Connecting the Fields of Conceptual Combination and Metaphor Processing

by

Juana Park

A thesis submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

Department of Psychology
University of Alberta

Abstract

This dissertation analyzes three types of semantically opaque phrases (i.e., phrases that are composed of constituents whose literal meanings do not entirely contribute to the meaning of the overall phrase): opaque compound words (e.g., *hogwash*), metaphors that have a compound-like structure (e.g., *trophy wife*) and metaphors that follow the format *X is Y* (e.g., *Lawyers are sharks*). The purpose of the following projects is to point out that metaphors and compound words share more characteristics that most people would suspect and that, by taking into account these deeper commonalities, the study of both areas would benefit from applying theories and research methods from one field to the other.

Keywords: semantic opacity, metaphor, compound word, noun-noun, conceptual combination

Preface

This thesis is an original work by Juana Park. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "Processing of Figurative Language", No. Pro00050154, November 5, 2014. Chapter 3 of this thesis has been accepted as Park, J., Sana, F., Gagné, C. L., & Spalding, T. L., Is inhibition involved in the processing of opaque compound words? A study of individual differences. *The Mental Lexicon*, *15*(2), 272-310.

Dedication

I dedicate this thesis to my parents, for their unconditional love, support and encouragement.

Acknowledgments

The research presented in this thesis was supported by the Natural Sciences and Engineering Research Council of Canada (NSERC).

I would like to express my deep sense of gratitude and profound respect and admiration to my advisors, Drs. Christina Gagné and Thomas Spalding, who have supported and encouraged me through the toughest stages of my dissertation work with great patience and empathy. I will take their work ethic and professionalism as an example to follow.

I would also like to express my great appreciation to Drs. Elena Nicoladis and Herbert Colston, who have enlightened me with their valuable feedback and thoughtful insights.

I am immensely indebted to all the graduate students, post-doctoral fellows and undergraduate research assistants with whom I had the pleasure to work at the Complex Cognition Lab. This work would have not been possible without their help.

Last but not least, my gratitude goes to my parents, who have always believed in me.

Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction

The topic of this dissertation is situated in the intersection of two areas of psycholinguistics that have been studied separately: conceptual combination on one hand, and the processing of metaphors on the other. The goal of this work is to help readers understand that these two areas are more connected than they appear to be at first sight and that research in each of these fields would greatly benefit from extrapolating theories and research methods from the other.

For many decades, psycholinguists have been intrigued by the generativity of human language, that is, the ability to produce sentences never before said, and to understand sentences never before heard (Barnes-Holmes, Hayes, Barnes-Holmes, & Roche, 2001; Chomsky, 1959; Corballis, 1992). One of the simplest forms of conceptual productivity that is manifested in language is what cognitive psychologists call *conceptual combination* (Estes, 2003; Fodor & Lepore, 1996; Murphy, 1990; Spalding & Gagné, 2015; Wisniewski, 1996), which refers to the creation of a new meaning by simply combining a modifier and a noun into a two-word phrase (e.g., when the phrase *coffee mug* was created, it was meant to convey a new emerging meaning that was not present in *coffee* and *mug* considered separately; similarly, a person can perfectly understand the concept of *unicorn nest* or *ant pudding* without having been previously exposed to these completely novel combinations). If a modifier-noun phrase is repeatedly used, over time it can become a *compound word* whose meaning is well-established among language users (e.g., *snowball*, *strawberry*, *hogwash*).

Compound words can be written in three ways: as open compounds (i.e., spelled as two separate words) (e.g., *web page*, *peanut butter*, *coffee mug, paper bag*, *voice mail*), as closed compounds (i.e., joined as a single word) (e.g., *snowman*, *notebook*, *waistcoat*, *bookstore*), or as hyphenated compounds (i.e., separated by a hyphen) (e.g., *chat-room*, *life-size*, *air-*

crew). Indeed, in many languages, such as English (Gagné, Spalding, & Schmidtke, 2019; Juhasz, 2008; Libben, Gibson, Yoon, & Sandra, 2003), German (Hasenäcker & Schroeder, 2019), Dutch (Zwitserlood, 1994), Finnish (Hyönä & Pollatsek, 2000), Chinese (Tse, Yap, Chan, Sze, Shaoul, & Lin, 2017), Korean (Xun & Hee, 2016) and several sign languages (Santoro, 2019; Vercellotti & Mortensen, 2012) the introduction of new concepts is frequently done through nominal compounding (i.e., the combination of two or more nouns, or one adjective and a noun, to denote a single concept, such as *snowman*).

One of the questions that psycholinguists have been trying to answer regarding conceptual combination is what factors influence the processing of compound words. More precisely, researchers have focused on two types of variables that can facilitate or hinder the comprehension of this type of complex word: variables related to the compound word itself (e.g., word length or word frequency) (Baayen, Wurm, & Aycock, 2007) or variables related to the reader (e.g., reading experience) (Schmidtke, Van Dyke, & Kuperman, 2018). Researchers that have focused on the intrinsic characteristics of compound words that have an impact on their processing have given a significant amount of attention to the *semantic transparency* of the constituent words of a compound, that is, the degree to which the meaning of each component considered independently is related to the meaning of the whole compound word (e.g., the degree to which the meaning of *snowball* can be inferred from the meanings of *snow* and *ball*) (Libben, 1998). On the other hand, researchers that have decided to study characteristics of the reader that affect the ease of processing of compound words have focused on participants' previous exposure to printed materials, vocabulary size, and word recognition skills.

Another prolific area of psycholinguistics has been the processing of non-literal language (Cacciari & Glucksberg, 1991; Colston & Gibbs, 2007; Frisson & Pickering, 1999; Gibbs, 2008;

Lakoff, 2008; Ortony, 1978). For many decades, researchers in this field have been trying to understand how humans are able to easily comprehend figurative language, such as idioms (e.g., *kick the bucket*), ironies and sarcasms (e.g., *Oh, great! I've just broken my brand-new iPhone 11*), similes (e.g., *He is as agile as a monkey*), and, in particular, metaphors (e.g., *Time is money*), even though, by definition, the meaning of these phrases cannot be directly derived from the encyclopedic definitions of each of their constituent words. Researchers in this area have also focused on either the variables inherent to the figurative phrases themselves (e.g., how conventional they are considered among users of a specific language) or variables related to the individuals reading those phrases (e.g., IQ, working memory, executive functions) (Chiappe & Chiappe, 2007; Jones & Estes, 2006; Kazmerski, Blasko, & Dessalegn, 2003; Keysar, Shen, Glucksberg, & Horton, 2000; Thibodeau & Durgin, 2008).

Curiously, theories of compound word processing and metaphor processing have evolved in very similar ways, and the debates that have taken place in both fields are analogous. For instance, one of the most important controversies that have dominated the literature of compound word processing is whether compounds are decomposed into their constituents (Ji, Gagné, & Spalding, 2011; Libben, 1998; Libben, Gibson, Yoon, & Sandra, 2003) or, on the contrary, are simply accessed as units from the mental lexicon (i.e., the mental dictionary that contains information about words) (Sandra, 1990; Zwitserlood, 1994). Similarly, for metaphor comprehension, the main controversy has revolved around the question of whether conventional metaphors (i.e., metaphors that are commonly used in everyday language, such as *Time is money*) require an initial a word-by-word literal interpretation (Searle, 1979) or whether they behave like long words whose stored meaning is simply retrieved from long-term memory (Gibbs, 1979; Gibbs, 1989). But this resemblance between their respective theoretical paths is not the only similarity that connects the world of compound processing and metaphor comprehension. On the contrary, these two areas, despite having historically been studied in isolation from each other, share more commonalities that most people would suspect.

Another commonality that the study of compound words and metaphors share is related to how both fields have produced several theories that tried to elucidate the role that each component of a compound word or a metaphor plays during their processing. Note that compound words and metaphors that have an *X is Y* format (e.g., *Lawyers are sharks*) are structurally similar in the sense that both types of expressions are made up of two components that play very distinct roles. In the case of compound words, they are composed of two free morphemes (i.e., smallest meaningful units in a language that can be split and still stand alone to function as separate words). The second morpheme of a compound word (in English) is considered to be its *head* because the whole word belongs to the same word class as the head (e.g., *ball* is a noun, so *snowball* is a noun too), inflections are applied only to the head (e.g., the plural of *snowball* is *snowballs*, not *snowsball* or *snowsballs*), and the head also provides the basic meaning of the word as it often determines the category (e.g., a snowball is a type of ball). The first morpheme of a compound word, on the other hand, is the modifier that depends on the head, as it adds information that helps people derive a more detailed and restricted meaning (e.g., a snowball is specifically a subtype of *ball*: balls made of snow) (Gagné & Spalding, 2006). The RICE (Relational Interpretation Competitive Evaluation) theory of conceptual combination (Spalding, Gagné, Mullaly, & Ji, 2010), for instance, stated that the comprehension of a compound is done through a suggest–evaluate–elaborate process in which the head and the modifier play different roles: First, the modifier suggests possible relations to the head (e.g., *snowball* could be interpreted as *ball MADE OF snow*, *ball FOR snow*, *ball LOCATED IN snow*, etc.), then the head evaluates the appropriateness of the suggested relations and selects the best, and finally an elaboration stage takes place in which the meaning of the whole compound is computed. Similarly, in the case of *X is Y* metaphors, there is a topic (*X*) (e.g., *lawyers* in *Lawyers are sharks*) and a vehicle (*Y*) (e.g., *sharks*): The topic is the concept the speaker wants to describe, and the vehicle possesses the characteristics that the speaker wants to attribute to the topic (e.g., sharks are prototypically ferocious, so they are used to depict lawyers' high level of aggression) (Glucksberg & Keysar, 1990). The class-inclusion model of metaphor comprehension (Glucksberg, 2003; Glucksberg & Keysar, 1990), for instance, claims that the topic and the vehicle play very distinct roles: The topic is first assigned to a metaphorical category represented and named after the vehicle (e.g., lawyers are now considered to be members of the category of aggressive and scary beings, which is represented by sharks), and then the properties of the class are attributed to the topic (e.g., lawyers are now seen as ferocious and dangerous, just like sharks). Interestingly, the fact that compound words and *X is Y* metaphors are structurally similar, in the sense that both are composed of two constituents that play very different roles, becomes even more evident when we take into account the fact that some familiar metaphors widely used in everyday life can adopt a condensed noun-noun format (e.g., *tiger mom*, *trophy wife*, *helicopter parents*, *velvet lips*), similar to open compound words (e.g., *coffee mug*). Such conventional noun-noun metaphors are, in fact, a hybrid between *X is Y* metaphors and open compound words that is created when the vehicle of an *X is Y* metaphor takes generally the place of the modifier, and the topic takes generally the place of the head (e.g., *Her mom is a tiger* becomes *tiger mom*).

Another commonality between metaphors and compound words is related to the concept of *semantic transparency* or its counterpart, *semantic opacity*. Plag (2003) defined semantic transparency as the possibility of inferring the meaning of morphologically complex words or phrases from their constituent parts. In other words, semantic opacity occurs when the relationship between the meaning of the complex word or phrase and the meaning of their constituents is obscured (Bauer, 1988). Some compound words are semantically opaque (e.g., *hogwash* is opaque because the meanings of *hog* and *wash* are unrelated to the definition of the whole word). Metaphors are also opaque because they are a type of figurative language, which, by definition, implies that the literal encyclopedic definitions of the component words are not directly related to the speaker's real intended meaning (e.g., the receiver cannot fully extract the figurative meaning of the metaphor *Lawyers are sharks* from the definition *marine fish with cartilaginous skeleton*). It is worth noting that this semantic opacity that occurs in opaque compound words and in metaphors is far from being an all-or-nothing concept; on the contrary, both compound words and metaphors can be classified on a continuum of semantic opacity. Compound words can be fully opaque if neither of the two constituent parts is related to the meaning of the whole word (e.g., *hogwash*) or partially opaque if only one of the constituent parts is related to the meaning of the whole word (e.g., *strawberry*) (Libben, 1998; Gagné et al., 2019). In the case of metaphors, they are, by definition, semantically opaque, in the sense that the literal definition of the constituent words is not related to the intended meaning (Bowdle & Gentner, 2005). Interestingly, some compound words are considered to be opaque because one or more of their constituents are used metaphorically (e.g., in the compound word *jailbird*, *bird* is used figuratively to refer to a prisoner that was "caged" and that "flew away").

