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PROCESSING DIFFERENT TAXONOMIC AND THEMATIC CONCEPTUAL RELATIONS: A LIFESPAN INVESTIGATION

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ΠΕΡΙΛΗΨΗ

Στο πλαίσιο της παρούσας διατριβής διερευνήθηκαν οι μηχανισμοί επεξεργασίας ταξινομικών και θεματικών σημασιολογικών σχέσεων σε πληθυσμό ηλικίας από 6 έως 63+ ετών. Ο στόχος της έρευνας ήταν η διερεύνηση της επίδρασης διαφορετικών πειραματικών συνθηκών στην επεξεργασία σημασιολογικών σχέσεων στις ηλικιακές ομάδες του πληθυσμού της έρευνας. Διενεργήθηκαν τρία ξεχωριστά πειραματικά έργα, τα οποία διαφοροποιούνταν ως προς το σθένος της σημασιολογικής συσχέτισης ανάμεσα στο ζεύγος στόχου – δοκιμασίας (δυνατή ή αδύνατη συσχέτιση) και το είδος της σημασιολογικής σχέσης (ταξινομική ή θεματική σχέση). Στο πρώτο πείραμα, μελέτη προπαρασκευαστικών συμφραζόμενων (priming), καταγράφηκαν η ακρίβεια των απαντήσεων και ο χρόνος αντίδρασης. Τα αποτελέσματα υποδεικνύουν πως τόσο η ακρίβεια όσο και ο χρόνος αντίδρασης διευκολύνθηκαν στις ισχυρά συσχετιζόμενες σημασιολογικά έννοιες, για όλες τις πειραματικές ομάδες, γεγονός που υποδηλώνει την ύπαρξη συνειρμικής ώθησης. Το είδος της σημασιολογικής σχέσης και η ηλικία δεν φάνηκαν να αλληλοεπιδρούν, υποδεικνύοντας ότι τόσο οι ταξινομικές όσο και οι θεματικές σχέσεις διευκόλυναν ως προπαρασκευαστικά συμφραζόμενα την κατονομασία, τόσο στα παιδιά όσο και στους ενήλικες συμμετέχοντες, επιταχύνοντας την επεξεργασία. Το δεύτερο (τριάδες) και τρίτο (αναλογίες) πειραματικά έργα έδειξαν ότι τόσο οι ταξινομικές όσο και οι θεματικές σχέσεις αποτελούν σημαντικά στοιχεία του σημασιολογικού δικτύου. Αυτό αποδείχθηκε από την ευκολία των νεαρών συμμετεχόντων να ταξινομήσουν τόσο θεματικά όσο και ταξινομικά στο έργο με τις τριάδες; αλλά και από το πόσο όλοι οι συμμετέχοντες ήταν σε θέση να εντοπίσουν και τους δύο τύπους των σημασιολογικών σχέσεων (ταξινομικές και θεματικές) στην φάση αναγνώρισης του πειράματος με τις αναλογίες. Συνάγεται το συμπέρασμα ότι, οι συμμετέχοντες όλων των ηλικιών έχουν επίγνωση τόσο θεματικών όσο και ταξινομικών πληροφοριών που αφορούν στις έννοιες, αλλά καθώς οι απαιτήσεις της γνωστικής επεξεργασίας αυξάνονταν κατά την κατηγοριοποίηση (κάτι που φάνηκε να ισχύει στους νεαρότερους και γηραιότερους πληθυσμούς της έρευνας), οι συμμετέχοντες παρουσίασαν την τάση να επεξεργάζονται με μεγαλύτερη επιτυχία εκείνες τις σημασιολογικές πληροφορίες, οι οποίες φαίνεται να έχουν μεγαλύτερη σημασία και που ίσως να είναι ευκολότερες για τους ίδιους, και αυτές φαίνονται να είναι οι θεματικές πληροφορίες.

ABSTRACT

The processing of taxonomic and thematic conceptual relations was investigated in individuals ranging from 6 years of age to 63+ years of age. The associative strength between target and associates (strong or weak), as well as the type of conceptual relation (taxonomic and thematic) were manipulated independently in three different experimental tasks, in order to determine their respective effects on the processing behavior of the different age groups. In Experiment 1, the priming experiment, naming accuracy and reaction time were facilitated by strongly associated pairs for all age groups, suggesting an associative boost. The type of conceptual relation and participants' age group did not yield an interaction effect, indicating that both taxonomic and thematic pairs primed the naming abilities of children and adults by speeding their processing. Experiment 2 and 3, a triadic task and an analogies task respectively, revealed that both taxonomic and thematic relations are important in conceptual content. This was evidenced by how the young participants were equally likely to categorize thematically as well as taxonomically in the triadic task; but also by how all participants were able to identify both types of conceptual relations (taxonomic and thematic) in the identification phase of the analogical experiment. This supports that taxonomic information is interweaved with background knowledge of events and schemas. It is concluded that humans across all ages are generally aware of both thematic as well as taxonomic relations, but as cognitive demands required by category construction, become more demanding (something that was apparent in the younger and older groups of the study), they tend to attend to functions that are more salient and possibly easier for them to process, and these appear to be the thematic ones.

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Chapter 1
Introduction

The purpose of the present research is to investigate the processing of taxonomic and thematic relations across the life span. The document begins with a brief overview of key concepts, followed by a discussion on theories of semantic organization, before the presentation of each of the three experiments. It concludes with a general discussion aiming to integrate the findings from the three experiments.

Concepts are the mental representations that symbolize the world around us. Without concepts individuals would fail to communicate efficiently and effectively with each other. When we are exposed to an unfamiliar object, travel abroad, read a scientific article or the newspaper, talk to a colleague or resolve a conflict between our offspring, we certainly rely on our conceptual knowledge to help us decode what is happening.

Someone might not appreciate the accomplishment when a child successfully labels the house pet, or when an eighty year old grandmother uses a letter opener appropriately. However, patients as well as caregivers of patients suffering from a neurological condition that affects semantic memory (e.g., dementia of any type) will tell you that the effects of a disrupted conceptual system are devastating.

Semantic knowledge refers to the lexical representations that allow individuals to discuss and reason about objects and events around them; the memory system involved in the representation and processing of such knowledge is called semantic memory (Cree & McRae, 2003). As a result, semantic organization deals with how semantic memory is represented and organized.

Semantic memory is a well-organized system. This is evident by the speed and accuracy with which semantic information is activated and accessed when a word is encountered or retrieved (McClelland, 1994; Murphy, 2002; Rogers & McClelland, 2004). Intact semantic knowledge is an important requirement of linguistic competence. Linguistic competence refers to the system of linguistic knowledge possessed by the native speakers of a language and how this is used to effectively communicate (Chomsky, 1965). It does not rely solely on semantic memory. It involves all the components that make up language, namely content, form and use. The content domain refers to semantics. The form domain consists of specific structures of language, including phonology, morphology, and syntax. Pragmatics reflects the different uses, or functions, of language that the child communicates through verbal or non-verbal communication.

In the classic Bloom and Lahey (1978) model of language development, all features of language are intertwined, so a deficit in one may be accompanied by, or result in, a deficit in another. The authors argue that conceptual knowledge seems to carry more weight because it is a necessary requirement in order to develop form and use.

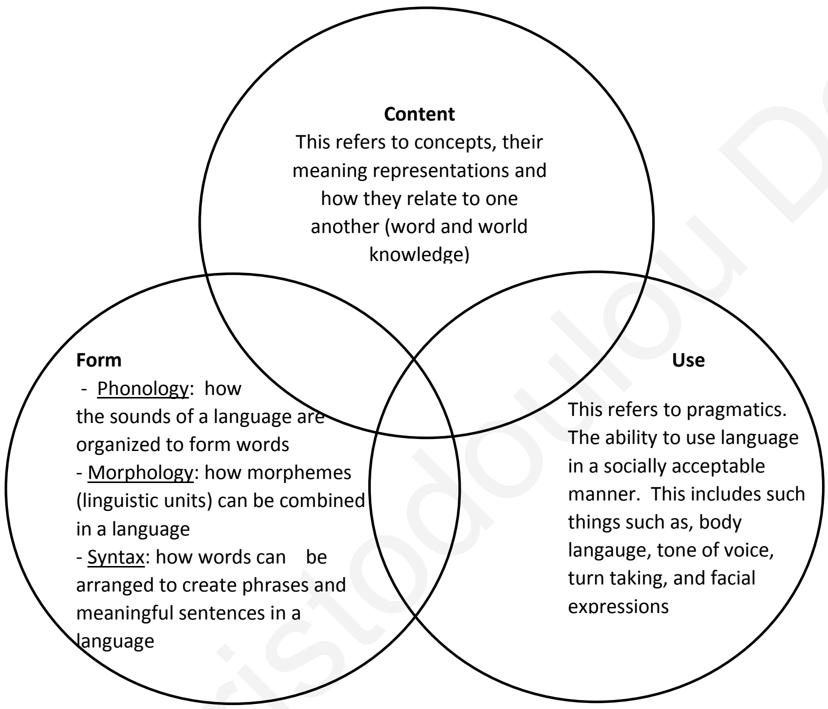


Figure 1 Bloom and Lahey's model showing how the three areas of language are interconnected.

Conceptual knowledge plays a primary role in language comprehension and production. As McCarthy (2006) argues, natural language processing is dependent on the knowledge of the vocabulary of the language being processed. As a result, it comes as no surprise that concept learning and conceptual representation has received wide attention in the cognitive neuropsychological literature.

Evidence suggests that words can be acquired quickly (Schafer & Plunkett, 1998) and that acquisition skills seem to be present throughout life (Saffran, Newport, Aslin, Tunick, & Barrueco, 1997). Estimates of children's vocabulary growth indicate that children typically will acquire 14000 words by age 6 (Carey, 1978). The present research will focus on conceptual representation. Specifically, the study will attempt to answer the following questions via three different experiments. (1) In an implicit task such as priming, would taxonomic or thematic relations prime faster, and would a taxonomic or thematic facilitation be consistent throughout the life span? (2) In an explicit task, such as a forced-choice category task, will categorization favor thematic or taxonomic relations, and will this be consistent throughout the life span?, (3) In an explicit task, such as justification of a conceptual relation as well as applying a conceptual relation to a new set of stimuli, would participants find it easier to justify and apply thematic or taxonomic relations, and would this be consistent throughout the life span?

Important definitions

Semantic Task: Rogers and McClelland (2004), define a semantic task as one that requires a person "*to produce or verify semantic information about an object, a depiction of an object, or a set of objects indicated verbally*" (p.2). For instance, verifying that an object presented in a picture is a dog, or that the pictured object can bark. A verification sentence like, "a canary is a bird", is also a semantic task. They define semantic information as, "information that has not previously been associated with the particular stimulus object itself … … and that is not available more or less directly from the perceptual input provided by the object or object depiction" (p.5). For example, verifying that two objects depicted in color, have the same color, is not a semantic task. This is because the judgment can be made based purely on the perceptual information (color), without reference to semantic information about the object.

Semantic relations: Khoo and Na (2006) defined semantic relations as "meaningful associations between two or more concepts, entities or sets of entities. They can be viewed as directional links between the concepts/entities that participate in the relation. The concepts/entities are an integral part of the relation as a relation cannot exist by itself but has to relate two things" (p.158). Therefore words can be related, categorically, if they have similar perceptual features (Medin & Ortony, 1989), in other words, if they share common essence (Hashimoto, McGregor, Graham, 2007). These, for example, include category co-ordinates whether those are living things (e.g., cat and dog) or artifacts (e.g., pen and pencil). Words can also be related thematically, if they are related by themes and are bound by an event schema (Shank & Abelson, 1977).

Taxonomic relations: Taxonomic structures are generally divided into superordinate, subordinate and coordinate links. Superordinate categories are those that are the highest in the structure (e.g., living things). Subordinate are lower in the structure (e.g., vegetables) and coordinates are the last link in the structure, and occur at the same level (e.g., carrot and zucchini) (Collins & Quillian, 1969).

Thematic relations: Words are related thematically, if they are related by themes and are bound by an event schema (Shank & Abelson, 1977). Some relations that bind objects into themes include: (1) *spatial* if "at x you can find y" (e.g., in a cellar you find wine), (2) *script* "if the relation was part of a learned schema" (e.g., a bear eats honey), (3) *part whole* if "x is literally part of y" (e.g., a wing is part of an airplane), (4) *functional* if "x is used to perform an action on y" (e.g., belt is used to hold up trousers), (5) *featural* if "y is an attribute of x" (e.g., a giraffe is tall), and (6) *causal* if "x results in y" (e.g., clouds can result in rain).

Associative relatedness: Associative relatedness comes from normative association norms. In this context, association between words is defined in terms of the probability that the second member of any word pair will be offered as a free associate in response to the first (Nelson, McEvoy, & Dennis, 2000). Word association response frequency is commonly used as an index of semantic relatedness and is assumed to reflect the strength of the connection between the semantic representations of the words in memory (Burke, Peters, & Harrold, 1987).

Therefore, if objects and events occur in an organized manner and in typical relationships then we should be able to identify the strong relations between concepts, whether those are taxonomic or thematic in nature.

Contributions of the current study and an Overview of the Methodology

It is commonly accepted that concepts have important connections. Research should explore which types of semantic relations are strongest. Given that semantic relations reflect the richness of human interactions with the world, they cannot be limited only to category membership (e.g., lion-animal). Instead, relations representing a wide range of thematic connections, such as conceptual functionality (e.g., key-lock), or bound by a script (e.g., wedding-bells) should also be investigated.

Existing research is restricted to investigating a limited number of semantic relations at a time. Researchers would often limit their experimental tasks to investigate only two types of semantic or associative relations. It is not enough to distinguish between associative and semantic relations. A need to identify and investigate specific types of semantic relations and how they compare to associative relations, is paramount. For instance, in many studies semantic relatedness has been treated to mean category membership and associative relatedness has been taken to refer to a functional association. Many semantic relations exist other than categorical membership. For instance, concepts might be related because they co-occur in space, or time, or because one is part of the other, to name just a few ways concepts can be associated. Sometimes it is impossible to define a word without referring to such associative information (Moss, Ostrin, Tyler, & Marslen-Wilson, 1995), which therefore makes it part of the concept's semantic representation and hence associative information calls for investigation.

The results of many conceptual studies, which include but are not limited to priming studies, picture naming interference studies, categorization studies (for example through free sorting paradigms, or forced choice paradigms), ERP and fMRI studies looking at brain activation for specific semantic relations, concept learning studies, false memory paradigm studies, and computational studies; both with normal as well as neurologically impaired individuals, seem to suggest that a wide range of semantic connections are activated when a word is encountered. However, in most of these studies a very limited range of semantic information has been investigated that often failed to control for normative association as well as semantic relatedness.

Further, most of the research done on concepts is in English with native English speakers. Given the intimate relationship between language and culture, investigating semantic organization with speakers of other languages may shed some additional information. The present study will incorporate native speakers of Greek in order to investigate the strength between different semantic relations, and whether this changes at different stages of life.

Finally, the pilot study, as described in Experiment 1, will create much needed word association databases for the Greek population and at the same time will contribute valuable artifacts to the international body of research regarding conceptual relations, as these were explored in a Greek speaking population.

The experiments will employ implicit and explicit tasks in order to explore the consistency of the conceptual relation effect. The study will investigate conceptual relations (taxonomic vs thematic) by systematically varying the type of relation between prime (one stimulus) and target (another stimulus), as well as their associative strength. Through a systematic attempt to study taxonomic and thematic conceptual relations, three experiments have been designed, in an effort to investigate the representation and manipulation of these conceptual relations throughout the lifespan. Stimuli for the experimental tasks were carefully selected through a pilot study that was completed to establish Greek word normative association norms, so that tasks could be formulated accordingly.

This experimental endeavor is differentiated from previous studies in three major ways. *First*, it differs from previous studies in terms of the number of conceptual relations used. As stated earlier, although previous studies have also looked at taxonomic and thematic conceptual relations and their representations in the human brain, yet the two categories were comprised of a limited amount of relations. For instance, many researchers when looking at taxonomic relations, only looked at subordinate relational pairs (e.g., animal-horse) or coordinate relational pairs (e.g., cow-horse). Similarly when thematic relations were studied, they were limited to a small number of thematic relations, such as functional pairs (e.g., broom-floor), script pairs (e.g., mouse-cheese), or causal pairs (e.g., cloud-rain).

This study attempted to investigate a number of different taxonomic conceptual pairs as well as a number of thematic pairs, while controlling for normative association strength. **Taxonomic pairs** included, (1) *superordinate living (e.g., leopard-animal)*, (2) *subordinate living (e.g., dove-bird)*, (3) *superordinate artifact (e.g., trumpet-musical instrument)*, (4) *coordinate living (e.g., gorilla-monkey)*, (5) *coordinate artifact (e.g., fork-knife)*. **Thematic pairs** included, (1) *spatial* (e.g., military camp-soldier), *script* (e.g., lollipop-child), *part whole* (e.g., shoe-shoe lace), *functional* (e.g., cup-coffee), *featural* (e.g., strawberry-red), *causal* (e.g., gun-death).

Secondly, this study differs from previous studies in that it aims to investigate conceptual relations throughout the lifespan. By utilizing six different age groups, it attempts to study conceptual representation and whether that changes at different ages. The same six groups used in all three experiments were: 6-year olds, 9-year olds, 12-year olds, 15-year olds, 18-35 year olds, and 63+ year olds.

Thirdly, this study utilizes both an implicit task (unconscious task – these are tasks that are not dependent on evaluating the semantic relationship between a prime and a target and hence are more automatic in nature) as well as two explicit tasks (connscious tasks – these are tasks that require participants to make a decision about a target and hence are not automatic in nature), in order to get a clearer picture of the representation of object concepts in a within experimental design.

Experiments and Hypotheses

Experiment 1: The priming study

The representation of conceptual relations (taxonomic and thematic) were studied, by comparing participants' performance in a naming priming task. Reaction times and accuracy measures were collected in order to determine which types of conceptual conditions resulted in faster priming.

Hypothesis:

Since previous research suggests that preference to thematic information seems to develop early (Mandler, 1983; Scott, Serchuk, & Mundy, 1982) and deteriorate later in life (Glosser & Friedman, 1991; Moss et al., 1995; Tyler & Moss, 1998), it is hypothesized that thematically related word pairs will facilitate faster responses for the very young and very old participants. An associative boost is also hypothesized for all conceptual relations for all participant groups.

Experiment 2: The triadic study

The goal of this experiment was to compare the relative effects of associative strength and type of conceptual relation on the categorical choices of young and older children as well as young and older adults, through a triadic, forced-choice category construction task.

Hypothesis:

It was hypothesized that if categorical choices were primarily driven by associative strength, then strong associates would be more frequently chosen than weak associates in all conceptual configurations [both homogeneous (i.e., taxonomic/taxonomic pairs) and heterogeneous (i.e., taxonomic/thematic pairs)]. Alternatively, if both associative strength and conceptual relation have an influence on categorical choices, then this would be observed in heterogeneous configurations. It was hypothesized that thematic relations will have an advantage in the preferences of 6-year olds and the elderly participants.

Experiment 3: The analogies study

This experiment had two aims. *Firstly*, it aimed to draw conclusions regarding thematic and taxonomic representations, through a justification task, where participants were asked to justify how two concepts were related and then assess their ability to switch to a different task, and extend the relationship identified to a new set of pictures. Therefore, the *second* aim, was to investigate whether the type of conceptual relation (taxonomic or thematic) would have an effect on switching, analogical thinking, and categorical flexibility performance across the six different age groups.

Hypothesis:

It was hypothesized that young children and older adults would have more difficulty to switch from justifying a relationship to extending it to a new set of pictures. Additionally, it was hypothesized that extending a taxonomic relation in the presence of a thematic associate (which seems to be more salient for younger children and older adults) involves a greater resistance to interference than would the opposite situation. Therefore, it was expected that the type of semantic relation should affect the extension performance of young children and older adults, with better performance when thematic relations are involved. Provided older children and younger adults have better abilities in resisting interference, this thematic relation effect should not be present.

Significance of the study

The study objectives and anticipated outcomes will have important implications for the development of evaluation and intervention programs to meet the needs of the largest growing social group of our society, the elderly population (WDI, 2009). Life expectancy has increased for both genders in the last century. In Cyprus, particularly, life expectancy for males is 79 years, while for females 83 years (WDI, 2009). In light of this extended life span, research has been investigating the exact neuroanatomical alternations and behavioural manifestations in this aging group in order to differentiate normal aging from populations with neurological damage. This study will incorporate participants across the life span and will obtain information on a continuum of semantic performance for healthy individuals. Results from this study will provide information on semantic organization and will mark the beginning of a systematic attempt in determining the effects of degenerative brain pathology on semantic organization. These findings will guide the development of theory driven diagnostic and management procedures in the future. This is important, as appropriate diagnosis and management of semantic deficits can enhance the quality of life and the productivity of older adults.

Of course analyzing the characteristics of semantic connections in the semantic network will not only have future implications for the aging population; establishing which semantic relations are the strongest could also have clinical implications for the developing brain as well. For instance, if semantic representations comprise a less distributed network in high-functioning adults with Pervasive Developmental Disorder (Beversdorf et al., 2000), then clinicians could concentrate their intervention to teaching the most important semantic relations first as a goal to more efficient communication. Similarly, children with Specific Language Impairment are reported to have difficulties with semantic representations manifested as limited semantic knowledge (McGregor, Newman, Reilly and Capone, 2002; Kail, Hale, Leonard and Nippold, 1984). With these children too, intervention could follow a hierarchy of semantic relation exposure from most powerful to least powerful allowing again for successful and efficient semantic integration which will have both ecological, as well as academic implications.

The study will provide important information to clinicians about semantic targets that are more likely to yield the most favorable outcomes. This will create a significant benefit and will have substantial implications for the clinical intervention of children and adults who face semantic difficulties. An identification of which semantic relations bear the most powerful connections will allow efficacy intervention techniques to be implemented with populations in need, in an attempt to develop, preserve and possibly restore lost abilities.

Of course one cannot disregard the benefits this will have on the normal aging adult as well. It is an empirical fact that response times for aging individuals decrease with age. An insight to important semantic connections could yield strategies that even the normal aging adult could implement to compensate for cognitive changes.

This challenging notion of conceptual structure, carries the essence of language (meaning) and makes communication efficiently possible. Furthermore, it is right at the intersection of language and cognition which makes it interesting and fascinating to study.

Chapter 2

Theories of Semantic Organization

In this chapter, classical theories of semantic organization are reviewed in laying the foundation for the proposed study. The question of how knowledge is represented has been troubling scientists for decades, with researchers still pursuing to resolve this issue.

Work conducted in the 1970s and 1980s promoted theories that supported a categorical representation of semantic knowledge. These models suggest that a representation exists in semantic memory that corresponds to a category and hence performance on semantic tasks depends on access to the relevant category representations.

Early accounts for taxonomic organization aimed to determine how categorical relationships were represented in memory and how these representations could be accessed for use. The idea that semantic memory was organized categorically bared some logical reasoning before it was supported by empirical evidence. For instance, many things in the world are observed to cluster together. Take into account human beings, who from the Paleolithic Age aimed at living in groups with people that shared the same characteristics as they did.

Similarly, attributes are not distributed randomly among concepts as they are experienced in the world. They have a tendency to clump together. Therefore it is not surprising to think that we would seek to identify clusters of words and classify them by giving them names. This would not only allow for simpler encrypting of the world, hence result in cognitive economy, but would also imply faster learning, as it would allow us to make predictions about novel concepts.

