = 47.84$, $p < .01$, $\eta^2 = .69$ and Stimuli Position $F(2, 44) = 91.03$, $p < .01$, $\eta^2 = .81$, as well as their interaction $F(2.60, 57.22) = 10.34$, $p < .01$, $\eta^2 = .32$, on percentage of trial time spent looking at the specific interest area.

As can be clearly seen in Figure 3.5., participants spent significantly more time looking at the central in comparison to the left and the right interest area ($p<0.01$). Patterns of the effects of Stimuli Type on looking time differed in three positions. Only in the central position all differences were highly ($p < .01$) significant (thematic vs. taxonomic, thematic vs. unrelated, and taxonomic vs. unrelated), while in the left position, only the difference between the thematic and the taxonomic option reached significant ($p = .05$). In the right position, the difference between the thematic and the taxonomic option was marginally significant ($p = .054$) and there was also a significant difference between the thematic and the unrelated option ($p < .01$).

Looking time (ms)

With total looking time (in ms) as a depended measure, the analysis revealed the main effect of Stimuli Type $F(1.44, 31.60) = 12.66$, $p < .01$, $\eta^2 = .37$ and the main effect of Stimuli Position $F(2, 44) = 81.30$, $p < .01$, $\eta^2 = .79$. The interaction was not significant. Here, the difference between thematically and taxonomically related items was significant ($p < .01$), as well as the difference between thematically related and unrelated items ($p < .01$), but there was no significant difference between the thematic and the taxonomic options. There was no difference between the left and the right position in time spent looking at them, but the central position attracted more looking time in comparison to both the left and the right interest area ($p < .01$).

Percentage of the number of fixations

The percentage of the number of fixations participants made was affected by Stimuli Type $F(2, 44) = 9.93$, $p < .01$, $\eta^2 = .48$ and Stimuli Position $F(2, 44) = 116.96$, $p <$

.01, η^2 = .84, with significant interaction of these two factors $F(2.70, 59.18) = 4.48$, $p < .01$, η^2 = .17.

In the same way as for the percentage of looking time, there was a significant difference between the central position, and the left and the right position ($p < 0.01$), but there was no difference in the percentage of the number of fixations between the left and the right stimuli position. Again, patterns of results differed for three positions. In the central position, the thematic option received more fixations than the taxonomic and the unrelated option, but there was no difference between the taxonomic and the unrelated items. In the left position, there was no difference in the number of fixations for the three types of stimuli, while in the right position, only the difference between the thematic and the unrelated option reached significance.

Number of fixations

The analysis revealed the main effect of Stimuli Type $F(2, 44) = 6.14$, $p < .01$, η^2 = .22 and Stimuli Position $F(2, 44) = 104.87$, $p < .01$, η^2 = .83. There was no significant interaction.

The thematic option was fixated significantly more often than the taxonomic ($p < .01$) and the unrelated option ($p < .01$), but the difference between the taxonomic and the unrelated option was not significant. Again, only the difference between the central position, and the left and the right position was significant ($p < .01$), but there was no difference in the percentage of the number of fixations between the left and the right stimuli position.

Furthermore, similarly to Experiment 1, data were scanned across trials and across participants in order to check whether the general thematic preference is true for individual participants and trials. Taxonomic advantage was found for 4 trials, and there was no difference between the thematic and the taxonomic option on 7 trials (which VAR). The unrelated option was preferred in 2 trials. Patterns of response were uniform across participants, showing clear thematic preference or no preference, but interestingly, participants with taxonomic preference were not registered.

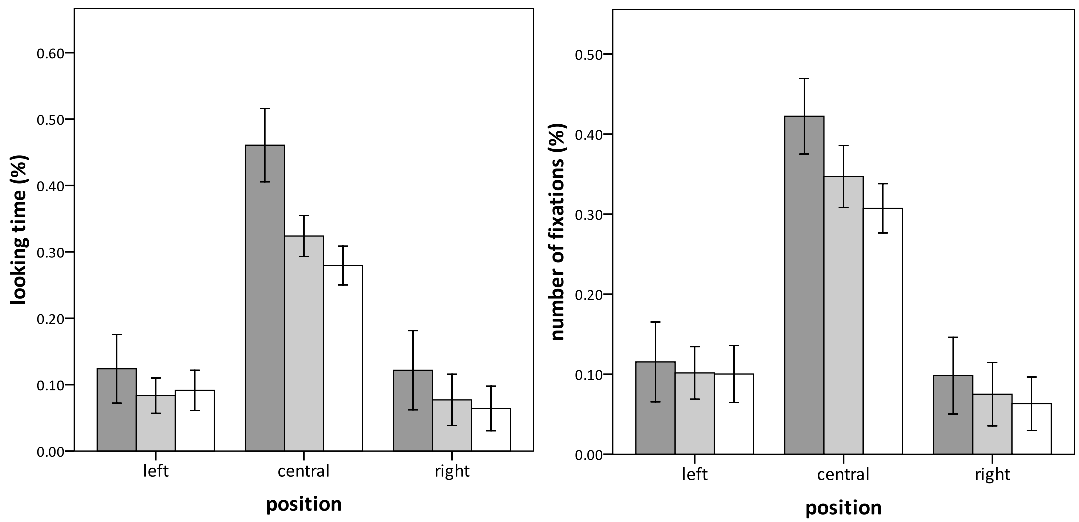

Figure 3.5. Average looking time (left) and average number of fixations (right): position by stimuli type. Dark grey bars represent thematic, light grey taxonomic and white bars represent nonrelated stimuli. Error bars represent confidence intervals.

Eye-tracking experiments have provided convincing evidence for strong thematic preference among adult Serbian participants in the standard matching task. In order to further investigate whether the preference reflects strategic, controlled processing, or speaks of the ease of processing of the two categories, in Experiment 3, we have investigated whether preference in matching task may be detected even when participants are requested to adopt one of the strategies: thematic, taxonomic or unrelated. If the found preference results only from the strategy, participants should be equally accurate and fast when required to match thematically and taxonomically. However, if participants prove to be more efficient using either one of them, that would give support to the thesis that preferences reflect conceptual organization.

Experiment 3: Forced choice matching

Method

Participants

The participants were 27 first-year undergraduate psychology students, all Serbian native speakers.

Stimuli

In this study, we have used same 26 stimuli sets that were used in Experiment 1 and Experiment 2 (2 practice and 24 test sets).

Procedure

Stimuli were presented on a desktop computer using Superlab 4.0 software (Cedrus Corporation). The approximate viewing distance was 50 cm.

The present experiment employed a modified matching task in which the participants were instructed to find the stimulus that was related thematically, taxonomically or was unrelated to the base. Before the experiment started, participants received definitions of thematic and taxonomic relationships with accompanying example stimuli. We have used the same formulations as in Chapter 2.

Each trial began with a centrally located fixation cross (500 ms), which remained on the screen during the presentation of the target stimuli (1500 ms). After the target stimulus was presented auditorily, the instruction was written on the screen (e.g. "find the THEMATICALLY related option") for 2500 ms, followed by the pictures of three objects (one thematically, one taxonomically related, and one unrelated to the base) presented on the same screen in the angles of an imagined triangle (Figure 3.3.). Option stimuli remained on the screen until the participant responded. There was no feedback on the accuracy of the participant's response.

Participants responded using computer keyboard. Accuracy and reaction times were recorded for each trial.

Results

In the very first step of the analysis of reaction times, we removed 9 trials with extremely long latencies (RT > 6800 ms) and log-transformed response latencies in order to fit normal distribution.

A 3x3 repeated measures ANOVA with Task (thematic, taxonomic, and unrelated) and Position (left, top, and right) as within-subject factors revealed a significant main effect of the Task ($F(2, 44) = 3.39$, $p < .05$, $\eta^2 = .13$). Participants were very slow when they were searching for the unrelated object (M = 1848.97, SD = 833.29), but there was no difference in speed across the thematic (M = 1706.18, SD = 1046.08) and the taxonomic (M = 1757.81, SD = 1073.94) conditions. Planned comparisons revealed only marginally significant difference between the speeds in the thematic and the unrelated task ($p = .067$).

Analysis of the number of errors showed that participants made errors in 8.9 % of all cases, and that they have made more errors matching taxonomically related than thematically related objects ($\chi^2(1) = 5.33$, $p < .05$). The difference in the number of errors between the unrelated and the taxonomic condition was also significant ($\chi^2(1) = 12.90$, $p < .01$), but there was no difference between the unrelated and the thematic condition. Furthermore, analysing mistakes, we found that most of the wrong choices were thematic ($\chi^2(2) = 12.74$, $p < .01$). In other words, not only that thematic matching was easier for our participants than taxonomic matching, but they tended to make thematic choices even when they were instructed to rely on taxonomic relatedness (27 out of 32 mistakes in taxonomic condition were thematic choices). In the thematic task, 13 out of 16 errors were taxonomic.

Table 3.1. Number of the three types of mistakes across the tasks

		choice		
		thematic	taxonomic	unrelated
task	thematic	0	13	3
	taxonomic	27	0	5
	unrelated	3	6	0

Discussion

Hearing the word *monkey* automatically activates the representation of this animal in our brain. At the same time, the representations of other concepts related to the concept of monkey become partially activated. The main goal of the models of semantic memory is to understand the principles of spreading of activation through our memory, that is, to understand the hierarchy of relation types between the concepts. What we hope to do in our experiments is to create a *time warp* and monitor the flow of activation of different facets of our knowledge, from the very moment a new piece of information becomes available, until the moment we evaluate its qualities, judge its importance, or make a decision about our actions towards what we have experienced. Just the way a high speed camera helps us uncover the principles of physics by capturing everyday events and allowing us to view them in slow motion, eye tracking gives us the opportunity to view the attention changes in slow motion.

In two eye-tracking experiments reported here, we tried to understand what happens before we make a decision about which two objects are most strongly related.

Experiment 1 participants' first look most frequently landed on the taxonomic object. For example, upon hearing the word monkey, participants first fixated a giraffe, and then images of a monkey and a bench. This result is in line with the observation of Huetting and Altmann (2005) - not only that eye movements are sensitive to taxonomic relations, but eye movements to taxonomic categories are fast. However, in Experiment 2, when option stimuli were presented verbally, there was no taxonomic effect on the first fixation. Two scenarios are possible. First, it is possible that the first fixation in Experiment 1 was mainly driven by visual similarity (see Huetting and Altmann, 2004), which is larger for the members of the same category, that is, taxonomic items, in comparison to the thematic and the unrelated options. Since visual similarity between taxonomic pairs and targets is less salient when items are presented verbally, the effect disappeared in Experiment 2. On the other hand, it is possible that the effect of the position was too strong to allow for the more subtle effect of semantic relatedness to make an influence.

Taking into account the whole period, from the beginning of the visual stimulation until the moment the decision was made and the button pressed, thematically related objects have received significantly more attention than taxonomically related items and the unrelated ones. This was the case in both of the experiments.

In Experiment 1, three relationship types were nicely differentiated on all four eye-tracking measures. The thematic option received the most attention, the taxonomic option significantly less, and the unrelated object the least. The effect of the position of the stimuli on eye movement patterns was minor. The right position was visited less often than the left and the central, as detected by the measures of the number and the percentage of fixations.

In Experiment 2, the pattern of results was a bit more complex. All measures were largely affected by the position of the stimuli, where the central position received significantly more fixations and time in comparison to the left and the right position which were equally rarely visited. More interestingly, the number of fixations and time spent were also affected by the relationship type and the interaction of the position of the stimuli and the relationship type. The thematic option received the most fixations and was fixated longest across all three positions, but the difference between the taxonomic and the unrelated object was significant only on one measure – the percentage of the time spent (only for the central position).

Again, as hypothesized, stimulus modality mediated the effect of the relationship type on eye movements. Although the effect of thematic relation persists throughout the experiments, taxonomic effect was attenuated in Experiment 2. As it can be seen in Figure 3.4. and Figure 3.5., the trend of results is the same in both studies. However, the differences between the taxonomic and the unrelated option in Experiment 2 were often too small to reach significance. On the other hand, it is interesting to note that thematic preference was not moderated by the visual similarity of the taxonomic items, as it could be expected based on the results of the previous studies (Huetting and Altmann, 2004, Lin and Murphy, 2001). Only the first fixation in Experiment 1 was guided by taxonomic relation (or visual similarity), but all other measures have shown clear preference for thematic objects in both experiments.

Behavioral results were equally convincing. The thematic options were consistently chosen in both eye-tracking experiments. Although thematic preference among Serbian adults was anticipated based on the results of the norming studies, the consistency in response is striking. Most importantly, response in preference is matched with the preference detected on the measures of attention. Hence, our results show that thematic preference is not only a strategy in response, but that the preference is present much before a decision is made and that it can be measured on subtle measures of attention.

Another confirmation that there is more to conceptual preference than just strategy comes from Experiment 3. When forced to group objects based on their thematic relatedness, taxonomic relatedness or unrelatedness, adult participants were equally fast in all three situations but made more errors when they needed to find a taxonomic pair than when finding a thematically related or unrelated object. In other words, reliance on taxonomic relations during categorization was harder than categorization based on thematic relations. This result may be surprising for at least two reasons. First, it contradicts the assumption of the dominance of taxonomic categorization in adulthood established through numerous studies of conceptual preference (Inhelder & Piaget, 1964; Tenney, 1975; Nelson, 1977; Siaw, 1984; Waxman and Namy, 1997). Second, having in mind the traditional definition of category, which is completely taxonomically oriented, it may be unexpected that grouping based on complementarities may be less demanding than grouping based on similarities. However, the thematic preference in Experiment 3 can be easily interpreted in the light of the results of the eye-tracking studies reported here that show salience of thematic relations in adult population.

It is important to note that participants' mistakes were not random. When making errors in taxonomic matching, participants were categorizing based on thematic relations. Likewise, most of the mistakes in thematic matching were taxonomic. Thus, fairly high error rate in the forced task is not due to inattentiveness but the result of the competition of the two types of concepts – thematic and taxonomic. This result is in line with the results other studies (Bassok and Medin, 1997; Wisniewski and Bassok, 1999; Gentner and Brem, 1999; Lin and Murphy, 2001) showing that thematic relations are intrusive and activated even in the tasks in which thematic processing is not required or may obstruct the task.

The importance of the experiments presented in this chapter is in demonstrating the salience of thematic relations in adulthood. Serbian university students consistently chose thematic in the presence of taxonomic options in the triads task. More importantly, the salience of thematic concepts was also detected in eye-movement patterns. When pitted against each other, thematic relations attracted more attention than taxonomic relations. Although the importance of the relations based on co-occurrence was noticeable in the visual world paradigm studies we refer to in the introduction of this chapter (Huettig et al, 2006; Yee, Overton and Thopmson-Schill, 2009), our study went one step further and provided evidence for the hierarchy of relations based on co-occurrence and relations based on similarity. The results of the eye-tracking studies were supported by the results of Experiment 3, where the preference for thematic processing was reflected in a higher rate of mistakes in taxonomic matching compared to the thematic matching task.

We further address the question of the hierarchy of conceptual relations using tasks designed to tap into the early, automatic processing. In the next chapter, four experiments that employed priming paradigm and ERP methodology will be presented.

Chapter 4

Temporal dynamics of activation of thematic and taxonomic knowledge

Experiment 4a: Masked priming

Experiment 4b: Masked priming

Experiment 5: Behavioural verification task

Experiment 6: ERP verification task

It takes only hundreds of milliseconds for human brain to make sense of a complex sound wave, recognize it is a word, identify which specific word it is, and retrieve from the knowledge base different kinds of information about the object denoted by that word. The speed and ease with which we recognize visual objects and sounds from our environment is truly impressive, making the question of the principles of organization of such efficient knowledge storage one of the most inspiring in psychology and beyond.

In order to understand how brain constructs meaning, one may like to know what information regarding a dog is available when this concept is activated. One may also like to know which kind of information about a dog is activated first, or what type of information is the most salient. One way to achieve this goal is to construct tasks in which intentional, controlled recovery of object's characteristics and/or object's relations with other objects is measured. However, performance on explicit semantic tasks, such as the matching tasks we have presented in the previous chapter, may be biased by intentional processes and may not reflect conceptual organization itself but the influence of specific experimental manipulations. Sometimes we know more than we can tell or we tell more than we know. To put it differently, while some knowledge may not be easily consciously accessed and therefore is unreachable in explicit tasks, quite often it is hard to untangle whether the specific pattern of response reflects structures already established in semantic memory or it measures participant's ability to construct new meanings and relations from the input given (for a discussion, see Moss et al, 1995).

Instead of constructing tasks that explicitly require assessing different kinds of information, it is sometimes more advantageous to employ tasks that will allow a more automatic access to conceptual knowledge and reduce the influence of deliberate, intentional processes. The method that has been most widely used to investigate conceptual representations and relations between concepts that promotes automatic access to semantic knowledge is called the semantic priming paradigm (Meyer and Schvaneveldt, 1971).