The last commonality that metaphors and compound words share is related to the cognitive functions involved in the comprehension of both types of expressions. More specifically, there is evidence that suggests that *inhibition* (i.e., the ability to suppress stimuli that is irrelevant to the task at hand) is necessary to compute the meaning of both figurative language and opaque compound words. It has been shown that, in order to understand metaphors (e.g., *Lawyers are sharks*) or idioms (e.g., *a piece of cake*), people need to inhibit the literal meaning coming from their constituent parts (e.g., *marine fish with cartilaginous skeleton* or *soft sweet food made from a mixture of flour, fat, eggs and sugar*) (Glucksberg, Newsome, & Goldvarg, 2001). When this inhibition fails as a consequence of disorders such as schizophrenia or Alzheimer's disease, people provide literal interpretations for figurative language (Iakimova, Passerieux, & Hardy-Bayle, 2006). Similarly, evidence, although scarce and indirect, suggests that the processing of compound words involves competition among possible meanings (e.g., in order to interpret *snowman*, the reader has to decide whether it refers to a man made of snow or a man that lives in the snow) (Schmidtke, Gagné, Kuperman, Spalding, & Tucker, 2018) and may even also require inhibition, particularly if the constituents are opaque: For instance, when inhibition fails, as in the case of patients suffering from aphasia, people paraphrase opaque compound words as if they were transparent (e.g., they may say a strawberry is a berry that has a straw) (Libben, 1993).

Taking into account that metaphors and compound words share all the aforementioned commonalities, this work seeks to present a new perspective that will help readers discover deeper connections between these two areas. The purpose of this dissertation is to build more bridges between these two areas that have barely been connected in the past (Gagné, Friedman, & Faries, 1996; Goldvarg & Glucksberg, 1998; Wisniewski, 1996, 1997; Wisniewski & Love, 1998) by pointing out that studies into each field might yield useful insights into the other. By applying theoretical points of view and methodological strategies originating from one field to the other, some gaps in these two traditionally separate literatures might be filled.

This dissertation is composed of three projects. The first project focuses on noun-noun metaphors, which, as mentioned before, are a hybrid between *X is Y* metaphors and open compound words, and its purpose is to determine whether noun-noun metaphors behave like compound words when they are processed by readers. The second project analyzes whether inhibition, a cognitive skill that is well known to be involved in the processing of metaphors, is also involved in the processing of compound words. Finally, the third project aims to investigate the possibility that the assumption that conventionalized metaphors do not require analogical thinking may be wrong, in the same way that the initial assumption that compound words do not require meaning computation because of being crystallized word-word combinations was later found to be wrong. All three studies have been conducted in English at the University of Alberta, using the Department of Psychology's research participant pool, which consists of students currently enrolled in introductory psychology classes, the majority of whom are young adults, with a preponderance of women. The pool consists of approximately five thousand students per academic year drawn from several faculties (e.g., Sciences, Arts, Education, Business and Engineering); sampling from this pool will provide a representative sample of the population. In the following section I summarize the rationale of each study.

1.1 Projects

1.1.1 Project 1: Applying What is Known About Compound Words to the Study of Noun-Noun Metaphors

Compared to *X is Y* metaphors, noun-noun metaphors have not yet been the subject of extensive research (Ferguson, Forbus, & Gentner, 1997) despite being frequently used in everyday language (e.g., *velvet skin*, *helicopter parents*, *trophy wife*). Given that noun-noun metaphors are structurally similar to open compound words (e.g., *coffee mug*), it is worth examining whether theories and findings originating in the field of compound words are applicable to the relatively unexplored field of noun-noun metaphor processing.

One of the most important well-established findings in the compound word literature is the fact that compounds with opaque heads (e.g., *side**burn***) take longer to be processed than compounds with transparent heads (e.g., *straw**berry***) (Libben et al., 2003). In light of this and taking also into account that figurativeness can be considered a type of semantic opacity, it is valid to investigate whether the same pattern of processing times is found in noun-noun metaphors, which are a hybrid of open compound words and *X is Y* metaphors. I am interested in exploring whether compound-like metaphors whose heads are opaque because they are used figuratively (e.g., *knowledge **ocean***) take longer to be responded to, compared to compound-like metaphors whose modifiers are used figuratively (e.g., ***trophy** wife*).

1.1.2 Project 2: Applying What is Known About Metaphor Comprehension to the Study of Compound Words

Many different studies using a large variety of tasks have shown that compound words are processed differently depending on their degree of semantic transparency (Brooks & Cid del Garcia, 2015; Gagné & Spalding, 2014; Ji et al., 2011; Juhasz, 2007; Libben et al., 2003; Sandra, 1990). In general, most studies suggest that opaque compound words (e.g., *hogwash*) are more difficult to process than transparent compound words (e.g., *blueberry*). However, despite this abundance of studies showing processing differences between transparent and opaque compound words, there is relatively little work that explores the mechanisms that cause this difference. Libben (2005) tried to explain the origin of this difference by suggesting that opaque compound words are harder to process because they may require the inhibition of the irrelevant meanings of their constituents, which may interfere with finding the real meaning of the whole word (e.g., readers may need to inhibit the meaning of *hog* and *wash* because they are completely unrelated to the meaning *rubbish*). However, it is necessary to point out that, until now, no researcher has provided direct behavioral evidence of Libben's assumption; only a few studies have suggested the involvement of inhibition in the comprehension of compound words by showing that readers must solve meaning competition during compound word processing (Gagné & Spalding, 2013; Schmidtke, Kuperman, Gagné, & Spalding, 2016).

In contrast, the essential role of inhibition is directly and well documented in the processing of metaphors (Galinsky & Glucksberg, 2000; Glucksberg et al. 2001). Now, given that, as mentioned before, both metaphors and opaque compounds are semantically opaque, it is valid to want to find more direct evidence of the involvement of inhibition in compound word comprehension by resorting to methods previously used in the study of metaphor comprehension. More specifically, given that using the individual differences perspective has been very useful to demonstrate that executive functions are required during figurative language comprehension (Columbus, Sheikh, Côté-Lecaldare, Häuser, Baum, & Titone, 2015), it is logical to want to analyze whether people's scores on an inhibition task can also predict performance on a task targeting the comprehension of opaque compound words. Our purpose is to combine two types of variables that have traditionally been studied separately in the compound word literature (i.e., intrinsic characteristics of compound words, such as semantic transparency, and characteristics related to the readers, such as their profiles of cognitive skills) to determine whether opaque compound words require inhibition.

1.1.3 Project 3: Applying What is Known About Compound Words to the Study of X is Y Metaphors

For a long time, researchers believed that opaque compound words, given that they have constituents whose meanings are completely unrelated to the overall meaning of the word, only required meaning retrieval and not meaning computation. In other words, it was traditionally thought that people accessed the meaning of opaque compound words through simply finding their stored definitions from the mental lexicon. Nowadays, we know that even opaque compound words involve meaning computation (Hyönä, 2015). Similarly, the most semantically opaque metaphors (i.e., novel metaphors, such as *Education is a lantern*) have also traditionally been thought to require specific cognitive mechanisms that are not involved in the processing of well-established metaphors (e.g., *Time is money*). For instance, the career of metaphor hypothesis (Bowdle & Gentner, 2005) states that, if the metaphor is novel, it is interpreted as a comparison: The topic and the vehicle are structurally aligned and an extensive search for shared semantic features is conducted (e.g., *education* and *lantern* are structurally matched and compared, until the property *enlightening*, which is common to both entities, is selected) (Gentner, 1983; Wolff & Gentner, 2000). In contrast, if the metaphor is conventional, the career of metaphor states that it is interpreted as a categorization: The topic is seen as a member of an ad-hoc superordinate category named by the vehicle (e.g., *time* is seen as a member of the category *precious and scarce things*, *money*) (Glucksberg, 2003; Glucksberg & Keysar, 1990). It is necessary to point out, however, that the career of metaphor has received both supportive and contradictory evidence.

The goal of this study is then to examine whether, in the same way that compound words of all levels of semantic opacity require decomposition and meaning computation, metaphors of all levels of conventionality (not only novel metaphors) require analogy.

1.2 Summary

After realizing that the study of conceptual combination and the study of metaphor processing are, in many aspects, parallel, I have decided to carry out three sets of experiments that aim at building bridges between these two domains by applying what is known in one field to the other. The first set of experiments will apply what is known about compound words to the analysis of the relatively understudied noun-noun metaphors. The second set of experiments will apply what is known about *X is Y* metaphor comprehension to the study of compound words. Finally, the third set of experiments will apply what is known about compound words to the study of *X is Y* metaphors.

1.3 References

Baayen, R. H., Wurm, L. H., & Aycock, J. (2007). Lexical dynamics for low-frequency complex words: A regression study across tasks and modalities. *The Mental Lexicon, 2,* 419–463.

Barnes-Holmes, Y., Hayes, S. C., Barnes-Holmes, D., & Roche, B. (2001). Relational frame theory: A post-Skinnerian account of human language and cognition. In H. W. Reese & R. Kail (Eds.), *Advances in child development and behavior* (pp. 101–138). Academic Press.

Bauer, L. (1988). *Introducing linguistic morphology*. Edinburgh: Edinburgh University Press.

Bowdle, B. F., & Gentner, D. (2005). The career of metaphor. *Psychological Review*, *112*(1), 193-216.

Brooks, T. L., & Cid de Garcia, D. (2015). Evidence for morphological composition in compound words using MEG. *Frontiers in human neuroscience*, *9*, 215. https://doi.org/10.3389/fnhum.2015.00215

Cacciari, C., & Glucksberg, S. (1991). Understanding idiomatic expressions: The contribution of word meanings. In G. B. Simpson (Ed.), *Advances in psychology, No. 77. Understanding word and sentence* (pp. 217–240). North-Holland.

Chiappe, D. L., & Chiappe, P. (2007). The role of working memory in metaphor production and comprehension. *Journal of Memory and Language, 56*(2), 172–188.

Chomsky, N. (1959). A review of B. F. Skinner's Verbal Behavior. *Language*, *35*(1), 26–58.

Colston, H. L., & Gibbs, R. W., Jr. (2007). A brief history of irony. In R. W. Gibbs, Jr. & H. L. Colston (Eds.), *Irony in language and thought: A cognitive science reader* (pp. 3–21). Lawrence Erlbaum Associates Publishers.

Columbus, G., Sheikh, N. A., Côté-Lecaldare, M., Häuser, K., Baum, S. R., & Titone, D. (2015).

Individual differences in executive control relate to metaphor processing: An eye movement study of sentence reading. *Frontiers in Human Neuroscience, 8,* Article 1057.

Corballis, M. C. (1992). On the evolution of language and generativity. *Cognition, 44*(3), 197–226.

Estes, Z. (2003). A tale of two similarities: Comparison and integration in conceptual combination. *Cognitive Science*, *27*(6), 911–921.

Ferguson, R., Forbus, K., & Gentner, D. (1997). On the proper treatment of noun-noun metaphor: A Critique of the Sapper model. In M. G. Shafto & P. Langley (Eds.), *Proceedings of the 19th Annual Meeting of the Cognitive Science Society* (pp. 913). Mahwah, NJ: Cognitive Science Society.

Fodor, J., & Lepore, E. (1996). The red herring and the pet fish: Why concepts still can't be prototypes. *Cognition, 58*(2), 253–270.

Frisson, S., & Pickering, M. J. (1999). The processing of metonymy: Evidence from eye movements. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*(6), 1366–1383.

Gagné, C., Friedman, A., & Faries, J. (1996). Effect of priming on the comprehension of predicative metaphors. *Metaphor & Symbolic Activity, 11*(2), 125–143.

Gagné, C. L. & Spalding, T. L. (2006). Using conceptual combination research to better understand novel compound words. *SKASE Journal of Theoretical Linguistics, 3*, 9-16.

Gagné, C., & Spalding, T. (2014). Typing time as an index of morphological and semantic effects during English compound processing. *Lingue e Linguaggio*, *13*(2), 241-262.

Gagné, C.L., Spalding, T.L., & Schmidtke, D. (2019). LADEC: The Large Database of English Compounds. *Behavior Research Methods, 51,* 2152–2179.

Galinsky, A. D., & Glucksberg, S. (2000). Inhibition of the literal: Metaphors and idioms as judgmental primes. *Social Cognition, 18*(1), 35–54.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science*, *7*, 155-170.

Gibbs, R. (1979). Contextual effects in understanding indirect requests. *Discourse Processes, 2*, 1-10.

Gibbs, R. (1989). Understanding and literal meaning. *Cognitive Science*, *13*(2), 243–251.

Gibbs, R. (2008). Metaphor and thought: The state of the art. In R. W. Gibbs, Jr. (Ed.), *The Cambridge handbook of metaphor and thought* (pp. 3–13). Cambridge University Press.