Following this logical idea of concepts clustering together to reflect a taxonomic categorization, researchers investigated models that would explain exactly how this organizational structure was comprised. As a result, many categorization based models have been proposed in the literature, and approaches usually fall under two theoretical frameworks: (1) Hierarchical mechanisms and (2) Similarity based mechanisms.

Categorization based models have a taxonomic class inclusion constraint. For example, if an object is a kind of bird, then it must also be a kind of animal. Here defining features that allow for category membership are sufficient. If something has the defining features, then it is automatically a category member.

Table 1 Categorization based models and their main premises

Taxonomic Hierarchies	Concepts are organized in a hierarchy from superordinate to subordinate to co-ordinate. Network links represent category membership relations and property relations. This model supports property inheritance where properties which are true of superordinate categories transfer to all links in the network. This implies that information is stored only once in the network which in turn supports cognitive economy.
Similarity Based Approaches	Concepts in this model are stored based on their similar properties (the more features they share the closer they will be in the network). Categories are not represented in the organization structure but can be computed based on featural overlaps.

Table 2 Empirical phenomena consistent with categorization based models

Taxonomic Hierarchies	1. Broad category representations are acquired first by children. Development follows the taxonomic structure to achieve finer differentiation of concepts. 2. Categorical representations at the top of the taxonomy are the first to be accessed during retrieval and the last to be lost in dementia.
Similarity Based Approaches	Children acquire basic category representations first. They use these basic level terms as the first names for the world around them.

(1) Hierarchical Model

One of the most studied semantic networks that were investigated in the 1970s was the one proposed by Collins and Quillian (1969) who presented a taxonomic hierarchical network model, with related categories, which they supported was an efficient mechanism for storing and retrieving semantic information.

This hierarchical model can be understood by reference to figure 2. In dealing with the terminology, superordinate categories are categories that are higher in the hierarchy to the lower level categories (e.g., as presented in figure 2 animal is the superordinate category of bird and fish). In turn lower level categories are subordinate to the higher level ones.

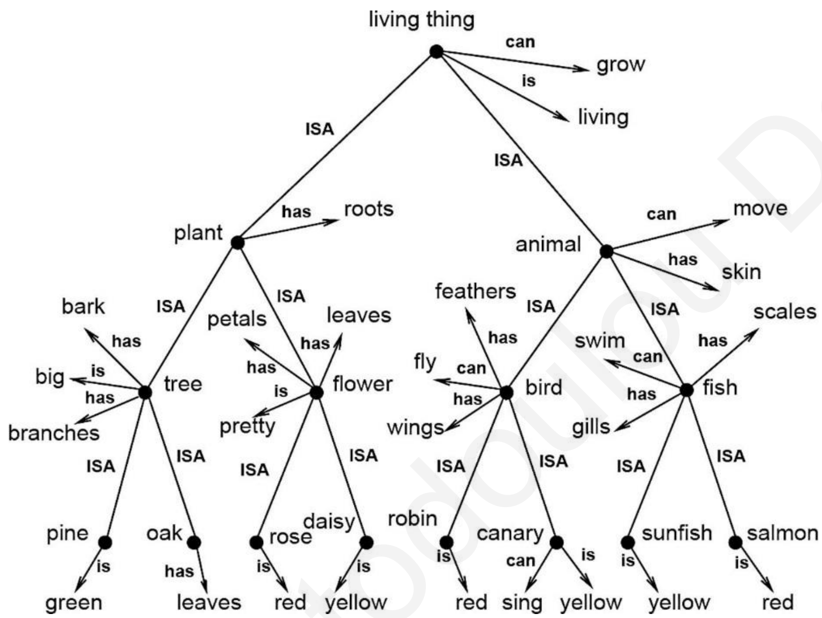


Figure 2 A hierarchical semantic network proposed by Collins and Quillian. The schematic indicates that living things is a superordinate category for plants and animals, and that properties of living things (e.g., can grow), directly transfer to the subordinates plant and animal as well as their subordinates without having to be stored directly at their level. Copied from figure 1.2 of "Semantic Cognition. A Parallel Distributed Processing Approach" (p. 6), by T. T. Rogers and J. L. McClelland, Cambridge: MA, MIT Press.

Note that concepts in the model are connected together by different types of relations. There are two different types of relations in this model. One is category membership relations, represented by the *IS-A* link, and the other relates to property relations, designated by the *is, has*, and *can* links.

One of the arguments in favor of the hierarchical account is the *property inheritance* amongst members of a category. Property inheritance dictates that every property true of the superordinate category must also be true of the category's subordinates. Therefore, this classification mechanism allows generalization of knowledge. It permits individuals to treat different things as similar and hence allows for successful predictions and reasoning about unfamiliar parts of the world (Rogers & McClelland, 2004). New information could be stored at the superordinate category node, and would then automatically be inherited by all subordinate concepts. Similarly, a new subordinate category could be added as a subcategory of a more general category, and existing knowledge about the superordinate category would automatically generalize to it.

Collins and Quillian's (1969) model then dictates that information in the hierarchical structure is stored only once in the network as hierarchies allow for inheritance of properties. This assumption therefore allows for *cognitive economy*. By representing "moves" with the animal node, one does not need to store the fact that mammals move, fish move, reptiles move, dogs move, bulldogs move, and so on (Murphy, 2002). This information is stored just once and is made available to other nodes through a network of relations. To explain the access to the nodes in their model, they proposed a transversing mechanism that permitted the activation of a category representation to spread to taxonomically superordinate and subordinate concepts. Under this view, when an object is categorized as fish, activation of the concept fish, also activates the related concept animal, and hence properties that are stored at the node animal, automatically are applied to the concept fish.

Although this model is appealing, and can explain quite a few of the experimental phenomena observed in the literature, certain key predictions of the model did not hold up to experimental tests. This was despite the data collected by Collins and Quillian that provided strong support for their model. Collins and Quillian assumed that traversing the links in their proposed network would take time, and that one could predict the response time for judging the truth/falsity of a sentence (e.g., "An ostrich is a bird") depending on the number of links needed to be traversed in order to verify the sentence. In other words, the time that is taken to verify a proposition is a measure of the distance between different concepts in the internal lexicon.

Based on this assumption they predicted that propositions stored directly with a concept would be verified the fastest, with verification time increasing in relation to the number of links that would have to be traversed to find the category in question. For instance, robin and ostrich are both subordinates of bird and one link away from bird, so they should take equal time to verify. To test this prediction, researchers devised a speeded category verification task. Subjects were shown propositions about object categories, and were asked to decide as quickly and as accurately as possible whether the proposition was true.

The results obtained from this speeded semantic task did not verify the theorized assumption. Although robin and ostrich are both subordinates of bird and one link away from bird, and should hence take equal time to verify, they do not. Work by Rips, Shoben, and Smith (1973), attributed this phenomenon to the *typicality* effect. They used statements in their verification task that utilized subordinates of a category (like robin and ostrich) that were both one IS-A link away from the superordinate category, and hence should take about the same amount of time to evaluate. However, Rips et al. (1973) found that statements which included typical terms, such as robin, took less time to verify than those including atypical terms, such as ostrich.

This suggests a graded membership phenomenon – not all members of a category are equally good (Rogers & McClelland, 2004). Category members vary widely in terms of typicality. For instance, a typical example of a bachelor would be Britain’s most famous bachelor, Prince Harry. An atypical example would be the Pope. In line with faster responses in semantic judgments regarding typical concepts, typical category examples are more readily produced than atypical examples in cognitive tasks where subjects are asked to list examples of a category (Rosch, 1975).

Further, Rips et al. also reported that some category relations that cross two IS-A links are verified faster than category relations that crossed only one IS-A link. For example, subjects were faster at verifying “A dog is an animal” than “A dog is a mammal”, because a dog is a more typical animal than a mammal.

The notion of cognitive economy suggested by the hierarchy was challenged by Conrad (1972). She argued against the idea that properties are only stored ones at the superordinate concept to which they apply. She supported instead that the degree of association between the concept and the property is a very important factor and should be taken into account. She tested subjects with verification statements such as “A robin is red-breasted” and “A robin can breathe”. Her results indicated faster responses as the degree of association between the subject and predicate increased.

Additionally, Hampton (1982) showed that people do not follow the rules of transitivity that are dictated by a hierarchical model. For example his subjects verified that a car seat was an example of chair. They also agreed that a chair is a piece of furniture, but failed to recognize a car seat as a kind of furniture. If his subjects were relying on the IS-A links in their hierarchical networks, they would not have dismissed this relation. Similar findings regarding transitivity were reported by Osherson, Smith, Wilkie, Lopez & Shafir (1990).

Finally, Sloman (1993) also provided evidence that do not support a hierarchical network. Sloman gave his subjects one-step logical inferences for which subordinates varied in their typicality. For example "Birds have an unlnar artery. Therefore, robins have an ulnar artery" for the typical member, or "Birds have an unlnar artery. Therefore penguins have an ulnar artery" for the atypical member. He found that statements with typical items were stronger than statements with atypical items. Sloman argued that subjects are more likely to compute the similarity of category members to their superordinate, rather than reflect back to a pre-stored hierarchical structure.

Findings that served to discredit the Collins and Quillian's hierarchical model, in summary the typicality effects, intransitivity of class inclusion, and evidence from reaction time experiments provided the ground for the similarity based models.

(1) Similarity Based models

Smith, Shoben and Rips (1974) proposed the Feature Comparison Model, which was an alternative to Collins and Quillian's model. The main premises of this model are: (a) concepts in semantic memory are not hierarchically stored, rather they are stored as sets of attributes, called semantic features, (b) the primary determinant of verification time is the relatedness of the subject and predicate, and (c) category membership relationships are computed.

Similarly, Collins and Loftus (1975) proposed the spreading activation model, which moved away from the hierarchical model proposed by Collins and Quillians to a model where links between concepts represent the degree of their relatedness and semantic similarity. Alternatively, the links could be the result of co-occurrence in the language. And hence, reaction times for conceptual tasks in this model would depend on the length of the link between concepts. Therefore, the activation of one of the links in the model, will lead to the activation of connected nodes. The degree of activation is expected to decrease as a function of distance.

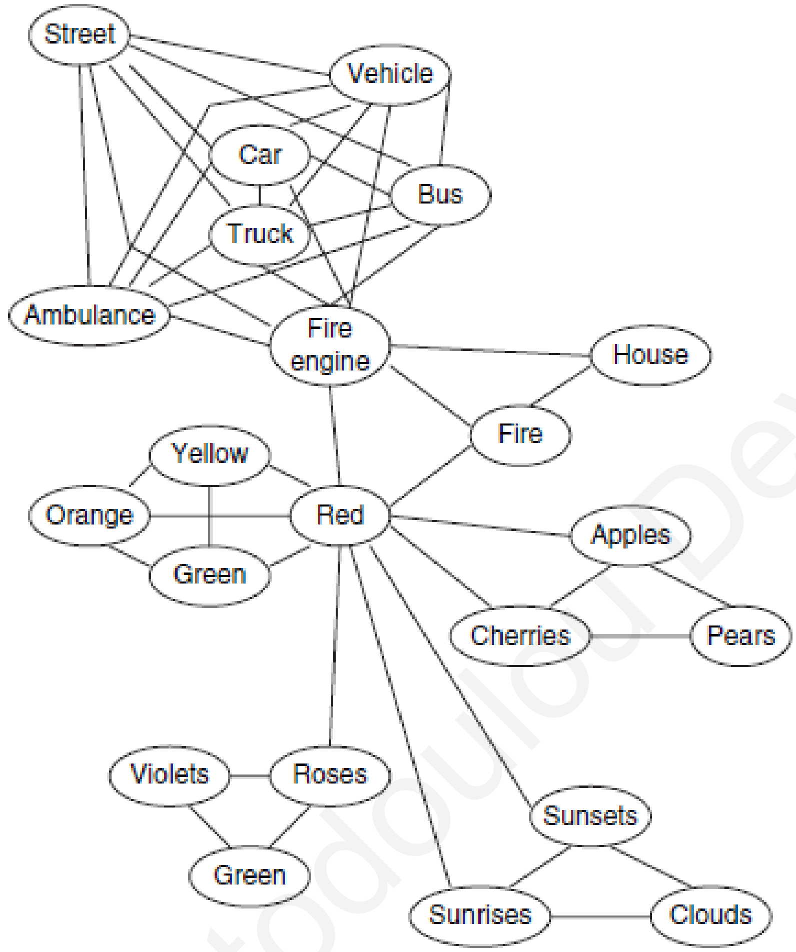


Figure 3 The spreading activation model proposed by Collins and Loftus. Copied from figure 1.2 of "Semantic Cognition. Semantic Memory (p. 514), by D.A. Balota and J. H. Coane, which appears in Byrne, Eichenbaum, Menzel, Roediger, and Sweatt (Eds.), Handbook of learning and memory: A comprehensive reference. Amsterdam:Elsevier.

Smith et al. (1974) identified *defining features* as opposed to *characteristic features*. Defining features are the ones that are essential in defining a concept and characteristic features are the ones not essential in defining a concept. Attributes that are shared by all members of a category are defining features. Characteristic features are shared by many but not all members of a category. Typical members of a category are those that possess many of the category's characteristic features. In this model, the total number of features associated with a concept increase as the concept becomes more subordinate. The superordinate will always have less defining features than its subordinate. To illustrate, both robin and bird share the same defining features but robin will have additional defining features, such as red-breasted.

Smith's et al. (1974) model was an advancement over Collins and Quillian's model. This model accounted for semantic relatedness, typicality effects and category size effects, and hence did a better job at predicting verification times for true/false statements.

Eleanor Rosch (1975), by also reflecting on typicality and similarity features, put forth the idea of a *prototype*. The prototype view suggests that the prototype is a summary representation of a category as a whole. It is important to note, by referring to a prototype, Rosch did not refer to a single best example of a category. Possibly the best way to understand this view is to view summary representations as lists of features. Think of concepts being represented as features that are most common among category members but also taking into account that some features are more important than others (Murphy, 2002).

In this case concepts will be graded along a dimension of protoypicality, which determines their position within the conceptual organization, from central (including instances which share most or all of the attributes that characterize that concept) to peripheral (including instances which have few of the characteristic attributes).

These prototypes are also referred to as basic-level terms. These can be viewed as lexical entries stored near the middle of the hierarchy to which most of the distinguishing features are assigned. They are the terms that children learn first and adults use when asked to name an example of a category. Items higher in the hierarchy are more abstract. For example, chair is a basic level term, and we can identify several distinguishing features of chairs. In contrast, the superordinate furniture does not readily lead to many such features. In essence, Rosch and Mervis (1975) argued that categories are formed by means of family resemblance.

Rosch, Mervis, Gray, Johnson and Boyes-Braem (1976) demonstrated that subjects performed best in semantic tasks requiring them to identify objects at the basic level. Basic level concepts generated faster responses in verification and discrimination tasks, larger priming effect and subjects preferred to use the basic label in picture naming tasks. For example, an individual dog might belong to the categories Rover, German shepherd, dog, animal, and living thing; of these, the category dog appears to be especially useful. Similarly, *X* will be a bird if it is closer to the bird prototype than to, let's say, the insect prototype. Olive and lemon are atypical members of the fruit category because they are farther away from the fruit prototype than apple and banana (Murphy, 2002).

A reasonable query then would be to question what makes some concepts central, basic level terms, and others, atypical. In other words, which features are more important in a way that they would carry more weight and hence be more important than others in determining inclusion in a category? Think of "natural semantic categories as networks of overlapping attributes" (Rosch & Mervis, 1975). Concepts with correlated features fall under the same category. Concepts with many correlated features will be in the middle of the category. Typical items will have the most overlap with other members of the same category, and the least overlap with members of a different category. In other words, the more often a feature is shared by members of a category the more important it will be in identifying members of that category.

Rosch's hypothesis that basic level terms are acquired first in development was tested (Mervis and Rosch, 1981). Sorting and naming tasks revealed that young children could sort toy objects into basic, but not superordinate categories. Interestingly, semantic dementia patients show a similar preservation of some basic-level names as their disease progresses. For example, in a picture naming task by Hodges, Graham and Patterson (1995), their patient showed preservation of the basic level names, "dog", "cat", and "horse" after he had lost such names for other animals. He even overextended these labels to other, similar animals, naming small animals "cat", medium-sized animals "dog", and large animals "horse".

The exemplar theory (Medin & Shaffer, 1978) was another theory that was proposed to explain the effect of typicality on reaction times in category and property verification tasks. According to the exemplar theory, individual instances (exemplars) are stored and reflected upon in order to decide whether an entity is a member of a category. The theory suggests that instead of forming an abstract representation (by averaging the features of the category members and creating a prototype), we remember each specific instance individually. Then we compare an object with all members of the category to determine its similarity with other category members and decide whether it belongs to the category or not.

To explain more, the exemplar view suggests that the representation of a concept is not a list of features that are found in varying degrees in a category. Rather, a person's representation of a concept relies on the instances the person remembers regarding that concept. As the prototype view, the exemplar view also suggests comparisons and relies on similarities between instances before one decides what something is.

Murphy (2002) points out that in the exemplar view, in order for you to make category decisions you need to already have labels for the superordinate and subordinate categories. Specifically he says: "*The examplar model requires that you have specifically categorized these memories. You can easily recognize a German shepherd as a dog because it is similar to other things you have identified as dogs. If you had just seen a lot of other German shepherds without knowing what they were, they couldn't help you classify this similar object"* (p. 51).

Drawbacks to a categorical organizational structure

Many phenomena have already been outlined that pose problems for the categorical organizational structure. Below, further constructs are discussed to indicate a variety of challenges to categorization-based accounts.

The notion of natural semantic categories as networks where concepts with many overlapping attributes will be found in the middle is in itself problematic. All models of categorical organization assume that categories will be formed on the basis of common features among their parts. However, an experiment by Rosch and Mervis (1975) clearly revealed that their 400 subjects, when asked to list the features/attributes of category members, produced very few features that applied to all category members. Features seemed optional for category membership and no one feature seemed to be necessary for category inclusion. In a simple everyday case, think of the category sports. Volleyball and rope jumping are both sports but share limited features. It seems that categorization based theories have a difficulty in explaining why some kinds of properties are more important than others for determining category membership.

Further, we discussed previously that if something has the defining features (defining features already challenged in the previous paragraph) then it will be a category member. This is not always such a clear cut task. For instance, Wittgenstein (1953) referred to games to illustrate this phenomenon. He argued that many activities we all categorize as games have very little in common (consider chess and Simon Says). The same holds true for the bachelor example provided earlier. Being an unmarried male does not automatically classify as a bachelor.

Another problem with this organizational structure is that there are instances where the membership in a particular category is not clear cut or consistent. McCloskey and Glucksberg's

(1978) experiment provides evidence that categories are not well defined sets of concepts, where clear boundaries separate category members from nonmembers. They asked their subjects to complete a category membership decision task twice (each session separated by one month). Their results indicated both between subject disagreement and within subject inconsistency (e.g., are cuff links a clothing item). It seems highly unlikely and inefficient for individuals to adjust their conceptual organization at any given time.

Moreover, the fact that processing latencies (as they relate to superordinate category concepts and basic level category knowledge) are sometimes explained with reference to similarity-based mechanisms and at other times with reference to taxonomic processing structures, creates a conflict in itself that is problematic for the theory (Rogers & McClelland, 2004).

Rogers and McClelland also point out that "the flexibility with which children and adults can generalize new knowledge suggests that more than one taxonomy is needed to direct semantic induction" (p.47) and that human performance in semantic tasks "may be sensitive to multiple high order dependencies among stimulus features; the discrete nature of category representations makes it difficult to explain these dependencies without sacrificing the qualities that make such representations appealing in the first place" (p.47).

The notion that categories are a reflection of the strength of the correlations among elements in memory was also demonstrated by Barsalou (1985). Barsalou revealed the ease with which ad hoc categories can easily be generated from traces that do not inherently have natural category structure. In the example "what do photographs, money, children and pets have in common?, on the surface, these items appear to share no features. However, when given the category label "things to take out of the house in the case of a fire", these items seem to fit the category label perfectly.

In addition to the difficulties expressed so far, categorization-based theories face additional challenges that derive from a different perception of semantic cognition, namely, the theory-theory approach (Gopnik and Meltzoff, 1997; Meltzoff, 1999; Murphy and Medin, 1985). Meltzoff refers to the theory-theory approach to cognition and semantic development, as the idea that infants and young children, like scientists, learn about the world by forming and revising theories. It emphasizes a combination of innate structure and qualitative reorganization in children's thought based on input from the people and things in their culture.

The above statements imply that concepts that represent the world are not formed as a result of mere observations but through theory revisions that reflect a combination of both action and observation. Therefore, the basic tenet of the theory-theory is that semantic cognition is constrained to a large extent by the naive domain knowledge – often referred to as a "theory"- that people hold about the causal relations that exist between entities in a domain (Rogers & McClelland, 2004).

Following this trail of thought, Murphy and Medin (1985) talk about category coherence. This is the tendency for some groups of concepts to "hang together" because they are related to one another in some causal way, whereas other groupings don't. The example by Rogers and McClelland (p. 32), initially paraphrasing Boyd (1986) makes the case quite clearly:

"For example, wings, hollow bones, feathers, and flight hang together and render birds a coherent category, because these properties are related to one another in a causal theory of flight: hollow bones make birds light, feathers and wings provide lots of air resistance, and these properties together allow birds to fly… … Feathers, wings, flight, and light, don't just co-occur; they all tend to mutually support the presence of each other, and, by doing so, segregate the set of things known as birds into a natural kind".

Table 3 Phenomena that challenge categorization based models

Taxonomic Hierarchies	1. Verification time seems to be influenced by typicality effect. Ostrich and robin are both subordinates of bird and one link away from it but ostrich verified as bird at a slower rate than robin. This implies graded membership – not all members of a category are equally good. Also, a dog is recognized as an animal faster than a dog is recognized as a mammal, although dog and animal are further away in the network than dog and mammal. 2. Transitivity in the network is not always followed. For instance, a car seat was an example of chair. Chair is a piece of furniture but car seat was not recognized as a piece of furniture.

Similarity Based Approaches	1. Difficulty explaining why some kinds of properties are more important than others for determining category membership. 2. Having a defining feature does not always classify something in a category, e.g., tuna throwing – it is a form of physical exercise, and it does involve following rules but it is not classified as a sport. 3. Often, very few features apply to all category members, and sometimes features seem optional for category membership, as no one feature seems to be necessary for category inclusion. 4. Empirical data suggests that membership is not always consistent, e.g., cuff links could be classified as a clothing item some times and others not.

Distributed memory models

The limitations to the categorization based approaches, together with the evidence for a connectionist model supported by researchers in the theory-theory approach, warrant the exploration of another approach to semantic organization.

Researchers working on distributed memory models, use the back-propagation learning algorithm to support that the weights that support each representation can be learned. According to Rogers and McClelland, back-propagation is "an inherently gradual learning process, which depends on the presentation of many training examples" (p. 59).

In such a memory framework, cognition takes place via the interactions of a large number of interconnected elements organized into units. Processing is the result of cooperative and competitive interactions among this large number of processing units. Such systems learn from experience and the weights between the connections of the units are altered depending on the structure of the environment (Hinton, 1981; Plaut, McClelland, Seidenberg & Patterson, 1996; Rogers & McClelland, 2004; Rumelhart, Hinton & Williams, 1986).