Numerous studies have shown that the relationship between an item and its preceding context influences the processing speed and accuracy of that item (for review see Neely, 1999; Lucas, 2000; Hutchison, 2003). A target object - dog will be recognized faster and more accurately if it is primed by, that is, if it is preceded by a semantically related object - cat, compared to a neutral or unrelated object such as lamp (e.g. McRae & Boisvert, 1998; Moss, Ostrin, Tyler, & Marslen- Wilson, 1995; Perea & Rosa, 2002). Semantic priming effects have been reported in studies using different stimuli material: pictures, auditorily presented labels, written labels, when primes and targets are presented in different modalities and across a variety of tasks: semantic decision, perceptual identification, word naming and lexical decision (for reviews, see Jones & Estes, 2012; Hutchison, 2003). However, in the most common scenario, researchers have used written lexical decision task in which participants need to decide whether the presented string of letters is a word or not.

Semantic priming paradigm gives us a unique opportunity to uncover what type of semantic information is automatically accessed when a concept is activated. Since the relationship between items affects processing in simple, non-semantic tasks, it is assumed that semantic priming reflects the principles underlying conceptual organization (Meyer & Schvaneveldt, 1971). If the presence of the word cat facilitates recognition of the word dog, that suggests that overlapping semantic information between these two concepts is available when semantic representation of cat is activated. However, two objects rarely share only one type of information. *Dog* may be facilitated by *cat* because they share many features, they are members of the same semantic category, because dogs chase cats or because words cat and dog frequently co-occur in language. Coexistence of different types of relations makes the quest of uncovering the specific effects different types of knowledge have on semantic processing not an easy issue to be resolved. Although the literature on semantic priming effects is extensive, most of the studies have confounded different types of relations, making findings from such studies difficult to interpret and compare.

We will give a selective review on the semantic priming studies examining the effects of different types of knowledge. Although we do not find the most commonly used distinction associative-semantic satisfying (for thorough discussion see Chapter 1), we do believe that when taken with caution, these studies give valuable insights into semantic processing mechanisms and provide guidelines for future research on this subject.

First attempt to disentangle the nature of the information supporting semantic priming was made by Fischler (1977). Fischler (1977) made distinction between associative and semantic (non-associated, categorically related) primes, and has shown that both types of information can be spontaneously accessed. However, studies that followed offered somewhat inconclusive findings. Shelton and Martin (1992) failed to facilitate recognition in pure semantic priming (*flute* - *trumpet*) and concluded that "words that are very similar in meaning or sharing many features will not show automatic semantic priming if they are not also associated". On the other hand, the results of Thompson-Schill et al. (1998) suggest the complete opposite. While priming for semantically similar items (*cottage* - *house, crown* - *king*) was successful regardless of the degree of associative strength between them, for items that were only associatively but not semantically related (*foot* - *note*), associative relationship alone was insufficient to produce any facilitation[12].

In meta-analysis of 26 studies (116 experiments) testing for effects of "pure semantic" priming, that is, studies controlling for associative strength of prime-target pairs, Lucas (2000) concluded that semantic priming effects can be driven by feature overlap and obtained in the absence of association. She further reported that there is evidence for "associative boost", such that semantically related pairs show larger priming effects if they also share an association, but there was no evidence for semantic priming based purely on association due to the study selection criteria.

[12] Note here that by semantic relatedness, Thompson-Schill et al. (1998) considered all relations based on meaning (categorical, functional, part-whole, and themes), excluding only those pairs linked by their usage in language only (which they call associated semantically unrelated). On the other hand, Shelton and Martin (1992) have used only taxonomically related (not associated) pairs in semantic condition, while in associative condition only 10 out of 36 stimuli pairs were synonyms, close synonyms or antonyms, and the rest 26 shared either thematic or taxonomic links.

The conclusion on existence of pure semantic priming and associative boost was shared by Hutchison (2003) who has critically examined individual studies on semantic priming. His micro-analytic review has additionally shown that there are also reliable priming effects for pairs that are highly associatively related but semantically unrelated. The strongest support for this conclusion comes from studies of mediated priming that were not included in Lucas's (2000) study. However, the results of studies investigating pure associative priming using different experimental designs are still unclear and require further experimentation.

Lucas's (2000) and Hutchinson's (2003) analysis gives insights based on both: a) quantitative, objective summary of semantic priming phenomena based on more than one hundred experiments (Lucas, 2000) and (b) qualitative analysis, in-depth look on terminological inconsistencies and differences in design and stimuli selection of individual studies (Hutchinson, 2003). Combining information from these two studies, we got the overall picture that both association and feature overlap can support automatic priming, but also when these effects do and do not take place, as what could be the reason for conflicting patterns of results in the literature. One of the main problems detected is that, even when great care is taken to select stimuli that are purely semantically or associatively related, they usually contain "a conglomeration of different types of relations" (Hutchinson, 2003; Moss, Ostrin, Tyler, & Marslen-Wilson, 1995, see Chapter 1 for a thorough discussion). The concern that different types of stimuli, that is, different relationship subtypes, may lead to different priming effects, was confirmed by several examples in Hutchinson's (2003) study. While evidence for priming by category coordinates was weak (obtained mainly in lexical decision tasks), the strongest support for semantic priming was obtained from functional associates, such are *bow-arrow* (from Moss et al., 1995). It is interesting to note that functionally related objects are here classified as purely semantic, although they would not satisfy the most widely used definition of semantically related objects as those that belong to the same category (Murphy, 2002; Estes, Golonka & Jones, 2011). The close examination of the stimuli in the mentioned study (Moss et al., 1995) has shown that category coordinates group closely resemble what we have defined as taxonomic, while functional associates fit the definition of thematically related objects we have given in the first chapter. It may also be surprising that synonyms and antonyms were found under the category of stimuli types that support priming based on the feature overlap. Although the associative-semantic distinction has been recognized as not satisfying, the studies testing for the unique effect of different relational sub-types were extremely rare until recently.

The effects of thematic priming did not receive much attention among the researchers until recently. One of the first evidence for thematic priming was obtained in the study of Moss and colleagues (1995). Thematic relations (instrument relations: *bow-arrow, hammer-nail*) facilitated word recognition regardless of whether item pairs were associatively related or not[13], successful both in paired and single-word, auditory and visual priming. Thematic effects were also reported in other studies using auditory and visual lexical decision task (Chwilla & Kolk, 2005; Sachs et al., 2008; Sass et al., 2009; Estes & Jones, 2009; Estes et al, 2011; Jones & Golonka, 2012), producing robust facilitation effects in the presence or absence of an association (e.g. Chwilla & Kolk, 2005; Estes & Jones, 2009; Estes et al, 2011).

At the very beginning of this chapter, we have posed a question regarding which information about a dog is available when this concept is activated. So far, we have presented evidence that different types of relations, including semantic (taxonomic) and thematic, can produce semantic priming effects. In other words, we have presented evidence that both, information regarding dogs' features and regarding objects that frequently co-occur with dogs are spontaneously activated when the concept of dog comes to one's mind. The second question we posed goes a step further, questioning the time

[13] In the same study, in auditory version of paired and single-word lexical decision task, priming effects were found for both associatively related and associatively unrelated category coordinates and script relations. However, in single-word visual lexical decision task, category coordinates produced facilitation only when pairs were also associatively related, while there was no priming effect found for script relations (Moss et al., 1995).

course of activation of different information regarding a dog. We will address this problem next.

Several researchers have suggested that the time course of priming may be different for different types of semantic relations (Perea and Rosa, 2001; Warren, 1977). In order to find out what types of information are evoked first, researches have used masked semantic priming with brief prime presentation and short SOAs (Forster, 1998; Forster & Davis, 1984; Forster, Davis, Schoknecht, & Carter, 1987).

The most important procedural parameters of the masked semantic priming are prime duration, stimulus onset asynchrony (SOA), and masking type (Perea & Rosa, 2002; Van den Bussche, 2004). Although priming is the most robust when the relationship between the prime and the target is easy to detect, priming is possible even when participants are not aware of the prime-target relationship, or more interestingly, when they are not aware that prime was even presented (e.g. Foster and Davis, 1984). By manipulating the prime duration we can control the extent to which prime is processed and ensure that semantic priming is not due to controlled processing. The second parameter, SOA, is the time interval between the onset of the prime and the onset of the target. SOA determines the extent to which the prime may be processed before the target is presented. Masked semantic priming may use forward masking (mask precedes the prime), backward masking (mask succeeds the prime), or the combination of forward and backward masking to provide additional control of the prime visibility and duration, by eliminating the visual trace of the prime on the screen and replacing it with a new image-mask (usually a string of symbols, e.g. ####). In a typical masked priming experiment (e.g. Perea & Rosa, 2002) the target is presented immediately after the brief presentation of the prime stimuli, which is preceded by a mask (forward masking). Prime duration typically takes value between 30 and 100ms, while mask is presented for a longer period (~500 ms) (Van den Bussche, 2004).

We will shortly review studies using masked priming paradigm to investigate the effects of different prime types on latencies in the lexical decision task. Several studies by

Parea and his associates reported reliable masked associative priming effects at SOAs of 33 ms (Perea & Gotor, 1997), 50 ms (Perea & Gotor, 1997), 66 ms (Perea & Rosa, 2002; Parea et al, 1997) and 83 ms (Parea and Rosa, 2002). Same researchers failed to find pure semantic priming at 66 ms SOA (Parea et al, 1997; Parea and Rosa, 2002), although masked semantic priming was significant at SOAs of 67 ms (Perea & Gotor, 1997) and 83 ms (Parea and Rosa, 2002). Similarly, in a recent study by Sánchez-Casas, Ferré, Demestre, García-Chico, and García-Albea (2012), pure semantic priming was found in unmasked condition at short SOA of 150 ms. The same was true for semantic primes that were weakly associated, while the priming of strongly associated semantic pairs was significant at much shorter SOA of 56 ms (masked priming).[14] Thus, although both types of information are available very early, these results suggest that taxonomic information may become active more slowly. On the contrary, Williams (1996) has reported pure semantic priming effects at SOA of 50 ms within language (a. synonyms, b. high and c. low similarity category coordinates) and at 60 ms SOA across languages (Williams, 1994), making the presented evidence inconclusive.

The major problem in making the statement about the time-course of activation of different types of knowledge is (again) the problem of the heterogeneity of relation groups used in the previous studies, especially the heterogeneity of associative relations. In studies that report early associative priming effects (e.g. Perea & Gotor, 1997; Perea & Rosa, 2002), stimuli choice is typically based on the free association norms. As previously discussed, associatively related stimuli typically share some type of semantic relationship. For example, based on the definitions we gave in the first chapter, in the study of Perea & Gotor (1997), one third of associatively related stimuli pairs were synonyms and antonyms

[14] Supporting results for the faster activation of associative knowledge in comparison to pure semantic knowledge, come from the studies using another task designed to tap into automatic processes - the single-presentation lexical decision task. In this paradigm, in which primes and targets are not paired but only follow one another and participants respond to both of them, researchers have found priming effects associatively related, but not for semantically related items (Shelton & Martin, 1992; Kotz and Holcomb, 1996).

(33%, *auto-car, hard-soft*), one third taxonomic pairs (34%, *tooth-molar*), a quarter consisted of thematically related items (27%, *key-door*), and the rest (6%, *stain-dirty*) did not belong to the predefined categories. Unfortunately, studies using finer distinction of the relation types are quite rare. We have previously cited the distinction made by Moss et al. (1995) in a study using standard priming paradigm. Some other researchers tested for individual effects of synonyms (e.g. Williams, 1996; Perea & Gotor, 1997; Perea & Rosa, 2002) and category coordinates (e.g. Williams, 1996; Perea & Rosa, 2002). More frequently, general distinction has been made between strongly and weakly associated semantic primes (e.g. Sánchez-Casas et al, 2012) or associated and (pure) unassociated semantically related items (e.g. Williams, 1996; Perea & Gotor, 1997). The call for parsing the agglomerate of associatively related items is still new. Subtypes of semantic and associative relations are, with the exception of several studies (cited above) examining categorical (coordinates, taxonomic) and lexical (synonyms, antonyms) relations, still very rare in semantic memory research.

To our best knowledge, no previous published study has investigated thematic priming at very short SOAs (under 100 ms). Findings of the studies that used masked priming paradigm have shown that it is reasonable to expect priming effects very early. However, it is still unclear what type of information is first available. In order to study the earliest stages of recognition, we will test for masked priming effect of thematic and taxonomic relations at 50 ms (Experiment 4a) and 83 ms SOAs (Experiment 4b). The prime duration was selected following the example of the previous studies, by choosing the short SOA assumed to be below and short SOA assumed to be above levels of awareness (e.g. Holcomb, et al, 2005). However, we would like to stress here that the use of the masked priming and short prime exposure (and SOA[15]) does not have for a purpose to make primes invisible and we do not state that processing under the conditions specified is unconscious. The main aim of the manipulation described is to allow for potentially different patterns of

[15] Since targets were presented immediately after primes, in our studies, prime exposure and SOA refer to the same time interval.

activation of thematic and taxonomic information to be tested in a standard task that diminishes the effects of strategic processes. Thus we decide to mimic experimental conditions of the previous studies examining masked semantic priming in order to make results of this study comparable with the relevant studies in the area.

Under way to track the time-course of knowledge activation is to use techniques with high-temporal resolution. Although much of what we know about conceptual representations and semantic memory organization has been gleaned from pure behavioural studies, some brain processes are too fast to be captured by standard behavioural measures. For example, the recognition of an object happens in a split second (Potter, 2012). However, this seemingly effortless process requires activation of various brain structures and consists of multiple levels of analyses. Since reaction times (and accuracy) reflect summed activation across different stages of processing, it may not always be easy to untangle which of them are affected by the experimental manipulation. On the other hand, with even-related potentials (ERP) technique we can track brain processing of semantic information in real time with millisecond temporal precision. Since the brain signals are sampled continuously, it is possible to detect effects that occur at different times in one single experiment (task). Thus, in the context of the current question of the time course of activation of relational information, and compared to the priming paradigms, we could say that ERP technique offers an elegant alternative for examining effect changes using different SOAs. The main advantage of ERP technique is that it is a direct manifestation of brain activation sensitive to small, fast-decaying changes in neural signal that remain elusive to both behavioural and hemodynamic-based neuroimaging methods (e.g. fMRI, PET).

The ERP component that has been most widely used as a dependent variable in studies of semantic organization is N400. N400 is a negative-going deflection in ERP waveform peaking around 400ms after the onset of the critical stimuli that has been shown to vary systematically with appropriateness of semantic context. It was first reported by Kutas and Hillyard (1980) as a brain response to words that occurred out of context during sentence reading (e.g. "He spread the warm bread with socks"). Since then, N400 effects have been obtained in a variety of paradigms (priming, categorization, relatedness judgment, memory tasks and during passive listening), using different types of stimuli (written and spoken words, animal sounds, line-drawings, pictures, scenes, faces, movies), both within and cross-modalities. Importantly, N400 has proven not to be affected by variations that are non-semantic in nature (e.g. physical characteristics, grammatical violations), keeping the reputation of the component related to meaning computation.

The amplitude of the N400 is highly sensitive to the context of the critical item, be that context a sentence (Kutas and Hillyard, 1980), discourse (van Berkum et al, 1999) or an individual stimulus (Brown and Hagoort, 1993). Similarly as facilitation by context making target item more expected shortens response latencies, congruent context leads to the reduction of the ERP wave amplitude in time window between 250 and 550 ms after the target is presented, yielding a semantic priming effect (Kutas & Federmeier, 2000; Luck, 2005). As in behavioural studies, facilitation effect is computed as the difference between the speed of processing in related (identical in case of repetition) and unrelated context, N400 is relative negativity of the neural response in unrelated compared to related or identity condition. The reduction in amplitude is in this case interpreted as reflecting the easier semantic integration of the target and its context (Kutas & Federmeier, 2000).

Different types of semantic information have proven to affect N400. The effect of semantic/associative priming has been demonstrated in studies using visual and auditory linguistic stimuli across a range of SOAs (Anderson & Holcomb, 1995; Holcomb & Anderson, 1993, Holcomb & Neville, 1990) and in relatedness judgment and object decision task of pairs of line-drawings (Barrett and Rugg, 1990; Holcomb and McPherson, 1994).