Glucksberg, S. (2003). The psycholinguistics of metaphor. *Trends in Cognitive Sciences, 7*(2), 92-96.

Glucksberg, S., & Keysar, B. (1990). Understanding metaphorical comparisons: Beyond similarity. *Psychological Review, 97*(1), 3-18.

Glucksberg, S., Newsome, M., & Goldvarg, Y. (2001). Inhibition of the literal: Filtering metaphor-irrelevant information during metaphor comprehension. *Metaphor and Symbol, 16*, 277–293.

Goldvarg, Y., & Glucksberg, S. (1998). Conceptual combinations: The role of similarity. *Metaphor and Symbol, 13*(4), 243–255.

Hasenäcker, J., & Schroeder, S. (2019). Compound reading in German: Effects of constituent frequency and whole-word frequency in children and adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 45*(5), 920–933.

Hyönä, J. (2015). Are polymorphemic words processed differently from other words during reading? In A. Pollatsek & R. Treiman (Eds.), *Oxford library of psychology. The Oxford* *handbook of reading* (p. 114–128). Oxford University Press.

Hyönä, J., & Pollatsek, A. (2000). Processing of Finnish compound words in reading. In A. Kennedy, R. Radach, D. Heller, & J. Pynte (Eds.), *Reading as a perceptual process* (pp. 65–87). North-Holland/Elsevier Science Publishers.

Iakimova, G., Passerieux, C., & Hardy-Bayle, M. C. (2006). The understanding of metaphors in schizophrenia and depression. An experimental approach. *Encephale*, *32*, 995-1002.

Ji, H., Gagné, C. L., & Spalding, T. L. (2011) Benefits and costs of lexical decomposition and semantic integration during the processing of transparent and opaque English compounds. *Journal of Memory and Language, 65,* 406-430.

Jones, L. L., & Estes, Z. (2006). Roosters, robins, and alarm clocks: Aptness and conventionality in metaphor comprehension. *Journal of Memory and Language, 55*(1), 18–32.

Juhasz, B. J. (2008). The processing of compound words in English: Effects of word length on eye movements during reading. *Language and Cognitive Processes, 23*(7-8), 1057–1088.

Kazmerski, V. A., Blasko, D. G., & Dessalegn, B. G. (2003). ERP and behavioral evidence of individual differences in metaphor comprehension. *Memory & Cognition, 31*(5), 673–689.

Keysar, B., Shen, Y., Glucksberg, S., & Horton, W. S. (2000). Conventional language: How metaphorical is it? *Journal of Memory and Language, 43*(4), 576–593.

Lakoff, G. (2008). The neural theory of metaphor. In R. W. Gibbs, Jr. (Ed.), *The Cambridge handbook of metaphor and thought* (pp. 17–38). Cambridge University Press.

Libben, G. (1993). A Case of obligatory access to morphological constituents. *Nordic Journal of Linguistics*, *16*, 111-12.

Libben, G. (1998). Semantic transparency in the processing of compounds: Consequence for representation, processing, and impairment. *Brain and Language, 61*(1), 30–44.

Libben, G. (2005). Everything is psycholinguistics: Material and methodological considerations in the study of compound processing. *The Canadian Journal of Linguistics / La revue canadienne de linguistique*, *50*, 267–283.

Libben, G., Gibson, M., Yoon, Y. B., & Sandra, D. (2003). Compound fracture: The role of semantic transparency and morphological headedness. *Brain and Language, 84*(1), 50–64.

Murphy, G. L. (1990). Noun phrase interpretation and conceptual combination. *Journal of Memory and Language, 29*(3), 259–288.

Ortony, A., Reynolds, R. E., & Arter, J. A. (1978). Metaphor: Theoretical and empirical research. *Psychological Bulletin, 85*(5), 919–943.

Plag, I. (2003). *Word-formation in English*. Cambridge, England: Cambridge University Press.

Sandra, D. (1990). On the representation and processing of compound words: Automatic access to constituent morphemes does not occur. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 42*(3-A), 529–567.

Santoro, Mirko. (2019). Compounds in sign languages: The case of Italian and French Sign Language. *Sign Language & Linguistics*, *22*, 291–297.

Schmidtke, D., Gagné, C. L., Kuperman, V., Spalding, T. L., & Tucker, B. V. (2018). Conceptual relations compete during auditory and visual compound word recognition. *Language, cognition and neuroscience*, *33*(7), 923–942.

Schmidtke, D., Kuperman, V., Gagné, C. L., & Spalding, T. L. (2016). Competition between conceptual relations affects compound recognition: the role of entropy. *Psychonomic bulletin & review*, *23*(2), 556–570.

Schmidtke, D., Van Dyke, J. A., & Kuperman, V. (2018). Individual variability in the semantic processing of English compound words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 44*(3), 421–439.

Searle, J. (1979). Metaphor. In: A. Ortony (Ed.) *Metaphor and Thought* (pp. 92-123). New York: Cambridge University Press.

Spalding, T. L., & Gagné, C. L. (2015). Property attribution in combined concepts. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41*(3), 693–707.

Spalding, T. L., Gagné, C. L., Mullaly, A. C., & Ji, H. (2010). Relation-based interpretations of noun–noun phrases: A new theoretical approach. *Linguistische Berichte Sonderheft, 17,*283–315.

Thibodeau, P., & Durgin, F. H. (2008). Productive figurative communication: Conventional metaphors facilitate the comprehension of related novel metaphors. *Journal of Memory and Language, 58*(2), 521–540.

Tse, C.-S., Yap, M. J., Chan, Y.-L., Sze, W. P., Shaoul, C., & Lin, D. (2017). The Chinese Lexicon Project: A megastudy of lexical decision performance for 25,000+ traditional Chinese two-character compound words. *Behavior Research Methods, 49*(4), 1503–1519.

Vercellotti, M. L., & Mortensen, D. R. (2012). A classification of compounds in American Sign Language: An evaluation of the Bisetto and Scalise framework. *Morphology*, *22*, 545–579.

Wisniewski, E. J. (1996). Construal and similarity in conceptual combination. *Journal of Memory and Language, 35*(3), 434–453.

Wisniewski, E. J. (1997). When concepts combine. *Psychonomic Bulletin & Review, 4*(2), 167–183.

Wisniewski, E. J., & Love, B. C. (1998). Relations versus properties in conceptual combination. *Journal of Memory and Language, 38*(2), 177–202.

Wolff, P., & Gentner, D. (2000). Evidence for role-neutral initial processing of metaphors. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 529-541.

Xun, Z., & Hee, Y. E. (2016). Comparative study on the structures of Chinese and Korean compound words. *Lingua Cultura*, *10*(1), 7–12.

Zwitserlood, P. (1994). The role of semantic transparency in the processing and representation of Dutch compounds. *Language and Cognitive Processes, 9*(3), 341–368.

Chapter 2

Factors that influence the processing of noun-noun metaphors

2.1 Abstract

We analyzed the processing of noun-noun metaphors (e.g., *velvet lips*), which have been relatively understudied, compared to other types of figurative expressions, such as *X is Y* metaphors (e.g., *Her lips are velvet*) and similes (e.g., *Her lips are like velvet*). Experiment 1 revealed that noun-noun metaphors are semantically comparable to *X is Y* metaphors and similes, in the sense that the figurative meaning stays the same across these three different formats (e.g., participants agree to similar degrees that *Lips are velvet*, *Lips are like velvet* and *velvet lips* all mean that lips are soft). Experiment 2 showed that noun-noun metaphors behave similarly to compound words: In the same way that compound words with semantically opaque heads (e.g., *jail**bird***) are processed slower than compounds with transparent heads (e.g., *straw**berry***), noun-noun phrases with metaphorical heads (e.g., *relationship* ***patch***) are processed slower than noun-noun phrases with literal heads and metaphorical modifiers (e.g., ***bandaid*** *solution*). Experiment 3 determined that noun-noun metaphors behave similarly to *X is Y* metaphors: In the same way that *X is Y* metaphors require the inhibition of irrelevant features (e.g., *Some barrels are wooden* interferes with the interpretation of *Some stomachs are barrels* because the former activates irrelevant features of *barrel* that later need to be suppressed), noun-noun metaphors also involve inhibition (e.g., *jean patch* interferes with the interpretation of *relationship patch* because the former activates certain features of *patch*, such as being made of cloth, that are irrelevant for the proper comprehension of the noun-noun metaphor).

Keywords: noun-noun, metaphor, compound word, semantic transparency, head

2.2 Introduction

In this paper, we focus on the processing of noun-noun metaphors (e.g., *velvet skin*). Although this type of metaphor is frequently used in everyday life in conversations and in the media (e.g., *tiger mom*, *helicopter parents*, *sugar daddy*, *gold digger*) as well as in poetry and songs (e.g., *diamond sky*, *circus sands*), it is, as yet, understudied (Gagné, 2002; Jia, Zan, Fan, Yu, & Wang, 2014), relative to nominal metaphors that follow the standard format *X is Y* (e.g., *Her skin is velvet*), which have been the main focus of the metaphor comprehension literature (Glucksberg & Keysar, 1990). Thus, the goal of the current study is to analyze different factors that affect the processing speed and the accuracy of the interpretation of noun-noun metaphors. In particular, we examine whether factors that have been shown to influence the processing of compound words (e.g., *schoolteacher*) and standard-formatted *X is Y* metaphors also influence the processing of noun-noun metaphors.

Standard-formatted nominal metaphors consist of *X*, the topic (i.e., the concept the speaker wants to describe, such as *skin* in *Her skin is velvet*), and *Y*, the vehicle (i.e., the concept that possesses the properties the speaker wants to attribute to the topic, such as being smooth, conveyed by the word *velvet*). Many noun-noun metaphors, on the other hand, are *X is Y* metaphors that have adopted a condensed format (e.g., *velvet skin* is a compacted version of *Her skin is velvet*). Structurally, noun-noun metaphors are identical to open compound words (e.g., *coffee mug*, *peanut butter*, *voice mail*, *web page*, *dinner table*, *living room*), which are composed of two constituents too: a head (e.g., *mug* in *coffee mug*) that usually denotes the main category, and a modifier (e.g., *coffee*) that adds information that helps people derive a more detailed meaning (e.g., a coffee mug is a mug that is specifically used for drinking coffee) (Gagné, Spalding, & Gorrie, 2005; Spalding & Gagné, 2007).

Given that many noun-noun metaphors appear to be a hybrid between *X is Y* metaphors and compound words, it is useful to examine whether theories and findings originating in both the field of metaphor comprehension and the field of compound word processing can be applied to the relatively unexplored field of noun-noun metaphors. To this purpose, we will draw on what is already known about the roles of the head and the modifier in compound words, and the cognitive processes involved in the comprehension of *X is Y* metaphors and compound words. In the following sections we provide relevant insights from these two very vast research domains that helped us focus on a few factors that might be particularly relevant for understanding the processing of noun-noun metaphors.

2.2.1 Applying What is Known About the Head of Compound Words to the Study of Noun-Noun Metaphors

If we apply what is known about compound words to noun-noun metaphors, then in many cases the vehicle (e.g., *velvet* in *Her skin is velvet*) becomes the modifier (e.g., ***velvet*** *skin*), and the topic (e.g., *skin*) becomes the head. In this section, we will summarize the most significant findings in the compound word literature that have motivated our intention of studying the role that the head and the modifier might play in noun-noun metaphors.

A compound word is a word made up of two separate words that were juxtaposed. Compound words can be written in three ways: as open compounds (i.e., spelled as two separate words) (e.g., *web page*, *peanut butter*, *coffee mug*, *voice mail*), as closed compounds (i.e., joined as a single word) (e.g., *snowman*, *notebook*, *waistcoat*, *bookstore*), or as hyphenated compounds (i.e., separated by a hyphen) (e.g., *chat-room*, *life-size*, *air-crew*). The constituents of compound words (e.g., *snow* and *man* in *snowman*) vary in the degree to which their meanings are related to the overall meaning of the whole word; thus, compound words can be classified according to the *semantic transparency* of their constituents (i.e., the degree to which the meanings of the constituents contribute to the overall meaning of the word). Depending on whether both, none or only one of the constituents is semantically transparent, compound words can be classified into three categories: fully transparent (e.g., in *snowball* both the meanings of *ball* and *snow* are related to the concept of a ball made of snow), fully opaque (e.g., in *hogwash*, neither *hog* nor *wash* contribute to the meaning of the compound) or partially transparent (e.g., in *oddball* and *strawberry,* only the meaning of the first, *odd*, and the second constituent, *berry*, respectively, contribute to the meaning of the compound).