Therefore, in this system, internal representations differentiate progressively, so that the network can first discriminate taxonomic categories, such as animals from plants, but only gradually distinguish finer sub divisions of these clusters. This is the stage at which, children are observed to over-generalize. Perceptual similarities between class members are applied to all members. It is with gradual learning from experience that connections are altered to reflect sufficient, well differentiated representations.

Once this learning has occurred, each connection in the network carries such weights that constraint the kind of information to be activated during semantic tasks. For instance, in the network illustrated in the figure 4, the presentation of the word *canary* will give rise to a pattern of activation over several units, one representing the alphabetic content of the word, another its phonological content and a third its semantic content. Units that do not carry strong weights with *canary* will be switched off (McClelland, 1994).

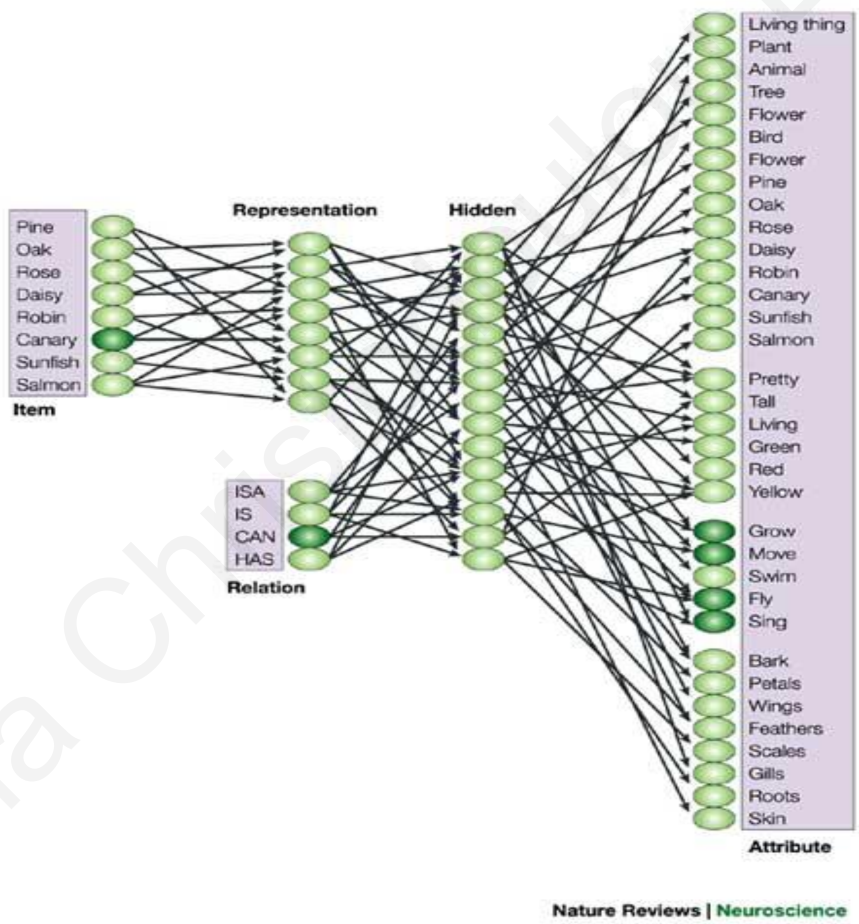


Figure 4 A depiction of a distributed connectionist model of semantic memory. Input units are shown on the left and activation spreads from left to right. Copied from figure 2.2 of "Semantic Cognition. A Parallel Distributed Processing Approach" (p. 56), by T. T. Rogers and J. L. McClelland, Cambridge: MA, MIT Press.

Think of the processing for semantic information as the spreading of activation among the units. For instance when asked what a *canary* ***can do***, for correct completion of this particular input pattern activation will spread to units such as *fly, sing, move, grow* and not to units such as yellow, or animal, or feather, or robin (Rogers & McClelland, 2004).

According to McClelland (1994), the knowledge in a parallel distributed processing system lays in the strengths of the excitatory and inhibitory connections among the processing units. As stated earlier, back propagation allows for the adjustment of the strengths of the connections among units according to a principle called error correction. Quoting McClelland, this principle states:

"*Adjust the strength of each connection in proportion to the extent that its adjustment will reduce the discrepancy between the response of the network and external teaching signals"* (p. 572).

This network differs from the hierarchical model by Quillian in that here information that relates to a category or subcategory of concepts is not stored at the highest possible level on the hierarchy. Rather, information about concepts is stored in such a way that it permits generalization from what it has learned, about certain concepts, to other related concepts "This is achieved by gradually learning to assign each concept a distributed representation, capturing its similarity relations to other concepts" (McClelland, 1994, p.573). In essence, if a network already makes a specific response to one pattern, it will make a similar response to a similar pattern. As Hinton and Anderson explain (1989), if objects are represented by similar patterns we get automatic generalization.

The capability for generalization is very important provided that hardly anything repeats itself exactly, making generalization essential for intelligent behavior. Therefore, the property of cognitive reserve that motivated categorical approaches to semantic organization is also captured by connectionist models provided that knowledge generalization allows for economy of storage (Rogers & McClelland, 2004).

This representational scheme is very different from that supported by the hierarchical model described above. In a hierarchical model concepts are represented as single nodes. In a distributed memory model conceptual knowledge is captured in connection weights that link processing units. Instead of single units in the network, weighted connections are established with every other unit in the network (Masson, 1995).

Supporting Evidence for Distributed Models

Hinton's (1981) model for representing semantic knowledge in a distributed connectionist network proposed that each node in the semantic network corresponds to a certain level of activity amongst a number of units. And that this activity is altered by adjusting the connection weights between nodes until a specific proposition can be effectively stored. Then Hinton and Anderson (1989) argue:

"In order to store a semantic net in the manner described above, it is necessary to choose a particular pattern of activity (i.e., a set of microfeatures) to represent each node in the semantic net. A simple first approach is to choose a random pattern for each node and to ensure that no two nodes are too similar. This allows associations between patterns to be implemented, but it fails to capture the similarities of nodes to one another. For example, the method of achieving property inheritance …relies on a particular kind of similarity in which the set of microfeatures for a token contains, as a subset, the microfeatures for the type. This example makes it clear that the "direct content" of a concept (its set of microfeatures) interacts in interesting ways with its "associative content" (its links to other concept). The reason for this interaction, of course, is that the associative content is caused by the direct content" (p. 204).

McClelland, McNaughton and O'Reilly (1995) also reflected on such a connectionist model of semantic memory. They supported that such networks that support changes amongst their connections are efficient in explaining semantic organization. By reviewing the neuropsychology of memory, and giving emphasis on the role of the hippocampal system on learning, they provide support for connectionist modeling research.

They reinforce that activation among neurons via synaptic connections is the unquestionable result of years of neurophysiological investigation and that strong evidence that the neocortical processing system consists of large interconnected brain areas is also undisputable. They also emphasize the bi-directional projections between brain areas (both feed-forward and feed-backward directions).

They repeated Rumelhart's (1986) simulations, and by using the gradient descent learning procedure, they trained a network for a total of 500 sweeps through the training set (epochs). Their results were consistent with what has already been stated about these kinds of models. At the early stages of learning (epoch 25), it seems that representations do not reflect the structure of the domain. At later stages of training however, differentiation between concept representations and their similarity structure begins to emerge. They too support that before learning begins, the network starts off with random weights. They suggest that the learning process takes place as follows:

"At first when an input is presented, the output is random and bears no relation to the desired output. The goal is to adjust these connection weights, through exposure to propositions from the environment, so as to minimize the discrepancy between desired and obtained output over the entire ensemble of training patterns. This goal can be achieved by interleaved learning using a gradient descent learning procedure: During training, each pattern is presented many times, interleaved with presentations of the other patterns. After each pattern presentation, the error – i.e., the discrepancy between desired and obtained output - is calculated. Each connection weight is then adjusted either up or down by an amount proportional to the extent that its adjustment will reduce the discrepancy between the correct response and the response actually produced by the network… … The patterns of activation in this module can be considered to be the learned internal representations of each concept; the connections from the concept input units to the representation units can be viewed as capturing the mapping between input patterns and internal representations… …In the course of learning, the network learns both how to assign useful representations, and how to use these to generate appropriate responses" (p.55).

As already established, distributed models of semantic organization have overlapping features (rather than categories) as the major organizing principle. According to these models semantic relationships other than categorical membership can be more significant. If these other semantic relations are reflected in the semantic structure, then we need to identify them as well as their connection weights. By investigating the different range of relations among words, the nature of conceptual connections can be charted.

Chapter 3

Experiment 1

The Priming Study

The purpose of Experiment 1 was to assess the representation of object concepts in six different age groups by comparing their performance in a naming priming task. Different types of target conceptual pairs were incorporated and reaction times and accuracy measures were collected in order to determine which types of conceptual conditions resulted in faster priming.

Priming refers to the phenomenon in which a target word (e.g., nurse) is recognized faster when preceded by a related word (e.g., doctor) than when it is preceded by an unrelated word (e.g., bread) (Masson, 1995; McNamara, 1992; Lucas, 2000; Seindenberg, Waters, Sanders & Langer, 1984). Priming paradigms are an ideal approach to testing semantic knowledge without requiring participants to explicitly reflect upon that knowledge (Lucas, 2000; Moss et al., 1995).

The paradigm of semantic priming first introduced by Meyer and Schvaneveldt (1971), has yielded an abundance of information regarding the semantic network. If a prime word facilitates the recognition of a target word, researchers can draw inferences, based on the nature of these observations and can formulate theories regarding the structure of our conceptual system. For example, if canary primes bird, this suggests that the superordinate category is accessed when canary is heard. If the canary can also prime small and yellow, then we can infer that perceptual attributes are accessed when bird is heard. Finally, if bird primes cage, then it suggests that information regarding where birds are encountered is accessed (Moss et al., 1995). Therefore, priming can be a valuable tool in accessing the range of prime-target relationships that support priming.

The advantage of the priming task is that it can give a relatively transparent measure of the information being accessed without the influence of metalinguistic tasks that might activate strategic processing (Malt, 1990), which might be employed when for example participants are asked to list as many members of a category as possible or to make judgements about the properties of words (Schoen, 1988), or making verifications about two objects based on their specific perceptual (color) information without a reference to the semantic information about the object (Rogers and McClelland, 2004). Therefore, in order to reliably determine the exact information accessed without contextual help, prime stimuli were presented in isolation rather than in sentential contexts.

Accounts in the literature dealing with conceptual representations, have not been consistent in distinguishing between the different types of relations among objects/events. Some make use of the term *semantically related* or *categorically related* when referring to concepts that are related because they share perceptual features, and *associatively* or *thematically related* to refer to concepts that are related because of an event schema (Lucas, 2000).

However, using the term *associatively related* to refer to event schema relations (e.g., bear-honey) complicates matters as the traditional definition of associative relatedness comes from normative association norms. In this pretext, association between words is defined in terms of the probability that the second member of any word pair will be offered as a free associate in response to the first. For the purposes of this study, normative association databases were created by asking subjects to provide the first word that came to mind when they heard a word. In such tasks, subjects are free to associate the word with no restrictions on the nature of the relation for creating the word pair.

Two observations can be made regarding items on the normative association databases. On the one hand, high association between words might occur between pairs of words whose referents happen to go together as a result of how the world operates or functions (i.e. *umbrella* and *rain*) or yet word pairs could arise because they are categorically related (i.e. *fork* and *knife*).

For the purposes of this study pairs of concepts that share common perceptual features will be referred to as categorically/taxonomically related, and pairs of concepts that are related due to an event schema will be referred to as thematically related. Reference to association will refer to the degree of association between two concepts as that arises from normative association databases.

Therefore, words can be related if they have similar perceptual features (Medin & Ortony, 1989), in other words, if they share common essence (Hashimoto et al., 2007). These include category co-ordinates whether those are living things (e.g., cat and dog) or artifacts (e.g., pen and pencil). Words can also be related by themes and are bound by an event schema (Shank & Abelson, 1977). Some relations that bind objects into themes include ***spatial*** (e.g., a *roof* is found ontop of a *house*, a *bear* lives in the *woods*), ***script*** (i.e., if they co-occur during the priming task (Plaut, 1995), e.g., a *mouse* eats *cheese*, a *monkey* eats *bananas*), ***part whole*** (e.g., *horns* are part of a *deer*, a *propeller* is part of a *helicopter*), ***functional*** (e.g., a *hat* protects the *head* from the sun, a *chalk* is used to write on a *blackboard*), ***featural*** (e.g., a *banana* is *yellow*, a *giraffe* is *tall*), ***causal*** (e.g., *spark* and *fire*, *onion* and *tears*).

How children represent these conceptual structures or how these structures deteriorate in old age or with neurologically impaired patients has been the topic of long-standing research. Developmental theorists have suggested that children are sensitive to the functional properties of spoken words from an early age (Mandler, 1983). Inhelder and Piaget (1964) observed preschoolers categorizing objects into thematic categories rather than taxonomic categories. Similarly, preschoolers demonstrated preferences for thematic relations during forced choice matching tasks (Smiley & Brown, 1979) and a variety of recognition and naming tasks (Fenson, Vella, & Kennedy, 1989; Scott et al., 1982).

In Keil's experiments with children (1979), his results revealed that children do start off with coarser distinctions before they proceed to finer ones. The notion that conceptual representations in children undergo changes from being concrete to being more abstract was also supported by Vygotsky and it complies with Piaget's views on assimilation and accommodation – how children apply previous knowledge (assimilation) and observations as well as changes in behavior around them to account for new knowledge (accommodation).

Evidence from semantic priming in developmental literature, also supports functional relationships rather than categorical ones. Nation and Snowling (1999) performed a study that explored priming for category co-ordinates (e.g., airplane-train) and for functionally related word pairs (e.g., shampoo-hair) in children with good and poor reading comprehension. Results revealed that both groups showed priming for functionally related word pairs, but children with poor comprehension only showed priming if categorical pairs were also highly associated.

Nelson (1982) proposed that young children represent information in generalized event-based scripts. As a result, functional information can be considered to be the driving force underpinning the development of semantic memory (Nation & Snowling, 1999). Consistent with this, in word association tasks, young children are more likely to generate nouns that are functionally related to a presented target than nouns that are category co-ordinates (Petrey, 1977). Similarly, using cued recall, Blewitt and Toppino (1991) found that children were more accurate at recalling functionally related word pairs (e.g., aeroplane-sky) than categorically related word pairs (e.g., aeroplane-train). However, by 8 years of age and into adulthood, categorical relations or taxonomies are preferred in semantic tasks, leading to the hypothesis that conceptual development is characterized by a thematic to taxonomic shift, called the shift hypothesis (see Lin & Murphy, 2001, for a review).

Priming studies with clinical groups of participants whose condition results in semantic impairment such as aphasia or dementia reveal semantic relationships may be differentially impaired. For instance, Moss, Tyler, Hodges and Patterson (1995) explored the nature of semantic memory through priming tasks in a patient with semantic dementia. Their stimuli included *categorical word pairs* (e.g., cat-dog, ruby-emerald) as well as *functional word pairs* (e.g., shampoo-hair, theatre-play). Although their controls showed priming for both types of semantic relations, their patient showed priming only for functional pairs but not categorical coordinates. Similar findings in single subject studies were also reported by Tyler and Moss (1998), Moss, Tyler and Jennings (1997), as well as a study by Glosser and Friedman (1991) who used a control as well as an experimental group of patients with Alzheimer's Disease (AD) who showed priming for words that were highly associated but not for words that were categorically related, as compared to the control group who showed priming for both pairs.

Consistent with studies suggesting that functionality plays a central role in language development, is empirical data from studies with adults with a neurological impairment as well as older healthy adults. Moss, McCormick and Tyler (1997) found that information about the function of an object was accessed more rapidly than information about their physical form. Furthermore, functional information seems to be resistant to breakdown from neurological disorders, such as progressive aphasia or dementia that affect (amongst other cognitive processes) the semantic network (Tyler & Moss, 1998).

Additional empirical data with participants with mild to moderate AD investigated the priming of semantically related and associatively related word pairs. Glosser, Friedman, Grugan, Lee and Grossman (1998) showed preserved priming of associated word pairs (e.g., cottage-cheese) but impaired priming for categorical relations (e.g., lemonade-beverage, or cashew-almond). Similar results were reported, among others, by Davidoff and Roberson (2004), Ober, Shenaut, and Reed (1995). Collectively considered, these findings support the view that functional information, perhaps more than any other semantic information, is central to word meaning and that this information is automatically accessed.

In terms of healthy adults, Fischer (1977), presented her subjects with a lexical decision task where they had to decide whether both words, presented to them in pairs were words. Pairs included associated words (e.g., lock-key), semantically related words (e.g., bread-cake) and unrelated control pairs (e.g., bread-stem). Both associated and semantically related pairs received faster responses than unrelated word pairs with associated word pairs receiving a larger and more reliable facilitation than semantically related pairs.

Similarly, Seidenberg et al. (1984), investigated priming through naming and lexical decision tasks, when prime and target pairs were related along different dimensions. The priming effect was smaller for semantically related pairs than for that found for associatively related words (especially in the lexical decision task).

Moss et al. (1995) investigated which types of relations produced the greatest automatic facilitation by administering 3 semantic priming experiments. In their tasks prime-target pairs included categorically related words (e.g., pig-horse), and two types of associative word pairs (functional associations, e.g., broom-floor, and temporal associations, e.g., restaurant-wine). The authors concluded that priming might be greater for word pairs that are both associatively and semantically related. Words are semantically and associatively related if their referents are categorical coordinates and the words are also normatively associated (e.g., cat-dog) than for word pairs that are only semantically related, an effect they called the associative boost.

Moss et al. (1995) tested priming for two different kinds of related word pairs; semantically related category pairs (e.g., pig-horse) and functionally related words (e.g., broom-floor). They constructed pairs that varied in association strength; half of the pairs were strongly associated, and half were not associated for both semantic and functionally associated categories. This was applied to four experimental conditions: +semantic/+associated (e.g., street-road), +semantic/-associated (e.g., stick-cane), -semantic/+associated (e.g., pillar-society), and –semantic/-associated (e.g., unrelated pairs such as light-tree).

Category coordinates and functionally related words showed significant and equal priming when non-associated. However, both conditions showed a significant increase in priming when prime and target were also strongly associated – an effect consistent with the associative boost discussed earlier. They discussed that these results demonstrate an associative boost over and above semantic relatedness of various types; that even pairs of words that share only associative links can support priming; and that the effects of the two types of priming are qualitatively different.

The false memory paradigm, was also used to document the phenomenon of strong thematic priming. The false memory paradigm was used to investigate how feature based relationships compared to associative based relationships. They would present their subjects with word lists (derived from a target word that was not itself presented – i.e. they would hear words like slumber and snore but not the target word sleep) and ask them to remember what they saw or heard in an immediate recall task. Participant reported seeing or hearing items that were not previously studied (Buchanan, Brown, Cabeza, & Maitson, 1999; Deese, 1959; Dewhurst, 2001; Roediger & McDermott, 1995). Deese (1959) found that the likelihood of these false recall was a function of the probability of the target word being an associate to the other words in the list.

Contrary to these studies that reported thematic preference, many other studies, using a variety of stimuli and methodologies, have reported that beyond age 8 and throughout much adulthood, similarity or taxonomic category membership remains the primary basis for sorting (Annett, 1959; Goldman & Levine, 1963; Olver & Hornsby, 1967; Smiley & Brown, 1979). Similarly, in developmental literature, there are studies to suggest that preschoolers can demonstrate flexible categorization, switching from thematic to taxonomic categories when context mandates (Blaye & Bonthoux, 2001; Nguyen & Murphy, 2003).

In summary, there is evidence to support that children represent thematic relations early in development and only begin to represent taxonomic relations roughly at around the age of 8. The current project, through a number of different experiments will investigate whether this proposed shift in development is really the case or whether both children and adults vary in their dependence on thematic and taxonomic systems according to task requirements and instruction (Osborne & Calhoun, 1998; Walsh, Richardson, & Faulkner, 1993; Waxman & Namy, 1997).

Although an abundance of studies investigated semantic networks by using the priming, and other experimental paradigms, many fell short of distinguishing between different types of conceptual relations or investigated a limited number of them. Others equated thematic association with functional association and yet others functional relations with normative association. Further, most studies investigated a limited range of semantic relations, while researchers often failed to control for normative association as well as semantic relatedness.

This study investigates a number of different categorical/taxonomic conceptual relations as well as a number of thematic conceptual relations which are clearly distinguished from association norm.

In Experiment 1, it was hypothesized that if a thematic to a categorical/taxonomic shift is a developmental phenomenon, then the shift should be apparent in a task such as priming that reduces performance demands. In other words, since preference to thematic information seems to develop early and deteriorate later, it is hypothesized that thematically related word pairs will facilitate faster responses for the very young and very old participants. An associative boost is also hypothesized for all conceptual relations for all participant groups.

Method

Participants

One hundred and eighty two participants were assigned to six age groups. All subjects were native Greek speakers with no language or cognitive disorder, as well as no reported neurological or psychiatric diagnosis. Language and cognitive ability was assessed using the Wechsler Abbreviated Scale of Intelligence (WASI). In the case of older adults, the Geriatric Depression Scale as well as the Mini Mental State Examination (MMSE) was also administered to further ensure good neuropsychological standing. All subjects had normal or corrected to normal vision and hearing. None of the participants that participated in the word association normative procedure (preliminary study) were included in the experimental part of the study.

Subjects participated in the study in the following 6 groups: (a) 31 6-year-olds, 17 boys and 14 girls (*Mean age* = 6 years, 4 months with *Mean education = 1 year*), (b) 32 9-year olds, 11 boys and 21 girls (*Mean age* = 9 years, with *Mean education* = 3.28 years) (c) 31 12-year olds, 12 boys and 19 girls, (*Mean age* = 11 years, 4 months, with *Mean education = 5.74 years*) (d) 31 15-year-olds, 15 males and 16 females, (*Mean age* = 15 years, 3 months, with *Mean education* = 10 years) (e) 30 18-35 year-old adults, 14 males and 16 females, (*Mean age* = 22 years, with *Mean education* = 14.93 years), and (f) 27 63+ year olds, 11 males and 16 females, (*Mean age* = 71 years, 2 months, with *Mean education* = 11.23 years) (Table 1.1).

Children were recruited with parental consent from two preschools and the community. Adult participants were recruited from undergraduate and graduate university classes as well as the community. All participants (in the case of the children, their guardians) signed an informed consent form before the experiment.

Stimuli

Eleven different types of conceptual relations were studied by investigating one hundred and ten different prime-target pairs. These belonged to either of two types of conceptual relatedness: **(a) taxonomically related pairs** or **(b) thematically related pairs**. The taxonomically related pairs included: (1) Superordinate Living (e.g., animal – leopard), (2) Subordinate Living (e.g., bird – dove), (3) Superordinate Artifact (e.g., musical instrument – flute), (4) Coordinate Living (e.g., apple – pear), (5) Coordinate Artifact (e.g., bowl – plate); and the thematically related pairs included: (6) Spatial (e.g., jungle – gorilla), (7) Script (e.g., mouse – cheese), (8) Part/whole (e.g., bells-church), (9) Functional (e.g., soup – spoon), (10) Featural (e.g., teddy bear – soft), (11) Causal (e.g., accident – injury) (look at Appendix A for a full list of stimuli).