Studies that dissociated effects of associative and categorical relations have demonstrated different patterns of modulation of N400 for these two types of information. Rhodes and Donaldson (2008) failed to find N400 response for pure categorical relations in a learning task, although the effect was observed for pure associative and associatively related semantic items. Similarly, Kovisto and Ravonso (2001) reported the effect only for associatively related items in time window between 375 and 500 ms, while both types of relations have attenuated amplitude in an earlier time window between 250 and 375 ms. On the other hand, Khateb et al. (2003) have found N400 effects for both associative and categorical relatedness, but reported no ERP differences for the two relation types. Although associative and categorical relations have shown the same pattern of ERP response, Khateb et al. (2003) reported an increase in the stimulus-averaged EEG signal for categorical relationships in the left medial-frontal area. Similar to Khateb et al. (2003), Maguire et al. (2010) failed to found difference in ERPs, comparing thematic and taxonomic relations, but they did find differences in EEG signal. While theta power, related to memory processes, was increased for thematic compared to taxonomic relationships, alpha power, often correlated with attention, increased for taxonomic compared to thematic relationships. In a recent study, Chen et al (2013) suggested that thematic and taxonomic processing do not differ in an initial stage of processing (N400: 300-400ms) when the general relatedness between the items is calculated, but that the dissociation happens in a later stage (P600: 500-600 ms) when, according to these authors, integration processes take place - P600 was larger for taxonomically related compared to unrelated and thematically related words. In her doctoral thesis, Kriukova (2012, pg.78-79) have found graded effect of relationship type during 350-470 ms post stimulus interval. Specifically, thematic relations have elicited less negativity than categorical and unrelated items, but there was no difference between the effects of categorical an unrelated condition.

It needs to be noted that most of the studies reported here have used different experimental paradigms and sets of stimuli. While, on one hand, this speaks in favour of the robustness of N400 as an indicator of semantic processing, on the other, it makes it hard to compare the subtle differences in semantic processing that may (or must) depend on the task requirements. However, several valuable conclusions can be made based on the findings of the previous studies.

a. The ERP response to target item that is preceded by associatively, categorically, and thematically related item has reduced N400 amplitude in comparison to ERP waveform in the situation when the same item appears after an item that is unrelated.

b. The size of the N400 effect for associative, categorical, and thematic relations vary across the tasks, with the largest variation for categorical relations. Several studies have reported no attenuation for categorical condition, that is, no significant differences in the amplitudes of the unrelated and categorically related responses (Rhodes & Donaldson, 2008; Holcomb & Grainger, 2009; Kriukova, 2012).
c. The time window of the N400 effect differs according to the task requirements, and it may also differ for different types of relations: some appearing earlier, or lasting for a shorter time (Koivisto & Revonsuo, 2001).
d. In addition to N400, differences between relation types are occasionally reported in a later time window P600 (Rhodes & Donaldson, 2008; Chen et al, 2013). Since the common view on the P600 is that is a purely syntactic component, evidence for "semantic P600" still lack a satisfying theoretical interpretation.
e. Several studies have reported qualitative differences in processing thematic and taxonomic relations reflected in different EEG response patterns (Khateb et al., 2003; Maguire et al, 2010).

Although consensus on this matter has not been reached yet, some of the findings reviewed suggest that the processing of thematic relations can be dissociated from the processing of taxonomic relations, in terms of the temporal dynamics, salience and ease of activation of the two types of information.

In this chapter, we will report the results of an ERP study examining the impact of taxonomic and thematic relations in an object verification task. In order for the results of this study to be comparable to the behavioural study examining automatic processing, the task will not require assessing relations between the pairs of items. Both of the items, the target and the preceding item, will be clearly visible to participants since there is no need to limit exposure duration in order to access the early stages of processing. This paradigm is advantageous in comparison to the behavioural semantic priming paradigm (we will use in Experiment 4) for at least two important reasons. First, it increases the chance for weaker relationship strength to make an effect. In comparison to non-semantic tasks (e.g. lexical decision task), which put minimal demands on semantic processing and thus may diminish subtle semantic effects, verification task (although it does not require processing the semantic relationship between items) requires processing items' meaning. Second, it is sensitive to effects with different time courses. Since the stimuli processing time is not limited (as it is the case in the masked priming experiments with short SOAs) it is tuned for the relations that may emerge more slowly.

Following the reviewed studies reporting N400 effect, we predict that both thematic and taxonomic relations will attenuate N400 component compared to unrelated condition. Further, we predict that graded effects will be observed. Specifically, we expect thematic relations to elicit less negativity than taxonomic relations. This prediction is based both on the findings of the previous ERP studies and behavioural findings presented in this thesis.

Although behavioural responses will be collected during the ERP study, the characteristics of the design suited for examining ERP effects, specifically delayed behavioural response, may disrupt latency measures and mask potential differences between the conditions. Giving that measuring ERPs requires specific time presentation, an additional study, the behavioural version of the ERP experiment, will be conducted in order to collect reliable reaction times.

General Method

Stimuli

The set of stimuli used in Experiments 4-6 consisted of 70 quadruplets. For each of the 70 target objects, one thematically, one taxonomically related, and one unrelated object were selected. We used the 69 stimuli normed in Chapter 2 with one additional quadruplet (*hand* - *watch* - *foot* - *leaf*).

Design

Experiment 4 had two versions: 4a and 4b. Both versions had the same set of stimuli and the same two-factorial design with Lexicality (a. words, b. pseudowords) and Prime Type (a. thematic, b. taxonomic, and c. unrelated) as within-subjects factors. However, the Prime Exposure varied in two versions of the experiment. In Experiment 4a, the prime was presented for 50 ms, while the exposure in Experiment 4b was 83 ms. Prime Exposure was a between-subjects factor.

In all four different experimental conditions in Experiment 4 (match, thematic mismatch, taxonomic mismatch, unrelated mismatch) primes were kept constant, in order to make sure that the relationship type was the only factor that varied across conditions. In the unrelated mismatch condition, we have used the same targets that were used as thematic and taxonomic matches, but we have paired them with different primes to which they were not related. In such a design, we can be sure that any priming effects are due to the relationship between the prime and the target and not due to the characteristics of the prime and target words per se.

In both versions of Experiment 4, half of the participants were instructed to respond to words by pressing the left button (using their left hand), and to respond to pseudowords by pressing the right button (using their right hand), while the other half received reverse instructions. We label this factor Button Order.

In Experiment 5 and Experiment 6, within-participants design was used. There were four experimental conditions: (a) match, (b) thematic mismatch, (c) taxonomic mismatch, (d) unrelated mismatch. Filler trials were used to balance the number of match and mismatch trials. This resulted in a total of 420 test trials: 70 trials per condition, plus additional 140 filler trials. Trials consisted of pairs of words and images. Target objects were presented pictorially and they were preceded by words denoting a specific relationship type. Analogous to the design of Experiment 4, target objects were the same across all experimental conditions, thus allowing for the differences between experimental conditions to be attributed exclusively to the effects of the relationship type.

In all experiments presentation order was randomized for each participant.

Experimental setup for the ERP experiment

EEG signals were recorded continuously from the scalp in monopolar setup from 12 electrode sites located over left and right frontal (F3, F4), central (C3, C4), parietal-central (PC5, PC6), parietal (P3, P4), temporal (T5, T6), and occipital (O1, O2) areas. Electrodes were positioned according to the international 10-20 standard (Jasper, 1958). All electrodes were referenced to linked earlobes, and the ground electrode was positioned on the forehead. The EEG was amplified by a PSYLAB EEG8 biological amplifier in combination with PSYLAB SAM unit (Contact Precision Instruments, London, UK). Skin-electrode contact impedance levels were maintained below 5 kΩ. The signal was amplified (20k) and a 0.03 - 40 Hz hardware band-pass filter was applied. EEG was recorded continuously at a sampling rate of 500 Hz using NI USB-6212 (National Instruments, Austin TX) card for analog-to-digital signal conversion. For signals acquisition and online display, custom software with graphical user interface developed in LabVIEW 2010 was used (National Instruments, Austin, TX, USA) (Savić et al., 2013).

ERP processing

Offline signal processing was conducted using custom MATLAB routines (version 2010a, The Mathworks, Natick, MA, U.S.A.). A zero-phase 4th order Butterworth bandpass filter with 0.1-25 Hz cut-off frequencies was applied. The near-DC drift was filtered out by the high pass component, while muscle artefacts and 50 Hz noise, along with related harmonics, were removed by the low pass component. Individual 1000-ms epochs, which included 100 ms baseline period preceding and 900 ms interval following stimulus onset, were extracted from the ongoing EEG. All EEG channels were baseline corrected by subtracting the mean amplitude of 100-ms prestimulus interval from each epoch. Only trials without eye-movements and other artefacts whose absolute value of the signal from any of the channels did not exceed determined threshold were included in further analysis. Threshold was manually determined for each subject, and it ranged from 40 – 60 μV, with a mean value of 48±6.4 μV. In order for participant data to be included in the further analysis, at least 60 trials from each experimental condition needed to be artefact-free. Data from three participants did not satisfy this criterion. For each participant and each condition at each electrode site, individual ERPs were calculated and segmented into 20-ms non-overlapping time bins. This resulted in 50 bins for which mean values were calculated. First 5 bins represented baseline period and the rest 45 the period after the stimulus onset.

Experiment 4: Masked priming

Method

Participants

Thirty-seven undergraduate psychology students, all native speakers of Serbian, took part in Experiment 6: 22 in the version 4a and 19 in the version 4b. Students received course credits for their participation.

Stimuli

A list of 210 words and 210 pseudowords was used in this study. The list of words consisted of stimuli from Appendix 1 – targets and their thematic and taxonomic matches. Pseudowords were constructed using the multilingual pseudoword generator Wuggy (Keuleers & Brysbaert, 2010). Since pseudowords were constructed based on the words used in the experiment, they had the same structure and number of letters as the word stimuli.

All stimuli, primes, and targets, were written words displayed in the centre of the screen as black letters on 5 percent gray background in the Courier New font, in lower case letters size 20.

Although targets were the same across the conditions, we included different stimuli characteristics that have proven to have potential to mediate priming effects, as control variables. The list of control variables included: Prime Length[16], Target Length, Prime Frequency[17], Target Frequency, and three measures obtained in the normative studies in Chapter 2: Thematic Relatedness, Taxonomic Relatedness, and Forward Association Strength (FAS).

Procedure

The schema of a typical trial is displayed in Figure 4.1. Each trial began with a pattern mask presented for 500 ms. The mask was the same length as the prime word that appeared immediately after the mask. Primes were displayed for 50 ms in Experiment 4a and for 83 ms in Experiment 4b. The prime was replaced by a target word which remained on the screen until the participant responded.

For stimuli presentation, standard 15.6-inch monitor laptop computers, with refresh rate of 60 Hz were used.

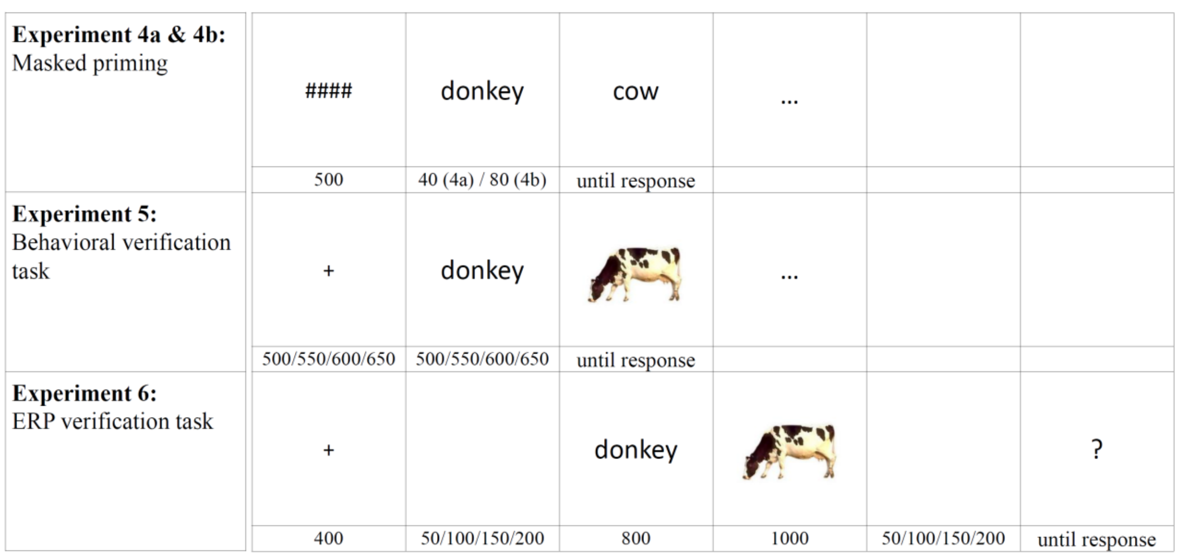

Figure 4.1. Illustration of the presentation order across the experiments

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[16] Number of graphemes in Latin alphabet.

[17] Frequency measures were based on Vasic & Vasic (2004).

Participants performed a lexical decision task. They needed to determine whether the presented string of letters (target) has a meaning in Serbian language, that is, whether it is a real word or not. They responded by pressing one of the two buttons.

Results

Data from 4 subjects (2 from each experiment) were excluded because they responded incorrectly on more than 10% of the trials. Additionally, extremely long response latencies (>1500ms) were excluded, which resulted in the removal of less than 0.5% of the trials. In order to approximate normal distribution, reaction times were transformed using the logarithm function.

In order to test for the overall effect of priming, we compared effects of related and unrelated primes on accuracy and speed of processing word stimuli.

The overall accuracy was 94.7% in Experiment 4a and 95.2% in Experiment 4b. In both experiments, participants were equally accurate when targets were preceded by related and when they were preceded by unrelated primes.

In the analyses of reaction times, only trials on which participants responded correctly were analyzed. Again, the analyses included only the data collected on word stimuli. Since Prime Exposure and Button Order were between-subjects factors, it would be hard to untangle whether the difference in response latencies between the levels of these factors should be attributed to the effects of the factors or differences between the participants. To account for this problem, log-RTs were standardized for different groups of participants (Rabbitt, Osman, Moore, & Stollery, 2001; Bielak, Hultsch, Strauss, MacDonald, & Hunter, 2010).

Although there was no effect of priming on accuracy, we found significant effect of priming on reaction times. Participants were faster in recognizing targets when they were preceded by related primes than when they were preceded by primes that were not related. Two analyses of covariance with Type of Prime (related and unrelated) and *Button Order* (left and right) as factors, Prime Length, Target Length, Prime Frequency, and Target Frequency as covariates, and standardized log-RTs as dependent variables were conducted. In Experiment 4a, when prime was presented for 50 ms, in addition to significant main effect of Type of Prime ($F(1, 552) = 4.02$, $p < .05$, $\eta^2 = .01$), Target Length ($F(1, 552) = 10.33$, $p < .01$, $\eta^2 = .0$), and Prime Frequency ($F(1, 552) = 76.02$, $p < .01$, $\eta^2 = .12$) were also significant. In Experiment 4b, when prime was presented for 83 ms, Type of Prime ($F(1, 552) = 11.34$, $p < .01$, $\eta^2 = .02$) and Prime Frequency ($F(1, 552) = 58.26$, $p < .01$, $\eta^2 = .10$) affected response latencies significantly. There were no significant interactions. It is worth noting that although we found priming effect in both experiments, the effect size was much larger when prime was presented for 83 ms ($\eta^2 = .10$), than when it was presented for 50 ms ($\eta^2 = .02$).

In order to answer our main question regarding the effect of thematic and taxonomic primes when primes are exposed for short periods of 50 ms and 83 ms, we conducted two analyses of covariance. Prime Type was entered as a three-level factor (thematic, taxonomic, and unrelated), and there were four covariates: Prime Length, Target Length, Prime Frequency, and Target Frequency. When prime was exposed for 50 ms, participants reaction times were only affected by the Target Length ($F(1, 553) = 10.32$, $p < .01$, $\eta^2 = .02$) and Prime Frequency ($F(1, 553) = 74.80$, $p < .01$, $\eta^2 = .12$). When exposition time of the prime was 83 ms, Target Length was not significant, but Prime Frequency ($F(1, 553) = 58.64$, $p < .01$, $\eta^2 = .10$) and Prime Type ($F(2, 553) = 5.88$, $p < .01$, $\eta^2 = .02$) were.

Although Prime Type as a three-level factor did not reach statistical significance in Experiment 4a, contrast tests between the levels of this factor have revealed that the difference between thematic and unrelated primes was marginally significant ($p = .07$). In Experiment 4b, in addition to the significant difference between the thematic and unrelated primes ($p < .05$), taxonomic primes were also significantly different from unrelated ones ($p < .01$). The pattern of results can be seen in Figure 4.2.