It is worth noting that compound words and noun-noun metaphors, besides being structurally similar, share another interesting commonality: Some compound words are considered to be opaque because their constituents are used metaphorically. For instance, in the compound word *jailbird*, *bird* is used figuratively to refer to a prisoner that was previously "caged". It is also interesting that in some novel compounds (e.g., *coat shirt*, *magazine newspaper*), the head and the modifier are interpreted as being linked by the figurative relation RESEMBLE/LIKE (e.g., a coat shirt is a shirt that is thick LIKE a coat, a magazine newspaper is a newspaper that RESEMBLES a magazine) (Gagné, 2000). The ability to produce compounds based on a metaphoric relation appears quite early; for example, Gottfried (1997) found that children as young as three years old are able to produce appropriate noun-noun combinations in which the connection between the two constituents is a metaphorical resemblance (e.g., *leaf-bug* for a bug shaped like a stick) .

One of the most important well-established findings in the compound word literature is the fact that compounds with opaque heads (e.g., *jail**bird***) are more difficult to process than compounds with transparent heads (e.g., *straw**berry***). For instance, people's latencies during lexical decision tasks are longer for compounds with opaque heads than for transparent compounds (Ji, Gagné, & Spalding 2011; Libben, Gibson, Yoon, & Sandra 2003). In addition, when a compound word with a transparent head and an opaque modifier is preceded by a prime whose meaning is related to the meaning of the first constituent, the production of the whole compound is facilitated (e.g., exposure to the prime *bread* aids the processing of the target *butterfly*); however, this facilitation does not happen with compounds with opaque heads and transparent modifiers (e.g., the production of *brainchild* is not facilitated by the prime *mind*) (Gagné & Spalding, 2014).

In light of this, and taking also into account that figurative language is, by definition, semantically opaque in the sense that the literal encyclopedic definitions of its component words are not directly related to the speaker's real intended meaning (e.g., the figurative meaning of the metaphor *Lawyers are sharks* cannot be directly extracted from the definition *marine fish with cartilaginous skeleton*), it is worth examining whether noun-noun metaphors with figurative heads (e.g., *knowledge* ***ocean***) are harder to process than noun-noun metaphors with literal heads and figurative modifiers (e.g., ***helicopter*** *parents*), in the same way that compound words with opaque heads are harder to process than compound words with transparent heads. This question is addressed in Experiment 2 of the current paper.

2.2.2 Applying What is Known About the Cognitive Processes Involved in the Comprehension of *X is Y* Metaphors and Compound Words to the Study of Noun-Noun Metaphors

In the field of compound word processing, it is well-established that transparent compound words (e.g., *snowman*) are responded to more quickly than opaque compounds (e.g., *hogwash*, see, for example, Ji et al., 2011; Libben et al., 2003). This need for additional processing time for opaque compound words has also been observed in eye-tracking data, which indicate that opaque compounds receive longer gazes than transparent compounds (Juhasz, 2007), as well as in typing data, which suggest that opaque constituents are typed more slowly on the computer keyboard than are transparent constituents (Gagné & Spalding, 2014). The key factor that might explain why opaque compounds need extra processing time is *cognitive inhibition* (i.e., the ability to suppress stimuli that are irrelevant to the task at hand): When an opaque compound word is encountered, the reader needs to suppress the automatically activated irrelevant meanings of its constituents (e.g., the reader needs to inhibit the distracting meanings of *hog* and *wash* to access the compound's real meaning, that is, *nonsense*) (Libben, 2005; Ji et al., 2011). When inhibition fails, as in the case of patients suffering from aphasia, opaque compound words are paraphrased as if they were transparent (e.g., an aphasic patient might paraphrase *strawberry* as *a berry that has a straw*) (Libben, 1993). Surprisingly, Park, Sana, Gagné and Spalding (2020) have recently revealed that not only opaque, but also transparent compound words require inhibition: Transparent compounds seem to require inhibition not because the meanings of the constituents interfere with the word's overall meaning, but rather because transparent compound words allow different interpretations, depending on the relation that connects the head and the modifier, and the reader has to choose the correct relation and suppress the incorrect ones (e.g., to access the meaning of *snowman*, the language system has to settle for *man MADE OF snow*, and discard *man that HAS snow* or *man that RESEMBLES snow*).

Analogously, in the field of figurative language processing, inhibition has been shown to be involved in the comprehension of metaphors and idioms (Galinsky & Glucksberg, 2000). For instance, when readers encounter a piece of figurative language such as *Lawyers are sharks*, they need to inhibit the irrelevant meaning *fish with cartilaginous skeleton* to compute the real intended meaning of the metaphor (George & Wiley, 2016; Glucksberg, Newsome, & Goldvarg, 2001; Rubio-Fernández, 2007; Weiland, Bambini, & Schumacher, 2014). When this inhibition fails as a consequence of disorders such as schizophrenia or Alzheimer's disease, people provide literal interpretations for figurative language (Iakimova, Passerieux, & Hardy-Bayle, 2006).

Given that many noun-noun metaphors are a hybrid between open compound words and *X is Y* metaphors, and that it has been demonstrated that the processing of both compound words and *X is Y* metaphors require the inhibition of irrelevant meanings, it seems logical to investigate whether noun-noun metaphors involve cognitive inhibition too. This question is addressed in Experiment 3 of this study.

2.2.3 Overview of the Experiments

The goal of this study is to fill different gaps in the literature of metaphor comprehension. In this project we present three experiments that address three different but related questions. First, given that there are very few studies investigating how noun-noun metaphors are processed, we want to answer a basic question that nobody has addressed before: Do noun-noun metaphors have the same figurative meaning as their corresponding *X is Y* metaphors or, is the figurative meaning altered when a *X is Y* metaphor is converted into a noun-noun phrase? Our objective is to determine whether noun-noun metaphors are semantically equivalent to *X is Y* metaphors; for instance, will participants agree that *Lips are velvet*, *Lips are like velvet* and *velvet lips* all mean that lips are soft?

Once we establish that noun-noun metaphors and *X is Y* metaphors are indeed semantically comparable, we will take into account the fact that noun-noun metaphors are a hybrid between compound words and *X is Y* metaphors to analyze whether the similarity between noun-noun metaphors and compound words is not purely structural, but also related to the way they are comprehended. More specifically, we will apply what it known about the role of the head in compound word processing to the study of the head of noun-noun metaphors, and we will determine whether noun-noun metaphors with figurative heads (e.g., *knowledge* ***ocean***) are slower to process than noun-noun metaphors with literal heads and figurative modifiers (e.g., ***velvet*** *skin*), in the same way that compound words with semantically opaque heads are slower to process than compounds with transparent heads.

Finally, given that many noun-noun metaphors are a hybrid between compound words and *X is Y* metaphors, and it is well-established that both compound words and *X is Y* metaphors require inhibition of irrelevant features, we will investigate whether the processing of noun-noun metaphors also need inhibition.

2.3 Experiment 1

In this experiment, we analyzed whether the form in which a metaphor is expressed (i.e., as a noun-noun phrase, *X is Y* metaphor or simile), influences its figurative interpretation. In particular, we examined whether the main property that is conveyed in a *X is Y* metaphor or simile (e.g., being aggressive in *Lawyers are sharks* or in *Lawyers are like sharks*) stays the same when the metaphor is presented in a noun-noun format (e.g., *shark lawyer*). Previous research has shown that people may prefer one syntactic format over the other (Aisenman, 1999; Chiappe, Kennedy, & Chiappe, 2003; Zharikov & Gentner, 2002). If these reported preferences affect the meaning that is conveyed by *X is Y* metaphors, similes and noun-noun metaphors, then it would mean that these three types of expressions are not semantically equivalent. The goal is this experiment is to examine whether noun-noun metaphors, *X is Y* metaphors and similes are semantically equivalent, that is, whether their figurative meaning remains constant across all syntactic forms (e.g., participants agree to similar degrees that *Lawyers are sharks*, *Lawyers are like sharks* and *shark lawyer* all mean that lawyers are aggressive).

2.3.1 Methods

2.3.1.1 Materials

Inspired from previous articles (Chiappe et al., 2003; Gentner & Wolff, 1997; Glucksberg, McGlone, & Manfredi, 1997; Jia et al., 2014; Jones & Estes, 2005; Jones & Estes, 2006; Wolff & Gentner, 2000), we created 114 novel noun-noun metaphors (e.g., *poison job*), all of which were rated as apt by five research assistants. Five undergraduate research assistants independently read each metaphor and wrote the first figurative interpretation that came to mind. Then, we selected the interpretation that was mentioned by the majority of the research assistants. This interpretation was the noun-noun's dominant metaphorical meaning (e.g., *a job that kills* for *poison job*). Moreover, for each noun-noun metaphor, the same five research assistants also had to write another plausible –but less likely—figurative interpretation. This interpretation was the noun-noun's non-dominant metaphorical meaning (e.g., *a job that is dangerous* for *poison job*).

Each noun-noun metaphor was transformed into its corresponding *X is Y* metaphor (e.g., *Jobs are poison*) and simile (e.g., *Jobs are like poison*). The items were counterbalanced across lists such that each participant saw all 114 items in only one of the three formats, followed by either the dominant or the non-dominant interpretation. The full set of materials is presented in Appendix A.

2.3.1.2 Procedure

The participants performed a rating task on a desktop computer. On the screen, they read, one by one, the figurative expressions, followed by either the dominant or the non-dominant interpretation. Using the mouse, they had to move the slider that appeared on the screen to rate, from 0 to 100, how much they agreed that the presented interpretation conveyed correctly the figurative meaning of the phrase. The order of the items was randomized for each participant. The items were presented one at a time at the center of the screen. Once the participant made a decision about an item, he or she was automatically directed to the next trial.

2.3.1.3 Participants

Two hundred and eleven participants were recruited from introductory psychology classes in exchange for partial course credit. All participants were native speakers of English.

2.3.2 Results

The data were analyzed using linear mixed-effect (LME) analyses (Pinheiro & Bates, 2000), using the function *mixed* in Stata 13. Participant and item were included in the models as random effects, and type of format of the figurative expression (i.e., noun-noun metaphor, *X is Y* metaphor or simile) and dominance of the figurative meaning (i.e., dominant or non-dominant) as fixed effects.

There was no interaction between the type of format of the figurative expression (i.e., noun-noun metaphor, *X is Y* metaphor or simile) and meaning dominance (i.e., dominant or non-dominant), $X^2(2) = 0.88$, $p = .64$. There was no main effect of format of the figurative expression, $X^2(2) = 3.54$ $p = .17$, which indicates that participants agreed to similar degrees that the dominant and the non-dominant figurative interpretations stayed the same regardless of whether they were presented in the noun-noun format ($M = 66.5$, $SD = 31.10$), *X is Y* format ($M = 63.72$, $SD = 29.63$) or simile format ($M = 64$, $SD = 29.16$). Not surprisingly, there was a main effect of dominance, $X^2(1) =97.05$, $p <.001$, which means that participants agreed more that the dominant interpretation correctly conveyed the figurative meaning of the phrase, compared to the non-dominant meaning. This result was expected because the dominant meaning is the first interpretation that come to the reader's mind during comprehension, whereas the non-dominant meaning may require more controlled processing to come to consciousness.

2.3.3 Discussion

The most important outcome of this experiment is that we have data from a large number of participants to address a very basic question that nobody had addressed before: Does the meaning of a metaphor stay the same when it is converted from the *X is Y* format to the more compact noun-noun format? We found that noun-noun metaphors are semantically equivalent to *X is Y* metaphors, in the sense that the figurative property (e.g., being aggressive in *shark lawyer*) stays the same when switching from the standard *X is Y* format to the more condensed noun-noun format.

The finding that noun-noun metaphors are semantically equivalent to *X is Y* metaphors or similes in terms of their figurative interpretations indicates that the syntactic form in which a non-literal expression is presented does not affect its ultimate meaning. In other words, the generation and evaluation of figurative properties do not seem to be influenced by the linguistic (syntactic) form. Instead, the figurative property conveyed by the different metaphorical expressions seems to depend more on the processing of the concepts used. In summary, the figurative meaning does not depend on its structural characteristics, but rather on the semantic and conceptual content of the constituents used.