Half of the related primes were strongly normatively associated to their targets, and half had a weak associative strength. This variable of association was crossed with conceptual relation. Each conceptual relation had five instances of strongly associated prime-target pairs (+semantic/+associative) and five instances of weakly associated prime-target pairs (+semantic/-associative). Therefore, there were 5 pairs in each Association x Conceptual relation condition.

Nouns were used as stimuli in this study as research findings established that this part of speech yields robust priming (Moss et al., 1995). Nouns are also easy to depict pictorially and picture naming is a widely used technique of lexical access (Glaser, 1992). Pictures were chosen to avoid any contributions of reading difficulties. Additionally, the Greek language tends to have lengthy words, with monosyllabic content words occurring rarely as opposed to the English language where monosyllabic content words are frequent. Furthermore, the words in the Greek language have a complicated syllabic structure. Matching printed word stimuli on length and composition in addition to their association and conceptual relatedness would be a complex endeavor.

Association Strength There are no published association norms for the Greek language. Therefore, before any of the experiments could have been designed, these association norms had to be created so that stimuli for the experiments could have been selected. As a result, a preliminary study aimed at establishing a normative association database for a number of words in the Greek language.

Procedures used by Nelson et al. (2000) were used in a dual association norm procedure. Six hundred participants were asked to engage in a free association task where they had to produce the first two words that came to mind when presented with a stimulus word. Words chosen to act as cues were nouns, selected from already published association norms (Burke et al., 1987; Palermo & Jenkins, 1964; Shapiro & Palermo, 1968).

Participants were adults, male and female, that ranged in age (ages 18-55), social status and formal education (minimum 12 years of education). Each participant was given one of three lists of stimulus words, each containing 171 of the to-be-normed words, so that a total of 200 participants would respond to each item. Each word list contained instructions to the particular task, followed by the stimulus words. Related words (e.g., mouse and cheese) were assigned to different word lists. Participants with a neurological or a psychiatric diagnosis were excluded from this process.

Participants were asked to read each word and write the first two words that came to mind, while emphasis was given to the fact that their responses should be as spontaneous as possible, although no time restriction was given. It was also stressed that they should not repeat their first response when responding to the same word. With this procedure, each stimulus word generated a first and second response. Participants had the option of working on their questionnaires either on a computer or traditionally through a paper and pencil booklet.

The strength of association was measured by counting the number of people that produced each response and then dividing that by the sample size to determine the response probability. Set size was also determined by counting the number of different responses made by two or more participants (Nelson et al., 2000).

The strength of association was determined as follows and was based on Hutchison suggestions (2003): (a) no association for any responses generated less than 1% of the time, (b) weak association for any responses generated 1% - 10% of the time, (c) moderate association for any responses generated 10% - 20% of the time, and (d) strong association for any responses generated more than 20% of the time.

Categorical pairs. Word pairs were selected on the basis that they were clearly members of the same superordinate category. The following **taxonomic** pairs were used: (1) *superordinate living (e.g., leopard-animal),* (2) *subordinate living (e.g., dove-bird),* (3) *superordinate artifact (e.g., trumpet-musical instrument)*, (4) *coordinate living (e.g., gorilla-monkey),* (5) *coordinate artifact (e.g., fork-knife).*

Thematic pairs. To ensure that the thematic relation really existed between the prime and target pairs, a thematic relatedness judgment task was performed. Ten adults (on average with 15 years of education) were given a booklet containing all of the potentially thematically related test pairs, and were asked to rate the thematic relation within selected pairs on a scale from 1 (strongly agree) to 5 (strongly disagree), if the following **thematic** conditions applied: (1) *spatial* if "at x you can find y" (e.g., in a cellar you find wine), (2) *script* "if the relation was part of a learned schema" (e.g., a bear eats honey), (3) *part whole* if "x is literally part of y" (e.g., a wing is part of an airplane), (4) *functional* if "x is used to perform an action on y" (e.g., belt is used to hold up trousers), (5) *featural* if "y is an attribute of x" (e.g., a giraffe is tall), and (6) *causal* if "x results in y" (e.g., clouds can result in rain). In all pairs, the target was judged to be a typical element of the situation described by the prime. No pair was chosen if it received a score above 2 in the judgment task.

Procedure

All materials were depicted as pictures on a computer screen in a within subject design. Participants were tested individually in a quite environment. They were told that pictures will be presented on the computer screen in pairs; the first picture would appear very briefly, followed by another picture that they would have to name aloud in a microphone. Instructions were followed by a practice set of six prime-target pairs that represented the different conditions used in the study. Immediately following the practice set the participants completed the experiment.

Every participant saw every word pair once. Order of stimulus presentation was randomized. Each prime was presented for 200 ms with an inter-stimulus interval of 200 ms, making the stimulus onset asynchrony (SOA) 400 ms. The target was presented for a maximum of 3000 ms. The inter-trial interval was set at 1500 ms. Reaction Time (RT) was measured from the onset of the target picture to the time the participant initiated vocalization. The experiment key was set up with E-Prime 2.0, and was run on a Lenovo V570 laptop with a 15.6

inch monitor. E-prime recorded RTs in milliseconds. The procedure is illustrated in Appendix B.

The SOA between prime and target was short so that it would be unlikely for strategic processes to contribute to facilitation (Posner & Snyder, 1975; Ratcliff & Mckoon, 1981). With a short SOA, no contribution of higher level mechanisms to the priming effect was expected (Hodgson, 1991). A word naming task was adopted in this study as opposed to a lexical decision task in a further attempt to avoid strategic processes (namely post-lexical decision processes).

A response was considered correct if provided in the three second window allocated to each target. If no response was recorded after three seconds, then the trial was classified as timed out. A trial was considered an error if the reaction time was longer than 3000ms or if a target picture was named incorrectly. The test session lasted approximately 20 minutes.

Results

The purpose of this experiment was to investigate the representation of different conceptual relations in six different groups, by comparing their performance in a naming priming task. An average of accurate responses and reaction times respectively, were calculated for each subject for each conceptual relation (taxonomic and thematic). Total compound scores for type (categorical/taxonomic vs thematic pairs) and strength (strong vs weak) were then subjected to a repeated MANOVA with the two factors, (type and strength), as the within factors and age as the between factor. Accuracy analysis will be presented first followed by the reaction time analysis. The independent variable here was type of conceptual relation and the dependent variable was reaction time and accuracy.

Reaction Time (RT) is likely to be more sensitive to priming effects than accuracy. However, by analysing accuracy levels as a preliminary step served as a check on the children's comprehension of the task. A trial was scored as incorrect if the subject misnamed the target (only actual synonyms were accepted as correct) or the naming latency was longer than three ms. Gender was not a significant covariate for accuracy nor reaction time.

Accuracy. Overall accuracy rates were high. Table 1.2 and figure 1.1 indicate accuracy scores per group. Examination of the descriptive findings indicates that the younger and oldest groups scored lower than the other groups. Young adults had the highest accuracy performance according to the descriptive analyses.

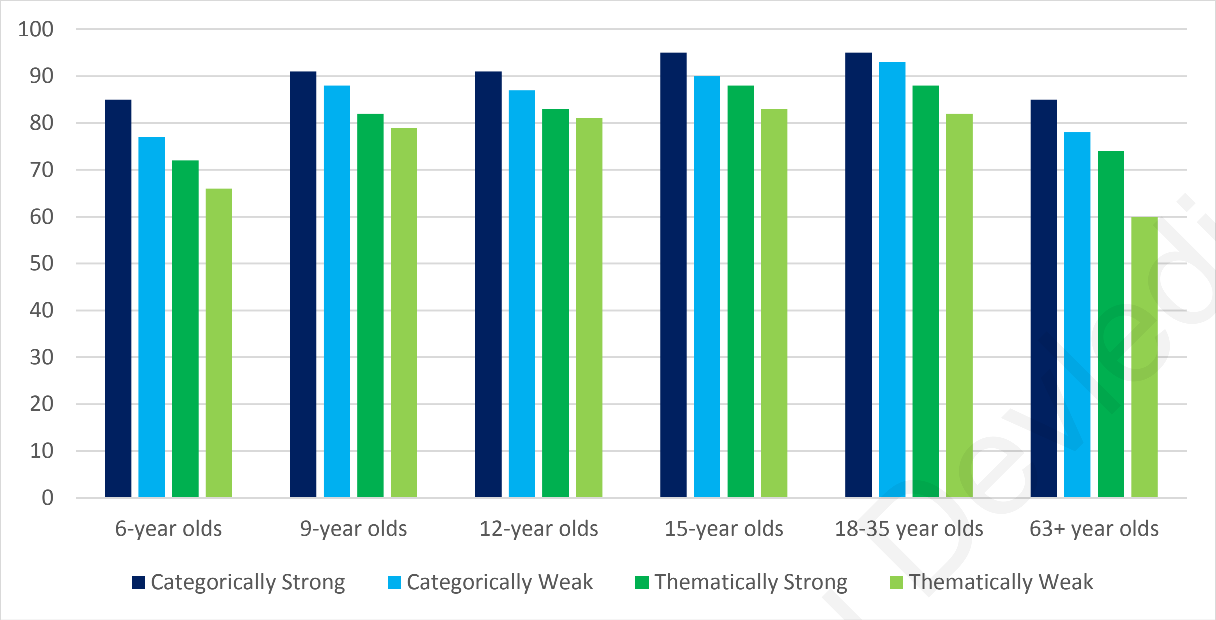


Figure 1.1 Percentage of correct responses in the priming task for each conceptual pair for each age group.

There was a main effect of age, $F(1,5) = 21.935$, $p<.001$, partial $\eta^2 = .384$. Participants in the six-year old group ($p<.001$) and 63+-year olds ($p<.001$) had an overall lower accuracy score as compared to the other groups. All the other groups did not differ significantly in their accuracy scores ($p>.4$).

There was also a main effect of type of conceptual relation on accuracy, $F(1,176) = 330.248$ $p < .001$, partial $\eta^2 = .652$. The results indicated that all age groups were more accurate when naming categorical relations compared to thematic relations. This effect was driven by the prominence of more accurate responses for taxonomic pairs by the two young groups and the two older groups. There was no significant effect on accuracy by type for either the 12-year olds or the 15-year olds. This was qualified by a significant two way interaction between age and type $F(5,176) = 5.681$, $p<.001$, partial $\eta^2 = .139$ (Figure 1.2).

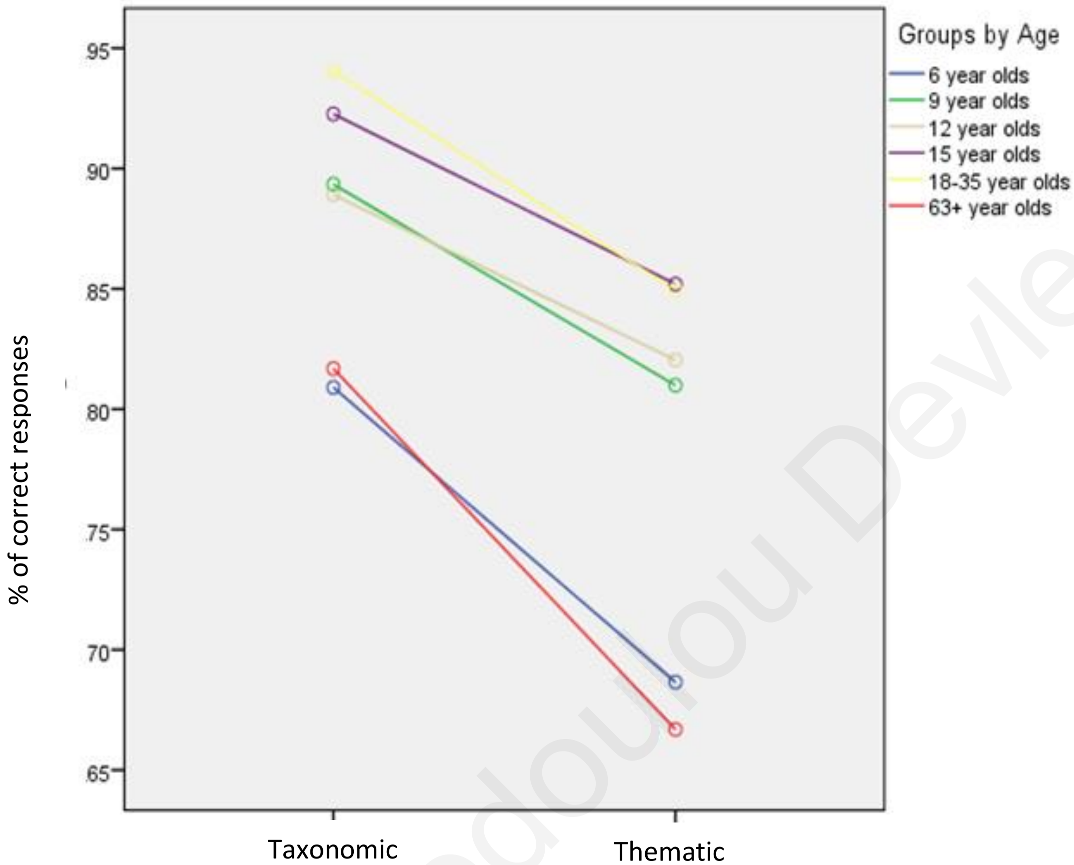


Figure 1.2 Percentage of correct responses in the priming task, based on type of conceptual relation for each age group.

The second within subject effect, strength, also resulted in a significant main effect. Strong pairs were more accurately named than weak pairs, $F(1,176) = 120.586$, $p < .001$, partial $\eta^2 = .407$ (Figure 1.3). This was significant for all groups. Patterns of performance varied among the 6 groups. Specifically, age and strength yielded a two way interaction, $F(5,176) = 4.674$, $p < .001$, partial $\eta^2 = .117$. As figure 1.3 shows, the impact on accuracy depends on strength. For strong relations there is no significant effect on accuracy, and that is true for all age groups. However, when it came to responding to weak conceptual relations, 6-year olds were substantially more successful than 63+ year olds. There was no significant interaction between type and strength, $p > .05$. Finally, there was a three-way interaction between age, type, and strength, $F(5,176)=3.486$, $p<.005$, partial $\eta^2=.090$.

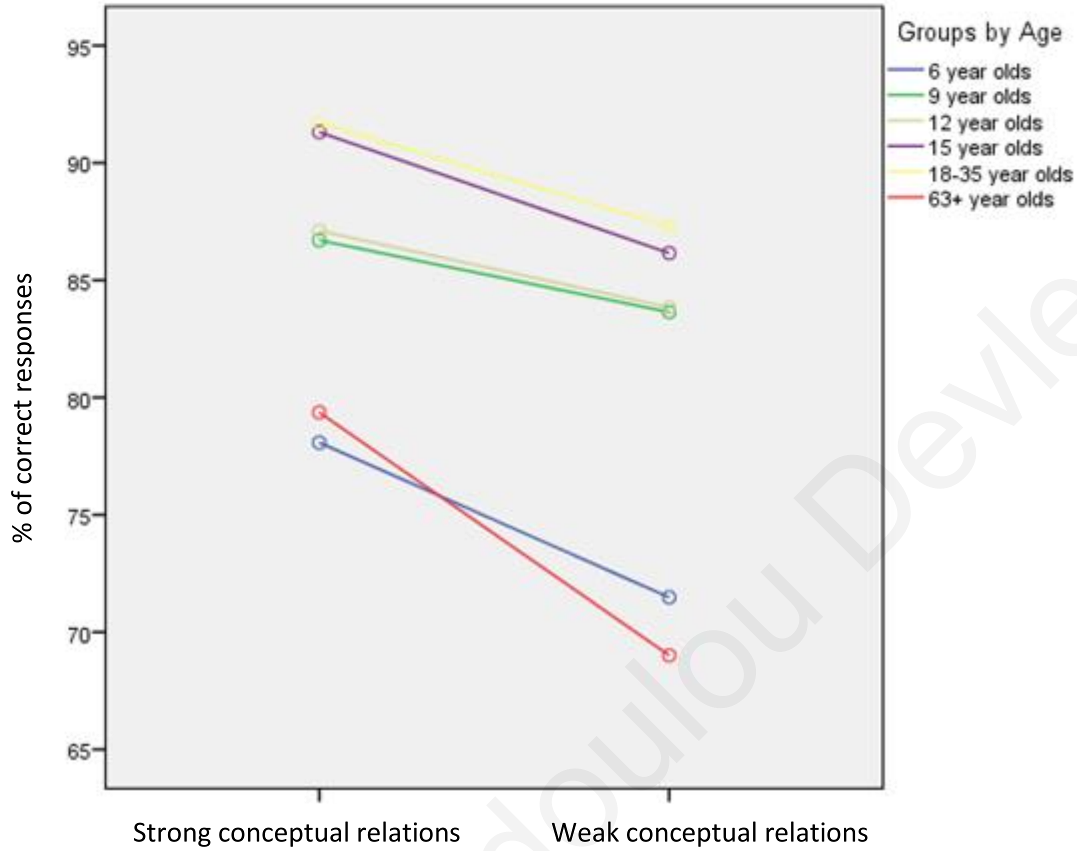


Figure 1.3 Percentage of correct responses in the priming task, based on strength of conceptual relation for each age group.

Reaction times. The analysis of reaction times (RTs) included only trials that were answered correctly and within the three second time out criterion.

Compound mean reaction times were entered into a multivariate mixed model analysis of variance (MANOVA) with strength (strong vs weak) and type (categorical vs thematic) as the within subject factors and age as the between subject factor.

Table 1.4 and figure 1.4 display the descriptive statistics per group. It indicates that the younger and eldest groups responded slower than the other groups. According to the descriptive analysis, young adults responded the fastest of all the groups. This was qualified by a main effect of age on RT $F(5,176) = 24.213$, $p < .001$, partial $\eta^2 = .408$, with 6-year olds and 63+-year olds being the slowest of all the groups, with no statistically significant difference between the two groups (Table 1.3).

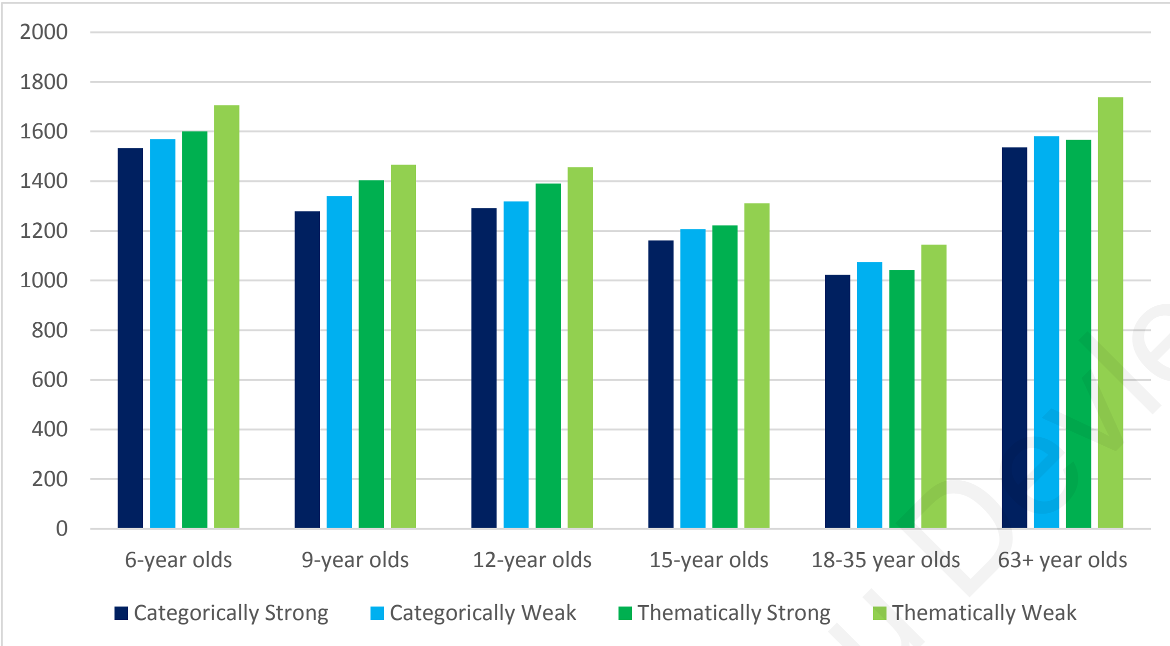


Figure 1.4 Priming reaction times for each conceptual relation for each age group.

There was also a main effect of type on RT $F(1,176) = 101.734$, $p < .001$, partial $\eta^2 = .366$, with categorical pairs priming faster than thematic ones, an effect that was significant for all age groups (Figure 1.4). There was also a significant priming effect on RT values to words in the strongly related condition being faster than in the weakly related condition, $F(1,176) = 65.058$, $p < .001$, partial $\eta^2 = .270$ (Figure 1.5).

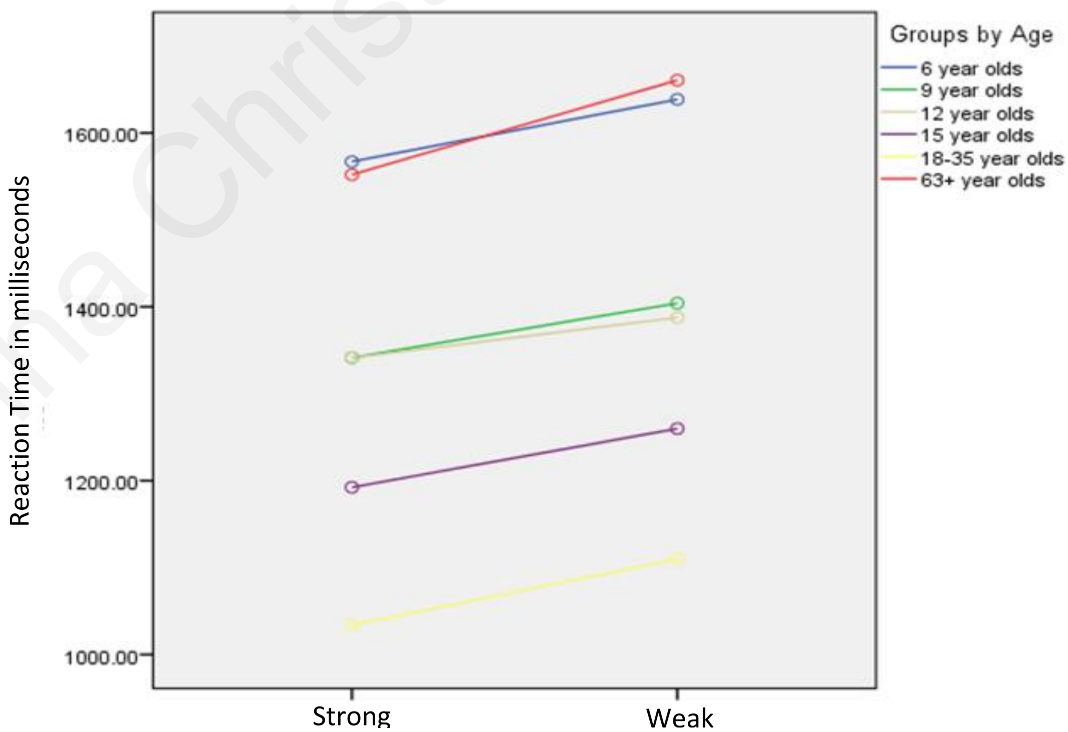


Figure 1.5 Priming reaction times to strong and weak conceptual pairs for all age groups.