Although the difference between the thematic and taxonomic primes did not reach significance in the previous analysis, we tested this difference with additional covariates included. Analysis of covariance with the two-level Prime Type (thematic, taxonomic) as a factor and a set of covariates was conducted on standardized log-RTs. The set of covariates included Prime Length, Target Length, Prime Frequency, Target Frequency, Thematic Relatedness, Taxonomic Relatedness, and Forward Association Strength (FAS). Response latencies for words primed with related context were in both experiments affected by the frequency of the prime word (Experiment 4a: $F(1, 267) = 34.66$, $p < .01$, $\eta^2 = .12$; Experiment 4b: $F(1, 267) = 27.64$, $p < .01$, $\eta^2 = .09$). When primes were exposed for 50 ms, the strength of taxonomic relatedness also affected the speed of recognition $F(1, 267) = 4.14$, $p < .05$, $\eta^2 = .02$. However, when primes were exposed for 83 ms, the associative strength significantly modulated response times $F(1, 267) = 3.81$, $p = .05$, $\eta^2 = .01$. There were no other significant effects.

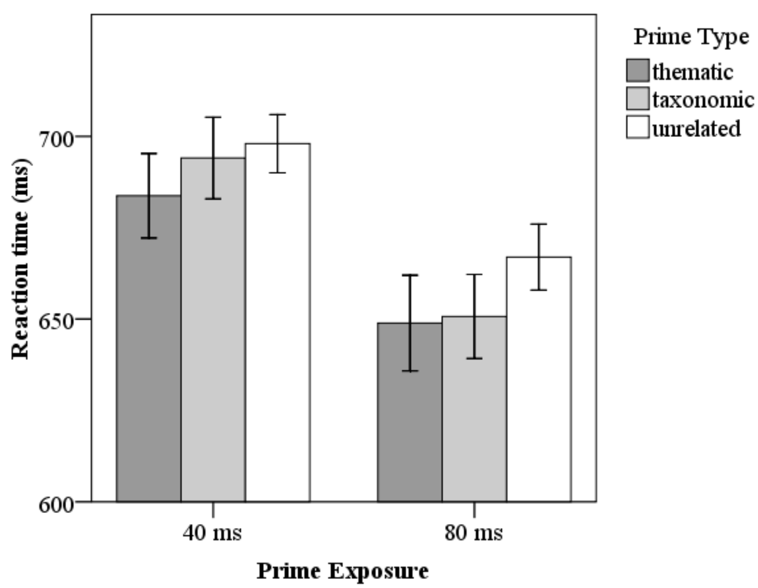

Figure 4.2. Reaction time according to SOA group and prime type. Error bars represent confidence intervals.

Experiment 5: Behavioural verification task

Participants

Nineteen adults, Serbian native speakers, were recruited to participate in this study. Participants were second-year psychology students participating for course credit.

Stimuli

The testing stimuli consisted of 70 images of target objects and 280 Serbian words denoting familiar object's labels of: (a) target objects (70), (b) thematically related objects (70), (c) taxonomically related objects (70), and (d) unrelated objects. Additional 140 Serbian words denoting objects not related to the target objects were used for filler trials.

Images were full colour high-quality photographs of real objects chosen from the Hemera image database (Hemera, 2000), The Hatfield Image Test (Adlington, Laws, & Gale, 2008), and some of them were chosen from commercial websites. All images represented highly typical exemplars of their object categories. Typicality and familiarity ratings for all images were collected from a separate group of participants as reported in Chapter 2. All images were of the same size and all of them were presented within a white rectangle located in the centre of a black background. Images had a size of 300 x 220 pixels (Figure 4.3.).

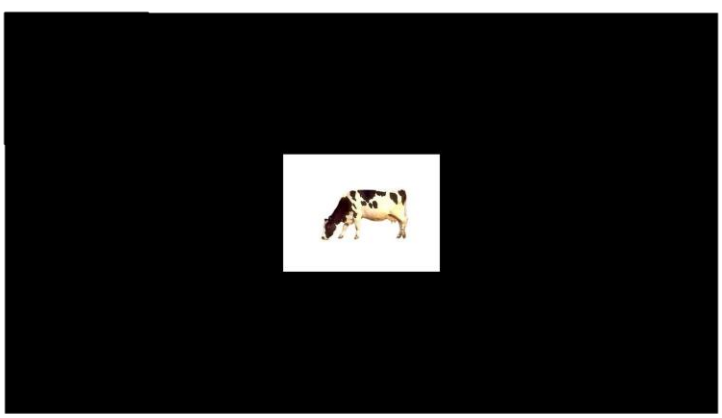

Fig. 4.3. An example of the typical trial

Written words were presented in Serbian using the Latin alphabet, with black text (30 pixels high) within a white rectangle (300 x 220 pixels) located in the centre of a black background.

Procedure

Participants performed a label verification task. They were presented with word - image pairs and they were instructed to judge whether the word and image matched.

A typical trial started with the presentation of the fixation cross in the centre of the screen for the jittered[18] time range (500/550/600/650 ms) that varied from trial to trial. The fixation cross was followed by the presentation of the written object name at the place of the fixation cross (for 500/550/600/650 ms). As soon as the word disappeared, the centrally located target object photograph was presented. The photograph remained on the screen until the participant responded.

Results

Accuracy analysis showed that the number of errors differed across 4 conditions ($\chi^2(3) = 118.75$, $p < .01$). It was easiest for our participants to respond in the case of unrelated mismatch condition (22 errors). In match condition, participants made more errors than in unrelated mismatch condition (64). Thematically (134) and taxonomically (152) related mismatch conditions provoked more errors than unrelated mismatch and match, but they were equally hard ($p > .10$).

In a preliminary analysis of reaction times, extremely long latencies (RT > 1500 ms) were excluded from the analysis. A repeated measures ANOVA with Match Type (match,

[18] The jitter (small variations in stimuli timing) is typically introduced in order to avoid noise caused by cognitive processes related to the expectancy of a stimulus. It is particularly important in ERP experiments, in order to avoid slow negative-going ERP (CNV - contingent negative variation) elicited when a target stimulus is anticipated (Luck, 2005).

thematic, taxonomic, and unrelated) as within-subjects factor revealed a significant main effect of the Match Type ($F(1.45, 24.62) = 28.17$, $p < .01$, $\eta^2 = .62$). Related mismatch trials were verified significantly slower ($p < .01$) than match trials and unrelated mismatch trials ($p < .01$), but there was no difference in the speed of rejecting unrelated mismatch and verifying match trials. There was no significant difference in speed between thematic and taxonomic mismatch trials (Figure 4.4.).

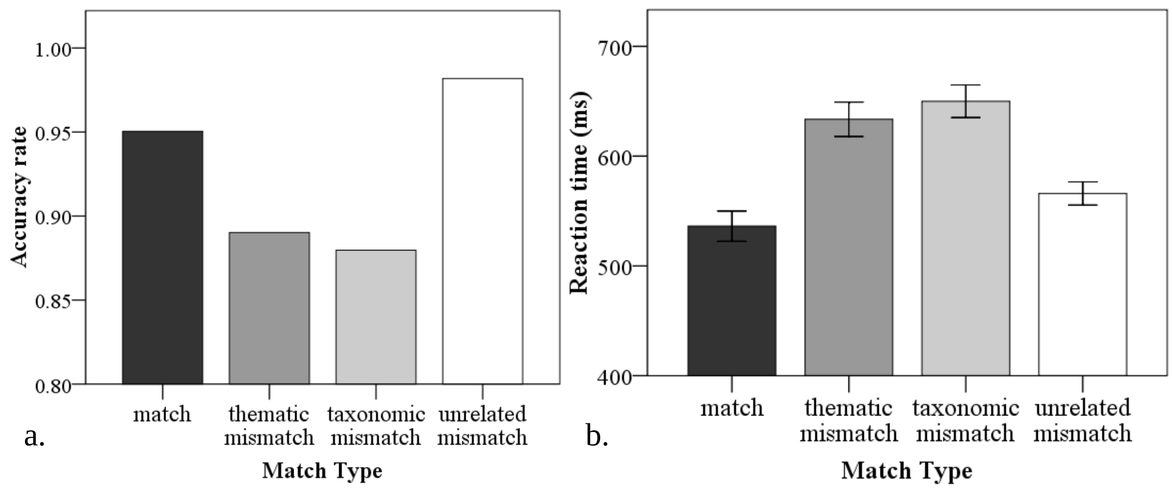

Figure 4.4. Accuracy rate (a) and average reaction time (in ms) across the four match types. Error bars represent confidence intervals.

Experiment 6: ERP study

Method

In Experiment 6 we have used the same experimental design and stimuli as in Experiment 5.

Participants

Twenty-five adult Serbian native speakers voluntarily participated in this study.

Procedure

Stimulus presentation was controlled by Superlab 4.0.

The procedure was very similar to the one described for Experiment 5 (Figure 4.1.). Participants were instructed to judge whether the word and image matched. Each trial started with a fixation cross (400 ms), followed by the blank screen (100 ms +/-50 ms jitter). Next, the test word appeared (800 ms), immediately followed by the target image (1000 ms). After the image disappeared, the blank screen appeared again (100 ms +/-50 ms jitter) and was followed by the presentation of the question mark, which was the signal for participants to respond. The question mark remained on the screen until participant indicated whether the previously presented word-image pair was a match or a mismatch, by pressing C key for "match" and N key for "mismatch", using the index fingers of each hand. That way, participant response was delayed in order to reduce the interference of motor responses in the EEG signal.

Results

Behavioural results

In a preliminary analysis of reaction times, extremely long latencies (RT > 1500 ms) and extremely short latencies (RT < 100 ms) were excluded from the analysis. The variation in timing due to jitter did not affect response times and accuracy.

Repeated measures ANOVA with Match Type (match, thematic, taxonomic, and unrelated) as within-subjects factor revealed no significant effects regarding the reaction times.

Accuracy analysis showed that the number of errors differed across 4 conditions ($\chi^2(3) = 54.06$, $p < .01$). It was easiest for our participants to respond in the case of unrelated mismatch condition (5 errors) and they made the most errors in thematic mismatch condition (65). The match condition (33) and taxonomically (31) related mismatch condition were equally hard.

ERP results

Statistical Approach

Data recorded from the 12 electrode sites were grouped into 6 zones - three bands, each subdivided into two lateral regions (left-right): fronto-central (F3, C3; F4, C4), temporal (T5, PC5; T6, PC6), and parieto-occipital (O1/P3, Pz, P4/O2). Figure 4.5.

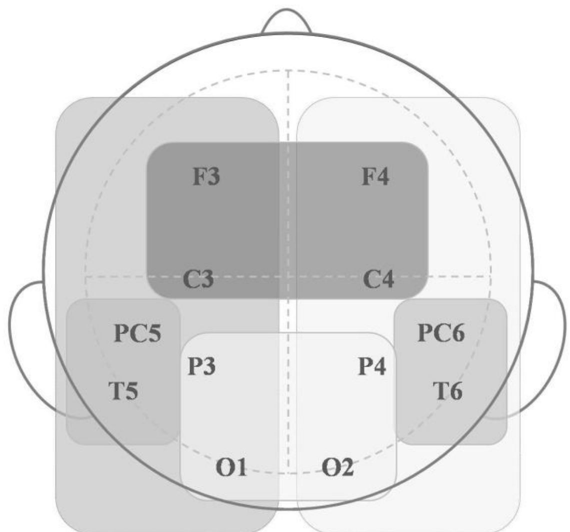

Figure 4.5. Scheme of the electrode sites: three bands, subdivided by the hemisphere

The order of analyses was as follows:

1. In the first step, repeated measures analyses of variances on mean amplitude ERP values in each 20 ms time window across six zones were performed. This allowed for the onsets and offsets of time windows of the effect of Match Type to be identified. Table 6.1. in Appendix 4 shows statistics for all time epochs where Match Type was found to be significant.

2. We have identified two time windows of interest. The first ranges from 280 ms to 460 ms (N400) and the second spreads from 520 ms to 600 ms (P600) post-stimulus interval. After time windows of interest were identified, mean amplitudes for each experimental condition were calculated.

3. Two 4x3x2 repeated measures ANOVAs with within-subjects factors of Match Type (match, thematic mismatch, taxonomic mismatch, and unrelated mismatch), Band (fronto-central, temporal and parieto-occipital), and Laterality (left and right) and mean amplitude as depended measure were conducted.

4. Zone-by-zone repeated measures ANOVAs with Match Type as within-subjects factor were conducted for both time windows of interest.

Results

Baseline

The experimental conditions did not differ during the baseline period. There was no effect of laterality; however, the effect of the band reached statistical significance (Band: $F=(2, 28) = 4.90$, $p < .05$, $\eta = .26$). Pairwise comparisons of Band levels did not reach significance.

Time window 280-460 ms

The ERP differed across the scalp (Band: $F=(2, 28) = 27.33$, $p < .01$, $\eta = .66$; Laterality: $F(1, 14) = 7.37$, $p < .05$, $\eta = .35$). Fronto-central region (more negativity) differed from temporal and parieto-occipital. There was less negativity in the left than in the right hemisphere.

In this window, the ERP differed significantly between match types ($F(3, 42) = 17.01$, $p < .01$, $\eta = .55$), with generally more negativity for mismatch than for match trials ($p < .01$). Differences between mismatch trials were not significant, except there was a difference between thematic and taxonomic mismatch ($p < .05$) with more negativity for taxonomic mismatch. The effect of match did not differ across the scalp.

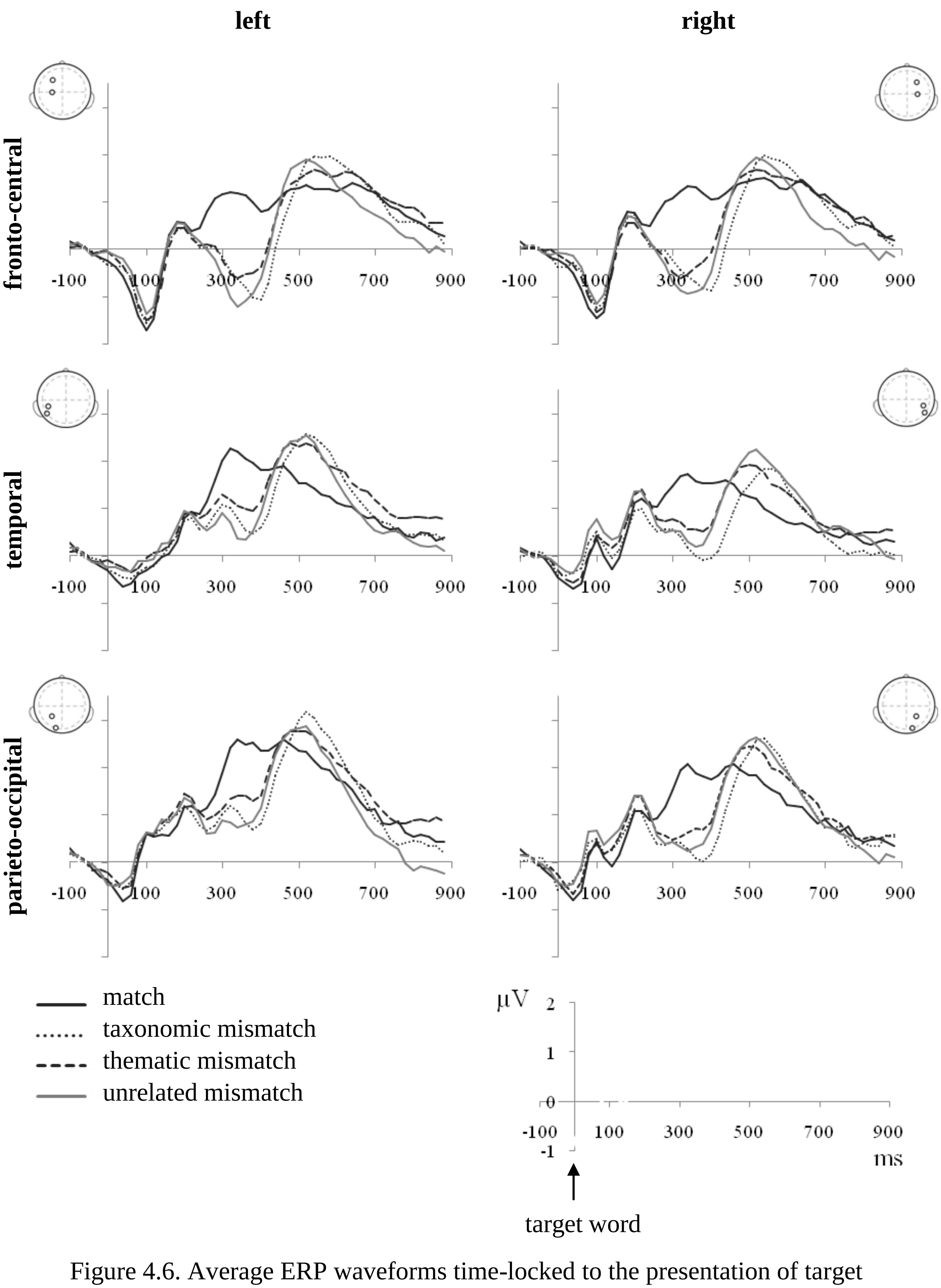

Figure 4.6. Average ERP waveforms time-locked to the presentation of target words in each of the four Match Type conditions for six zones.