There is abundant literature on referential communication (Brennan & Clark 1996; Clark & Wilkes-Gibbs, 1986; Garrod & Anderson, 1987; Gagné, Spalding, Burry, & Adams, 2019; Krauss & Weinheimer, 1964; Metzing & Brennan, 2003) that has established that as people refer to the same concept repeatedly over time, the phrase used to designate that concept becomes progressively shorter (e.g., a geometric figure that was initially referred to as looking like *a person who is ice staking while sticking out the two arms* becomes simply *the ice skater* after repeated use; *a dog that is blue* becomes *the blue dog*). Therefore, we can advance the hypothesis that many conventional noun-noun metaphors (e.g., *helicopter parents*, *tiger mom*) actually started out as full phrases (e.g., *Their parents are like helicopters*, *Her mom is a tiger*) and were repeatedly used, adopting a more compact format over time, until one day, when finally there was enough common ground among users (Wilkes-Gibbs & Clark, 1992), they became crystalized and were lexicalized. Our results suggest that metaphors can be shortened over time for the sake of efficiency in communication, but this reduction in the length of the metaphorical expression does not result in a loss of meaning. People do not greatly alter the meaning of the figurative property for the sake of conciseness (e.g., parents are perceived as being equally overprotective in *helicopter parents* as in the full sentence *Parents are helicopters*).

2.4 Experiment 2

Now that we have established that, indeed, noun-noun metaphors are semantically equivalent to *X is Y* metaphors, we can focus on analyzing more in detail the role of the two constituents of a noun-noun metaphor, that is, the head and the modifier. As mentioned in the introduction, noun-noun metaphors (e.g., *helicopter parents*) have the same structure as literal compound words (e.g., *snowball*) in the sense that they consist of two words that are juxtaposed (i.e., the modifier and the head). Inspired in the literature of compound words, which has revealed that compounds with opaque heads (e.g., *jail**bird***) are more difficult to process than compounds with transparent heads (e.g., *straw**berry***), and taking into account that figurativeness is a type of semantic opacity, Experiment 2 aims at determining whether noun-noun metaphors with figurative heads (e.g., *knowledge ocean*) are harder to process than noun-noun metaphors with literal heads and figurative modifiers (e.g., *velvet skin*). In summary, we want to investigate how the position of the metaphorical constituent (i.e., as modifier or head) affects the ease of processing of noun-noun metaphors.

2.4.1 Methods

2.4.1.1 Materials

From the stimuli used in Experiment 1, all of which, as pointed above, had been rated as apt and novel, we selected eighty-four noun-noun metaphors. All noun-noun phrases had one literal constituent and one metaphorical constituent but varied in terms of whether it was the head or modifier that was metaphoric. Forty-two noun-noun metaphors had figurative heads and literal modifiers (e.g., *marriage leash*), and forty-two noun-noun metaphors had figurative modifiers and literal heads (e.g., *velvet lips*). In addition to these experimental items, we created eighty-four nonsense noun-noun fillers (e.g., *cucumber script*, *wait grow*) that were matched in length and frequency to the experimental items using SUBTLEX-US corpus (Brysbaert & New, 2009). These nonsense fillers were supposed to elicit a "no" response. Exact item by item matching of the experimental items by type was not possible, due to the limited number of items we had to choose from. However, the phrases were very similar in average letter length (13 vs. 12), and the words used figuratively were very similar in frequency (3.14 vs. 3.17 log word frequency), as were the words used literally (2.81 vs. 2.55). The items used are presented in Appendix B.

2.4.1.2 Procedure

Participants performed a sense/nonsense judgment task in which they had to indicate, as quickly as possible, whether each presented noun-noun phrase had a sensible metaphorical interpretation or not (i.e., if it could be attributed a figurative meaning or not). They pressed the key “j” if the noun-noun could be interpreted figuratively, or the key “f” if it could not. The order of the items was randomized for each participant. The items were presented one at a time at the center of the screen. Each trial began with the message “Ready?” and the participants had to press the spacebar on the keyboard to see each item. The reaction times were automatically collected by the computer timer, which measured the number of milliseconds elapsed between the stimulus appearance on the screen until the moment the participant responded with the key stroke.

2.4.1.3 Participants

Thirty-nine participants were recruited from introductory psychology classes in exchange for partial course credit. All participants were native speakers of English. One participant was removed from all analyses due to low accuracy rate (51%) on the sense/nonsense task and unusually fast reaction times.

2.4.2 Results

The data were analyzed using linear mixed-effect (LME) analyses using the function *mixed* for reaction time data and the function *meqrlogit* for accuracy data in Stata 13. Participant and item were included in the models as random effects, and position of the metaphorical constituent (i.e., head or modifier) as fixed effect. Responses with reaction times that were more than 2.5 standard deviations greater than each participant’s mean were removed. Additionally, two reaction times that were smaller than 500 ms were also removed, as the Q-Q plots revealed them to be outliers. The total number of observations removed represented 2.88% of the original data set. Log-transformed response time was used for the reaction time analysis because the Q-Q plots revealed that this transformation was better at correcting for skewness in the residuals than was the inverse transformation. The response time analysis was based on correct trials only.

Participants were slower when responding to noun-noun phrases with metaphorical heads (*M* = 1808 ms, *SD* = 1030) than when responding to noun-noun phrases with metaphorical modifiers (*M* = 1649 ms, *SD* = 890), $X^2(1) = 5.49$, $p = .02$. However, accuracy was unaffected by the position of the metaphorical constituent: Accuracy for noun-noun phrases with metaphorical heads (*M* = 76%, *SD* = 43) did not differ from accuracy for noun-noun phrases with metaphorical modifiers (*M* = 81%, *SD* = 39), $X^2(1) = 2.78$, $p = .10$.

These results suggest that noun-noun metaphors are analogous to compound words: In the same way that compound words with opaque heads (e.g., *jailbird*) are more difficult to process than compounds with transparent heads (e.g., *strawberry*), noun-noun phrases with metaphorical heads (e.g., *relationship patch*) are also more difficult to process than noun-noun phrases with literal heads and metaphorical modifiers (e.g., *parasite paparazzi*). This confirms the idea that figurativeness can be considered as a subtype of semantic opacity.

2.4.3 Discussion

This experiment revealed that noun-noun phrases with metaphorical heads (e.g., *relationship patch*) are more difficult to process than noun-noun phrases with literal heads and metaphorical modifiers (e.g., *parasite paparazzi*). There are two possible explanations for this finding. The first explanation is based on the relationship between the category denoted by the phrase and the category denoted by the head noun. Hyponymy refers to whether a compound is a member of the head noun class or not; *gemstone* is a type of *stone*, but *buttercup* is not a type of *cup*. Gagné, Spalding, Spicer, Wong, Rubio and Cruz (2020) recently reported that that items with low hyponymy ratings were more difficult to process (as measured by lexical decision latencies) than items with higher hyponymy ratings. The current results from Experiment 2 suggest that this phenomenon might also apply to metaphoric compounds. In terms of metaphoric phrases, given that the head of noun-noun phrases usually designates a category (e.g., a coffee cup is a type of cup), noun-noun metaphors with figurative heads activate two different categories, one literal and one figurative (e.g., *patch* designates very different categories, depending on whether it is used figuratively in *relationship patch* or literally in *jean patch* or *leather patch*), and the reader needs to suppress the literal category to access the intended figurative meaning. Moving from the more dominant literal-based category to a metaphoric-based one requires extra processing time. For instance, when a reader encounters *relationship patch*, he or she has to inhibit the literal category *cloths used to mend or strengthen a torn or weak point* and think, instead, of another very different figurative category of "healing" things (e.g., a category that includes members such as couples therapy, quality time or learning effective communication skills). However, when a noun-noun metaphor has a literal head and a figurative modifier (e.g., *parasite paparazzi*), the category of things that is designated by the phrase is a subcategory of the head noun category in which the head is used literally (e.g., both the figurative phrase *parasite paparazzi* and the literal phrase *high-profile paparazzi* refer to actual paparazzi with *parasite paparazzi* referring to a subset of *paparazzi*).

A second possible explanation for the finding that noun-noun phrases with metaphorical heads take longer to process than noun-noun phrases with literal heads and metaphorical modifiers is that in *X is Y* metaphors (e.g., *His parents are helicopters*), *Y* is, by definition, always used metaphorically because it is the vehicle that carries the figurative properties. When a *X is Y* metaphor is transformed into its corresponding noun-noun version, it usually adopts the format *YX* (e.g., *helicopter parents*). Therefore, people are more accustomed to expecting the metaphorical constituent to be in the modifier position, but when that is not the case and readers encounter a metaphorical constituent in the head, they need additional time for processing the noun-noun. This explanation, though with a somewhat different emphasis, is similar to that above, in that both the hyponymy results and the YX metaphor structure suggest that readers of noun-noun phrases generally expect the head to establish the category, and that when this is not true, processing is slowed.

It is worth noting that future research needs to further explore two issues that are beyond the scope of this study. First, follow-up studies have to determine why, even though most *X is Y* metaphors that can be converted into noun-noun metaphors have their vehicle in the modifier position (e.g., *Paparazzi are parasites* becomes *parasite paparazzi*), there seems to be a minority of *X is Y* metaphors that end up having their vehicle in the head position (e.g., *Marriage is a leash* becomes *marriage leash*). Second, this study has investigated the processing of noun-noun metaphors in comparison to *X is Y* metaphors, but future studies need also to analyze noun-noun metaphors in comparison to adjective-noun metaphors (Forgács, Bardolph, Amsel, Delong, & Kutas, 2015; Sakamoto & Utsumi, 2014), and, more specifically, determine why some metaphors sound very natural in a noun-noun format (e.g., *cookie face*, *velvet skin*, *parasite paparazzi*), whereas others sound equally or more natural in an adjective-noun format (e.g., for some people *thunderous crowd* might sound more natural than *thunder crowd*). In fact, factors such as semantic neighbourhood density and concreteness of the two constituents (Al-Azary & Buchanan, 2017; Al-Azary, McAuley, Buchanan, & Katz, 2019) may play a role that needs to be further investigated.

2.5 Experiment 3

Experiment 1 has established that noun-noun metaphors are semantically equivalent to standard-formatted *X is Y* metaphors. Experiment 2 has revealed that, in the same way that compound words with semantically opaque heads are processed slower than compounds with transparent heads, noun-noun phrases with metaphorical heads are processed slower than noun-noun phrases with literal heads and metaphorical modifiers. This finding suggests that theories of conceptual combination and compound words can also be applied to the study of noun-noun metaphors. In Experiment 3, we investigate whether findings from the literature of *X is Y* metaphor processing can be applied to the study of noun-noun metaphors. Our question is: Given that *X is Y* metaphor processing involves the inhibition of irrelevant features, does the same hold for noun-noun metaphors?

We examined whether the ease of processing a noun-noun metaphor (e.g., *soul patch*) is affected by the previous activation of irrelevant features (e.g., reading *jean patch* before *relationship patch* can activate irrelevant features of *patch*, such as the fact of being made of cloth, that can interfere with the comprehension of the noun-noun metaphor). If noun-noun metaphors are similar to *X is Y* metaphors in that they require the inhibition of irrelevant features too, then we can expect that the comprehension of a noun-noun metaphor will be slower when it is preceded by a prime that activates features that are irrelevant for the accurate comprehension of the noun-noun metaphor, compared to when it is preceded by a prime that activates the same relevant aspects of the constituent involved (e.g., *relationship patch* should be slower when preceded by *jean patch* than when preceded by *soul patch*). Additionally, we also manipulated whether the constituent that appeared repeated in the prime was the modifier or the head so that, if we find that there is indeed a cost of inhibiting irrelevant features, we can examine whether the inhibition cost is greater for noun-noun metaphors with metaphorical heads or for noun-noun metaphors with metaphorical modifiers.

2.5.1 Methods

2.5.1.1 Materials

From the stimuli used in Experiment 2, we selected seventy-six noun-noun metaphors: thirty-eight had figurative heads and literal modifiers (e.g., *marriage leash*), and thirty-eight had figurative modifiers and literal heads (e.g., *velvet lips*). Our two variables of interest were the type of prime (i.e., a prime that activates irrelevant features or a prime that activates relevant features) and the position of the metaphorical constituent (head or modifier). Each noun-noun metaphor was preceded by one of the two types of primes. For the noun-noun metaphors with metaphorical heads (e.g., *marriage leash*), the prime was a noun-noun phrase in which the same head (e.g., *leash*) activated irrelevant features (e.g., *dog leash* activates the irrelevant feature of being made of a rope) or relevant features (e.g., *contract leash* activates the relevant feature of restraining one's freedom). For the noun-noun metaphors with metaphorical modifiers (e.g., *velvet lips*), the prime was a noun-noun phrase in which the same modifier (e.g., *velvet*) activated irrelevant features (e.g., *velvet sofa* activates the irrelevant feature of being made of cloth) or relevant features (e.g., *velvet treatment* activates the relevant feature of being soft). In addition to these experimental items, we created three types of pairs of fillers such that the response to the prime would not be predictive of the response to the target. The first type of fillers consisted of seventy-six pairs of noun-noun combinations that prompted a "yes" response on the first item and a "no" response on the second (e.g., *trauma survivor* followed by *trauma penny*). The second type of fillers consisted of seventy-six pairs that prompted a "no" response on the first item and a "yes" response on the second (e.g., *laundry death* followed by *career death*). The third type of fillers consisted of seventy-six pairs that prompted a "no" response on both items (e.g., *clumsiness jury* followed by *dirt jury*). Half of the pairs of fillers had the head as the repeating item and the other half had the modifier as the repeating item. The items used are presented in Appendix C.