Patterns of performance were similar across the various age groups. There was no two way interaction between type and age, $p > .05$ and no interaction between strength and age $p > .05$. However, there was a two way interaction between type and strength, $F(1,176) = 12.081$, $p = .001$, partial $\eta^2 = .064$, indicating that the impact on reaction time for different types of relations depends on the strength of the relation (strong vs weak). Taxonomic relations didn't yield significant reaction time differences between strong and weak relations. However, weak thematic relations resulted in significant slower reaction times when compared to strong thematic relations. There was no three way interaction between type, strength and age, $p > .05$.

In order to further investigate exactly which conceptual pairs primed faster for the strongly associated conditions, a repeated ANOVA was carried out with the eleven strongly associated conditions as the within subject factor and age as the between subject factor. There was a main effect for type, $F(8.909,1567.952) = 16.336$, partial $\eta^2 = .085$, with functional pairs yielding the fastest reaction times than any other condition for all groups except the 6 and 9-year olds, who responded faster to superordinate artifact and superordinate living pairs respectively, with functional and featural pairs also yielding fast responses for these two groups (Figure 1.6). Pairwise comparisons revealed no significant differences between the fastest and the second fastest responses for all age groups.

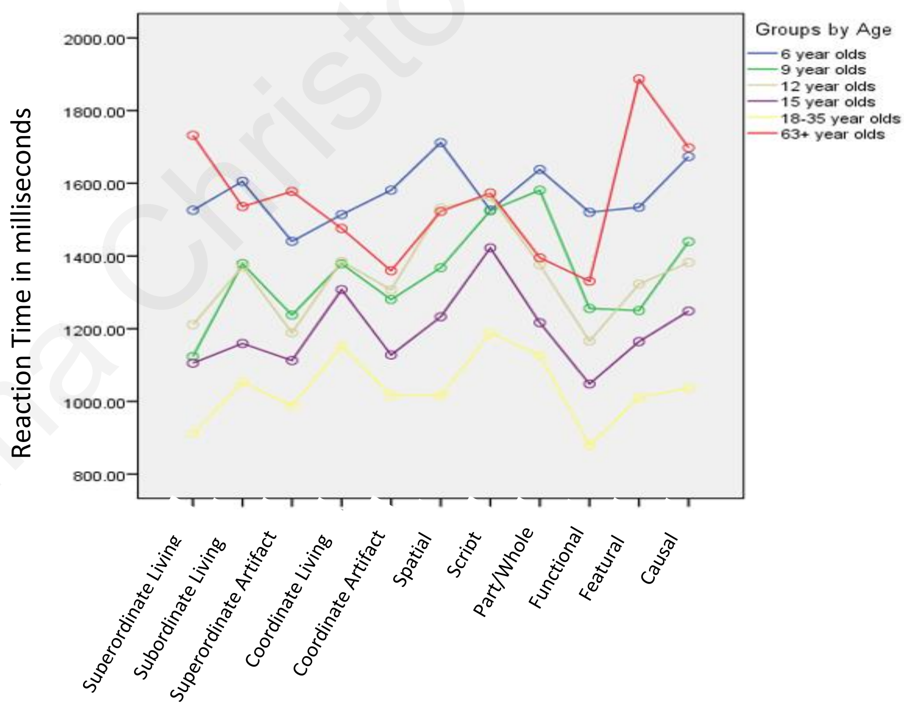


Figure 1.6 Priming reaction times for each strongly associated conceptual relation for each age group.

Discussion

This experiment was designed in order to determine whether different types of conceptual relations would yield different results between six different age groups. It produced two main findings. First, an analysis of naming accuracy and RT revealed a significant main effect of strength of conceptual relatedness. Target pictures in strongly associated pairs, regardless of type of relation, were named more accurately and faster than those in weakly associated pairs. This reduction in naming latency and increase in naming precision was independent of age group. This result is consistent with previous findings suggesting an associative boost (Moss & Marslen-Wilson, 1993; Moss et al., 1995; Tanenhaus & Lucas, 1987).

The second main finding of this study was that target pictures in taxonomic pairs produced more accurate and rapid naming than target pictures in thematic pairs. The patters of performance were similar across age groups. However, provided that strength of semantic relation yielded a significant effect, whereas type and age group did not yield an interaction effect, indicates that strong conceptual relations of both the taxonomic and thematic types primed the object naming of children and adults by speeding their processing. This is consistent with the findings of Hashimoto et al. (2007) who investigated the priming effect of taxonomic and thematic pairs in three different age groups (6 and 8-year olds and young adults); but it provides the added advantage of providing information as to the effects of several different taxonomic and thematic subtypes as this study incorporates many types of taxonomic pairs (in contrast to the Hashimoto et al. study which only included superordinate category pairs), as well as many types of thematic pairs (in contrast to the Hashimoto et al. study which only incorporated temporal, spatial and causal pairs); in addition to investigating the priming effect in six different age groups versus three in the before mentioned study.

The findings of this experiment are contrary to the shift hypothesis that children of 6 years of age do not represent categorical relations. Current data suggest that children as young as 6 years of age pose categorical knowledge since like adults, children showed robust priming for pairs of words that were categorically related as well as thematically related. Therefore it seems, that when a word is heard in isolation, semantic information concerning which category the word belongs to as well as the situation/event schema of its referent is rapidly and automatically accessed. Because these priming effects were obtained with no wider contextual support, and were consistent with different age groups of participants, it is plausible that this information is indeed revealing the properties of semantic representation.

It was apparent that children and adults demonstrate a similar conceptual activation for implicit tasks. Consistent with overall improvement in processing speed across childhood (Hashimoto et al., 2007; Nation & Snowling, 1999; Perraudin & Mounoud, 2009), 6-year olds made slower responses that did 9-year olds, who were slower than 12-year olds, who were slower still than 15-year olds who were slower than young adults. Also consistent with the aging literature, older adults performed more slowly than did young adults (Cerella, 1990; Fisk & Rogers, 1991; Laver & Burke, 1993; Rogers & Fisk, 1990). However, as indicated earlier there were no type effects on degree of priming between age groups.

Study data suggests that although children and adults attend to taxonomic information when confronted with words, it seems that the meaning of a word involves much more than the understanding of its taxonomic relations. All language learning takes place within a context. Lund and Burgess (1996) have suggested that inferences about a word's meaning is driven by our implicit tracking of the patterns of co-occurrence in our language. Current models of word meaning acquisition (i.e. Latent Semantic Analysis (LSA) by Landauer & Dumais's (1997) or Lund & Burgess's (1996) Hyperspace Analogue to Language (HAL)) concentrate on the acquisition of word meaning from within context. These models relay on frequency of co-occurrence in natural language, or lack thereof, in order to infer the meanings of words. Lund and Burgess (1996) found that near neighbours in a co-occurrence space shared both taxonomic and thematic properties.

The theoretical notions of LSA (Landauer & Dumais, 1997) or HAL (Lund & Burgess, 1996) are similar to Mandler's (2000) that children's initial conceptual categories may be formed based on events' associations, suggesting that an understanding of thematic relationships may also be important to our categorization and understanding of novel words.

Nelson (1996) also suggests that early conceptual understanding of a word is often context bound. Contextual information may be encoded with each new experience with a word so that, although attention is focused on taxonomic relationships, thematic information may also be part of the early representation of a word's meaning. Madole and Oakes (1999) suggested that initially language users attend to basic level taxonomic information and as the conceptual knowledge base builds, thematic information is incorporated into the knowledge of a word's meaning. Together all these findings suggest that a representation of a word's meaning might include both taxonomic and thematic information.

Additionally, although there was an overall significant priming effect for category conceptual pairs, a closer inspection for each conceptual condition, revealed some interesting differences in the priming for the various subtypes. Specifically, priming was strong for functional relations, such as belt-trousers and barrel-wine, for all participants older than 9 years of age. For participants for whom functional relations did not yield the fastest responses, namely the 6-year old group and the 9-year old group, superordinate artifact and superordinate living relations primed fastest respectively. The important finding here is that the second fastest RT for groups that responded fast to functional pairs were pairs from categorical relations, and for groups whose fastest RT came from pairs in the categorical relations, their second fastest RT came from functional pairs. Equally important is that these differences were not statistically significant. This further supports the claim that both category membership as well as thematic properties are important for conceptual meaning.

One finding of the priming study stands contrary to prediction. It was expected that participants, especially the 6-year-olds, would demonstrate a larger priming effect in response to thematic than to taxonomic relations. That these effects were instead highly similar might be taken as evidence against the shift hypothesis. However, did these effects depend on the task? Namely the naming task that involves a great deal of language, or could these findings be replicated with other tasks, in which language is less salient? Several studies that used other experimental paradigms (e.g., classification) have shown that naming has an influence on how children structure their knowledge (Dunham & Dunham, 1995; Markman & Hutchinson, 1984). In particular it has been demonstrated that in the absence of naming, young children tend to group objects thematically whereas in naming tasks they tend to group primarily categorically (Liu, Golinkoff, & Sak, 2001; Waxman, 1999).

Thus, in an attempt to further investigate the shift hypothesis, a second experiment was set up. In this second experiment, following the priming results, the shift hypothesis could be further challenged, if we could demonstrate a thematic advantage with the same 6-year old participants. One task that could elicit such an advantage is the triadic task. In Experiment 2, this task was administered to test the prediction that children, as well as the elderly, who demonstrated equivalent automatic processing of thematic and taxonomic relations (in the implicit object naming priming task), would prefer to categorize thematically over taxonomically, in a more demanding task (the triadic categorization task). These predictions follow directly from an alternative to the shift hypothesis, the performance hypothesis.

Unfortunately, targets for each word pair could not be matched for frequency of occurrence for the different relational types. This is because there are no published databases in the Greek language for word occurrence frequency. As a result, it was not possible to address the possibility of high frequency words being recognized more quickly than low-frequency words, possibly because they have lower activation thresholds. Further, in an attempt to carefully control for normative association as well as conceptual relatedness, categorical pairs were not matched on typicality (based on the Battig & Montague, 1969 norms), and hence it was not ensured that all pairs were equally typical of their category (Moss et al., 1995). Perruchet, Frazier, and Lautrey, (1995), concluded from their results that category exemplar typicality may be an important variable, as young 7 and 9-year old participants showed comparable amounts of priming when study items were typical members of their categories. This is something future research could address.

Finally, this study investigated differences in the processing of taxonomic and thematic conceptual relations with the two types having several sub-types each. It was not possible for this study to analyze results at the subtype level as the cell power would be very low for any meaningful interpretations. However, exploring the different sub-types would be an interesting future research project. Studying possible processing differences between the specific sub-types of thematic or taxonomic relations might prove valuable in the future.

Chapter 4

Experiment 2

The Triadic Study

"Making comparisons is a very human occupation. We spend our lives comparing one thing to another, and behaving according to the categorizations we make. Patterns govern our lives, be they patterns of material culture, or patterns of language." (Dienhart, 1999).

Categorization is a fundamental cognitive process, as it involves the ability to group objects and representations about the world and to communicate those concepts to others. Language competence and the formation of the mental lexicon rely heavily on one's ability to group items into categories based upon common sets of features or common functional and motor relations (Markman, 1989; Mervis & Bertrand, 1994; Nelson, 1982).

According to Sloutsky (2003), categorization is essential in most cognitive activities, including problem-solving, memory, and perception. This is because it allows for cognitive economy as it efficiently incorporates a potentially infinite number of individual information into a smaller number of categories. Further, by organizing the knowledge of concepts into categories makes processing less demanding cognitively. Finally, categorization supports induction processes, since members of a category often possess unobserved common properties (Sloutsky, 2003).

Taxonomic vs Thematic categories

Imagine a category as things that cluster together, as groups of objects of the same kind (Pennequin, Fontaine, Bonthoux, Scheuner, & Blaye, 2006). As a result, taxonomic categories refer to an overlap in perceptual features (e.g., carrot and zucchini) (Collins & Loftus, 1975; Mervis & Rosch, 1981; Smith et al., 1974). To reiterate what was clarified in the first chapter, these types of categories are generally divided into superordinate, subordinate and coordinate within the taxonomic structure. Superordinate categories are those that are the highest in the structure (e.g., living things). Subordinate are lower in the structure (e.g., vegetables) and coordinates are the last link in the structure (e.g., carrot and zucchini). Characteristic features are shared by many, although sometimes not all members of a category. Typical members of a category are those that possess many of the category's characteristic features. The superordinate will always have less defining features than its subordinate. To illustrate, both robin and bird share the same defining features but robin will have additional defining features, such as red-breasted. Likewise, members at the coordinate level have more features in common than members at the subordinate level. Hence, taxonomically related entities can be related, if they have similar perceptual features (Hashimoto et al., 2007; Medin & Ortony, 1989). These can include category members whether those are living things (e.g., cat and dog) or artifacts (e.g., pen and pencil).

Thematic categories refer to concepts that are related because of an event schema, a theme, or a scene (e.g., a dog and bone, as dogs usually eat bones) (Pennequin et al., 2006). Events and objects in our world do not occur at random; they occur in an organized manner and in typical relationships. Then human memory, Rescorla (1967) explains, forms associations among events and objects that co-occur. Objects related by themes do not necessarily share common features; rather they are bound by an event schema (Shank & Abelson, 1977). Some additional examples to the ones provided in the second chapter for some thematic relations that bind objects into themes include ***spatial*** (e.g., a *fish* lives in the *sea*), ***script*** (e.g., if they co-occur during training (Plaut, 1995), e.g., a *pig* rolls in the *mud*), ***part whole*** (e.g., a *bell* is part of a *church*), ***functional*** (e.g., a *bee's* major function is to produce *honey*), ***featural*** (e.g., a *frog* is g*reen*), ***causal*** (e.g., a *cloud* will result in *rain*).

Taxonomic and Thematic Categorization across the lifespan

Both taxonomic and thematic relations seem to be available early in life (Daehler, Lonardo, & Bukatko, 1979; Greenfield & Scott, 1986; Scott et al., 1982). Yet, when categorization behavior is compared between pre-school children and older children and adults, there is evidence to support that the former have a conceptual preference for thematic over taxonomic relations, whereas adults generally sort taxonomically (Annett, 1959; Denney, 1974; Greenfield & Scott, 1986; Kagan, Moss, & Siegel, 1963; Scott, Scott & Serchuk, 1980; Scott et al., 1982; Smiley & Brown, 1979).

Most studies investigating taxonomic versus thematic preferences have used forced choice paradigms such as the triads task or a forced-choice category construction task; in which participants are presented with a target item (e.g., a monkey) and are asked to choose which of two alternatives, one bearing a thematic relation to the target (e.g., banana) and the other bearing a taxonomic relation to the target (e.g., gorilla) is most related to the target. A free sorting paradigm, where subjects were asked to group drawings of common objects *"in any way they wish"* or to group the ones *"that go together well"*, was also commonly used to investigate categorical preferences.

Healthy older adults, when asked to group objects in any way they like (free sorting paradigm), they were less likely than younger adults to use taxonomic categories as criteria for grouping (Annett, 1959; Fontaine & Toffart, 2000). In these studies, taxonomic categories seemed less available for older people, than for younger adults. Likewise, the results of Smiley and Brown (1979), in a matching-to-sample task, revealed that the majority of the elderly subjects made thematic choices, compared to a majority of taxonomic choices made by young adults. Similarly, Denney and Lennon (1972) in a free sorting task, showed that the elderly participants (65+ years of age) made more thematic choices compared to younger adults (25-55 years of age) who made predominantly taxonomic choices.

Tyler and Moss (1998) in an interesting case study of a patient with semantic dementia investigated the progressive deterioration of functional as well as perceptual properties and category relations. Interestingly, functional properties were most resilient to brain deterioration, as these properties were preserved longer than category information. Schwartz et al. (2011) in a study of picture naming with individuals with aphasia, showed that participants were far more likely to make a taxonomic error rather than a thematic error.

Studies that investigated patients with a range of neurological disorders (including Alzheimer's dementia (AD), CVA, traumatic brain injury (TBI), Herpes Simplex Encephalitis (HSE) to name a few) identified specific category deficits in their patients; namely performance for living things was impaired while performance for non-living things was preserved (Basso, Capitani, & Laiacona, 1988; Farah, Hammond, Mehta, & Radcliffe, 1989; Hillis & Caramazza, 1991; McCarthy & Warrington, 1988; Warrington & Shallice, 1984).

Therefore, studies which compared the categorization abilities of participants ranging in age from very young to very old, have supported the notion that very young participants as well as the elderly will exhibit an increase in the use of thematic relations compared to older children or young adults. Two explanations could be proposed for this shift in categorical abilities across the life span. The first assumes that the ability to perceive and use taxonomic relations declines (Annett, 1959; Denney & Lennon, 1972). Provided taxonomic categories require greater inductive power (Markman, 1989), they are acquired later in life (Nelson, 1983) and are sensitive to neuro-physiological modifications (Pennequin & Fontaine, 2000). The second explanation involves stimuli selection and experiment instructions. For example, very few meaningful thematic relations were in Annett's (1959) and in Denney and Lennon's (1972) experimental stimuli. The stimuli in the studies that formed the original data base for proposing the categorical shift, used such stimuli such as geometrical designs, animate or inanimate objects, or stimuli that differed in certain dimension (shape or color) (Murphy, 2001). As a result young children who could not identify these categories would form thematic groupings of items. Older subjects, who could easily identify the taxonomic categories in the stimuli, which did not have any strong thematic organization, would sort taxonomically. Furthermore, some studies, like in the case of Annett (1959) used stimuli that could be broken into taxonomic categories of the same size, but they were not chosen so that they would exemplify thematic relations (Lin & Murphy, 2001). Therefore, stimuli of this sort did not provide a fair comparison of thematic and taxonomic categorization. In terms of experimental instructions, some authors raised the concern (i.e. Denney, 1975; Lin & Murphy, 2001) that certain instructions could strongly influence categorization performance. For example, if subjects were instructed to *"to find the things that form a category"*, they might have been more likely to sort taxonomically. Likewise, if subjects were instructed to *"which two of the three items best form a pair",* they might have been more likely to sort thematically. Hence using neutral instructions in these sort of studies is imperative.

These stimuli limitation were recognized by Lin and Murphy (2001), and Murphy (2001) who constructed a series of experiments in order to challenge this proposed thematic-to-taxonomic shift in young adults. Lin and Murphy (2001) in a triadic, forced-choice category construction task, varied their instructions in a series of experiments and found that when thematic relations are meaningful and salient, they **can** influence young adults' category construction so that they too can engage in thematic categorization.

The present study in an attempt to investigate this shift in categorization ability, explored the performance of six groups ranging in age from 6-year olds to 63+ year olds in a traditional triadic sorting category construction task. In light of the poor stimuli selection in previous studies, and conflicting findings between earlier studies and results from Lin and Murphy's (2001) experiment, the goal of the present experiment was to compare the relative effects of associative strength and type of relation on the categorical choices of young and older children as well as young and older adults.

It was hypothesized that if categorical choices were primarily driven by associative strength, then strong associates would be more frequently chosen than weak associates in all configurations (both homogeneous and heterogeneous). Alternatively, if both associative strength and conceptual relation have an influence on categorical choices, then this would be observed in heterogeneous configurations. It was hypothesized that thematic relations will have an advantage in the preferences of 6-year olds and the elderly participants.

Method

Participants

The same six groups of participants that were used for the priming study were used for this experiment with the same inclusion and exclusion criteria.

Stimuli

The stimuli consisted of colored pictures of concrete nouns, presented on a computer screen. All conceptual pairs and their degree of association were determined based on the Greek Normative Association Database as that was described in the priming experiment. Each trial comprised of a target (x) and two choice items (y and z). The two choices were related to the target in different degrees of normative association (strong vs weak) as well as in varying types of conceptual relation (taxonomic (Tx) vs thematic (Th)), creating different configurations.

Procedure

In order to show the influence of association strength and type of relation on categorization, each target was paired with 2 associated pictures in the following configuration:

Homogeneous configuration	Th+ Th-	(e.g., butterfly → spring or wings)
	Tx+ Tx-	(e.g., table → chair or desk)
Heterogeneous configuration	Th+ Tx-	(e.g., sheep → white or animal)
	Th- Tx+	(e.g., hand → foot or glove)
	Th- Tx-	(e.g., apple → snow-white or pear)
	Tx+ Th+	(e.g., pear → apple or green)

Note that a "+" association refers to a strong association according to the Association Norms and a "–" association refers to a weak association according to the Association Norms as these were created in the preliminary study.

For the heterogeneous configurations, a total of 20 trials were created for each configuration (4 configuration x 20 trials for a total of 80 stimulus trials). For the homogeneous configuration, 10 trials were created for each configuration (for a total of 20 trials).

All materials were depicted as pictures on a computer screen in a within subject design. Participants were tested individually in a quite environment. They were told that they will be presented with a picture target and two other picture cards that were related to the target picture (as per table above) and were asked to choose the best match with the target. It was made clear that there was no right or wrong answer, so that they could freely select whichever choice they thought was the most appropriate, as per example below:

Consider x

"*Which one of the picture choices goes best with x*"

Y Z

In each trial the target and the two associated pictures were shown. Associates were placed side by side below the target. After pointing at the target (saying "see x?"), the experimenter would ask: "which one (naming successively the 2 associated pictures) goes best with x?" Selection was made by pressing either the "z" button or the "m" button on the keyboard, corresponding to the Y and Z options respectively. There was no time constrain for each trial, however, participants were encouraged to respond as quickly as possible. Instructions were followed by a practice set of six trials that represented the different conditions used in the study. Immediately following the familiarization trials the participants completed the experiment. Every participant saw every set of pictures once. The six types of configurations were randomized and the spatial position of the 2 associates (strong/weak and Tx/Th) was counterbalanced across items for each block.

Results

The purpose of this experiment was to investigate whether categorical choices would be primarily driven by associative strength and/or type of conceptual relation. The effect of relational strength on categorical preference was studied first with a MANOVA. An average of preferred choices were calculated for each subject for each configuration. Total compound scores for homogeneous configuration (Th+/Th- and Tx+/Tx-) and heterogeneous configuration

(Th+/Tx- and Th-/Tx+) were then subjected to a repeated MANOVA with type of configuration as the within factors and age as the between factor.

Following the analysis for the effect of strength on categorical choices, an analysis of type of conceptual relation on categorical choices was performed. Similarly, it was studied with a one-way Repeated MANOVA. An average of preferred choices were calculated for each subject for each heterogeneous configuration (Th+/Tx-, Th-/Tx+, Th-/Tx, Tx+/Th+). Total compound scores for heterogeneous configurations were then subjected to a repeated MANOVA with type of configuration as the within factors and age as the between factor.

Strength analysis will be presented first followed by the type of conceptual relation analysis. The dependent variable in the first analysis was number of strong choices made by each age group for the different configurations. The dependent variable in the second analysis was the number of thematic vs taxonomic choices made by each age group for the different configurations. Gender was not a significant covariate for strength nor type of conceptual relation.

Strength of association.

The one-way repeated MANOVA showed a statistically significant effect of strength on the choices made, $F(2.695,474.252) = 37.314$, $p < .0005$, partial $\eta^2 = .175$. Age also affected significantly the type of choices made, $F(5,176) = 6.890$, $p < .0005$, partial $\eta^2 = .164$.