Zone-by–zone analysis revealed different patterns of effects over the six zones.

In left (Match Type: $F = (3, 54) = 20.86$, $p < .01$, $\eta = .54$) and right (Match Type: $F = (3, 57) = 23.91$, $p < .01$, $\eta = .56$) fronto-central region, all three types of mismatch trials elicited more negativity than match trials ($p < .01$), but there were no significant differences between mismatch trials.

In left temporal region, the pattern of results is exactly the same as in the fronto-central regions (Match Type: $F = (3, 57) = 14.88$, $p < .01$, $\eta = .44$), but in the right temporal region (Match Type: $F = (3, 48) = 16.26$, $p < .01$, $\eta = .50$), in addition to the difference between mismatch and match trials, the difference between thematic and taxonomic mismatch was also significant ($p < .05$), with more negativity for taxonomic mismatch.

Similar to the asymmetry in temporal regions, in left parieto-occipital region (Match Type: $F = (3, 63) = 14.40$, $p < .01$, $\eta = .41$), only the difference between mismatch and match trials was found, while in the right parieto-occipital region (Match Type: $F = (3, 60) = 19.93$, $p < .01$, $\eta = .50$), the difference between thematic and taxonomic mismatch was marginally significant ($p = .06$); again, taxonomic match elicited more negativity.

Time window 520-600 ms

In the 520-600 ms time window, the ERP differed across the scalp (Band: $F = (2, 28) = 5.79$, $p < .01$, $\eta = .29$; Laterality: $F(1, 14) = 5.90$, $p<.05$, $\eta =.30$; Band x Laterality: $F(2, 28) = 3.59$, $p < .05$, $\eta = .20$) and it also differed according to Match Type ($F(3, 42) = 5.34$, $p < .01$, $\eta = .28$).

We found larger negativity for match than for taxonomic mismatch ($p < .01$) and thematic mismatch ($p < .05$) – the effect opposite to the one detected in the earlier time window.

Zone-by-zone analysis uncovered that, in the left fronto-central region, only the difference between taxonomic mismatch and match was marginally significant ($p = .058$), while in the right fronto-central region, the effect of match type was not significant.

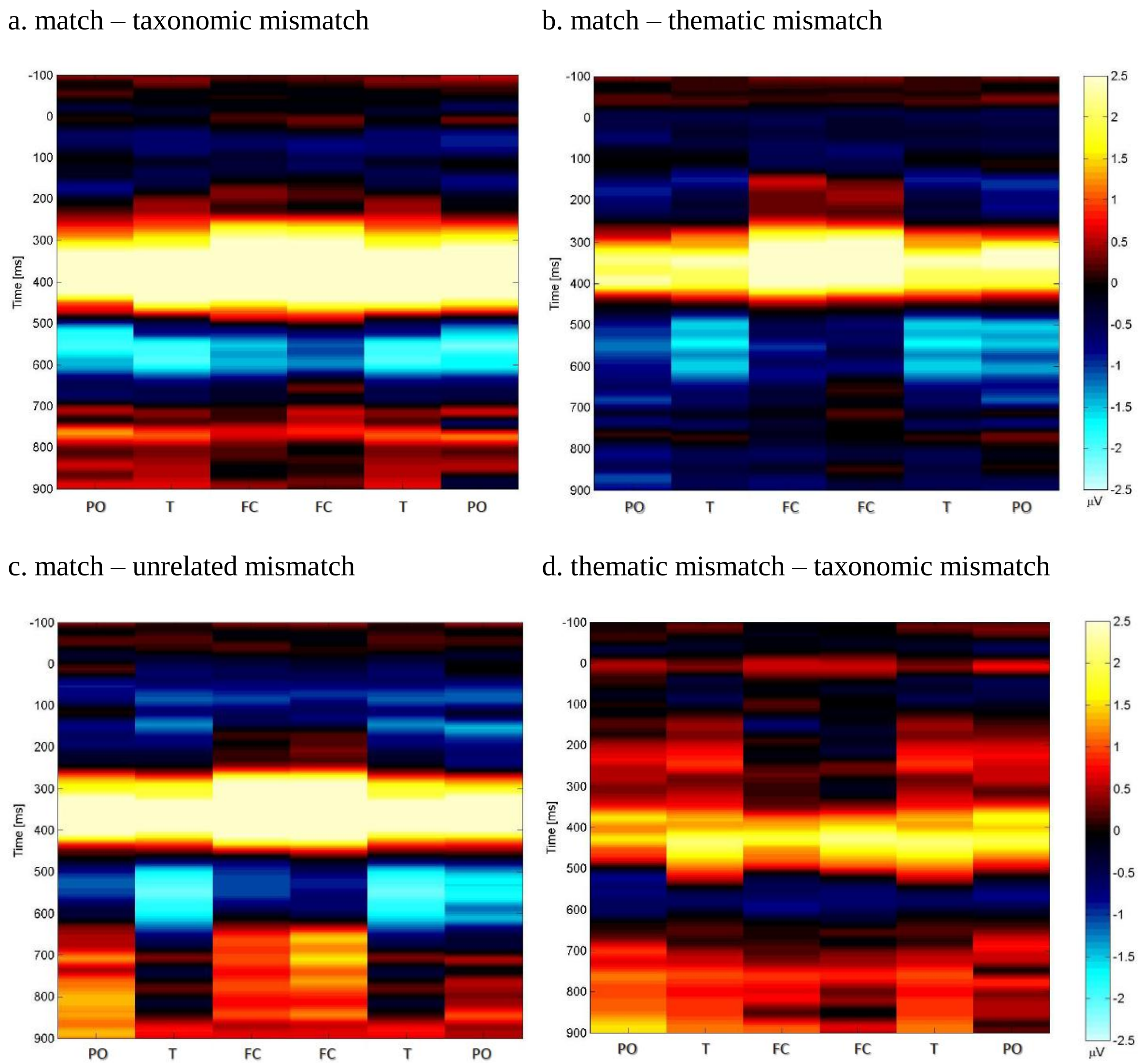

Figure 4.7. Dynamic maps showing the difference in ERP waves for match type conditions: match – taxonomic mismatch (top left), match – thematic mismatch (top right), match – unrelated mismatch (bottom left), thematic mismatch – taxonomic mismatch (bottom right). Time in milliseconds is shown on the vertical axis, starting in the baseline period 100 milliseconds prior to the onset of the critical stimuli. Labels on the horizontal axis stand for the six zones-of-grouping: P/0: parieto-occipital, T/PC: temporal, F/C: fronto-central. The colour codes the value of the difference in the amplitudes of the waves. The scale on the left describes the difference in the amplitude of two waves in microvolts (µV).

In the temporal region, match elicited more negativity than mismatched trials. In the right temporal region all three types of mismatch differed from match trials ($p < .05$), while in the left region, the difference between match and unrelated mismatch did not reach significance (related match).

In left and right parieto-occipital regions, only taxonomic mismatch elicited less negativity than match ($p < .05$).

Discussion

As mentioned earlier, the main goal of the studies presented in this chapter was to examine the temporal dynamics and salience of thematic and taxonomic categories in the tasks that minimize the influence of intentional, strategic processing. In order to achieve this goal, we have conducted four experiments that employed tasks that do not explicitly require the use of thematic or taxonomic relations and used paradigms suited for the investigation of automatic processing: masked semantic priming and ERP.

Masked semantic priming experiments have demonstrated that both thematic and taxonomic knowledge is available and can be accessed automatically during conceptual processing. The automatic taxonomic priming has been reported in several previous studies (e.g. Parea et al, 1997; Sánchez-Casas et al, 2012), however, the effects of thematic relations have not been tested before using SOAs shorter than 100 ms. This study is the first to have provided evidence on thematic priming with brief, masked primes. Some previous findings suggested that thematic integration may be beyond strategic control, based on the findings that thematic priming occurs even when the proportion of trials on which prime and target are related is very low (Estes and Jones, 2009). The results of this study add to the previous findings, showing that thematic priming occurs without intention and that it occurs at the early stages of processing.

By manipulating prime exposure duration, we have shown that both types of knowledge are activated early, but with potentially different time courses. When primes were presented for 83 ms, both types of relations facilitated target processing speed. However, when prime duration was shorter, 50 ms, only thematic relations have shown marginally significant effect on response latencies. Although this result should be taken with caution, it does suggest that thematic information may be generated more quickly than taxonomic. This result is in accordance with recent findings from the visual-world paradigm experiments (Kalénine, Mirman, Middleton, & Buxbaum, 2012; Pluciennicka, Coello, & Kalénine, 2013) in which competition effects in thematic condition were detected earlier than competition effects of distracters that shared categorical relation with the target. The slower activation of taxonomic in comparison to thematic information is also expected following studies suggesting more effort is need to process categorical information (Sachs, Weis, Krings, Huber, & Kircher, 2008; Sass, Sachs, Krach, & Kircher, 2009). The slower comprehension of taxonomic relations is especially expected in language domain where similarity between the taxonomic items is not as salient as in the case of pictorial stimulation.

Having in mind that inconsistencies of the previously published results may be due to bias in stimuli selection and individual (and cultural) differences between participants, one of the important characteristics of the present study is that thematic relations were pitted against the taxonomic in the same experiment, using within participants design. We have also used the exact same target items across the conditions. Furthermore, we have selected highly thematically and highly taxonomically related items (as confirmed by the studies reported in Chapter 2). We have already discussed the trade-off effect between purity and representativeness of the stimuli relations. In order to avoid selecting stimuli containing only weak to moderate relationship strength, (it would be particularly hard to obtain any facilitation in masked priming paradigm using weakly/moderately related stimuli), we have controlled for the effects of the mediating variables statistically. This approach enabled testing of specific contribution of different stimuli and stimuli pair characteristics across different priming conditions.

During short prime exposure (50 ms), response latencies for the three prime types depended on the frequency of the prime and the number of letters of the target. However, when prime exposure was longer (83 ms), response latencies became more affected by the type of prime, prime frequency had the comparable effect, but the number of letters of the target was not significant anymore. This pattern of results nicely captures the differences in the depth of processing across different SOAs – while at shorter SOAs, the effects of lexical variables (word length) may have larger effects than when primes are exposed in a longer interval, the pattern of results is opposite for the effect based on accessing meaning, that is relationship type effects.

Analysis that compared the effects of thematic and taxonomic priming, additionally tested the effect of the strength of thematic, taxonomic and associative relations. The strength of thematic relations did not have an effect on response latencies. However, the strength of taxonomic relatedness and associative strength affected the speed of recognition at different stages of processing. The strength of taxonomic relatedness affected the speed of recognition when primes were exposed for 50 ms, while when primes were exposed for 83 ms, the associative strength significantly modulated response times. Hodgson (1991) has also reported that the role of the associative strength may differ at different levels of processing. In his study, associative strength significantly predicted priming effect only at SOA of 66 ms, and it was not significant at SOAs of 83 ms and longer.

Experiment 5 tested relationship type influence in object verification task. Similarly to masked priming experiments, participants were not required to assess the relationship between item pairs. However, in contrast to masked priming, here, both stimuli in a pair were available long enough to be easily perceived and estimated. Although related mismatches yielded more errors and took more time to be processed than unrelated mismatches and match trials, there was no significant difference in speed and accuracy between thematic and taxonomic trials. Behavioural results of the ERP studies that have used the same design, with the exception of the delay introduced between the target item presentation and the moment when participants were allowed to respond, were somewhat different. The null result in the analysis of the relationship type effect on response times is expected, since delayed response obstructed the detection of subtle differences in the speed of processing. Regarding the accuracy, the unrelated condition was once again the easiest for our participants. Match condition and taxonomic condition were equally hard, while participants made the most errors in thematic condition. One possible interpretation of the difference in accuracy across the condition may be attributed to the difference in processing times. It is possible that prolonged response allowed for the integration of thematically related items to take place, which resulted in a higher number of false positives. It should be noted that accuracy was high in both experiments (94 and 98 percent, respectively), but that participants were even more careful in the ERP experiment, making more than three times fewer errors on average.

In the ERP study of object verification reported in this chapter, semantic mismatches were followed by a negative component N400, in a time window between 280 and 460 milliseconds after the onset of the target. Concerning the processing of thematic and taxonomic relationships, which is more relevant to our question, analysis has revealed differences in the right temporal (and parieto-occipital) region, with more negativity for taxonomic mismatch. Similarly to some previous studies (Kovisto and Ravonso, 2001), amplitudes of thematic and taxonomic responses were not significantly different from the amplitude of the unrelated response[19]. However, there was a trend towards an attenuation of the N400 component for thematically related pairs. This trend was statistically detected in the difference between thematic and taxonomic mismatches. Less negativity for thematic mismatches would typical be taken as evidence for easier semantic integration of thematically related items, such as cow and milk, compared to taxonomically related items, cow and donkey. In other words, milk is more appropriate semantic context for cow, than donkey.

[19] In order to compare N400 effects across studies, it is important to take into account how the N400 effect was computed. While some researchers define N400 as a difference in amplitude between related and unrelated condition, another approach is also possible. N400 can be expressed as a difference in amplitude between the match and the mismatch condition, as it was originally defined and computed by Kutas and Hillyard (1980). In our study, the robust N400 effects were reflected by comparing related and unrelated mismatch with match trials, but if we were to compare only the differences between the related and unrelated pairs, we would miss to detect N400. However, not all experimental designs allow for such a comparison, since there might be no “match” condition.

Some researchers also interpret N400 component in terms of ease of accessing information from semantic memory (see Kutas and Federmeier, 2000). Since initial N400 article was published (Kutas and Hillyard, 1980), it has been repeatedly shown that N400 is sensitive to the degree of semantic overlap, that is, to the similarity of the target item and the expected object or the perfect match (see Kutas and Federmeier, 2000). Analogous to the priming effects, semantic similarity decreases response latencies and reduces N400 amplitude. In other words, search through semantic memory may be more efficient when using thematically related objects as cues or context, that is, the links in semantic memory may be stronger for thematically related compared to taxonomically related objects.

To date, ERP difference between thematic and taxonomic was previously reported by Kriukova (2012), who has also found less negativity for thematic in comparison to taxonomic pairings. Other studies failed to find a difference in ERP responses of these two types of relationships (Maguire et al., 2010; Khateb et al., 2003), at least when it comes to the differences during the N400 time window.

Unexpectedly, we have also detected differences in amplitude of the ERP wave in a later time window between 520 and 600 milliseconds. In this time window (P600), mismatches elicited less negativity than match trials. Taxonomic mismatch was different from the match condition across left fronto-central region, and temporal and parieto-occipital regions, while thematic match has shown difference only across temporal regions. Unrelated mismatch differed from match solely on the right temporal sites. Differences between the mismatch waves were not found in this time window.

Chen et al (2013) reported larger P600 for taxonomically related compared to unrelated and thematically related words, suggesting that dissociation between processing thematic and taxonomic relations happens during semantic integration phase taking place between 500 – 600 ms after stimuli onset. Since the P600 is associated with the reprocessing or re-evaluation of the content (Murdoch, 2013), the larger P600 for taxonomic items may be interpreted in terms of additional resources, or additional effort needed to process taxonomic relatedness as it was suggested based on the findings of fMRI studies (Sachs, Weis, Krings, Huber, & Kircher, 2008; Sass, Sachs, Krach, & Kircher, 2009).

In this chapter, we have presented four studies designed to examine how similarity and contiguity organize semantic memory, that is, to understand differences in representations of thematic and taxonomic categories. All four studies have shown that both thematic and taxonomic knowledge are coded quickly, unintentionally and that they facilitate recognition of the succeeding information. We have also provided evidence for differences in speed and salience of thematic and taxonomic knowledge activation, showing that the distinction long recognized in the psychological literature is also grounded in neural representations of knowledge.

Chapter 5

General discussion

The study of semantic memory has been for decades devoted to the understanding the roles that different types of taxonomic knowledge play in its organisation, shaping the view of semantic memory as a taxonomically organised system (e.g. Rogers and McClelland, 2004). The limitations of a knowledge system which would include only taxonomic knowledge may be best understood by an example. Consider someone, let us call him Tosha, who knows a lot about animals, and wants to put that knowledge to use by taking care of animals in the zoo. However, Tosha has acquired only information on similarities of different animal kinds. Based on this knowledge, Tosha can describe what foxes look like, he can provide us with the information that some other species are similar to foxes, for example wolves, and that based on their common characteristics, foxes and wolves belong to the category of animals. However, no matter how detailed these descriptions and categorizations might be, for Tosha to be a zookeeper, this knowledge may not be enough. Tosha would rather seem like someone who has heard a lot or read a lot about foxes but does not have a true understanding of this species, since he lacks some of the fundamental information about the interactions of the foxes with their environment and with the other species. So, you might decide not to hire Tosha because he wouldn't know where to look for a fox, (in the cave, in the tree, in the pool) or more importantly, he would not be familiar with the information that foxes and birds do not get along well. Thus, it is clear that a person who possesses only taxonomic knowledge about the world would encounter innumerable problems in their day-to-day functioning.