2.5.1.2 Procedure

The procedure was identical to the one used in Experiment 2, except that participants were told that both items that had a sensible literal interpretation and items that had a sensible figurative interpretation needed a “yes” response.

2.5.1.3 Participants

Sixty-two participants were recruited from introductory psychology classes in exchange of partial course credit. All participants were native speakers of English and had participated in neither Experiment 1 nor Experiment 2.

2.5.2 Results

The data were analyzed using linear mixed-effect (LME) analyses using the function *mixed* for reaction time data and the function *meqrlogit* for accuracy data on Stata 13. Participant and item were included in the models as random effects, and type of prime (i.e., primes that activate irrelevant or relevant features) and position of the metaphorical constituent (i.e., head or modifier) as fixed effects. Responses with reaction times that were more than 2.5 standard deviations greater than each participant’s mean were removed. Additionally, nine reaction times that were smaller than 100 ms were also removed, as the Q-Q plots revealed them to be outliers. The total number of observations removed represented 0.40% of the original data set. Log-transformed response time was used for the reaction time analysis because the Q-Q plots revealed that this transformation was better at correcting for skewness in the residuals than was the inverse transformation. The response time analysis was based on correct trials only.

In terms of the reaction time analysis, there was no interaction between the type of prime (i.e., primes that activate irrelevant or relevant features) and the position of the metaphorical constituent (head or modifier), $X^2(1) = 0.29$, $p = .59$. There was no main effect of the position of the metaphorical constituent, $X^2(1) = 0.35$, $p = .56$. As predicted, there was a main effect of type of prime, $X^2(1) = 33.69$, $p <.001$, in that participants were slower when a noun-noun metaphor was preceded by a prime that activated irrelevant features (*M* = 1208 ms, *SD* = 675), compared to when it was preceded by a prime that activated relevant features (*M* = 1125 ms, *SD* = 569). In regard to the accuracy analysis, there was no interaction between the type of prime and the position of the metaphorical constituent (head or modifier), $X^2(1) = 0.05$, $p = .82$. There was no main effect of the position of the metaphorical constituent, $X^2(1) = 0.33$, $p = .57$. As predicted, there was a main effect of type of prime, $X^2(1) = 23.96$, $p <.001$, which means that participants made more errors when a noun-noun metaphor was preceded by a prime that activated irrelevant features (*M* = 69%, *SD* = 46), compared to when it was preceded by a prime that activated relevant features (*M* = 75%, *SD* = 43).

In summary, both the response time and accuracy data revealed that it is more difficult to process a noun-noun metaphor (e.g., *relationship patch*) when it was preceded by a prime that activated irrelevant features (e.g., *jean patch*), compared to when it was preceded by a prime that activated relevant features (e.g., *soul patch*).

2.5.3 Discussion

The results of this experiment suggest that interpreting a noun-noun metaphor involves the inhibition of irrelevant features[1]. One thing worth noting is that including primes removed the processing disadvantage of noun-noun phrases with figurative heads that we found in Experiment 2. Recall that Experiment 2' s results suggest that there is a processing cost

[1] However, we acknowledge that, as Gibbs (2011) pointed out, people's performances in different psycholinguistic tasks may not be caused by single variables, such as inhibition in this case, but are rather likely shaped by multiple interacting constraints (e.g., people's lexical and grammatical knowledge, people's experiences with different discourse genres).

associated with creating a meaning that refers to a category that is not a subcategory of the head noun; we argued that that noun-noun phrases with metaphorical heads were more difficult to process because they required the suppress of the literal meaning of the head due to the figurative category that the head indicated was different than the literal category (e.g., *patch* in *soul patch* does not refer to the category *cloths used to mend or strengthen a torn or weak point* but rather to a superordinate figurative category of "healing" things). So, what explains the disappearance of this "headedness effect"? First, we propose that the heads of noun-noun phrases, given that they point out the category, usually have a tendency to be interpreted literally or, in other words, are generally expected to have a literal meaning. Therefore, when a noun-noun metaphor with a literal head and a metaphorical modifier is preceded by a prime that activates irrelevant features by using the same head literally, the presence of the prime does not add much additional processing difficulty: In fact, the head is usually already biased to be interpreted literally. On the other hand, modifiers are more likely than heads to be used figuratively: In fact, even children as young as three years old use noun-noun phrases in which the modifier is used metaphorically (e.g., *leaf-bug* for a bug shaped like a stick) (Gottfried, 1997). This means that when a noun-noun phrase with a metaphorical modifier is preceded by a noun-noun that activates irrelevant features by using that same modifier literally, there is an additional processing difficulty, because, from the start, there was less of an expectation for the modifier to be used literally. This balances out the headedness effect we encountered in Experiment 2. However, when a noun-noun metaphor is preceded by a prime that already refers to the relevant properties, the inhibition of irrelevant features has already occurred, so it becomes easier to process the noun-noun phrase, regardless of whether the inhibition was needed for features related to the head or the modifier.

Together, the results from Experiments 3 suggest that noun-noun metaphors behave like standard-formatted *X is Y* metaphors in the sense that they too involve the inhibition of irrelevant features.

2.6 General Discussion

This project has contributed to the relatively underexplored field of noun-noun metaphors by establishing three primary observations. First, we determined that the meaning of a *X is Y* metaphor is conserved when it is converted into a noun-noun metaphor. Second, we revealed that noun-noun metaphors are analogous to compound words in the sense that both the figurativeness of the head in the former and the opacity of the head in the latter create processing difficulties for readers, which confirms, once again, the importance of the head in noun-noun phrases. Third, we showed that noun-noun metaphors require the inhibition of irrelevant features, similarly to what occurs with *X is Y* metaphors. These findings have important theoretical implications, which will be discussed in the following sections.

2.6.1 Implications for the Theories of Metaphor Processing

The finding that noun-noun phrases with metaphorical heads are more difficult to process than noun-noun phrases with literal heads and metaphorical modifiers and that exposure to a prime alters this processing disadvantage has several implications for the different theories that explain metaphor processing and conceptual combination. Various theories of metaphor comprehension have tried to explain the roles that topic and vehicle play in the comprehension of standard-formatted nominal metaphors. In particular, two major schools differ in the emphasis that they place on these two constituents. The alignment model considers that the roles of the two components are symmetrical, whereas the class-inclusion model places a greater emphasis on the vehicle.

The alignment model (Gentner, 1983; Gentner & Wolff, 1997; Wolff & Gentner, 2000; Wolff & Gentner, 2011) states that metaphors (e.g., *Lawyers are sharks*) function like analogies (e.g., *An atom is like the solar system*). According to this view, the first stage of metaphor comprehension is symmetrical, in the sense that the topic and the vehicle do not play different roles. During this initial role-neutral stage, the topic and the vehicle are merely aligned to detect similarities between them (e.g., the concepts of *lawyer* and *shark* are mapped onto each other until the commonality *being aggressive* is highlighted and the reader realizes that, in the same way that sharks are aggressive on their prey, lawyers are also aggressive when defending their clients). Once this match is established, a second, role-specific and directional stage begins, in which additional properties are projected as inferences from the vehicle to the topic (e.g., the knowledge that sharks are feared by other fish results in the inference that lawyers are feared by other people, and the knowledge that sharks can sense the presence of a potential prey over long distances results in the inference that injury lawyers appear at the scene of an accident to get new clients among the victims). In summary, in the alignment model, metaphor comprehension begins symmetrical, with alignment and matching, and ends directional, with projections of inferences from the vehicle to the topic. The shift from a role-neutral mapping to a role-sensitive inference process occurs late in the time course of the processing. In support of the alignment model, Gentner and Wolff (1997) have shown that priming a metaphor with the topic has the same effect on comprehension times as priming it with the vehicle. In addition, Wolff and Gentner (2000) have demonstrated that the amount of time the readers take to decide that a metaphor is literally false is the same for forward metaphors (e.g., *Some rumors are viruses*) and for reversed metaphors (e.g., *Some viruses are rumors*), which suggests that the initial processing is role-neutral. Finally, in agreement with the alignment model, comprehensibility judgments for forward and reversed metaphors at early stages of processing appear to be equal (Wolff & Gentner, 2011).

Now, the alignment model, when applied to noun-noun metaphors, would predict that during the early stage of processing, the modifier and the head are aligned, to later allow a projection of the relevant properties from the vehicle to the topic, regardless of whether the vehicle is found in the head position, as in *marriage leash*, or in the modifier position, as in *parasite paparazzi*. The alignment model does not explain why our results show that the property projection seems to be easier when going from left to right (as when the vehicle is in the modifier position) than when going from right to left (as when the vehicle is in the head position).

In contrast to the alignment model, the class-inclusion model (Glucksberg, 2003; Glucksberg & Keysar, 1990), claims that the topic and the vehicle play very distinct roles even from the beginning of processing. According to this view, metaphors function like categorical assertions: The topic belongs to a superordinate category exemplified by the vehicle. Once the topic is assigned to a metaphorical category represented and named after the vehicle, the topic is classified as part of that category and the properties of that class are then transferred and attributed to the topic. For instance, when people hear *Lawyers are sharks*, they know that lawyers are members of a superordinate category of beings that are aggressive and scary, represented by the word *shark*. The first piece of evidence that supports this asymmetry between the topic and the vehicle is the fact that metaphors are not reversible (e.g., *Lawyers are sharks* cannot be reversed into *Sharks are lawyers*) (Glucksberg et al., 1997). In addition, it has been shown that priming a metaphor with a property that belongs to the topic but that is irrelevant for the metaphor (e.g., *Lawyers can be married*) facilitates metaphor comprehension, whereas priming a metaphor with a property that belongs to the vehicle but that is irrelevant for the metaphor (e.g., *Sharks can be blue*) impedes comprehension (McGlone & Manfredi, 2001).

If the class-inclusion model is applied to noun-noun metaphors, it would expect that the head is placed inside the category designated by the modifier if the vehicle is in the modifier position (e.g., *parasite paparazzi*), or that the modifier is placed inside the category designated by the head if the vehicle is in the head position (e.g., *marriage leash*). Then, given that noun-noun metaphors are structurally equivalent to open compound words, whose heads designate a literal category (e.g., a coffee cup is a type of cup), it seems normal to find that noun-noun phrases with metaphorical heads are harder to process than noun-noun phrases with metaphorical modifiers because the head in a noun-noun with a figurative head can designate two possible categories, which can slow participants down. For instance, in *marriage leash*, *leash* can designate the literal category *rope used to control animals*, or the figurative category *things that restrict a person's freedom*.

2.6.2 Implications for the Theories of Conceptual Combination

Various theories of conceptual combinations have tried to explain the mechanisms that underlie the processing of crystalized compound words (e.g., *coffee cup*) and novel noun-noun phrases (e.g., *unicorn nest*, *mushroom cloud*). In general terms, these theories can be categorized into two groups: those that focus on property attribution and those that focus on the relation that connects the two constituents of a compound word or a noun-noun phrase. The former addresses how properties belonging to the modifier are attributed to the head (e.g., in *mushroom cloud* the unique shape of mushrooms is attributed to the cloud), whereas the latter addresses how the compound word is interpreted in terms of a relationship between the modifier and head (e.g., *unicorn nest* can be interpreted as a nest FOR unicorns, a nest that RESEMBLES a unicorn or a nest MADE OF unicorns, depending on what relation between the two constituents is chosen).