There was a two way interaction effect of strength by age, $F(13.473,474.252) = 3.085$, $p < .001$, partial $\eta^2 = .081$. All groups chose the strong associate for homogeneous configurations (Th+/Th- and Tx+/Tx-). The same was true for the heterogeneous configurations (Th+/Tx- and Tx+/Th-), with the exception of the 63+ year olds in the Tx+/Th- configuration, who showed a preference for the stronger associated word to form a pair with the target (Figure 2.1). It is evident from figure 2.1 that although strong associates were chosen for all configurations by nearly all age groups, strong choices were easier to make in a homogeneous configuration rather than in a heterogeneous configuration, making it clear that association strength was not the only deciding factor in making a categorical choice; conceptual relation also plays a role.

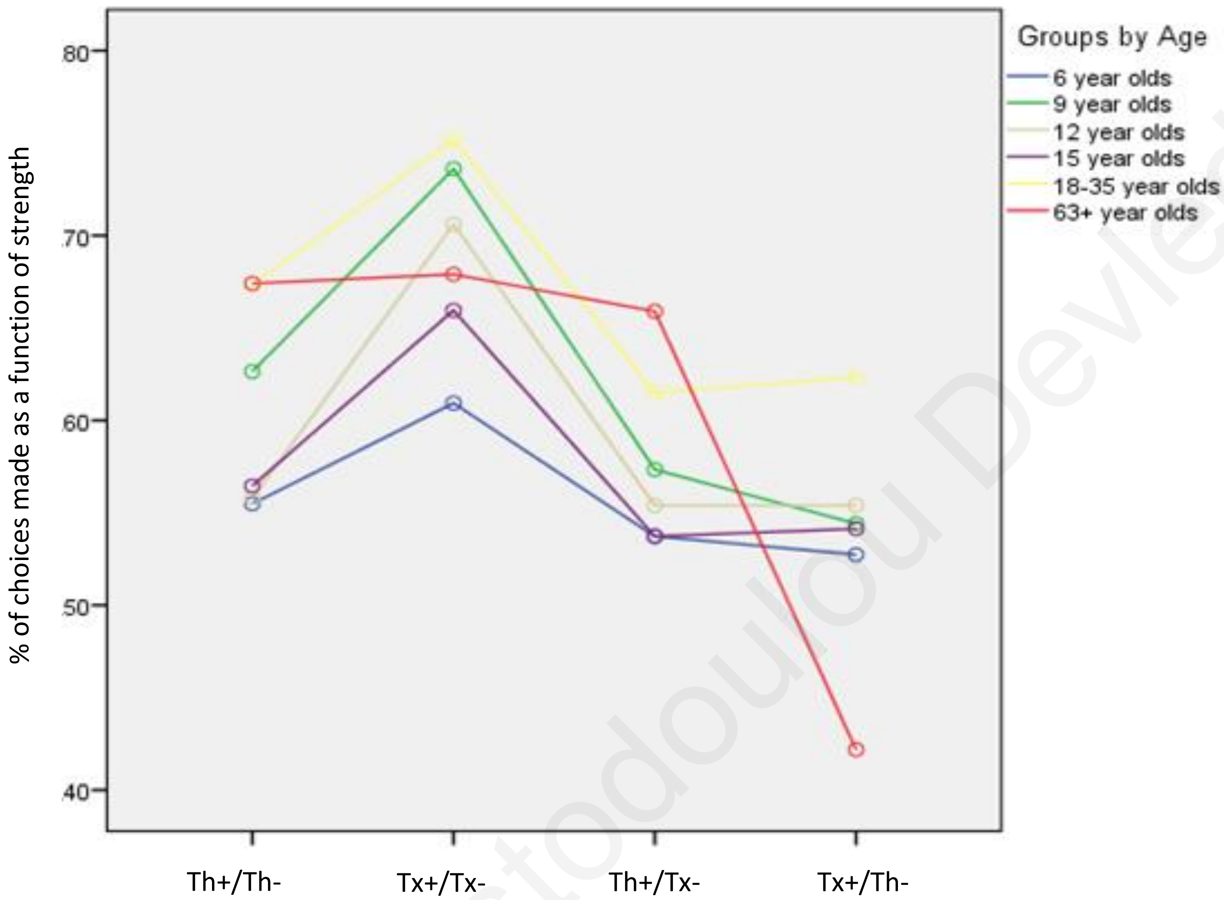


Figure 2.1 Choices made in the triadic experiment, by each age group, as a function of strength. Choices closer to 100 indicate strong association and choices closer to 0 indicate a weak association.

Conceptual relation.

A one-way repeated MANOVA was further performed with age groups as the between subject factor and type of heterogeneous configuration as within subject factors. The analysis revealed main effects of configuration, $F(3,528) = 65.904$, $p < .005$, partial $\eta^2 = .272$. More importantly with a heterogeneous configuration Tx+/Th+, all groups made more taxonomic categorizations with the exception of the 6-year olds and the 63+ year olds who made more thematic categorizations. With a heterogeneous configuration Tx-/Th-, all groups made more thematic categorizations, with the exception of the 15 and 18-35 year olds who were equally likely to make a thematic categorization as they were to make a taxonomic categorization. A chi-square test to investigate whether the results for this latter type of configuration for these two groups could be attributed to chance, revealed that the preference for thematic pairings was evident in every opposition pair, $x^2(17,61) = 88.20$, $p < .001$.

There was also a main effect of age, $F(5,176) = 5.882$, $p < .0005$, partial $\eta^2 = .143$. 63+ year olds behaved similarly to 6 year olds and significantly different from the rest of the groups $p < .05$ (Figure 2.2). This was validated by a type by age interaction effect, $F(14.763,519.664) = 5.127$, $p < .001$, partial $\eta^2 = .127$.

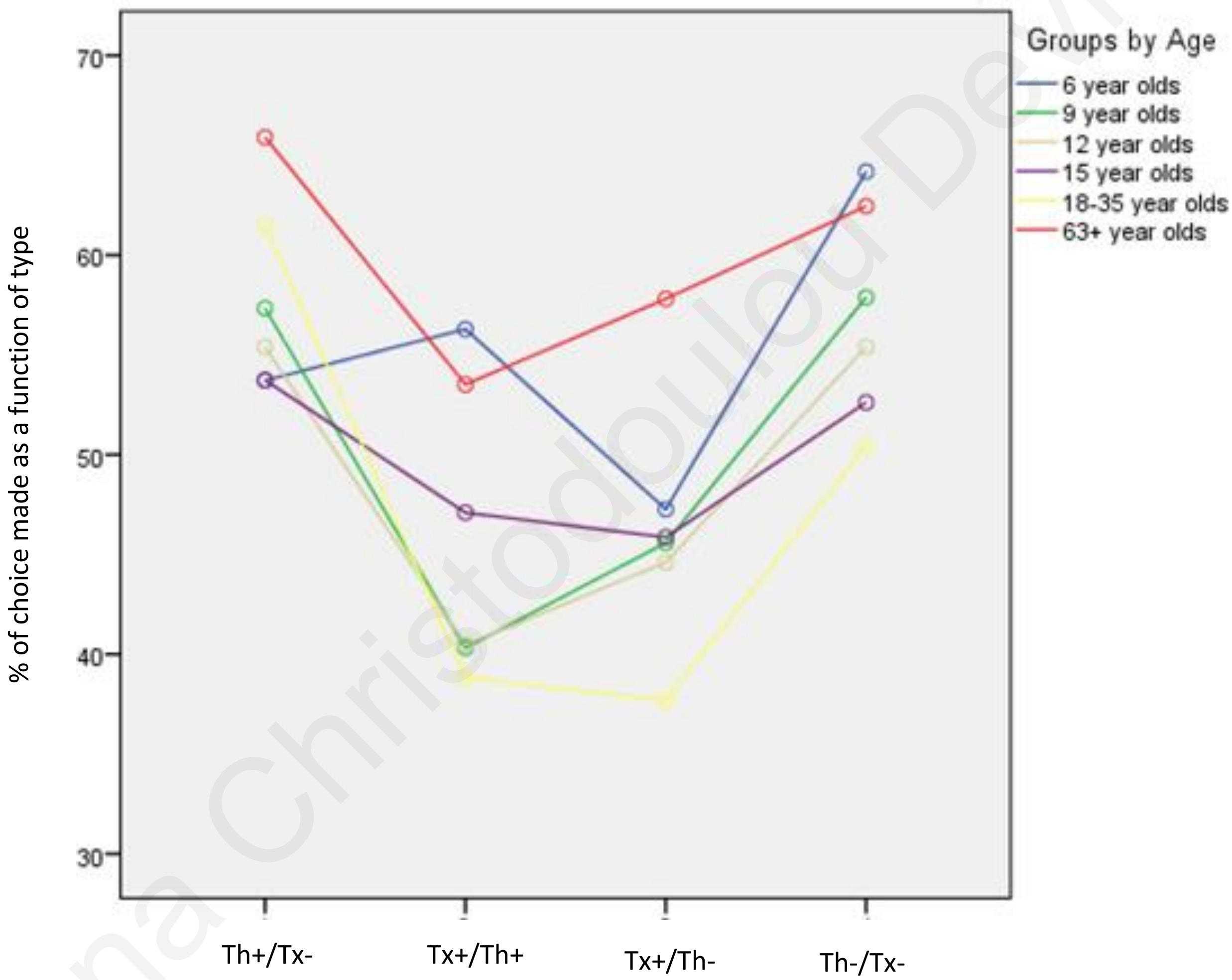


Figure 2.2 Choices made by each age group as a function of type of heterogeneous configuration. Choices closer to 100 indicate thematic choices and choices closer to 0 indicate taxonomic choices.

Discussion

The main objective of this study was to (1) determine whether categorical choices were driven primarily by association strength, and (2) to investigate the categorical choices of young and older children as well as young and older adults when a forced choice task between a taxonomic or a thematic preference was to be made.

In response to the first objective, it was evident that strength of association played a significant role in subject choices across configurations (both homogeneous and heterogeneous). Results in homogeneous configurations (two thematic or two taxonomic associate choices), indicated that choices were based on the associative strength for all ages since strong choices were always predominant. Similarly, all age groups preferred to categorize the target with the more strongly associated pair option rather than the weakly associated pair option in the heterogeneous configurations as well (Tx+/Th- or Tx-/Th+), except the elderly group, who insisted on categorizing thematically despite the strong taxonomic alternative.

However, although strong associates were chosen for all configurations by nearly all age groups, it was evident that strong choices were easier to make in a homogeneous configuration rather than in a heterogeneous configuration, making it clear that association strength was not the only deciding factor in making a categorical choice (Figure 2.1 and 2.2).

This preference for strong associates is consistent with the findings of experiment 1 as well as previous studies that suggest an associative boost when studying semantic relations in priming experiments. Lucas (2000) in his meta-analysis paper on semantic priming, supports that adding association to a semantic relationship increases the size of the priming effect. In other words, strong association has a positive effect on lexical access over and above that provided by the conceptual relationship alone. It is possible that stronger associated concepts, are more automatically activated and might prevail in a controlled comparison process when choosing between two competing associates (Crowley, Shrager, & Siegler, 1997).

In terms of the second objective, namely investigating the issue of cross categorization, when association was equated between the choices (either both choices strongly associated or both choices weakly associated), it was shown that when categorization choices were strongly associated, subjects consistently made taxonomical categorizations except for the two extreme age groups on either side of the age range; the 6 year olds and the 63+ year olds. When the two choices were weakly associated, all age groups made a thematic categorization except the 15 year old and the 18-35 year old groups who were equally likely to choose a thematic pair as they were to choose a taxonomic pair.

Several categorization studies have proposed that detection of similarity between taxonomically related units of information requires a more advanced level of analysis (Lin & Murphy, 2001; Mandler, 1983; Markman & Callanan, 1983) because forming taxonomic categories requires extracting a more abstract relationship between a target and a match pair (Sachs, Weis, Krings, Huber & Kircher, 2008). On the other hand thematic relations among objects come mainly from individual experience with specific scenes in which these objects were involved.

From a neurophysiological perspective, studies support distinct brain area activation for taxonomic and thematic categories. Thematic categories seem to activate left superior and middle temporal regions, while taxonomic relations lead to mainly right fronto-temporal signal changes (Sachs et al., 2008; Sachs et al., 2008a; Sass, Sachs, Krach, & Kircher, 2009). Additionally, taxonomic processing requires activation of the thalamus, which is associated with rule-based categorization (Grossman et al., 2002).

Jung-Beeman (2005) supports that one preliminary conclusion is that, as language input gets increasingly complex, there is increasing involvement of anterior temporal regions and of right hemisphere homologues (Bookheimer, (2002); Demonet, Thierry, & Cardebat, (2005); Humphries, Willard, Buchsbaum, & Hickok, (2001); Xu, Kemeny, Park, Frattali, & Braun, (2005)) to classic left hemisphere language areas. As a result, these evidence suggest that in addition to well-known left hemisphere language processing, the right hemisphere also contributes to language comprehension.

Moreover, studies report that the activity of the right hemisphere is greater than the left hemisphere when subjects perform higher level language tasks, such as deriving themes (St. George, Kutas, Martinez, & Sereno, 1999) or drawing inferences (Mason & Just, 2004). This does not suggest that the right hemisphere performs these actions entirely on its own, but it appears to contribute to them (Jung-Beetman, 2005).

This distinct brain activation for taxonomic and thematic categories, could explain the consistent thematic preferences of the 6 year old group and more so of the elderly group. There is an abundance of evidence to support that the development of the frontal lobe is a staging process that begins in early childhood, with a great period of development after 6 (Passler, Isaac, Hynd, 1985; Romine & Reynolds, 2005), with the maturation of frontal functioning into adolescence and early adulthood. Similarly, experimental data supports a decline in the total brain volume of a normal aging brain, mainly due to the contributions of the frontal lobe and hippocampus alterations, along with the functional changes in executive function processes (Drag and Bieliauskas, 2009).

As a result, provided taxonomic categories require the contribution of frontal lobe processes, then structural changes in frontal lobe in the elderly brain as well as developmental formation in the young brain, it will make it difficult for both of these groups to implement the necessary strategies required to identify commonalities between concepts in order to make taxonomic categorization.

This is further supported by the thematic choices made by nearly all groups when the heterogeneous configuration involved weakly associated choices for the target. In light of taxonomic categories being made on the basis of "things of the same kind" judgement, or in identifying common perceptual features, it is not surprising that when association was weak between target and possible choice that groups would resort to thematic choices as these would be more easily accessible and would require less effort. The fact that the two groups with the most developed executive function processes in the study (15 and 18-35 year olds) were able to choose equally between the two options proves the point even further.

The present findings underline the importance of thematic relations and provide evidence that both taxonomic as well as thematic categorization are possible ways of organizing semantic knowledge. Taxonomies can prove very useful when information that needs to be organized is enormous, and would be able to reduce the level of complexity to a more manageable fashion, something that thematic categories would not be able to do due to their lack of structure. On the other hand, thematic categories are particularly good at representing information as to what happens in a particular event or situation, so much that sometimes it is impossible to talk about one concept without making reference to another (Lin & Murphy, 2001). Therefore, both kinds of knowledge are necessary, although the two seem to require two very different cognitive processes.

This study, similar to the study by Lin and Murphy (2001) who clearly showed that young adults can engage in thematic categorization and in specific circumstances prefer it over taxonomic categorization, showed that young adults are equally likely to engage in thematic organization as well as taxonomic organization when the variable of association strength is minimized. However, this study adds the added advantage of systematically matching stimuli on association strength, a variable that was not controlled in the Lin and Murphy study. Further, the thematic matching in the Lin and Murphy study, was done on the bases of their own perceptions, such that *"to ensure that thematic relations were salient in the stimuli, we selected thematic matches that we believed were integral to people's concepts of the targets or were meaningfully and coherently related to the targets"* (p. 7). Finally, the taxonomic matches that were related to the targets were at the superordinate level only. All of these variables were controlled in this study.

Future Research

This study investigated the effect of associative strength on categorical abilities, relying on associative strength as that was revealed on association norm databases. However, if we accept Pennequin's et al. (2006) argument that "*thematic relations among objects come mainly from individual experience with specific episodes in which these objects were involved" (p.2)*, then association strength depends on individual experience. If this is the case, then judgements of associative strength vary between individuals in a given age group, and might evolve with age. It would be valuable for future research to explore whether this variable would yield different results regarding the categorization choices both of children and adults.

Further, since categorization is such a valuable cognitive activity which allows us to reduce the complexity of the world in which we live in, then studying categorical flexibility might prove a fruitful future research endeavour. "*Categorical flexibility is a within-subject variable, corresponding to one's ability to switch successively between different representations of a given object (or a set of objects)*" (Blaye, Bernard-Peyron, Paour, & Bonthoux, 2006, p.164). Therefore, investigating whether the same target items (e.g., cow, chicken, sheep) can be cross-classified across ages, being considered as members of a taxonomic category (e.g., animals), or members of thematic categories, for example a spatial category (e.g., things that live on a farm), or a functional category (e.g., animals that give us products), could provide additional information as to how we organize semantic information.

In the literature review several studies were mentioned were adults with particular neurological disorders showed preserved processing for thematic versus taxonomic relations. Could categorical ability for particular kinds of conceptual relations detect neurological difficulties or decline when no other cognitive decline is obvious? For instance, through careful selection of stimulus materials and categorization paradigms and via systematic investigation, could we develop a categorization screening tool that could possibly detect children at risk for language difficulties, or adults with mild cognitive impairment?

This study used a triadic, forced-choice paradigm to investigate categorization ability. Would a different paradigm, such as a free sorting paradigm yield different results for young adults? Muprhy (2001), while using a free sorting paradigm with young English speaking undergraduate students revealed that indeed young adults prefer to sort thematically and not taxonomically as previous research suggested. A free sorting paradigm entails a greater number of stimulus sets than a triadic task does. Would the number of the potential thematic and taxonomic categories influence the performance of Greek speaking young adults and reveal similar findings to Murphy's?

Finally, another question that remained unanswered in this experiment is whether certain types of thematic relations (e.g., functional) would promote thematic categorization more than other types would (e.g., causal). Or whether induction on the basis of categorical members, such as, *"if apples have property x, do pears have property x?"* would be easier to make than induction on the basis of thematic members, such as, for the thematic category "things you find on a farm", *"if cows can x, then can sheep x?"*.

Chapter 5

Experiment 3

The Analogies Study

Experiment 1 required participants to name picture items in a priming task, in an attempt to assess the representation of taxonomic and thematic conceptual relations in six different age groups. It was hypothesized that thematically related word pairs will facilitate faster responses for the very young and very old participants. Results revealed that children as young as 6 years of age, as well as healthy older adults, possess categorical as well as thematic knowledge since, both groups, like young adults, showed robust priming for pairs of words that were categorically related as well as thematically related. Experiment 2 presented participants with a triadic sorting category construction task in order to investigate the categorical choices of young and older children as well as young and older adults, for taxonomic and thematic conceptual relations. One of the primary hypotheses was that thematic relations will have an advantage in the preferences of 6 year olds and the elderly participants, and that strength of association between the targets in a pair will affect performance. Results indicated that children, as well as young and older adults are influenced by the strength of association between the target picture and each categorical associate proposed as candidates for matching. Furthermore, young children and older adults consistently made thematic preferences regardless of associative strength. A couple of questions remained answered.

One question that remained unanswered was whether the same effects regarding conceptual relations will be evident in a justification rather than an identification task. If conceptual knowledge of taxonomic categories might still undergo important developments during the preschool years and deterioration during aging, then despite the ability of young and elderly subjects to identify these conceptual relations, they might not be able to justify them. Therefore, the purpose of the third experiment was to investigate the ability of the six different groups to justify how two pictures are related and then assess their ability to extend the relationship identified to a new set of pictures. Here, in the first phase of each experimental trial, subjects were asked to justify how two pictures were related before they were asked to make an analogical decision in extending the identified relationship to another set of pictures. Which brings us to another question. Would a developmental or an aging effect be evident in situations requiring a decision based on the type of conceptual relation at hand or the categorical rule that was used?

As argued in the previous chapter, categorization is an essential activity of human cognition. Categories created on the basis of shared perceptual features, form taxonomic categories, and objects that can be encountered together in a scene/event form thematic categories. One does not exclude the other. That is an object can be considered as a member of multiple categories; depending on the specific characteristics of a situation, it may be appropriate to favor one category over another. This selection of the most appropriate categorical representation for an object is ensured by categorical flexibility (Blaye et al., 2006; Ngugen & Muprhy, 2003). "*Flexibility of access to different categorical representations of an object raises the question of the control one can intentionally exert over the use of categorical relations" (Blaye, Chevallier, & Paour, 2007a, p. 792).* This control over the use of categorical flexibility is the main interest of this experiment.

The first aim of this experiment was to investigate lifespan changes in justifying conceptual relations, and hence draw conclusions regarding thematic and taxonomic representations. In the first phase of each trial, participants were presented with two colored pictures and asked to decide how these two pictures were related. This involved some degree of reasoning in order to detect the relation connecting the two stimuli, as well as general knowledge regarding their underlying representations. In this identification phase, thematic as well as taxonomic semantic relations were used; namely, the taxonomic relations used included, category superordinate/subordinate living, category superordinate/subordinate artifact, category coordinate living, category coordinate artifact, and the thematic relations used included, spatial, script, part/whole, functional, featural, causal, as an attempt to test the role played by these relationships in determining access to the concepts involved. The *second* aim of the study, was to investigate whether type of conceptual relation (taxonomic or thematic) would have an effect on switching, analogical thinking, and categorical flexibility performance across the age groups.

More precisely, there was an interest in both the ability to justify a conceptual relation as well as the ability to switch to a different task, while maintaining one type of categorical behavior across a series of new objects, while another potential categorization was possible. In order for a relationship to be justified between two concepts, one must have developed, and sustained, sufficient conceptual knowledge of thematic and taxonomic representations.

Furthermore, if the task requires participants to extend the identified relationship to a new set of pictures, this activity requires participants to switch to a different task, which implies task flexibility and sufficient executive control (Blaye & Jacques, 2009). Executive control processes include various kinds of judgments made on stimuli held in working memory (e.g. comparison of the relative recency of stimuli, judgments of the relative saliency or novelty of stimuli, etc) and active (voluntary) retrieval of specific information held in long-term form (Petrides, 1994).

As Blaye and Jacques (2009) point out in their paper, important components of executive control that have been proposed include cognitive flexibility, inhibition, and working memory (Diamond, 2006; Garon, Bryson & Smith, 2008; Hughes, 2002). Cognitive flexibility can be defined as *"the ability to flexibly switch perspectives, focus of attention, or response mappings"* (Diamond, 2006, p.70). Therefore, for the participants in this experiment to maintain a representation they would have to activate it in working memory and resist interference of distracting information (i.e. prevent irrelevant information from entering working memory; Friedman & Miyake, 2004). Likewise, switching from a justification to an extension task that requires analogical thinking and categorical flexibility, would entail inhibiting a previously activated representation (hence resisting its proactive interference, Friedman & Miyake, 2004) and activating an alternative one. Inhibition refers to the ability to exert inhibitory control on dominant prepotent responses (Carlson & Moses, 2001).