Although different kinds of information may be acquired through different learning mechanisms and their representations in the brain may differ in terms of localization, density, robustness to damage and strength of connections, despite all the differences it would be hard to imagine that mental representations of objects could selectively rely on only one type of information. It seems more plausible to assume that a mental representation is in fact a unity of different kinds of information.

Most of the cognitive science researchers nowadays would agree that semantic information is not only categorical in its nature, as it was once suggested, but that there are other types of knowledge that are relevant for concept representation (Sass, Sachs, Krach, and Kircher, 2009; Kalenine et al, 2009; Golonka & Estes, 2009). The studies described in this thesis support the hypothesis that thematic relations are a salient aspect of semantic knowledge organisation. The support for this hypothesis has been found across a range of paradigms (rating, categorisation, priming) and it was reflected in various measures (from pure behavioural to neural) in tasks examining automatic or controlled processing.

Measuring products of the human mind

In the introduction, we made a point that the role that different types of information play in theories of the semantic memory depends upon the perspective one brings to the study of the nature of conceptual organization. If taxonomic knowledge was the only kind of knowledge to be considered semantic, the other types (e.g. information about the object's interaction with other objects) would be neglected or ill defined, leading to a blurred, incomplete picture of semantic memory. In the same chapter, we have stressed the problem of quantifying relations based on temporal and spatial associations between objects. Due to the nature of the task (free production) and the nature of the material (language), associative relations, unjustifiably, became a synonym for a relation that is not semantic. We argue that in order to gain insight into the roles that different relationship types play in shaping semantic memory structures, the approach in measuring relations based on contiguity needs to be reconsidered, and that the conglomeration of the relations captured by association norms, needs to be fragmented into groups based on the semantic nature of these relations.

However, the issue of quantifying the strength of relatedness is not easily resolvable. As was shown in studies presented in Chapter 2, there are several fundamental problems inherent in measuring characteristics of concepts' relations. The review of the major findings in Chapter 2 will be followed by a discussion of these problems.

The first norming study (Study 1) in Chapter 2 has employed free production task. Study 1 revealed that participants more frequently produced thematic matches from our set in response to the cue words, than pairs denoting objects from the same category. The low proportion of same category answers among educated adult population is surprising from the stand of the traditional theories of conceptual development (Inhelder & Piaget, 1964; Bruner, 1964; Vigotsky, 1977) and it contradicts the findings of the studies showing age-related differences in types of answers in free production tasks (e.g. Francis, 1972).

Some could argue that low proportion of taxonomic answers could be simply due to stimuli choice, that is, that thematically related words chosen for this study were simply more strongly associated in terms of their linguistic association strength than the taxonomic word pairs. There are at least two reasons why this is not likely to be the case. Firstly, if associative strength of thematic pairs was not primarily due to the perceived thematic relatedness between the items, but due to some extraneous factors (e.g. words are phrasal associates, compound words, etc.), then we would expect asymmetry in forward and backward association strength. The asymmetry in relatedness strength is by many authors (e.g. Thompson-Schill et al, 1998; Yee, Overton & Thopmson-Schill, 2009) assumed to be the main difference between the relatedness based on meaning and "pure", that is, linguistic association of semantically unrelated items. However, there was no statistical difference in forward and backward association strength of the thematically related pairs.

The second argument for interpreting high association strength of thematically related objects in terms of conceptual preference comes from Study 3. We have asked psychology students to come up with items from the same category as items indicated by the cue words. Since there is no doubt that our participants have developed structures needed for taxonomic thinking, the proportion of answers that did not satisfy task requirements was striking. As much as 44% of the answers could be classified as errors. However, the errors were not random. Our participants were consistently producing thematic responses. On the other hand, cross-category errors in Study 2 (taxonomic responses in thematic production task) were far more uncommon, revealing that cross-category errors cannot be attributed to inattentiveness of our subjects. The tendency to produce thematic associates in the task that explicitly required producing taxonomic matches gave further support to the hypothesis of the effect of conceptual preference and relationship type in production tasks.

The profound influence of conceptual preference on norms in production tasks questions using these norms as control variables. This is particularly important since most studies that investigated the role of different types of knowledge in semantic memory organisation, have typically relied on association strength based on free production norms (see Lucas, 2000; Hutchinson, 2003). Since associative norms are intertwined with conceptual preferences, by equating stimuli groups on the dimension of association strength, we introduce bias towards specific types of relations in our stimuli. Furthermore, since there is evidence that conceptual preferences are age and culture dependent, there is also the issue of generalisation of the findings based on these norms. We would like to make it clear that we do not state by any means that association strength is not a useful concept in investigating conceptual organisation, but that we should be aware of its limitations in use in semantic memory research.

An alternative in measuring relatedness strength is offered by rating tasks. Although it may be reasonable to expect that the conceptual preference of participants or items may be expressed in open tasks such as free production tasks, when a task is more structured, the influence of the conceptual preference is less expected since the constraints of the task guide the participant. Thus, if relatedness strength estimate based on production norms is heavily affected by the conceptual preference, this is not expected to be the case when strength of relatedness is estimated on rating tasks. Additionally, production norms may be biased by frequency and recency of objects, and moderate and weak relatedness strength may be underestimated due to the nature of the norms. Thus, rating procedure may more adequately reflect relatedness strength for a broader range of items.

Participant judgments of relatedness on rating scales collected in Study 4 and Study 5, significantly correlated with the strength of thematic and taxonomic relatedness obtained in production tasks (Study 2 and Study 3). However, the correlation was only moderate for both thematic and taxonomic relatedness. Although relatedness strength estimates collected in the production and the rating task are not easily alignable, a general observation is that the difference in strength of relatedness between thematic and taxonomic pairs was smaller in the rating task; in other words, both thematic relatedness of thematic and taxonomic relatedness of taxonomic items were estimated as strong with an average above 5.5 (on a seven-point scale). This may be expected, since due to the high proportion of thematic answers in the taxonomic task, taxonomic items consequently gained lower proportion of hits.

Whilst making the differentiation between the thematic and taxonomic relations in the introduction, we have stated that, although these two relation types are theoretically orthogonal, real life objects typically share more than one type of relatedness. Selecting stimuli for this study, we have chosen items from previous studies with special care to include only pairs that are dominantly thematically or dominantly taxonomically related. Thus, since pairs that are both highly thematically and taxonomically related – like *dog - cat* - were not included, we expected for thematic pairs to be judged high on the scale of thematic relatedness and low on the scale of taxonomic relatedness, while for the taxonomic pairs the reverse was expected. Statistical tests did show that differences in judgments were in predicted direction, however, the size of the difference was surprisingly small. Thematic and taxonomic pairs were judged high on both dimensions, with average ratings on the incongruent dimension above 4 on a seven-point scale. For a taxonomic pair to be rated as highly thematically related, participants needed to find a way to integrate objects in a scenario in which the two would interact. The high thematic relatedness of taxonomic pairs may suggest that participants did not rely only on the experience and knowledge about the co-occurrences of objects when rating their thematic relatedness, but rather relied on affordance, that is, the possibility for two objects to interact based on the nature of their features. For thematic objects to be rated as taxonomically related, one needs to find a superordinate category that gathers two objects. Although for any two objects a superordinate category can be found (real objects, living things), it is still surprising that thematic objects received such high rates since they most often came from different domains (living – non-living). However, it is possible that our participants took a broader view on what category might be, one different from the conventional taxonomic view of categories. They might use categories that gather objects based on participation in an event, and thus employ categories such as *cutting*, which are more often referred to as themes[20]. Although similar pattern of results was obtained in some previous studies (Schwartz et al, 2011; Mirman & Graziano, 2012), it did not received much attention, since rates were collected only as a control variable.

This result is in line with the results of other studies showing intrusiveness of thematic and taxonomic thinking in different types of tasks in which not only that they may not be needed, but might even interfere with the situation-appropriate performance (for a review see Estes, Golonka & Jones, 2011). For example, in a matching task in which participants were instructed to identify the taxonomic option, they were more prone to making a mistake if taxonomic match was presented together with a thematically related item, than if it was presented with an unrelated option (Gentner and Brem, 1999). Thus, mere presence of thematically related item inhibited taxonomic categorization. On the other hand, Lin and Murphy (2001) reported facilitation effect of thematic relations. In a speeded categorization task after reading category label (e.g. *animal*) participants decided whether either of the two items subsequently presented were members of the named category. Participants were faster to verify the existence of a category member when it was presented together with a thematically related item, than when it was presented with an unrelated item. Thus, although thematic information was irrelevant to the task, it affected task appropriate processing, which suggests that thematic information may be spontaneously, automatically activated.

One of the main differences between taxonomic and thematic categories is that taxonomic grouping is based on the feature similarity of items, while thematically related objects typically do not share common features, but are rather different, and are based on

[20] Some researchers (e.g. Sass, Sachs, Krach, and Kircher, 2009) support this view, by treating both thematic and taxonomic groupings as categories.

their different, complementary features. Hence, by their definitions, taxonomic objects are similar and thematic objects are different. In Study 6 and Study 7 we asked a group of participants to verify what seemed to be inherent characteristics of stimuli pairs' relations. They rated thematic and taxonomic pairs on similarity and difference dimensions. However, it turned out that there is a difference between the common sense of similarity and how the brain computes similarity. Although hardly anyone would dispute that cow is more similar to donkey than to milk, when asked to judge pairs of thematic and taxonomic objects without context of the third element of the triad, participants judged thematic and taxonomic pairs to be equally similar, or in the case of the example given, that cow is more similar to milk than to a donkey. The question is, what could drive our participants towards such an unexpected choice?

Wisniewski and Bassok (1999) have proposed that stimulus compatibility can override the task required processing. In their study, the high similarity rates for *man-tie* pair were elaborated in manner that man and tie are similar, since man might wear a tie. Although this answer might sound child-like, participants in their study were university students. Thus, although the task was to compare two objects, participants tended to integrate them. Wisniewski and Bassok (1999) suggested that different types of stimuli may be compatible with the different types of processing. While taxonomically related objects are more compatible with the comparison process, thematic pairs are more compatible with the process of integration. This hypothesis can also help us understand the results of Study 4 and Study 5. It seems that the processing of the nature of relations between the objects happens automatically, possibly even during the object recognition phase, and thus thematic and taxonomic relations are hard to ignore when the task requires processing different from the one compatible with the stimulation. In other words, processing may be seen as a competition of two processes. The first is provoked by the nature of stimulation (bottom-up) and the second is controlled process required by the task (top-down). Hence, when interpreting participants' judgments of conceptual similarity one should be aware that they result from the interaction of these two processes. It is important to note that in the studies presented in this thesis, both types of relations, thematic and taxonomic, intruded on processing in the tasks they were irrelevant for. For example, not only that thematic relations intruded on taxonomic relatedness judgments, but taxonomic processing also interacted with judging thematic relatedness.

Although thematic and taxonomic relations were judged to be equally similar, thematic pairs were rated as more different than taxonomic pairs. The non-inversion of similarity and difference was previously reported in studies in which participants directly compared which of the two objects, thematic or taxonomic match, is more similar to/different from the target (Simmons & Estes, 2008; Golonka & Estes, 2009). Although we have used a different approach in which we avoided to directly pit thematic and taxonomic option, the difference in processing similarity and difference was evident. Simmons and Estes (2008) have attributed non-inversion of similarity and difference judgments to the difference in weighing thematic relations. While thematic relations affect perceived similarity by increasing contribution of commonalities, the effect is weaker in weighing differences of objects.

In Study 10, differences in co-occurrence of thematic and taxonomic pairs in language was examined by analysing Google hits. Contrary to our predictions, taxonomic pairs had higher frequency of co-occurrence than thematic pairs. Co-occurrence estimates only weakly correlated with association norms obtained in Study 1, and it was in modest correlation with similarity judgments of thematic and taxonomic items (Study 6) and difference estimate of thematic pairs (Study 7). The nature of the co-occurrence measure that accounted only for immediate collocates imposes limitations to the conclusions that can be made based on these results. We could say that there is evidence that computational measures do have capacities to capture some kind of concept similarity or relatedness, but it is still not clear what they actually measure. Similar to the association norms, they depend on a number of parameters (nature of materials, co-occurrence algorithms) apart from the overlap in meaning between the two items. Thus, they may be useful as predictors of speed of semantic processing but may not be sensitive enough to the subtle differences in meaning.

Summarizing results of the norming studies, we can conclude that there is evidence that thematic and taxonomic information may be spontaneously accessed and affecting processing even when not being required or even being counterproductive for the task. Furthermore, thematic information in some cases may be more salient than taxonomic information, making it hard for participants to ignore them in order to access the taxonomic information. These results shed light on the complexity of the processes underlying judgements of conceptual relations and inextricability of the nature of the stimuli and task requirements, thus, indicating that relatedness measures should be used with caution.

Conceptual preference: strategy or conceptual salience

Although tasks in Chapter 2 were not primarily designed to measure conceptual preference, the profound influence of thematic relatedness on cognitive processing was demonstrated. The task that more closely addresses the question of the preference for thematic and taxonomic relation types is triads task (Chiu, 1972; Smiley and Brown, 1979). In Chapter 3, we have reported a number of studies showing age and cultural differences in conceptual preference for thematic and taxonomic processing.

For a long time, the shift from thematic to taxonomic thinking was viewed as reflecting a normal course of cognitive development and thematic thinking in adulthood was considered rare and most often interpreted as a deficit (e.g. resulting from a lack of formal education (Luria, 1976, cited in Lin & Murphy, 2001)). Studies showing thematic preference among adults typically contrasted Anglo-Saxon and East Asian population. Thematic preference of East-Asians was explained by the specific cultural practices (e.g. Nisbett and Miyamoto, 2005) or peculiarities of Chinese and Japanese language and writing system (e.g. Ji, Zhang & Nisbett, 2004), treating thematic preference of East-Asian adults as a special case of conceptual preference different from the way people in the rest of the world think and behave. Both lines of research, examining age and cultural differences, have taken an approach by which the role of thematic concepts in adulthood is rather small in comparison to the role of taxonomic relations.

In contrast with this predominant view, in the experiments reported in Chapter 3, the strong thematic preference was found among educated young adults, Serbian native speakers. Participants consistently grouped objects based on their thematic relations in the presence of taxonomic matches. This was true both when option objects were presented pictorially and when verbal stimuli were used. This result adds to a growing body of evidence on the importance of thematic concepts in adulthood (Estes, Golonka & Jones, 2011).

However, it has been discussed that participants' answers in this kind of slow tasks, such are matching tasks, could be simply reflecting participants strategy and not telling much about conceptual organisation itself (Smiley and Brown, 1979; Waxman & Namy, 1997; Lin & Murphy, 2001). For example, understanding of the instructions may make participants to intentionally respond in thematic manner although they were perhaps initially inclined towards the taxonomic option. Even when the instruction was neutral as it is the case in our study, some words (e.g. relatedness) may be more frequently used when talking about one of the relationship types and thus bias participants' choices.

In order to untangle whether the conceptual preference in matching tasks measures participants' strategy or salience of conceptual relations, we have tracked participants' eye-movements in two experiments that have employed the standard matching task. The eye-tracking methodology made it possible to monitor participants' behaviour in a time interval before they made a decision.

Previous studies have shown that eye-movements are sensitive to semantic relations between the objects in the visual field. Furthermore, eye-movements are proven to be sensitive to the degree of the semantic overlap, being it taxonomic or contextual, but they are not sensitive to pure associative relations (Huettig and Altmann, 2005; Huettig, Quinlan, McDonald, and Altmann, 2006; Yee, Overton, and Thopmson-Schill, 2009). Thus, measures of visual attention in visual world paradigm could be understood as an improved extension of reaction times in semantic priming, giving more detailed information on the effects of semantic relations on the strength of activation of the concepts.

In Experiment 1, in which option stimuli were presented in pictures, participants tended to fixate the taxonomic option first. This was not the case in Experiment 2, when options were presented in words. The fast activation of taxonomic knowledge is not surprising, especially when it is facilitated by salience of visual similarity between the objects, as it was the case in Experiment 1. Importantly, the first fixation was the only measure of eye-movement behaviour on which taxonomic items have shown an advantage in comparison to thematic items. On the other measures of visual attention, the pattern of results was the opposite. Participants directed their gaze towards the thematic items more often than towards the taxonomic items and they also spent more time fixating thematically related objects. This was true both when the option stimuli were presented pictorially and when they were presented verbally, showing that the effect is not due to the higher visual salience of thematic items (e.g. colour or shape). Regarding the visual salience, it is important to note that thematic items received more attention even when the salience of taxonomic relations was boosted by presenting items as pictures of objects.