As part of the group of theorists who focus on property attribution, Wisniewski (1996, 1997) has proposed an alignment and comparison model of how people interpret noun-noun combinations. Inspired by Gentner's (1983) alignment model of metaphor comprehension, Wisniewski suggests that the processing of noun-noun phrases is analogous to the processing of nominal metaphors, in the sense that the two constituents first have to be aligned so that the dimensions of one constituent are put into correspondence with analogous dimensions of the other constituent and once the dimensions are aligned, the features of the two concepts are compared. For instance, when a reader encounters *car truck*, *car* and *truck* are aligned and dimensions such as the number of doors and seats are matched; then, through a process of comparison, the similarities and differences between *car* and *truck* are detected and the reader realizes that both cars and trucks have four wheels, but cars have four doors and seat four people, whereas trucks have two doors and seat two people; finally, the reader realizes that a car truck is therefore a special type of truck that has four doors and seats four people (Goldvarg & Glucksberg, 1998; Wisniewski & Love, 1998). As an alternative to the alignment and comparison model, Estes and Glucksberg (2000) propose an interactive property attribution model in which the modifier and head play very distinct functions. The focus of these authors' model remains property attribution, but instead of stating that the language system exhaustively compares the features of the two constituents, they suggest the idea that the head proposes the dimensions that are relevant, and the modifier provides salient features for attribution. For example, in *shark lawyer*, the head *lawyer* provides relevant dimensions for attribution (e.g., personality, competence, cost) and the modifier *shark* provides salient candidate properties (e.g., predatory, aggressive, vicious) that can be attributed.

On the other hand, there are theories that focus on the relation that connects the head and the modifier of a compound word, rather than on property attribution (Gagné & Shoben, 1997; Gagné & Spalding, 2009). In particular, the Relational Interpretation Competitive Evaluation (RICE) theory of conceptual combination (Spalding, Gagné, Mullaly, & Ji, 2010) states that the two constituents that compose a compound word are connected through an underlying relational structure (e.g., a *webpage* is a page LOCATED on the web, a *snowman* is a man MADE OF snow, a *chat-room* is a room FOR chats). According to this view, compound words are interpreted through a three-stage process named suggest-evaluate-elaborate: First, the modifier suggests different possible relations (e.g., *peanut butter* can be interpreted as *butter MADE OF peanut*, or *butter FOR peanuts*); second, the head evaluates these relations; third, once a suggested relation has been selected, world knowledge and pragmatics intervene during the elaboration stage by helping construct the overall meaning of the phrase. In other words, according to the RICE theory, the comprehension of a noun-noun phrase involves several stages, such as competition between different possible relational interpretations, accessing semantic information associated with the head and the modifier, generation of several relational meaning candidates and selection and evaluation of the best possible interpretation.

The advantage of the RICE theory of conceptual combination is its parsimony: It can be applicable to all types of noun-noun phrases, including noun-noun metaphors. Note that some metaphorical noun-noun combinations allow matching and property attribution, whereas some do not. For instance, although it is true that *knowledge ocean* may involve matching *ocean* and *knowledge* until the property of being immense is detected, and *knowledge ocean* is then interpreted as having an immense amount of information, there are other noun-noun metaphors, such as *sugar daddy*, *couch potato*, *gold digger*, *duty mountain*, *rainbow policy*, *crater face*, just to mention a few, that are less likely to require matching and property transfer, and are more likely to be interpreted through connecting the head and the modifier using a relation. For instance, it does not seem likely that *couch* and *potato* are matched because there is no commonality between these two concepts; instead a couch potato is a figurative “potato” (i.e., a person who is as lazy as a potato) that is usually found on the couch (a potato LOCATED IN the couch). Similarly, there is no matching and finding commonalities between *sugar* and *daddy*; instead, a sugar daddy is a figurative “daddy” (i.e., an older man) who HAS figurative “sugar” (i.e., money). A duty mountain is a mountain MADE OF lots of duties; a rainbow policy is a policy ABOUT a figurative “rainbow” (i.e., LGBTQ+); a crater face is a face that HAS figurative “craters” (i.e., large pores. Therefore, instead of proposing two different theories of noun-noun metaphor processing (i.e., a property attribution theory vs a relation theory), depending on whether the combination allows or not property attribution, it is more parsimonious to assume that all noun-noun metaphors, including those that allow property transfer, are interpreted through a modifier-head relation (e.g., *knowledge ocean* is knowledge that RESEMBLES an ocean). This seems logical given that the language system cannot know beforehand if a noun-noun phrase will allow alignment and matching or not. In conclusion, the RICE theory of conceptual combination can also be applied to the study of noun-noun metaphors.

2.6.3 General Conclusion

The processing of metaphoric noun-noun phrases remains mostly unexplored. However, the current set of experiments has contributed to an initial understanding to this matter by pointing out that noun-noun metaphors and compound words share many similarities. This realization opens up new avenues for exploring metaphor processing and suggests that theories of conceptual combination and findings from research on compound word processing can be applied to the study of noun-noun metaphors to further explore the common cognitive mechanisms that may underlie the processing of both types of linguistic constructions.

2.7 References

Aisenman, R. A. (1999). Structure-mapping and the simile-metaphor preference. *Metaphor and Symbol, 14*(1), 45–51.

Al-Azary, H., Buchanan, L. (2017). Novel metaphor comprehension: Semantic neighbourhood density interacts with concreteness. *Memory & Cognition*, *45*, 296–307.

Al-Azary, H., McAuley, T., Buchanan, L., & Katz, A. N. (2019). Semantic processing of metaphor: A case-study of deep dyslexia. *Journal of Neurolinguistics, 51,* 297–308.

Brennan, S. E., & Clark, H. H. (1996). Conceptual pacts and lexical choice in conversation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*(6), 1482-1493.

Brysbaert, M., & New, B. (2009). Moving beyond Kuçera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods*, *41*(4), 977–990.

Chiappe, D., Kennedy, J., & Chiappe, P. (2003). Aptness is more important than comprehensibility in preference for metaphors and similes. *Poetics*, *31*, 51-68.

Clark, H. H., & Wilkes-Gibbs, D. (1986). Referring as a collaborative process. *Cognition*, *22*, 1-39.

Estes, Z., & Glucksberg, S. (2000). Interactive property attribution in concept combination. *Memory & Cognition, 28*(1), 28–34.

Forgács, B., Bardolph, M. D., Amsel, B. D., DeLong, K. A., & Kutas, M. (2015). Metaphors are physical and abstract: ERPs to metaphorically modified nouns resemble ERPs to abstract language. *Frontiers in Human Neuroscience, 9,* Article 28.

Gagné, C. L. (2000). Relation-based combinations versus property-based combinations: A test of the CARIN theory and the dual-process theory of conceptual combination. *Journal of Memory and Language*, *42***,** 365-389.

Gagné, C. L. (2002). Metaphoric interpretations of comparison-based combinations. *Metaphor and Symbol, 17*(3), 161-178.

Gagné, C. L., Spalding, T. L., Spicer, P., Wong, D., Rubio, B., & Cruz, K. P. (2020). Is buttercup a kind of cup? Hyponymy and semantic transparency in compound words. *Journal of Memory and Language, 113*. https://doi.org/10.1016/j.jml.2020.104110

Gagné, C. L., & Shoben, E. J. (1997). Influence of thematic relations on the comprehension of modifier-noun combinations. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *23*, 71-87.

Gagné, C. L., & Spalding, T. L. (2009). Constituent integration during the processing of compound words: Does it involve the use of relational structures? *Journal of Memory and Language, 60*(1), 20–35.

Gagné, C. L., & Spalding, T. L. (2014). Typing time as an index of morphological and semantic effects during English compound processing. *Lingue e Linguaggio*, *13*(2), 241-262.

Gagné, C. L., Spalding, T. L., Burry, J. C., & Adams, J. T. (2020). Production of multi-word referential phrases: Inclusion of over-specifying information and a preference for modifier-noun. In S. Schulte im Walde & E. Smolka (Eds.). *The role of constituents in multiword expressions: An interdisciplinary, cross-lingual approach* (pp. 135-158). Berlin: Language Science Press.

Gagné, C. L., Spalding, T. L., & Gorrie, M. C. (2005). Sentential Context and the Interpretation of Familiar Open-Compounds and Novel Modifier-Noun Phrases. *Language and Speech*, *48*(2), 203–219.

Galinsky, A. D., & Glucksberg, S. (2000). Inhibition of the literal: Metaphors and idioms as judgmental primes. *Social Cognition, 18*(1), 35–54.

Garrod, S., & Anderson, A. (1987). Saying what you mean in dialogue: A study in conceptual and semantic co-ordination. *Cognition*, *27*(2), 181-218.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science*, *7*, 155-170.

Gentner, D., & Wolff, P. (1997). Alignment in the processing of metaphor. *Journal of Memory and Language*, *37*(3), 331-355.

George, T., & Wiley, J. (2016). Forgetting the literal: The role of inhibition in metaphor comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 42*(8), 1324–1330.

Gibbs, R. (2011). Multiple constraints in theories of metaphor. *Discourse Processes*, *48*(8), 575–584.

Glucksberg, S. (2003). The psycholinguistics of metaphor. *Trends in Cognitive Science*, *7*, 92–96.

Glucksberg, S., & Keysar, B. (1990). Understanding metaphorical comparisons: Beyond similarity. *Psychological Review, 97*, 3-18.

Glucksberg, S., McGlone, M. S., & Manfredi, D. (1997). Property attribution in metaphor comprehension. *Journal of Memory and Language, 36*(1), 50-67.

Glucksberg, S., Newsome, M., & Goldvarg, Y. (2001). Inhibition of the literal: Filtering metaphor-irrelevant information during metaphor comprehension. *Metaphor and Symbol, 16*, 277–293.

Goldvarg, Y., & Glucksberg, S. (1998). Conceptual combinations: The role of similarity. *Metaphor and Symbol, 13*(4), 243–255.

Gottfried, G. M. (1997). Using metaphors as modifiers: Children's production of metaphoric compounds. *Journal of Child Language, 24*(3), 567–601.

Iakimova, G., Passerieux, C., & Hardy-Bayle, M. C. (2006). The understanding of metaphors in schizophrenia and depression. An experimental approach. *Encephale*, *32*, 995-1002.

Ji, H., Gagné, C. L., & Spalding, T. L. (2011). Benefits and costs of lexical decomposition and semantic integration during the processing of transparent and opaque English compounds. *Journal of Memory and Language, 65,* 406-430.

Jia, Y., Zan, H., Fan, M., Yu, S., & Wang, Z. (2014). Word Relevance Computation for Noun-Noun Metaphor Recognition. In: Su X., He T. (Eds.), *Chinese Lexical Semantics. CLSW 2014. Lecture Notes in Computer Science* (pp. 251-259). Switzerland: Springer, Cham.

Jones, L. L., & Estes, Z. (2005). Metaphor comprehension as attributive categorization. *Journal of Memory and Language, 53*(1), 110-124.

Jones, L. L., & Estes, Z. (2006). Roosters, robins, and alarm clocks: Aptness and conventionality in metaphor comprehension. *Journal of Memory and Language*, *55*(1), 18-32.

Juhasz, B. J. (2007). The influence of semantic transparency on eye movements during English compound word recognition. In R. von Gompel, W. Murray, & M. Fischer (Eds.), *Eye movements: A window on mind and brain* (pp. 373–389). Boston, MA: Elsevier.

Krauss, R. M., & Weinheimer, S. (1964). Changes in the length of reference phrases as a function of social interaction: A preliminary study. *Psychonomic Science*, *1*, 113-114.

Libben, G. (1993). A Case of obligatory access to morphological constituents. *Nordic Journal of Linguistics*, *16*, 111-12.

Libben, G. (2005). Everything is psycholinguistics: Material and methodological considerations in the study of compound processing. *The Canadian Journal of Linguistics / La revue canadienne de linguistique*. *50*. 267-283.

Libben, G. (2010). Compound words, semantic transparency, and morphological transcendence. *Linguistische Berichte Sonderheft*, *17*, 1-14.

Libben, G., Gibson, M., Yoon, Y. B., & Sandra, D. (2003). Compound fracture: The role of semantic transparency and morphological headedness. *Brain and Language, 84*, 50–64.

McGlone, M.S., & Manfredi, D.A. (2001). Topic-vehicle interaction in metaphor comprehension. *Memory & Cognition*, *29*(8), 1209-1219.

Metzing, C., & Brennan, S. E. (2003). When conceptual pacts are broken: Partner-specific effects on the comprehension of referring expressions. *Journal of Memory and Language*, *49*(2), 201-213.

Myers, J. (2007). Generative morphology as psycholinguistics. In G. Jarema & G. Libben (Eds.), *The mental lexicon: Core perspectives* (pp. 105-128). Amsterdam: Elsevier.

Park, J., Sana, F., Gagné, C. L., & Spalding, T. L. (2020). Is inhibition involved in the processing of opaque compound words? A study of individual difference. *The Mental Lexicon*, *15*(2), 255-291.

Pinheiro, J. C., & Bates, D. M. (2000). *Mixed-effects models in S and S-PLUS*. New York, NY: Springer.