Several studies have been informative about the ability of children's and adults' categorization behavior. One test that is often used to study this behavior is the Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948) which involves switching between different sorting criteria. In this task, participants must first infer a categorical rule and then switch unexpectedly to different rules, based on the experimenter's feedback. Here the sorting rules are perceptual in nature, based on shape, size, color, and number. Another test used to study categorization behavior is the Dimensional Card Change Sorting task (DCCS, Zelazo, 2006). On the DCCS, participants have to sort objects according to a perceptual dimension (e.g., color) across a first series of trials and then switch to another dimension (e.g., shape) for a second series of trials. Findings from such studies show that executive control is efficient enough by 5 years of age to maintain and switch representations as long as perceptual categorical rules are at stake (Zelazo, Muller, Frye, & Marcovitch, 2003). However, in situations in which the relevant categorical relation must be inferred from response feedback (like in the WCST), maintenance and switching continue to improve until early adolescence (Cianchetti, Corona, Foscoliano, Contu & Sannio-Fancello, 2007; Huizinga & van der Molen, 2007).

Additional findings from studies that used these sorts of tests indicate that performance decreases in these tasks during normal aging (for a review see Rhodes, 2004; Ridderinkhof, Span & van der Molen, 2002). Further, as Maintenant, Blaye & Paour (2011) support, adults' abilities to resist interference (Davidson, Zacks, & Williams, 2003; Hasher & Zacks, 1988) and to switch between mental task sets (Hawkins, Kramer, & Capaldi, 1992; Kramer, Hahn, & Gopher, 1999; Kray, Li, & Lindenberger, 2002; Kray & Lindenberger, 2000) decline with age. Zacks and Hasher (1997) suggested that inhibitory processes are impaired with aging making it difficult for the elderly to ignore irrelevant information and attend to the task at hand. Like the aging brain, there are significant changes in cognitive flexibility during the preschool years (Carlson & Moses, 2001; Jacques & Zelazo, 2001; Zelazo, 2006).

The important thing to note here is that although these sort of tasks (i.e. the WCST or the DCCS) provide important information as to categorical flexibility in using perceptual rules, they provide little information about categorical flexibility involving conceptual relations (taxonomic and thematic relations); something that would prove much more functional for daily living, as daily activities involve semantic representations that include objects, events and people, rather than colored geometric shapes. Thus, in the present study maintenance and categorical flexibility is investigated by using conceptual relations of objects (taxonomic and thematic). The first phase of the study was a simple evaluation of conceptual relational knowledge. The second phase assessed the ability to maintain a categorical relation in the presence of distracting and conflicting response options.

Studies with adults diagnosed with mild cognitive impairment and AD, have led to the conclusion that these individuals, like very young children (Blaye et al., 2006; Blaye, Chevalier, & Paour, 2007b; Blaye & Jacques, 2009), have more difficulty using taxonomic relations rather than thematic ones, in various tasks (priming studies, categorization studies, match-to-sample studies etc). Similarly, when healthy older adults are asked to group objects in a free sorting paradigm, they are more likely than younger adults to use thematic criteria for their grouping (Cicirelli, 1976; Kogan, 1974). An interpretation for this performance could be attributed in terms of the differences in salience between thematic and taxonomic relations. Because of the salience of thematic relations (Pennequin et al., 2006), thematic relations may be easy to justify but particularly difficult to switch away from.

Whether certain conceptual relations will be easier to identify than others remains to be investigated provided this study involved several different types of taxonomic and thematic conceptual pairs. The developmental effects as well as the effects of aging on maintaining attention and switching between mental tasks have been repeatedly demonstrated and hence the difficulty to switch from justifying a relationship to extending it to a new set of pictures should be greater for young children and older adults than older children and younger adults (Kramer et al., 1999; Kray & Lindenberger, 2000; Kray et al., 2002). In other words, performance for the very young and very old groups is expected to decrease as executive demands increase across phases. Finally, it is hypothesized that extending a taxonomic relation in the presence of a thematic associate (which seems to be more salient for younger children and older adults) involves a greater resistance to interference than would the opposite situation (Blaye et al., 2007b; Maintenant et al., 2011). Therefore, an effect of conceptual relation (thematic vs taxonomic) on performance is expected, especially for the very young and very old groups. In other words, it is expected that young children and older adults, will have a better performance when thematic relations will be involved. Provided older children and younger adults have better abilities in resisting interference, this thematic relation effect should not be present.

Method

Participants

The same six groups of participants that were used for the priming study were used for this experiment with the same inclusion and exclusion criteria.

Stimuli

The stimuli consisted of colored concrete noun pictures, presented on a laptop computer screen. All conceptual pairs and their degree of association were determined based on the Greek Normative Association Database as that was described in the priming experiment. Each trial involved an identification phase and an extension phase. In the identification phase, two pictures were presented, one next to each other. Degree of association between pictures in the identification phase was high, and pictures were conceptually related in 10 different ways. The taxonomic pairs included, category superordinate/subordinate living, category superordinate/subordinate artifact, category coordinate living, category coordinate artifact relations; and the thematic pairs included, spatial, script, part/whole, functional, featural, causal relations . There were 5 instances for each relational pair, for a total of 50 trials (see Appendix D for a complete list of stimuli).

Each identification phase was followed by an extension phase. Stimuli and targets were not equated on association in this phase. A new target (x) was presented on the top of the page with 3 potential associates placed one next to each other (x, y, z) below it. Target and each possible associate shared a different conceptual relation.

Reliability Analysis

Tasks for conceptual relations in the three different experiments consisted of 20 items. Reliability analysis was conducted to assess internal consistency of the 20 items implemented in the three different experiments. The analysis resulted in a Cronbach's $\alpha = .758$, indicating an acceptable level of reliability and internal consistency among the three experiments (George & Mallery, 2003).

Procedure

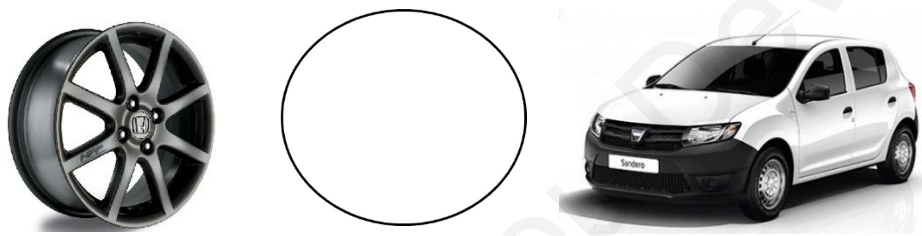
All materials were depicted as pictures on a computer screen in a within subject design. Participants were tested individually in a quite environment. They were told that they will be presented with two pictures, and told priori that these pictures are related in some way. Their task was to identify and name this relationship. Once the relationship was identified it was recorded by the experimenter, and the participant was asked to extent this previously identified relationship to a new set of pictures. Each trial included the following, as per example below:

Phase	Trial Example	
Phase 1 Identification	 A	 B

Phase 2

Extension

O



X Y Z

In each trial, the pictures from phase 1 were presented first. After pointing at the picture A (saying “see A?”), the experimenter would ask: “it is related to B in some way. Can you say which way that is?” Once identification was made, the experimenter would record the answer and present the next set of pictures for the extension phase. Here, the experimenter would say “Can you identify which picture in these set goes best with picture O so that you create the same “relationship x”, as for picture A and B?” Instructions were followed by a practice set of six trials that represented different conceptual relations used in the study. Immediately following the familiarization trials the participants completed the experiment. Every participant saw every set of pictures once. The ten types of conceptual relations were randomized and the spatial position of the 2 associates in the first phase as well as the extension phase was counterbalanced across items for each block.

Results

The purpose of this experiment was to investigate the ability of the six different groups to justify how two pictures are related and then assess their ability to extend the relationship identified to a new set of pictures. An average of correct identification and extension scores respectively, were calculated for each subject for each conceptual relation. Total scores were then subjected to a mixed model MANOVA with one within subjects factor with two levels (taxonomic vs thematic relations) and age as the between factor. Identification analysis will be presented first followed by the extension analysis. Gender was not a significant covariate for identification nor extension performance.

Accuracy of identification.

Table 3.1 indicates identification scores per group. Examination of the descriptive findings indicates that the 6-year olds and 63+ year olds found it much harder to justify a relationship between two concepts, as compared to the young adults who were the most capable to identify successfully conceptual relations. Differences between groups were significant, $F(5,176) = 5.031$, $p = .0001$, partial $\eta^2 = .125$ (Table 3.2).

The repeated MANOVA detected no reliable effect of conceptual type on identification performance ($F = .003$, $p = .960$), indicating that conceptual relation did not influence the success of identification. However, there was a significant interaction between conceptual type and age group, $F(5,176) = 2.786$, $p < .05$, partial $\eta^2 = .073$. Pairwise comparisons revealed that this was mostly driven by a statistically significant difference for the 9-year olds ($p<.05$), who found it easier to identify taxonomic relations rather than thematic relations. Identification of the different conceptual relations for all other groups did not reach significance, indicating that all other age groups were equally likely to identify taxonomic as well as thematic relations (Figure 3.1 and Figure 3.2).

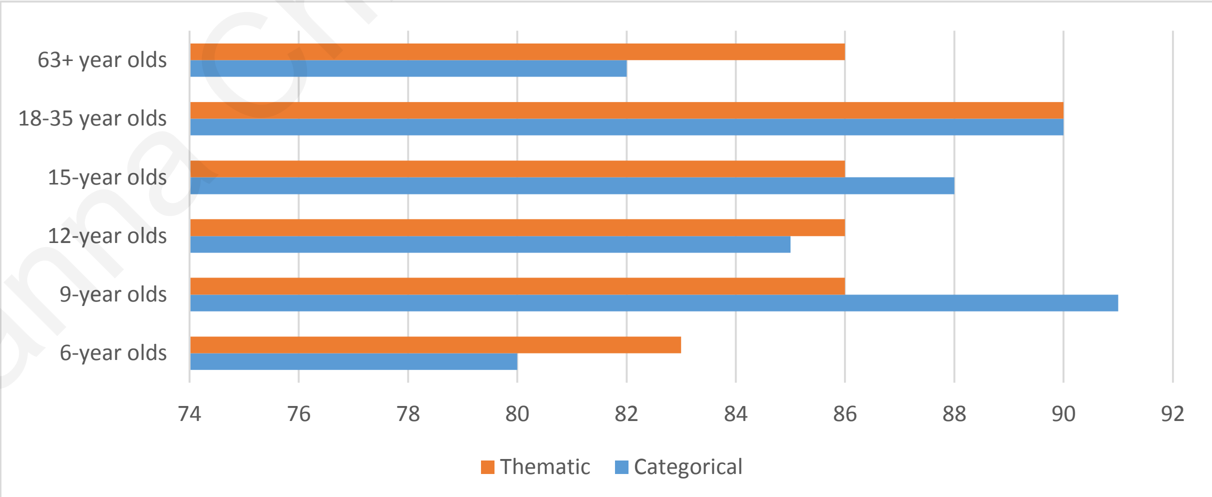


Figure 3.1 *Percentage of correct identification for each conceptual relation for each age group, in the analogies task.*

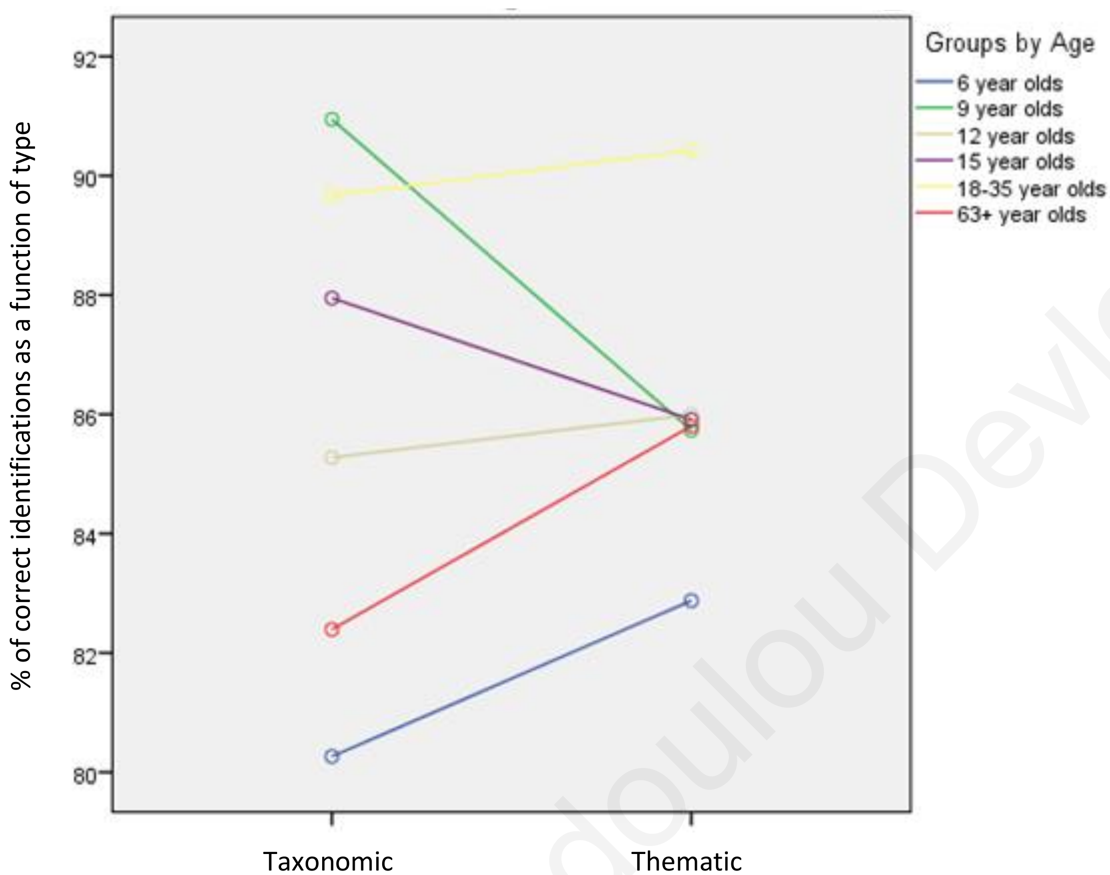


Figure 3.2 *Percentage of correct identification for each conceptual relation for each age group, in the analogies task.*

Accuracy of extension.

Table 3.3 indicates extension scores for each group. Examination of the descriptive findings indicates, as in the identification phase, that the 6-year olds and the elderly group had the most difficulty to extend the previously identified relationship to a new set of pictures. Once again differences between groups were significant, $F(5,176) = 15.224$, $p < .001$, partial $\eta^2 = .302$ (Table 3.4).

The type of semantic relation did not significantly affect extension performance ($F=1.073$, $p>.05$), however there was an interaction effect between type of conceptual relation and age group, $F(5,176) = 8.853$, $p < .001$, partial $\eta^2 = .201$. Pairwise comparisons revealed that 6-year olds and 63+ year olds found it easier to extend thematic relations versus taxonomic relations, and this was statistically significant. Further, 12-year olds and 18-year olds found it easier to extend taxonomic relations versus thematic ones, and this was also statistically significant. Although 9-year olds and 15-year olds also found it easier to extend taxonomic relations rather than thematic ones, this difference did not reach significance (Figure 3.3 and Figure 3.4).

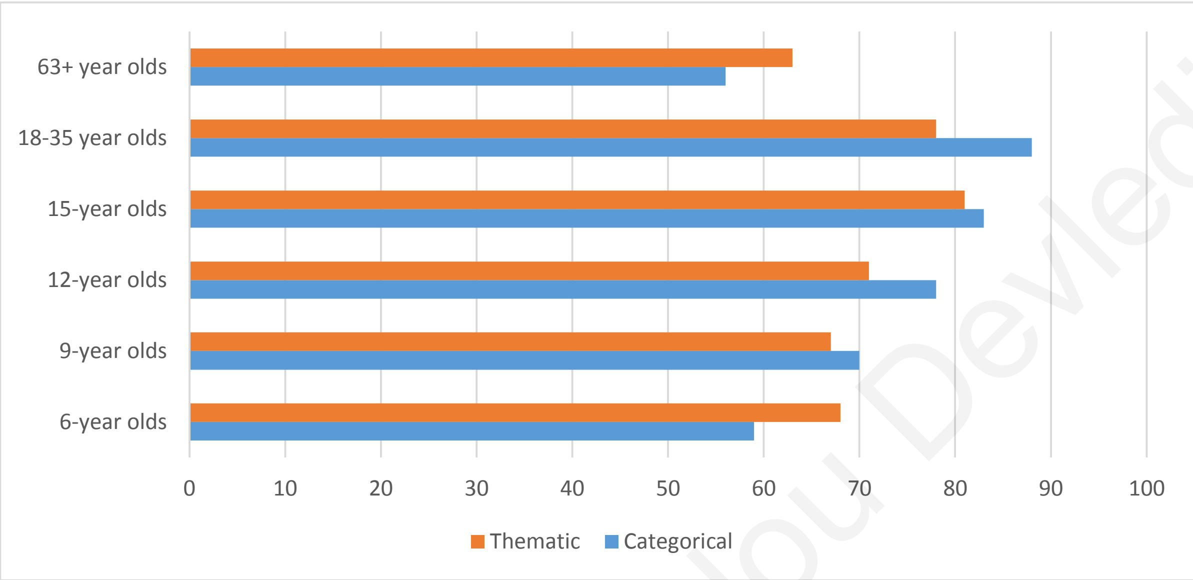


Figure 3.3 Percentage of correct extensions for each group as a function of type of relation, in the analogies task.

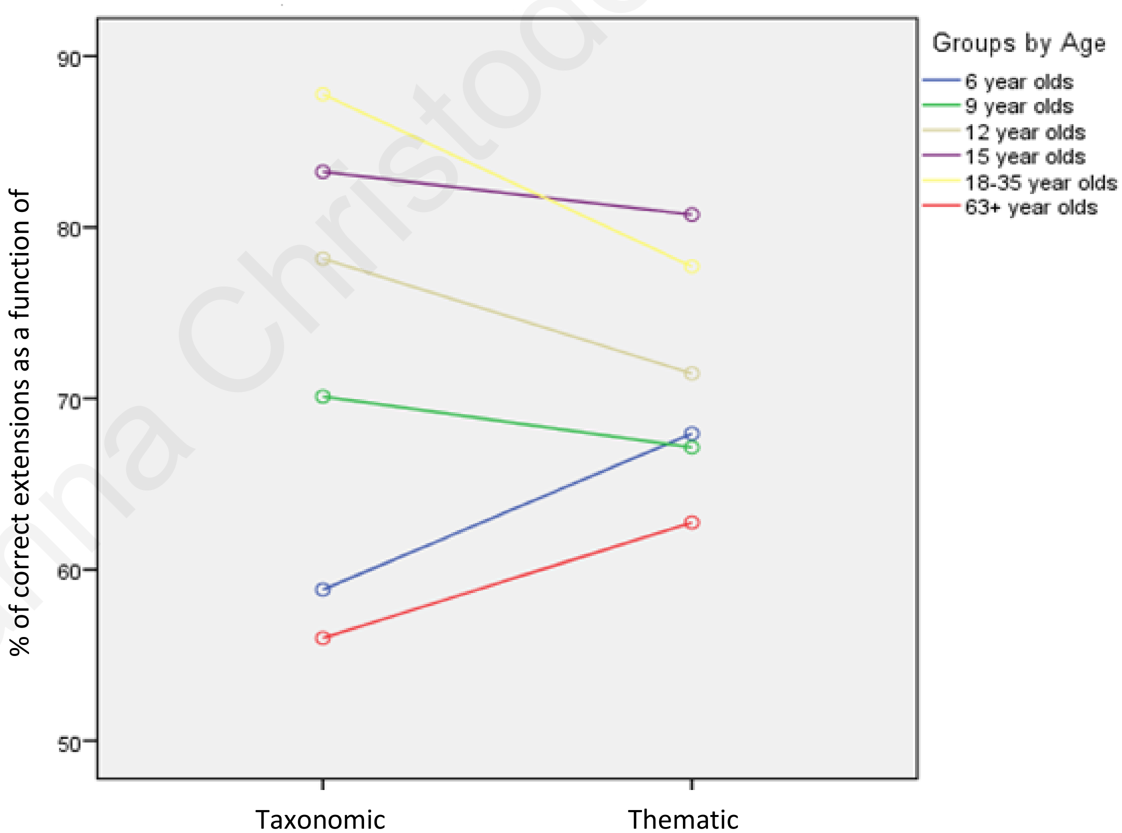


Figure 3.4 Percentage of correct extensions for each group as a function of type of relation, in the analogies task

Discussion

A key purpose of this experiment was to determine whether the type of semantic relation connecting two concepts will affect the ability to identify these semantic relations and whether justification ability would be affected by age. Indeed, performance was influenced by age, as young children and older adults were less able to justify a conceptual relation as compared to older children and younger adults, despite the absence of time pressure for responding. However, in terms of type of conceptual relation, all participants, including the very young and very old subjects, succeeded in the first phase of the task, demonstrating that participants had no difficulty identifying the different conceptual relations that were used to represent the two types of relations (taxonomic and thematic). This result, along with results from experiment 1, suggests that children, by the age of six, have acquired conceptual knowledge and are able to apply this knowledge to novel situations. This ability is maintained throughout the lifespan as demonstrated by the performance of older adults.

However, in phase 2 of this experiment, when subjects had to switch from a justification task to an analogical extension task, as expected, an effect of conceptual relations was revealed. Younger children and older adults were more successful in extending thematic relations rather than taxonomic ones. In other words, the effect of age was specific to the type of conceptual relation at hand. Present findings suggest that maintaining in order to extend a thematic relation when switching between tasks was less challenging than switching between tasks while maintaining a taxonomic relation.

It seems that maintaining and extending between available, but conflicting, representations is more difficult for taxonomic rather than thematic relations. An interpretation could be made in terms of the salience between thematic and taxonomic relations to account for young children's and older adult's performance. The salience of relations may modulate the degree of control required to maintain and extend between relations (Maintenant et al., 2011). Poorly salient taxonomic relations may be difficult to maintain in order to extend to a new set of stimuli especially when competing with salient themes, and hence requiring more executive resources than do thematic relations to be maintained and extended (Blaye et al., 2007b). Future research could aim to investigate whether better performance for thematic relation extensions were indeed the result of saliency by systematically matching thematic and taxonomic stimuli on association and frequency, something that was not done in this study.

These findings raise the possibility that younger children's and older adults' increased ability with thematic relations relative to young adults and older children was not due to differences in conceptual knowledge but rather due to cognitive limitations. *"As more advanced executive control is required to override highly salient representations than poorly salient ones, the difference in saliency between thematic and taxonomic relations may modulate the degree of control required to maintain and/or switch between relations"* (Blaye et al., 2007b, p. 804). A more definitive conclusion regarding this statement would require a thorough assessment of executive function, which was not within the scope of this experiment. Although, this executive interpretation is in accordance with previous studies showing that age-related effects observed on semantic fluency task with switching could be explained by executive control rather than by semantic processes (for a review see Laver & Burke, 1993; Mayr & Kliegl, 2000), future research should aim at establishing a correlation between executive control and conceptual representation as these interact at different stages in life.

Chapter 6

General Discussion

Young children as well as older adults are sensitive to both kinds of organizational networks (taxonomic and thematic) but they can be biased to favour one over the other depending on the cognitive demands imposed by the task at hand. The fact that the type of conceptual relation (taxonomic or thematic) did not have a significant effect on the degree of priming for the different age groups suggests that children as young as 6-years of age as well as elderly adults do possess knowledge of relations binding object concepts into taxonomies.