The results of the eye-tracking studies have shown that conceptual preference may be detected on subtle measures of visual attention, even before the participants press the button and choose an option. Even if preference in choosing thematic options may be in part explained by intentional processes, the existence of thematic over taxonomic conceptual preference is strongly supported by eye-tracking measures. It is important to note that our results show that both types of information, thematic and taxonomic, are activated during matching processes but that thematic are activated more strongly than taxonomic.

In eye-tracking experiments, we have tested if there is more to conceptual preference than just strategy, by examining preference on measures of conceptual processing that are more subtle than participant choices. In Experiment 3, we have approached the same question by measuring the ease of processing of different relation types when strategic thinking is put under control. We have used more constrained matching task in which participants were not free to choose option type, but on the contrary, they were forced to rely on one relation type (e.g. thematic) in the presence of the other type (e.g. taxonomic). The salience of the competing conceptual relation should influence the ease of processing the target relation. Thus, if thematic relations are more salient, then participants should be slower and less accurate when matching taxonomic options – since the presence of the thematic information should inhibit taxonomic processing. On the other hand, if taxonomic relations are more salient, this should result in more errors and slower responses in thematic matching. Although participants were equally fast when asked to match thematically and when they were asked to match taxonomically, they made more errors in taxonomic condition. Thus, thematic processing hindered taxonomic processing more heavily than did taxonomic hinder thematic processing. This result is in accordance with the findings from the studies in Chapter 1, showing that thematic relations are more intrusive in comparison to taxonomic.

However, the effects of the competition of thematic and taxonomic processing were not detected in reaction times analysis. The possible explanation could be found in the fact that the task was slow, both in terms of the timing of the stimuli presentation and in terms of response times. In order to make sure that participants had enough time to understand the instruction and that they would not forget it, the instructions succeeded presentation of the target word and were presented for 2.5 seconds. Furthermore, participants were very slow with an average speed above 1.7 seconds in both thematic and taxonomic condition. Subtle differences in speed of processing are hard to capture in such conditions. Thus, future research may try to overcome these problems by speeding up the processing by limiting time participants have to give an answer and by shortening presentation times which may be possible if participants acquire the terms thematic and taxonomic in a separate training section.

Are thematic primes and taxonomic primes equally good?

In the fourth chapter of this thesis, we have further explored the processing implications of the hypothesis that thematic knowledge is a salient aspect of semantic representation using priming paradigm and ERP methodology.

Based on the previous studies and studies reported in the first chapter of this thesis, it has been predicted that both thematic and taxonomic knowledge may be activated automatically (e.g. Sachs, Weis, Zellagui, Huber, Zvyagintsev, Mathiak, & Kircher, 2008; Mirman, Walker and Graziano, 2009), and that thematic information might even be activated more rapidly than taxonomic (e.g. Kalénine, Mirman, Middleton, & Buxbaum, 2012).

These hypotheses were evaluated in Experiment 4 using masked semantic priming paradigm which enables examining the automatic activation of semantic information. In this experiment we have manipulated the prime duration. The idea was to choose two time intervals so that one would be the shortest prime duration which may exert priming effects in lexical decision task, and the second one would be longer, but still under 100 ms, in order to make it only possible to attribute potential priming effects to automatic processing.

The previous literature on semantic priming gives arguments both for and against automaticity of taxonomic and thematic priming. Although previous studies have shown such contradictory results, and thus resulted in contradictory hypotheses regarding the saliency and importance of different relation types in conceptual organisation, there is empirical and theoretical support that both types of information, thematic and taxonomic, may be automatically activated.

If we were to take the approach of the distributed models of semantic representation, we could predict that items that share large number of semantic features should exert strong priming effects since their patterns of activation overlap to a greater extent than items that do not share common features (Kawamoto, 1988; Masson, 1995). Thompson-Schill, Kurtz and Gabriely (1998) reported evidence that gives support to the distributed models of semantic representation, by showing priming effects for semantically related unassociated pairs, but not priming for associated semantically unrelated pairs. Hence, they concluded that semantic relatedness is not only sufficient, but also necessary for priming to occur.

However, the priming based on feature overlap cannot explain possible thematic priming effects, since thematically related objects are not similar. In contrast to the feature overlap approach, some other models have emphasized the effects of integration processes on priming, suggesting that target recognition can be facilitated if target and prime can perform complementary roles in the same theme (Coolen et al., 1991; Estes and Jones, 2008, 2009). Recent evidence suggests that this type of priming may be beyond strategic control, that is, that it can occur automatically (Estes and Jones, 2009; Estes et al., 2011).

Thus, different mechanisms are suggested to underlie facilitation in recognition of words preceded by thematic and taxonomic matches. It remains unclear which of these process may be more efficient, and thus facilitate recognition stronger or faster.

In Experiment 4, we have obtained priming effects for both thematic and taxonomic pairs in the masked semantic priming paradigm with short SOA. However, there was some evidence that thematic priming may occur faster than taxonomic priming. Priming effect for taxonomic pairs were significant only when primes were presented for 83 ms, while thematic priming effect was also significant (though marginally) when primes were presented for 50 ms. Despite the possible difference in timing of thematic and taxonomic priming, we have not found difference in the size of the priming effects.

Our results provide evidence that process which rely on feature similarity may occur very early and quickly even when processing language material, thus giving support to the distributed account of memory organisation. On the other hand, the automatic thematic priming adds to the body of literature suggesting that integration processing is also automatic and happens without participants' intention.

In Experiment 4, special care was taken in order to tap into processes that are beyond strategic control of participants, and test for the effect of semantic relations in situation in which intentional processing of these relations is disabled. In Experiment 5, both items in a pair were available to participant for evaluation, thus allowing for more natural processing to take place. However, in this kind of task it is usually hard to capture subtle behavioural differences in processing since we measure summed activation across the several phases of processing. The analysis of the data in Experiment 5 has shown the effect of relatedness (related vs. unrelated) on speed and accuracy, but no differences between thematic and taxonomic condition were found.

Although there were no behavioural differences in thematic and taxonomic processing in verification task, the ERP data (Experiment 6) revealed different influences of thematic and taxonomic priming on the amplitude of the N400 component. Thematic pairs elicited less negativity than taxonomic pairs in a time window between 280 ms and 460 ms, suggesting easier semantic integration of thematically in comparison to taxonomically related items. The variation in N400 amplitude has proven to be sensitive to the degree of semantic overlap between the item and its preceding context, and thus variation in N400 has been taken as an analog of variation in reaction times during semantic priming – higher similarity – faster response and smaller N400 amplitude. As we have previously discussed in Chapter 4, the ERP differences in thematic and taxonomic thinking have rarely been reported so far, with several studies reporting no differences (Khateb et al, 2003; Maguire et al, 2010) and one study reporting the similar pattern of results obtained in our study (Kriukova, 2012). Thus, this result is among the first to offer evidence for the neural distinction of thematic and taxonomic thinking in early phases of conceptual processing. It is interesting to note here that study that has reported on smaller N400 for thematic in comparison to taxonomic processing has been conducted on a sample of German students, thus showing that greater salience of thematic relations may not be a specific case of Serbian sample.

Although differences in the amplitude of N400 were hypothesised since this component is well established as sensitive to semantic processing, the difference found in the later time window between 520 ms and 600 ms was less expected. For a long time, the P600 was interpreted as a syntactic processing component, but recently, findings of semantic P600 started to accumulate. Although the nature of the P600 is still controversial, the difference found in our study may offer evidence of taxonomic processing being more effortful than thematic processing, since P600 is often interpreted as being related to content re-evaluation.

Taken together, differences found between thematic and taxonomic condition in our ERP study speak in favour of easier processing of the thematic information during semantic integration phase that takes place around 400 ms after the stimuli onset and a need for an additional reprocessing of taxonomic information in a later time window around 600 ms after stimuli onset.

Conclusions

In order to capture the genuine complexities of the nature of thematic and taxonomic conceptual knowledge, we have approached this subject through a variety of paradigms. It is not rarely the case that findings that seem perfectly plausible and easily interpreted in one study, become incomprehensible in the context of the findings of the study employing (sometimes just slightly) different approach. However, that was not the case with the studies in this thesis. The notable match between the patterns of results, obtained across the series of studies reported in this thesis, has proven the robustness of the effects. In this final section of this thesis, we would like to draw attention to the main points of similarity in the presented studies and thus articulate the conclusions adding to our understanding of the nature of conceptual knowledge.

Thematic and taxonomic knowledge are automatically activated. a.k.a. The activation of thematic and taxonomic relations is fast.

Automatic activation of thematic and taxonomic information is most directly evidenced by the facilitation effects in masked priming experiment (Experiment 4), N400 effects during the item verification (Experiment 6), but also by the effects of relationship type in norming studies (relatedness judgments – Study 4 and Study 5; similarity judgments– Study 6 and Study 7). Thematic and taxonomic relations affected processing in simple tasks in which relation information was not required or it was not even possible to access relationship information by controlled processing.

Thematic and taxonomic relations are intrusive.

Thematic and taxonomic information affected processing even in the tasks in which processing thematic/taxonomic relation was counterproductive for the task. However, participants could not ignore the presence of the task irrelevant information and thus the task appropriate performance was inhibited in Experiment 3 and Studies 3-5.

Thematic relations are more salient than taxonomic relations.

This is the most robust finding in this study. Thematic advantage was reflected through participant choices in matching task and the amount of attention devoted to thematic in the presence of taxonomic items (Experiment 1 and Experiment 2). Furthermore, the salience of thematic relations was evident in attenuated N400 amplitude in verification task, and across a number of norming studies that were not primarily designed to test for conceptual preference, especially as a proportion of thematic answers in free production task (Study 1) and presence of thematic errors in taxonomic production task (Study 3).

Taxonomic relations are activated more quickly. – Thematic relations are activated more quickly.

Although there is no doubt that both thematic and taxonomic information become quickly available, it is still unclear, which one may be available first. In eye-tracking experiment (Experiment 1), taxonomic items were fixated first (pictorial stimulation), while in the masked priming experiment (Experiment 4) thematic relations facilitated recognition at shorter SOA than the SOA needed for taxonomic priming to take place (verbal stimulation).

Thematic relations are easier to process – taxonomic relations require more effort.

This was suggested by differences in amplitude of the two ERP components (Experiment 6). The N400 amplitude was smaller in thematic condition, and again P600 was larger in taxonomic condition. The dominance of the thematic relations in production task and its intrusiveness may also speak in favour of more effortless processing of thematic relations.

Finally, we believe that the main contribution of this thesis is in providing robust evidence for the salience of thematic information across a variety of tasks, and calling attention to the issue of the negligence of this type of knowledge in the models of semantic memory organization.

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Appendices

Appendix 1

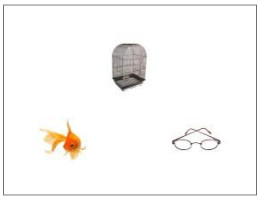
Table 1: Stimuli set

	target		thematic		taxonomic		unrelated	
1	cvet	*flower*	vaza	*vase*	drvo	*tree*	lepeza	*fan*
2	kokos	*coconut*	palma	*palm tree*	ananas	*pineapple*	alarm	*alarm*
3	čamac	*boat*	vesla	*oars*	jahta	*speedboat*	keks	*cookie*
4	čekić	*hammer*	ekser	*nail*	klešta	*pliers*	stepenik	*step*
5	crv	*worm*	jabuka	*apple*	puž	*snail*	tastatura	*keyboard*
6	biser	*pearl*	školjka	*shell*	dijamant	*diamond*	televizor	*TV*
7	kaiš	*belt*	pantalone	*suspenders*	tregeri	*pants*	telefon	*telephone*
8	akvarijum	*aquarium*	riba	*fish*	kavez	*cage*	vaga	*scales*
9	kokoška	*hen*	jaje	*egg*	golub	*sparrow*	tepih	*rug*
10	konj	*horse*	sedlo	*saddle*	svinja	*zebra*	slika	*painting*
11	maslina	*olive*	ulje	*oil*	šljiva	*plum*	utičnica	*socket*
12	krava	*cow*	mleko	*milk*	magarac	*donkey*	ćebe	*blanket*
13	kreda	*chalk*	tabla	*blackboard*	bojica	*pencil*	bubamara	*ladybug*
14	olovka	*pencil*	gumica	*eraser*	penkalo	*pen*	kada	*bathtub*
15	vrabac	*sparrow*	gnezdo	*nest*	guska	*goose*	luster	*chandelier*
16	majmun	*monkey*	banana	*banana*	žirafa	*giraffe*	futrola	*case*
17	makaze	*scissors*	papir	*paper*	testera	*saw*	kesa	*bag*
18	miš	*mouse*	sir	*cheese*	lisica	*fox*	kamera	*camera*
19	pas	*dog*	kost	*bone*	tigar	*leopard*	kalendar	*calendar*
20	pčela	*bee*	med	*honey*	leptir	*butterfly*	terasa	*balcony*
21	cipela	*shoe*	pertla	*shoelace*	čizma	*boot*	polica	*shelf*
22	top	*cannon*	đule	*cannonball*	pištolj	*pistol*	nalepnica	*sticker*
23	slon	*elephant*	kikiriki	*peanuts*	kamila	*camel*	kutija	*box*
24	veverica	*squirrel*	lešnik	*hazelnut*	kengur	*kangaroo*	bazen	*pool*
25	zec	*rabbit*	šargarepa	*carrot*	lav	*lion*	kamen	*stone*
26	ključ	*key*	brava	*lock*	otvarač	*opener*	most	*bridge*
27	lopta	*ball*	plaža	*beach*	balon	*balloon*	turpija	*rasp*
28	mač	*sword*	štit	*shield*	koplje	*spear*	dvorište	*backyard*
29	zvono	*bell*	škola	*school*	sirena	*siren*	bašta	*garden*
30	žaba	*frog*	bara	*swamp*	gušter	*lizard*	šnicla	*steak*
31	šešir	*hat*	glava	*head*	turban	*turban*	kupina	*blackberry*
32	tiganj	*frying pan*	luk	*onion*	šerpa	*pot*	lubenica	*watermelon*
33	broš	*brooch*	rever	*lapel*	bedž	*badge*	paprika	*paprika*

34	prsten	*ring*	ruka	*hand*	ogrlica	*necklace*	dinja	*melon*
35	ovca	*sheep*	vuna	*wool*	zebra	*zebra*	krastavac	*cucumber*
36	dvorac	*castle*	princ	*prince*	katedrala	*cathedral*	ležaljka	*hammock*
37	kralj	*king*	kruna	*crown*	predsednik	*president*	parfem	*perfume*
38	crkva	*church*	krst	*cross*	džamija	*mosque*	pita	*pie*
39	krevetac	*crib*	beba	*baby*	stolica	*chair*	dugme	*button*
40	peškir	*towel*	sapun	*soap*	maramica	*handkerchi ef*	zavesa	*curtain*
41	puter	*butter*	hleb	*bread*	kajmak	*cream cheese*	orao	*eagle*
42	knjiga	*book*	biblioteka	*library*	novine	*newspaper*	pernica	*pencil case*
43	avion	*airplane*	pilot	*pilot*	voz	*train*	čokolada	*chocolate*
4	vrata	*door*	kuća	*house*	prozor	*window*	puder	*baby powder*
45	automobile	*car*	semafor	*traffic lights*	autobus	*bus*	ram	*frame*
46	sako	*coat*	ofinger	*hanger*	jakna	*jacket*	radijator	*radiator*
47	uho	*ear*	minđuša	*earring*	nos	*nose*	pidžama	*pyjama*
48	torta	*cake*	svećice	*candles*	pica	*pizza*	nosorog	*rhinoceros*
49	krevet	*bed*	jastuk	*pillow*	sto	*table*	žica	*wire*
50	čaša	*glass*	slamčica	*straw*	tanjir	*plate*	grožđe	*grapes*
51	more	*sea*	pesak	*sand*	jezero	*lake*	lonac	*pot*
52	kornjača	*turtle*	oklop	*shell*	aligator	*alligator*	trava	*grass*
53	lula	*pipe*	duvan	*tobacco*	cigareta	*cigarette*	fascikla	*folder*
54	pero	*feather*	mastilo	*ink*	krzno	*fur*	frižider	*refrigerato r*
55	zastava	*flag*	trka	*race*	barjak	*banner*	čaj	*tea*
56	naočari	*glasses*	oči	*eyes*	lupa	*magnifier*	jorgan	*quilt*
57	zlato	*gold*	narukvica	*bracelet*	srebro	*silver*	kasetofon	*tape recorder*
58	mesec	*moon*	nebo	*sky*	sunce	*sun*	đon	*sole*
59	brod	*ship*	sidro	*anchor*	gliser	*speedboat*	čiviluk	*hanger*
60	sunđer	*sponge*	deterdžent	*detergent*	krpa	*dishcloth*	rotkva	*radish*
61	bunar	*well*	voda	*water*	česma	*tap*	skije	*skis*
62	jež	*hedgehog*	bodlja	*spines*	medved	*bear*	paun	*peacock*
63	roda	*stork*	dimnjak	*chimney*	galeb	*seagull*	sanke	*sled*
64	klupa	*bench*	park	*park*	kauč	*couch*	rame	*shoulder*
65	bicikl	*bicycle*	staza	*path*	trotinet	*scooter*	šapa	*paw*
66	četka	*brush*	kosa	*hair*	češalj	*comb*	pšenica	*wheat*
67	kašika	*spoon*	supa	*soup*	viljuška	*fork*	senka	*shadow*
68	pegla	*iron*	košulja	*shirt*	mikser	*mixer*	činija	*bowl*
69	tašna	*purse*	novčanik	*wallet*	ranac	*backpack*	kukuruz	*corn*

Appendix 2

Visual stimuli triads used in Experiment 1

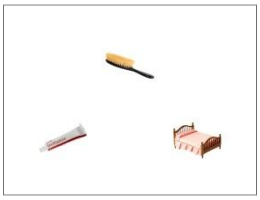

aquarium

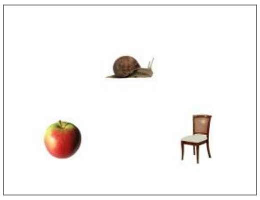

pearl

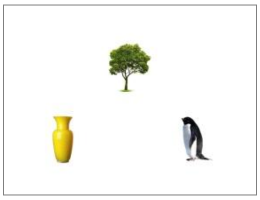

drums

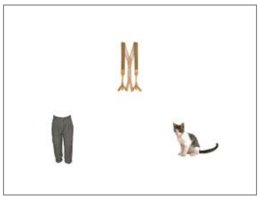

boat

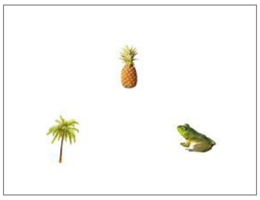

hammer

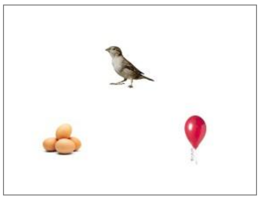

toothbrush

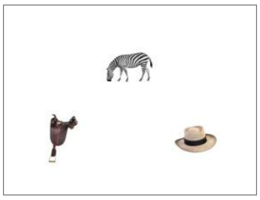

worm


flower


belt

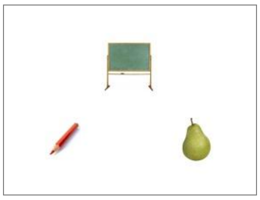

coconut


hen


horse


shirt

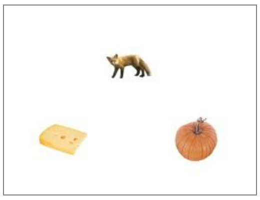

cow


chalk


sparrow


monkey


scissors


mouse

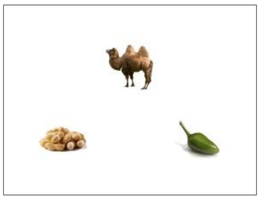

dog

bee

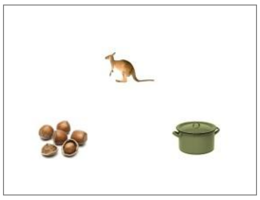
shoelace

pistol

rabbit



elephant

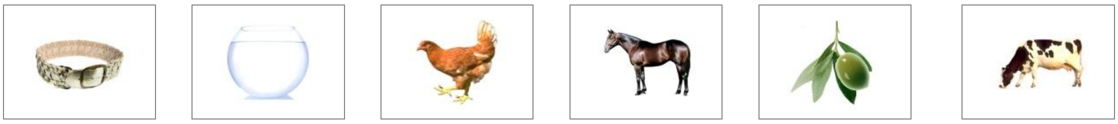


squirrel

Appendix 3

Visual stimuli used in Experiment 5 and Experiment 6

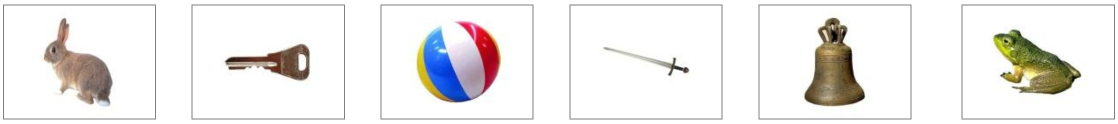
flower *coconut* *boat* *hammer* *worm* *Pearl*



belt *aquarium* *hen* *horse* *olive* *cow*

chalk *pencil* *bird* *monkey* *scissors* *mouse*

dog *bee* *shoe* *cannon* *elephant* *squirrel*

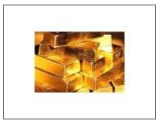
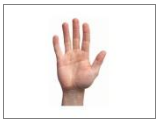


rabbit *key* *ball* *sword* *bell* *frog*

hat *frying pan* *brooch* *ring* *sheep* *castle*

king *church* *crib* *towel* *butter* *Book*

airplane *door* *car* *coat* *Ear* *Cake*

					
bed	*glass*	*sea*	*turtle*	*pipe*	*Feather*
					
flag	*glasses*	*gold*	*hand*	*moon*	*Ship*
					
sponge	*well*	*hedgehog*	*stork*	*bench*	*Bicycle*
					
brush	*spoon*	*iron*	*purse*		

Appendix 4

The pattern of results of the effect of Match Type across six zones

FRONTO-CENTRAL (time windows)

LEFT	M - TX	M - TH	M - NR	TX - TH	TX - NR	TH - NR	RIGHT	M - TX	M - TH	M - NR	TX - TH	TX - NR	TH - NR
baseline	x	x	x	x	x	x	baseline	x	x	x	x	x	x
240	x	x	x	x	x	x	240	x	x	x	x	x	x
260	.02	.04	.05	x	x	x	260	.01	.02	.03	x	x	x
280	.01	.01	.01	x	x	x	280	.00	.00	.00	x	x	x
300	.00	.00	.00	x	x	x	300	.00	.00	.00	x	x	x
320	.00	.00	.00	x	x	x	320	.00	.00	.00	x	x	x
340	.00	.00	.00	x	x	x	340	.00	.00	.00	x	x	x
360	.00	.00	.00	x	x	x	360	.00	.00	.00	x	x	x
380	.00	.00	.00	x	x	x	380	.00	.00	.00	x	x	x
400	.00	.00	.00	x	x	x	400	.00	.01	.00	x	x	x
420	.00	x	x	x	x	x	420	.00	x	.02	x	x	x
440	.02	x	x	x	x	x	440	.01	x	x	x	x	x
460	x	x	x	x	x	x	460	x	x	x	x	x	x
480	x	x	x	x	x	x	480	x	x	x	x	x	x
500	x	x	x	x	x	x	500	x	x	x	x	x	x
520	x	x	x	x	x	x	520	x	x	x	x	x	x
540	x	x	x	x	x	x	540	x	x	x	x	x	x
560	x	x	x	x	x	x	560	x	x	x	x	x	x
580	.03	x	x	x	x	x	580	x	x	x	x	x	x
600	.02	x	x	x	x	x	600	x	x	x	x	x	x
620	x	x	x	x	x	x	620	x	x	x	x	x	x

TEMPORAL (time windows)

LEFT	M - TX	M - TH	M - NR	TX - TH	TX - NR	TH - NR	RIGHT	M - TX	M - TH	M - NR	TX - TH	TX - NR	TH - NR
baseline	x	x	x	x	x	x	baseline	x	x	x	x	x	x
240	x	x	x	x	x	x	240	x	x	x	x	x	x
260	x	x	x	x	x	x	260	x	x	x	x	x	x
280	x	x	x	x	x	x	280	.02	x	.02	x	x	x
300	.01	x	.01	x	x	x	300	.00	.02	.01	x	x	x
320	.00	.00	.00	x	x	x	320	.00	.00	.00	x	x	x
340	.00	.00	.00	x	x	.04	340	.00	.00	.00	x	x	x
360	.00	.00	.00	x	x	.03	360	.00	.00	.00	.01	x	x
380	.00	.00	.00	x	x	x	380	.00	.00	.01	.03	x	x
400	.00	.03	.03	x	x	x	400	.00	.04	x	x	x	x
420	.01	x	x	x	x	x	420	.00	x	x	.05	x	x
440	x	x	x	x	x	x	440	.00	x	x	.04	.03	x
460	x	x	x	x	x	x	460	x	x	x	x	.02	x
480	x	x	x	x	x	x	480	x	x	x	x	x	x
500	x	x	x	x	x	x	500	x	x	x	x	x	x
520	.01	x	.05	x	x	x	520	x	x	.05	x	x	x
540	.00	.02	.05	x	x	x	540	.02	.03	.04	x	x	x
560	.00	.03	x	x	x	x	560	.01	x	.04	x	x	x
580	.03	x	x	x	x	x	580	.02	x	.02	x	x	x
600	x	x	x	x	x	x	600	.04	x	.05	x	x	x
620	x	x	x	x	x	x	620	.03	x	x	x	x	x

PARIETO-OCCIPITAL (time windows)

LEFT	M - TX	M - TH	M - NR	TX - TH	TX - NR	TH - NR	RIGHT	M - TX	M - TH	M - NR	TX - TH	TX - NR	TH - NR
baseline	x	x	x	x	x	x	baseline	x	x	x	x	x	x
240	x	x	x	x	x	x	240	x	x	x	x	x	x
260	x	x	x	x	x	x	260	.05	x	x	x	x	x
280	x	x	x	x	x	x	280	.01	x	.01	x	x	x
300	.00	.02	.00	x	x	x	300	.00	.01	.00	x	x	x
320	.00	.00	.00	x	x	x	320	.00	.00	.00	x	x	x
340	.00	.00	.00	x	x	x	340	.00	.00	.00	x	x	x
360	.00	.00	.00	x	x	x	360	.00	.00	.00	.02	x	x
380	.00	.00	.00	x	x	x	380	.00	.00	.00	x	x	x
400	.00	.01	.01	x	x	x	400	.00	.04	.01	x	x	x
420	.01	x	x	x	x	x	420	.01	x	x	x	x	x
440	x	x	x	x	x	x	440	x	x	x	x	x	x
460	x	x	x	x	x	x	460	x	x	x	x	x	x
480	x	x	x	x	x	x	480	x	x	x	x	x	x
500	x	x	x	x	x	x	500	x	x	x	x	x	x
520	.01	x	x	x	x	x	520	x	x	x	x	x	x
540	.00	x	x	x	x	x	540	.01	x	x	x	x	x
560	.02	x	x	x	x	x	560	.01	x	x	x	x	x
580	x	x	x	x	x	x	580	x	x	x	x	x	x
600	x	x	x	x	x	x	600	x	x	x	x	x	x
620	x	x	x	x	x	x	620	x	x	x	x	x	x

Curriculum vitae

Olivera M. Ilić was born on November 29, 1987. In October 2006, she began her studies of psychology at the Faculty of Philosophy in Novi Sad. In June 2009, she received her bachelor's degree. The same year in October, she enrolled in the master's studies of psychology at the same faculty, under the mentorship of Prof. Vanja Ković, and received her master's degree in September 2011. The title of her master's thesis was "What Drives the Animacy Effect?". She began her PhD studies of psychology in November 2011 at the Faculty of Philosophy in Novi Sad, under the mentorship of Prof. Vanja Ković, and continued the studies under the mentorship of the same professor at the Faculty of Philosophy in Belgrade in November 2012.

During her undergraduate and graduate studies, she was an active member of the Laboratory of Experimental Psychology at the University of Novi Sad. In the fall of 2012, she participated in the activities of the Department of Experimental Psychology, at the University of Oxford, with the funds for her stay at the university stemming from a research visit grant received from the British Scholarship Trust. In 2013, a research visit grant received from the Professor Borislav Lorenc Foundation enabled her to spend two months at the Cognitive Developmental Lab of the Ohio State University, in the spring of 2014.

She has participated in numerous Serbian and international conferences and has also attended international summer schools (ESCoP 2014). She has had her article "In the Absence of Animacy: Superordinate Category Structure Affects Subordinate Label Verification" published in an international journal (PLOS ONE) in 2013.

Прилог 1.

Изјава о ауторству

Потписани-а Оливера Илић

број уписа 4П12-1

Изјављујем

да је докторска дисертација под насловом

The Nature of Conceptual Knowledge - The Role of Thematic and Taxonomic knowledge in the Organisation of Semantic Memory

- резултат сопственог истраживачког рада,
- да предложена дисертација у целини ни у деловима није била предложена за добијање било које дипломе према студијским програмима других високошколских установа,
- да су резултати коректно наведени и
- да нисам кршио/ла ауторска права и користио интелектуалну својину других лица.

Потпис докторанда

У Београду, 22.12.2014.

Olivera Ilić

Прилог 2.

Изјава о истоветности штампане и електронске верзије докторског рада

Име и презиме аутора Оливера Илић

Број уписа 4ПЛД-1

Студијски програм ПСИХОЛОГИЈА

Наслов рада The Nature of Conceptual Knowledge - The Role of Thematic and Taxonomic Knowledge in the Organisation of Semantic Memory

Ментор prof. Vanja Ković

Потписани Оливера Илић

изјављујем да је штампана верзија мог докторског рада истоветна електронској верзији коју сам предао/ла за објављивање на порталу **Дигиталног репозиторијума Универзитета у Београду.**

Дозвољавам да се објаве моји лични подаци везани за добијање академског звања доктора наука, као што су име и презиме, година и место рођења и датум одбране рада.

Ови лични подаци могу се објавити на мрежним страницама дигиталне библиотеке, у електронском каталогу и у публикацијама Универзитета у Београду.

Потпис докторанда

У Београду, 22.12.2014.

Olivera Ilić

Прилог 3.

Изјава о коришћењу

Овлашћујем Универзитетску библиотеку „Светозар Марковић“ да у Дигитални репозиторијум Универзитета у Београду унесе моју докторску дисертацију под насловом:

The Nature of Conceptual Knowledge - The Role of Thematic and Taxonomic Knowledge in the Organisation of Semantic Memory

која је моје ауторско дело.

Дисертацију са свим прилозима предао/ла сам у електронском формату погодном за трајно архивирање.

Моју докторску дисертацију похрањену у Дигитални репозиторијум Универзитета у Београду могу да користе сви који поштују одредбе садржане у одабраном типу лиценце Креативне заједнице (Creative Commons) за коју сам се одлучио/ла.

1. Ауторство
2. Ауторство - некомерцијално
3. Ауторство – некомерцијално – без прераде
4. Ауторство – некомерцијално – делити под истим условима
5. Ауторство – без прераде
6. Ауторство – делити под истим условима

(Молимо да заокружите само једну од шест понуђених лиценци, кратак опис лиценци дат је на полеђини листа).

Потпис докторанда

У Београду, 22.12.2014.

Olivera Ilić

1. **Ауторство** - Дозвољавате умножавање, дистрибуцију и јавно саопштавање дела, и прераде, ако се наведе име аутора на начин одређен од стране аутора или даваоца лиценце, чак и у комерцијалне сврхе. Ово је најслободнија од свих лиценци.

2. **Ауторство – некомерцијално.** Дозвољавате умножавање, дистрибуцију и јавно саопштавање дела, и прераде, ако се наведе име аутора на начин одређен од стране аутора или даваоца лиценце. Ова лиценца не дозвољава комерцијалну употребу дела.

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4. **Ауторство - некомерцијално** – делити под истим условима. Дозвољавате умножавање, дистрибуцију и јавно саопштавање дела, и прераде, ако се наведе име аутора на начин одређен од стране аутора или даваоца лиценце и ако се прерада дистрибуира под истом или сличном лиценцом. Ова лиценца не дозвољава комерцијалну употребу дела и прерада.

5. **Ауторство – без прераде.** Дозвољавате умножавање, дистрибуцију и јавно саопштавање дела, без промена, преобликовања или употребе дела у свом делу, ако се наведе име аутора на начин одређен од стране аутора или даваоца лиценце. Ова лиценца дозвољава комерцијалну употребу дела.

6. **Ауторство** - делити под истим условима. Дозвољавате умножавање, дистрибуцију и јавно саопштавање дела, и прераде, ако се наведе име аутора на начин одређен од стране аутора или даваоца лиценце и ако се прерада дистрибуира под истом или сличном лиценцом. Ова лиценца дозвољава комерцијалну употребу дела и прерада. Слична је софтверским лиценцама, односно лиценцама отвореног кода.