If Experiment 1 supports that young children and older adults have developed taxonomic concepts, why then did they prefer to categorize thematically rather than taxonomically in Experiment 2? Experiment 1, being an online implicit task, required only that participants recognize the concepts, allowing only projections on whether this knowledge is possessed. It didn't allow projections on the ability to use this knowledge, as the efficiency of thinking and using conceptual knowledge results primarily by the linkage of concepts and the possibility of activating these conceptual connections (Giacomo et al., 2012). When semantic deterioration in AD patients was investigated with semantic priming methodologies a priming effect in patients with mild to moderate AD was revealed, which did not differ from that in healthy elderly subjects (Beauregard, Chertkow, Gold, & Bergman, 2001; Randolph, Braun, Goldberg, & Chase, 1993). Whereas when studies looked at the processing of semantic relations (through more demanding semantic tasks, i.e., categorization or free sorting paradigms) in these patients they revealed very specific difficulties with certain types of conceptual relations (i.e., difficulty with superordinate relations and no difficulty with functional or part/whole relations) (Giamono et al., 2012; Peraita, Diaz, & Anllo-Vento, 2008). This suggests that reliance on priming results might not provide the full picture regarding semantic representations.

Experiment 2, being an offline explicit task, encouraged the conscious reflection upon conceptual relations. Together with the fact that taxonomic concepts are generally more abstract than thematic concepts (Maintenant et al., 2011; Scott, Greenfield, Urbano, 1985), as well as increased task demands, Experiment 2 required a more robust level of knowledge to support performance. Further to the findings in Experiment 2, as well as findings from the second phase of Experiment 3, where young and older participants extended thematic relations more easily than taxonomic relations, suggests that thematic relations are less exposed to task demands as predicted by the performance hypothesis.

Taken together, these findings support that although both taxonomic and thematic types of information are available throughout the lifespan, the value of thematic information may be greater in real word situations and maybe this is why it withstands the aging process and seems to be preserved longer. It appears that establishing a general category to which an object belongs or identifying common features of objects that would suggest sharing the same category, is more challenging and demanding than the requirements involved with thematic relations. For instance it would be much easier to identify a relation between an aeroplane and a wing (part/whole relationship) or between comb and hair (functional relationship), because these concepts have often been encountered in physical proximity, and thus, are closely related, familiar and more useful to a person, than identifying that a flute is a wind instrument. The latter is more abstract as it would require some degree of deductive reasoning before one recognizes the resemblance between the two concepts and the properties they share with each other.

An understanding of a taxonomic relationship may be useful when inferring the meaning of novel words. Taxonomic information may have been encoded during the initial encounters with the words, in such a way that it could allow for an inference as to the meaning of a new concept. However, there is a limit as to how useful taxonomic information could be as it is bound by class inclusion based on common perceptual features. Thematic information on the other hand increases more across word levels as the word is encountered within context, and hence seems to be much more useful to deeper understanding of a word's meaning across different contexts. For example, if one encounters the word *emptra* in the following sentence, "I put a nice *emptra* in the salad", the learner might encode that *emptra* is some sort of vegetable. This could reflect both taxonomic and thematic knowledge surrounding the new word. Taxonomic, as vegetables and *emptra* share common features, and a script thematic relationship as *emptra* is something nice! Upon additional encounters with the word *emptra,* such as "I used *emptra* to color my Easter eggs", the learner added additional thematic information provided by the new context (*emptra,* something nice, has the functional capability of coloring other objects), but little additional taxonomic information was added to his existing knowledge for the word *emptra.*

The difference between thematic and taxonomic categories is that thematic relations are defined by external relations rather than by internal properties. Although the *emptra* example challenges Markman's (1989) claim that thematic categories are not useful for learning and induction about kinds of things; yet one cannot disregard that many things in the world are observed to cluster together, with beneficial outcomes. Take into account cell bodies. The ones that share similar functions group together as nuclei and ganglia to perform their operations. Another example of clustering is experimental data. Human beings tend to behave in a consistent and similar manner, which allows for this grouping of data.

However, as indicated previously in chapter 2, category construction is not a simple process. In order to form a category one would first have to consider its *defining* and *characteristic* features. To reiterate what was previously stated in chapter 2, Smith et al. (1974) identified *defining features* as the ones that are essential in defining a concept and *characteristic features* as the ones not essential in defining a concept. Attributes that are shared by all members of a category are defining features. Characteristic features are shared by many but not all members of a category. *Typical members* of a category are those that possess many of the category's characteristic features. In this model, the total number of features associated with a concept increase as the concept becomes more subordinate. The superordinate will always have less defining features than its subordinate. To illustrate, both robin and bird share the same defining features but robin will have additional defining features, such as red-breasted.

Therefore, models of categorical construction assume that categories will be formed on the basis of common features among their parts. However, as indicated in chapter 2, it is difficult to explain why some kinds of features are more important than others for determining category membership (remember the volleyball and rope jumping example). Further, it was explained earlier, that membership in a category is not always consistent (remember the cuff link example in chapter 2 which was considered a clothing item in one instance and not a clothing item in another). Also remember, that having a defining feature might not necessarily classify something in a particular category (remember the tuna throwing example which although it is a physical exercise, it did not classify as a sport).

Taking all this together, it seems that categorical concepts relate to rules as thematic concepts relate to relations. Consider semantic memory as a network where concepts share connections. According to McClelland (1994), the knowledge in such a system lays in the strengths of the excitatory and inhibitory connections among the processing units. In other words, consider these connections as having thresholds for activation. Therefore, in order for a concept to activate other concepts, the weighted connection of this concept to another concept needs to be high, in other words, the activation threshold low.

Therefore, related words will have similar patterns of activation. Masson (1995) explains that similarities in these patterns of activation arise because it is assumed that, (a) a concept's meaning is constructed from the context in which the concept occurs, and (b) concepts that frequently co-occur share many aspects of their contextually based meaning. These statements by Masson, taken together with the fact that categorical relations require more effort as explained earlier, thematic relations would share similar patterns of activation in contrast to taxonomic relations, which despite their perceptual similarities, rarely co-occur. The fact that thematic relations share similar patterns of activation is supported by Moss et al. (1994), who claim that if the appearance of one pattern is semi-predictive of the subsequent appearance of a second, the network will learn to anticipate the second pattern. Hence, concepts like cow and milk would share similar patterns of activation in contrast to cow and bull, which share many perceptual features but rarely co-occur.

The above statements are further supported by the reported strong and consistent effects of the age of acquisition on the ability to identify objects. Concepts acquired in late childhood, irrespective of pathology, are the most decayed in the presence of naming difficulties (Lambon Ralph, Graham, Ellis, & Hodges, 1988). This decay is probably because concepts acquired later in childhood have poorer connections in the network than concepts acquired earlier in childhood (Johnson, Palvio, & Clark, 1996). Similarly, studies have reported semantic deficits in the early stages of AD and related these deterioration of semantic linkages to the developmental processes that occur in childhood (Giacomo et al., 2012).

Lin and Murphy (2001) assert that, "some thematic concepts could be more tightly bound and strongly connected to each other than some taxonomically related concepts are. … … After all, people may spend more time in organizing their experiences by identifying the temporal, functional, or spatial relations that cause entities to form unified wholes, such as looking for chalk near a blackboard or expecting a bill after a meal" (p. 5), rather than spend time in categorizing objects, in trying to generate the taxonomies to which objects belong.

In conclusion, taking all three experiments together, one way to make sense of all the observations, is to infer that both taxonomic and thematic relations are important in conceptual content. That taxonomic information is interweaved with background knowledge of events and schemas. People are generally aware of both thematic as well as taxonomic relations, but as cognitive demands, required by category construction as analyzed above, become more demanding (something that was apparent in the younger and older groups of the study), they tend to attend to thematic functions because they are apparently more salient. Relating the present findings to neurophysiological brain activation as that was discussed in the second experiment, the left and right hemispheres probably store similar representations, but differ in the way they access this information. Semantic field areas are activated in response to input, and each hemisphere is particularly sensitive to different contexts, and this is differently modulated by attention and cognitive demands (Jung-Beeman, 2005). The present study however, did not include neurophysiological measures. Future research should investigate this hypothesis systematically.

Study Limitations and Future Research Directions

The stimuli selection for the present study was limited to the small number of association normed words that were created specifically for the three experiments. As a result, stimuli for the different trials in each experiment were limited in number and variety. For example, the categorical stimuli were mostly driven from the animal, fruit and vegetable categories. Furthermore, categorical stimuli in the superordinate and subordinate categories were mostly of the type member-category (cow-animal). It is very likely that presentation of these types of pairs in the reverse order (animal-cow) would yield different results. Finally, as stated in the second chapter, it was not possible to match targets for each word pair on frequency of occurrence and categorical pairs were not matched on typicality. All of these variables could have potentially yielded different results and future research should try to address them.

The study incorporated a small number of cognitive tools used primarily as a screening mechanism to ensure individuals with normal cognitive-linguistic abilities. It would be important to include additional measures of cognition in order to determine the relationship between the present experimental tasks and attention, executive functioning, and other cognitive control mechanisms. These tasks along with neurophysiologic measures could reveal the neurophysiological and neuropsychological underpinnings relating to conceptual and semantic organization across the lifespan. Finally, the use of larger sample sizes and longitudinal research designs would provide additional information on changes on semantic organization across the developmental and aging continuum.

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TABLES

Table 1.1 Sample size, means and standard deviations for age, for each age group in the study.

	6-year olds	9-year olds	12-year olds	15-year olds	18-35 year olds	63+ year olds
Sex	Males 17 Females 14	Males 11 Females 21	Males 12 Females 19	Males 15 Females 16	Males 14 Females 16	Males 11 Females 16
Group size	31	32	31	31	30	27
Mean age	6.29	8.97	11.38	15.28	22.02	71.18
SD for age	.67	.46	.83	1.14	2.59	5.16
Education	1	3.28	5.74	10	14.93	11.23
SD for Ed	0	.52	1.37	2.17	1.53	4.04

Table 1.2 Means and standard deviations of correct responses for categorical and thematic conditions, in the priming task, for each age group.

Age Group	Categorically Strong	Categorically Weak	Thematically Strong	Thematically Weak
6-year olds	85% (11)	77% (11)	72% (11)	66% (12)
9-year olds	91% (10)	88% (9)	82% (9)	79% (9)
12-year olds	91% (8)	87% (9)	83% (9)	81% (8)
15-year olds	95% (5)	90% (7)	88% (7)	83% (9)
18-35 year olds	95% (5)	93% (7)	88% (11)	82% (10)
63+ year olds	85% (9)	78% (12)	74% (13)	60% (16)

SDs in parenthesis

Table 1.3 Statistical significant differences between age group for Reaction Time, in the priming task.

Age Group	6-year olds	9-year olds	12-year olds	15-year olds	18-35 year olds	63+ year olds
6-year olds		*	*	*	*	
9-year olds	*				*	*
12-year olds	*				*	*
15-year olds	*					*
18-35 year olds	*	*	*			*
63+ year olds		*	*	*	*	

An * indicates a statistically significant difference at the .05 level

Table 1.4 Mean reaction times and SDs for Categorically Strong/Weak and Thematically Strong/Weak pairs for all age groups, in the priming task.

Age Group	Categorically Strong	Categorically Weak	Thematically Strong	Thematically Weak
6-year olds	1533.33 (331.62)	1570.33 (322.27)	1600.73 (269.04)	1706.92 (306.06)
9-year olds	1279.85 (230.31)	1341.96 (228.73)	1403.16 (270.53)	1466.35 (269.00)
12-year olds	1292.70 (267.46)	1318.40 (227.85)	1390.34 (239.63)	1456.84 (240.86)
15-year olds	1162.61 (230.18)	1207.78 (218.35)	1222.15 (211.04)	1311.87 (201.22)
18-35 year olds	1024.27 (229.21)	1074.74 (215.60)	1043.00 (174.24)	144.95 (162.56)
63+ year olds	1536.27 (307.37)	1581.87 (296.49)	1567.82 (286.64)	1739.48 (267.86)

SDs in parenthesis

Table 3.1 Mean accuracy of identification for categorical and thematic relations for all age groups, in the analogies task.

Age Group	Categorical	Thematic
6-year olds	80% (12)	83% (11)
9-year olds	91% (8)	86% (12)
12-year olds	85% (9)	86% (8)
15-year olds	88% (6)	86% (8)
18-35 year olds	90% (6)	90% (10)
63+ year olds	82% (8)	86% (8)

SDs in parenthesis

Table 3.2 Statistical significant differences between age group for identification accuracy, in the analogies task.

Age Group	6-year olds	9-year olds	12-year olds	15-year olds	18-35 year olds	63+ year olds
6-year olds		*			*	
9-year olds	*					
12-year olds						
15-year olds						
18-35 year olds	*					*
63+ year olds					*	

An * indicates a statistically significant difference at the .05 level

Table 3.3 Mean accuracy of extension for categorical and thematic relations for all age groups, in the analogies task.

Age Group	Categorical	Thematic
6-year olds	59% (22)	68% (16)
9-year olds	70% (13)	67% (12)
12-year olds	78% (14)	71% (14)
15-year olds	83% (14)	81% (6)
18-35 year olds	88% (17)	78% (15)
63+ year olds	56% (20)	63% (12)

SDs in parenthesis

Table 3.4 Statistical significant differences between age group for identification accuracy, in the analogies task.

Age Group	6-year olds	9-year olds	12-year olds	15-year olds	18-35 year olds	63+ year olds
6-year olds			*	*	*	
9-year olds				*	*	
12-year olds	*					*
15-year olds	*	*				*
18-35 year olds	*	*				*
63+ year olds			*	*	*	

An * indicates a statistically significant difference at the .05 level

APPENDIX

Appendix A. All stimuli used in Experiment 1 for each conceptual relation

Taxonomic	**Superordinate Living**	Strong	Prime	Target
			leopard	animals
			tiger	animals
			ox	animals
			mule	animals
			zebra	animals
		Weak	sheep	animals
			fish	animals
			duck	animals
			rabbit	animals
			cow	animals
	Subordinate Living	Strong	dove	Birds
			pear	fruits
			celery	vegetables
			eagle	birds
			grasshopper	insects
		weak	pumpkin	vegetables
			Butterfly	insects
			Chicken	birds
			Ostrich	birds
			lobster	fish
	Superordinate Artifact	strong	doll	Toys
			trumpet	instruments
			toytop	toys
			pliers	tools
			martini	drinks
		weak	axe	tools
			ball	toys
			dress	clothing
			ring	jewellery
			wine	drinks
	Coordinate Living	strong	foot	arm
			gorilla	monkey
			tomato	cucumber
			goose	duck
			infant	baby
		weak	ear	eye
			donkey	horse
			mosquito	fly
			peach	orange
			wheat	sweetcorn
	Coordianate	Strong	chair	table

	Artifact		telephone	cellphone
			fork	knife
			vest	shirt
			newspaper	magazine
		Weak	pan	pot
			hammer	axe
			chips	chocolate
			jacket	coat
			ruler	eraser
Thematic	**Spatial**	Strong	barn	straw
			fish	sea
			boat	sea
			military Camp	soldier
			farm	farm animals
		weak	church	church icon
			pencil	pencil case
			flower	garden
			magician	circus
			chalk	school
	Script	Strong	pig	mud
			carrot	bunny
			butterfly	spring
			needle	thread
			lollipop	child
		Weak	anchor	popey
			Birthday cake	candles
			frog	water lilly
			airplane	sky
			screwdriver	handyman
	Part/Whole	Strong	bell	church
			button	shirt
			deer	horn
			helicopter	propeller
			lock	door
		Weak	house	roof
			car	wheel
			house	roof
			shoe	shoe lace
			snail	carapace
	Functional	Strong	ashtray	cigarette
			barrel	wine
			bee	honey
			belt	trousers
			cup	coffee
		Weak	feet	shoes
			thimble	finger
			Watering can	plant
			pencil	sharpener

		infant	pacifier
Featural	Strong	banana	yellow
		frog	green
		pig	pink
		giraffe	tall
		strawberry	red
	Weak	vase	glass
		cat	black
		sock	wool
		sugar	white
		sea	blue
Causal	Strong	cloud	rain
		onion	tears
		spark	fire
		projector	light
		volcano	lava
	weak	fireplace	smoke
		lather	bubbles
		snake	fear
		clown	laughter
		spider	disgust

Appendix B. Priming procedure

Format of a Trial for the Priming Experiment

Priming Picture	**Inter-stimulus Interval**	**Target Picture**	**Inter-trial Interval**
			
200ms	**200ms**	**3000ms**	**1500ms**

Begin measuring RT

End measuring RT

Appendix C. All stimuli used in Experiment 2 for each configuration.

Homogeneous Configuration	**Target X**	**Option Y** +	**Option Z** -
Th+ / Th -	broom	cleaning	witch
	coat	cold	fur
	chicken	egg	chicken coop
	teeth	white	Chew
	hospital	sick	white
	butterfly	spring	wings
	boots	winter	heel
	box	gift	storage room
	cockroach	disgust	insecticide
	basket	fruit	Little red riding hood
Tx+ / Tx-	brush	comb	toothbrush
	chair	table	desk
	vest	shirt	tie
	prince	princess	king
	girl	boy	woman
	pony	horse	animal
	earth	planet	Sky
	plum	fruit	golden apple
	fly	insect	mosquito
	flute	musical instrument	clarinet
Heterogeneous Configuration	**Target X**	**Option Y** +	**Option Z** -
Th+ / Tx-	sheep	white	animal
	shovel	soil	tool
	watermelon	summer	melon
	zebra	stripes	horse
	shampoo	hair	soap
	mosquito	bite	fly
	Band aid	wound	bandage
	swan	white	bird
	cheese	mouse	halloumi
	brick	house	cement
	carrot	orange	vegetable
	Christmas	tree	Easter
	lettuce	green	celery
	monk	monastery	priest
	Living room	sofa	Dinning room
	jello	red	cream caramel
	sewing needle	thread	sewing pin
	gun	death	Revolver
	university	student	school
	war	death	Battle
Tx+ / Th-	pee nut	dry nuts	alcoholic drink
	ox	animal	farm

	pliers	tool	nail
	scorpion	zodiac	Sting
	harp	musical instrument	melody
	green	color	Tree
	snake	reptilian	Fear
	earth	planet	Soil
	hand	foot	glove
	rooster	chicken	morning awaking
	cat	dog	cat hair
	coin	bill	piggy bank
	town	village	air pollution
	bow	arrow	Robin hood
	salt	pepper	Sea
	square	triangle	Side
	gold	silver	expensive
	hill	mountain	green
	mule	animal	farm
	yacht	boat	luxury
Heterogeneous Configuration	**Target X**	**Option Y** +	**Option Z** +
Th+ / Tx+	olive tree	olive oil	Tree
	trumpet	music	musical instrument
	spinach	Popeye	vegetables
	apple	red	fruit
	flute	music	musical instrument
	infant	crying	baby
	fork	food	knife
	table	food	chair
	helicopter	propeller	airplane
	yacht	sea	boat
	sadness	tears	happiness
	pear	green	apple
	pencil	paper	Pen
	spoon	soap	fork
	avenue	car	road
	cheery	red	fruit
	grasshopper	green	insect
	celery	green	vegetable
	car seat	car	Chair
	rock	sea	stone
Heterogeneous Configuration	**Target X**	**Option Y** -	**Option Z** -
Th- / Tx-	squirrel	walnut	animal
	bee	sting	insect
	elephant	jungle	animal
	fox	forest	Animal
	lobster	sea	fish
	ear	earring	eye

donkey	saddle	horse
gorilla	jungle	animal
apple	snow-white	pear
banana	peel	apple
lion	jungle	animal
dress	lady	skirt
birthday cake	candle	chocolate
turtle	sea	animal
patrol car	police officer	car
shoe	heel	boot
airplane	wing	boat
ant	black	animal
Salt	pastry	sugar
Cannon	explosion	bomb
Tide	drowning	tsunami

Appendix D. All stimuli used in Experiment 3 for each configuration.

Subordinate Living	Identification Phase	Extension Phase
	Lion – Animals	Penguin Animals Black & White Ice
	Sea horse - animals	Pig Animals Tail farm
	Seal – animals	Pumpkin Food Orange Vegetables
	Lettuce – vegetables	Bird Parrot Feathers Nest
	Blouse - Clothing	Spaghetti Food Wheat Minced meat
Coordinate Living	Cat – Dog	Food Arm Nail Shoe
	Onion – Garlic	Sheep Cow Wool Farm
	Orange – Apple	Lobster Crab Claws Sea
	Thumb – Finger	Leopard Lion Jungle Animal
	Duck – Chicken	Ear Eye Face Earring
	Pineapple – melon	Doctor Nurse Hospital White Rope
Subordinate Artifact	Wind Instrument - Flute	Cup Prize Medal Podium Bouquet
	Saw – Tools	Doll Toys Girl Ball
	Chair – Furniture	Martini Alcohol Green olive Bar
	Pills – Aspirin	Wind instruments Trumpet Crier Orchestra
	Alcohol – Beer	Money Coins Piggy Bank Wallet
Coordinate Artifact	Broom – Mop	Truck Car Wheel Road
	Fridge – Oven	Salt Sugar Sea Salt shaker
	Sofa – Armchair	Bicycle Motorbike Helmet Wheel
	Pen – Pencil	Brush Comb Hair Hair Salon
	Screw – Nail	Wine Water Cheese Barrel
Featural	Rhino – Grey	Egg Oval Chicken Frying pan

	Pepper – Black	Mosquito Small Fly Insect
	Ball – Round	Beaver Brown Teeth Wood
	Teddy bear – soft	Chalk White Blackboard Marker
	Grass – green	Belt Black Trousers Shoes
Functional	Mug – Tea	School Bench Student School Desk
	Envelope – Letter	Screwdriver Screw Hammer Tools
	Helmet – Head	Jug Wine Glass Bottle
	Trash can – Trash	Iron Cloths Ironing Board Cord
	Stain – Detergent	Tweezers Ice Ladle Food
Script	Dwarf – Snow white	Watermelon Summer Melon Seeds
	Beach – Umbrella	Mouse Trap Cheese Mouse Bear Trap
	Beer – Dry nuts	Jello Birthday Party Birthday Cake Sugar
	Sewing Needle – Tailor	Bear Honey Woods Fox
	Whistle – Referee	Butter Bread Yellow Jam
Part Whole	Anchor – Ship	Wheel Car Rims Circle
	Olive – Olive Pie	Turtle Shell Sea Crab
	Boat – Paddle	Banana Peel Apple Monkey
	Ambulance – Siren	Egg Egg yolk Chicken Easter
	Trousers – Zipper	Razor Blade Shaving Shaving Foam
Spatial	Hanger – Closet	Farm Animals Fence Breeder
	Mushroom – Montain	Doctor Operating Room Stethoscope Sick
	Rooster – Coop	Pot Kitchen Pan Lid
	Church Stand – Church	Salt Shaker Salt Pepper Shaker Food

	Cellar – Drinks	Fox Woods Dog Animals
Causal	Corn seeds – pop corn	Storm Flood Umbrella Cloud
	Soap – Lather	Alcohol Drunkenness Wine Bar
	Match – Spark	Accident Wounded Police Officer Towing Car
	Toothache – Filling	Scorpion Stink Sting Desert
	University – Degree	Gun Death Bullet Police Officer