Rubio-Fernández, P. (2007) Suppression in metaphor interpretation: Differences between meaning selection and meaning construction. *Journal of Semantics*, *24*(4), 345-371.

Sakamoto, M., & Utsumi, A. (2014). Adjective metaphors evoke negative meanings. *PloS one*, *9*(2), e89008.

Spalding, T. L., & Gagné, C. L. (2007). Semantic property activation during the interpretation of combined concepts. *The Mental Lexicon*, *2*(1), 25-47.

Spalding, T. L., Gagné, C. L., Mullaly, A. C., & Ji, H. (2010). Relation-based interpretations of noun-noun phrases: a new theoretical approach. In S. Olson (Ed.), New impulses in word formation (Linguistische Berichte Sonderheft 17) (pp. 283–315). Hamburg: Buske.

Weiland, H., Bambini, V., & Schumacher, P. B. (2014). The role of literal meaning in figurative language comprehension: Evidence from masked priming ERP. *Frontiers in Human Neuroscience, 8,* Article 583.

Wilkes-Gibbs, D., & Clark, H. H. (1992). Coordinating beliefs in conversation. *Journal of Memory and Language*, *31*, 183–194.

Wisniewski, E. J. (1996). Construal and similarity in conceptual combination. *Journal of Memory and Language, 35*(3), 434–453.

Wisniewski, E. J. (1997). When concepts combine. *Psychonomic Bulletin & Review, 4*(2), 167–183.

Wisniewski, E. J., & Love, B. C. (1998). Relations versus properties in conceptual combination. *Journal of Memory and Language, 38*(2), 177–202.

Wolff, P., & Gentner, D. (2000). Evidence for role-neutral initial processing of metaphors. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 529-541.

Wolff, P., & Gentner, D. (2011). Structure-mapping in metaphor comprehension. *Cognitive science*, *35*(8). 1456-1488.

Zharikov, S., & Gentner, D. (2002). Why do metaphors seem deeper than similes? In W. D. Gray & C. D. Schunn (Eds.), *Proceedings of the Twenty-Fourth Annual Conference of the Cognitive Science Society* (pp. 976-981). Fairfax, VA: George Mason University.

2.8 Appendix A

2.8.1 Experimental Items Presented in Experiment 1

X is Y	Noun-noun	Simile
A bed is a boulder	boulder bed	A bed is like a boulder
A business is an organism	business organism	A business is like an organism
A campaign is a circus	campaign circus	A campaign is like a circus
A crowd is a sea	crowd sea	A crowd is like a sea
A divorce is a tornado	divorce tornado	A divorce is like a tornado
A friend is an anchor	anchor friend	A friend is like an anchor
A giraffe is a skyscraper	skyscraper giraffe	A giraffe is like a skyscraper
A granny is a turtle	turtle granny	A granny is like a turtle
A husband is a gem	gem husband	A husband is like a gem
A job is poison	poison job	A job is like poison
A judge is a balance	balance judge	A judge is like a balance
A jump is an earthquake	earthquake jump	A jump is like an earthquake
A librarian is a mouse	mouse librarian	A librarian is like a mouse
A persona is an armour	armour persona	A persona is like an armour
A pillow is a cloud	cloud pillow	A pillow is like a cloud
A smile is radiance	radiance smile	A smile is like radiance
A wife is a trophy	trophy wife	A wife is like a trophy
Adventure is spice	adventure spice	Adventure is like spice
Advices are gold	gold advices	Advices are like gold
An accountant is a juggler	juggler accountant	An accountant is like a juggler
Anger is a volcano	volcano anger	Anger is like a volcano
Arguments are journeys	argument journey	Arguments are like journeys
Arguments are wars	argument war	Arguments are like wars
Babies are angels	angel baby	Babies are like angels
Bankers are vultures	vulture bankers	Bankers are like vultures
Betrayal is a toxin	betrayal toxin	Betrayal is like a toxin
Bribes are traps	bribe trap	Bribes are like traps
Buffets are paradise	buffet paradise	Buffets are like paradise
Canaries are violins	violin canaries	Canaries are like violins
Cheaters are snakes	snake cheaters	Cheaters are like snakes
Corruption is a virus	corruption virus	Corruption is like a virus
Creativity is a blender	creativity blender	Creativity is like a blender
Crime is a disease	crime disease	Crime is like a disease
Crowds are thunder	thunder crowd	Crowds are like thunder
Dancers are butterflies	butterfly dancers	Dancers are like butterflies

Development is a tree	development tree	Development is like a tree
Disappointment is a stumble	disappointment stumble	Disappointment is like a stumble
Drivers are sloths	sloth driver	Drivers are like sloths
Duties are mountains	duty mountain	Duties are like mountains
The economy is a machine	economy machine	The economy is like a machine
Education is a lantern	education lantern	Education is like a lantern
Elections are hurricanes	election hurricane	Elections are like hurricanes
Emails are a flood	email flood	Emails are like a flood
Exams are filters	filter exams	Exams are like filters
Faces are cookies	cookie face	Faces are like cookies
Followers are sheep	sheep followers	Followers are like sheep
Forgiveness is a path	forgiveness path	Forgiveness is like a path
Friendship is a bridge	friendship bridge	Friendship is like a bridge
Friendship is a symbiosis	symbiosis friendship	Friendship is like a symbiosis
Genes are lottery	lottery genes	Genes are like lottery
Grief is an abyss	grief abyss	Grief is like an abyss
Hairs are noodles	noodle hairs	Hairs are like noodles
History is a mirror	history mirror	History is like a mirror
History is footprints	history footprints	History is like footprints
Humour is a cure	humour cure	Humour is like a cure
Hunger is an avalanche	avalanche hunger	Hunger is like an avalanche
Ideas are diamonds	diamond ideas	Ideas are like diamonds
Indecision is paralysis	indecision paralysis	Indecision is like paralysis
Insults are scars	insult scars	Insults are like scars
Judges are dinosaurs	dinosaur judge	Judges are like dinosaurs
Knowledge is an ocean	knowledge ocean	Knowledge is like an ocean
Language is a river	river language	Language is like a river
Lawyers are sharks	shark lawyers	Lawyers are like sharks
Legs are straws	straw legs	Legs are like straws
Lies are daggers	dagger lie	Lies are like daggers
Life is a game	life game	Life is like a game
Life is wind	life wind	Life is like wind
Lips are velvet	velvet lips	Lips are like velvet
Loneliness is a desert	loneliness desert	Loneliness is like a desert
Love is a drug	love drug	Love is like a drug
Love is an antidote	love antidote	Love is like an antidote
Love is madness	madness love	Love is like madness
Marriage is a leash	marriage leash	Marriage is like a leash
Melodies are hugs	hug melody	Melodies are like hugs
Memory is a warehouse	memory warehouse	Memory is like a warehouse

Midterms are torture	torture midterm	Midterms are like torture
Mosquitoes are darts	dart mosquitoes	Mosquitoes are like darts
Mosquitoes are vampires	vampire mosquito	Mosquitoes are like vampires
Mothers are mules	mule mother	Mothers are like mules
Muscles are steel	steel muscles	Muscles are like steel
Music is medicine	music medicine	Music is like medicine
News are bombs	news bombs	News are like bombs
Paparazzi are parasites	parasite paparazzi	Paparazzi are like parasites
Peppers are fire	fire pepper	Peppers are like fire
Professors are ogres	ogre professor	Professors are like ogres
Reassurance is a patch	reassurance patch	Reassurance is like a patch
Relationships are barter	barter relationship	Relationships are like barter
Relationships are journeys	relationship journey	Relationships are like journeys
Sarcasm is a veil	sarcasm veil	Sarcasm is like a veil
Saunas are ovens	oven sauna	Saunas are like ovens
Secretaries are slaves	slave secretary	Secretaries are like slaves
Sisters are megaphones	megaphone sister	Sisters are like megaphones
Skin is silk	silk skin	Skin is like silk
Slums are tumors	tumor slums	Slums are like tumors
Smiles are magnets	magnet smile	Smiles are like magnets
Society is a pillar	society pillar	Society is like a pillar
Solutions are a bandaid	bandaid solution	Solutions are like a bandaid
Spas are heaven	heaven spa	Spas are like heaven
Stomachs are barrels	barrel stomach	Stomachs are like barrels
Students are sponges	sponge student	Students are like sponges
Surgeons are butchers	butcher surgeons	Surgeons are like butchers
Teachers are encyclopedias	encyclopedia teacher	Teachers are like encyclopedias
Temper is gasoline	gasoline temper	Temper is like gasoline
The mind is a field	mind field	The mind is like a field
Thoughts are sparks	thought spark	Thoughts are like sparks
Time is an escalator	escalator time	Time is like an escalator
Tobacco is poison	tobacco poison	Tobacco is like poison
Toddlers are monkeys	monkey toddler	Toddlers are like monkeys
Traffic is a tumor	traffic tumor	Traffic is like a tumor
Tumor is a plague	plague tumor	Tumor is like a plague
Unemployment is a drought	unemployment drought	Unemployment is like a drought
Wealth is a road	wealth road	Wealth is like a road
Wind is a wrestler	wrestler wind	Wind is like a wrestler
Wisdom is a gift	gift wisdom	Wisdom is like a gift

2.8.2 Experimental Items Presented in Experiment 1

Dominant figurative interpretation	Non-dominant figurative interpretation
A bed is uncomfortable	A bed is durable
A business can grow	A business is autonomous
A campaign is funny	A campaign requires coordination
A crowd is vast	A crowd moves slowly
A divorce is destructive	A divorce is painful
A friend is supportive	A friend is stable
A giraffe is tall	A giraffe is noticeable
A granny is slow	A granny is wise
A husband is valuable	A husband is beautiful
A job kills you	A job is dangerous
A judge is fair	A judge makes decisions
A jump is shaking	A jump hits the ground
A librarian is quiet	A librarian is usually disregarded
A persona is protective	A persona is defining
A pillow is soft	A pillow is fluffy
A smile is bright	A smile is attractive
A wife is something people are proud of	A wife is aesthetically pleasing
Adventure is exciting	Adventure is intense
Advices are valuable	Advices are rare
An accountant multitasks	An accountant is talented
Anger is destructive	Anger is unexpected
Arguments are time-consuming	Arguments allow learning
Arguments last long	Arguments are aggressive
Babies are innocent	Babies are peaceful
Bankers are ruthless	Bankers are persistent
Betrayal is deadly	Betrayal is vicious
Bribes are deceiving	Bribes are unexpected
Buffets cause pleasure	Buffets involve abundance
Canaries are musical	Canaries evoke emotion
Cheaters are sneaky	Cheaters are not trustworthy
Corruption is contagious	Corruption is weakening
Creativity is a mixture	Creativity is changing
Crime is dangerous	Crime is treatable
Crowds are loud	Crowds are powerful
Dancers are graceful	Dancers move
Development involves growth	Development requires nurturing
Disappointment is something people can get over	Disappointment is sad

Drivers are slow	Drivers are patient
Duties are daunting	Duties are immovable
The economy is always working	The economy is powerful
Education is guiding	Education is a tool
Elections are messy	Elections are unpredictable
Emails are overwhelming	Emails are sudden
Exams are selective	Exams are a process
Faces are enticing	Faces come in different forms
Followers are dependant	Followers are weak
Forgiveness takes a lot of time	Forgiveness is a process
Friendship connects people	Friendship is strong
Friendship is mutually beneficial	Friendship involves sharing
Genes are related to luck	Genes are unpredictable
Grief is endless	Grief is difficult to escape from
Hairs are long	Hairs are fragile
History reflects things about us	History is informative
History is traceable	History is directive
Humour gives happiness	Humour is rejuvenating
Hunger is uncontrollable	Hunger causes rumbling sounds
Ideas are valuable	Ideas are profitable
Indecision makes people get stuck	Indecision is stressful
Insults are damaging	Insults are unforgettable
Judges are old	Judges are intimidating
Knowledge is vast	Knowledge is fluid
Language flows	Language is endless
Lawyers are aggressive	Lawyers are scary
Legs are thin	Legs are cylindrical
Lies cause pain	Lies are useful sometimes
Life involves decisions	Life is fun
Life is always changing	Life is unpredictable
Lips are soft	Lips are beautiful
Loneliness gives people a feeling of emptiness	Loneliness is harsh
Love is addictive	Love is pleasurable
Love is healing	Love is a solution to a problem
Love is intense	Love is uncertain
Marriage is controlling	Marriage involves ownership
Melodies are comforting	Melodies grab people's attention
Memory is a storage	Memory is compartmented
Midterms are stressful	Midterms last long
Mosquitoes make punctures	Mosquitoes target things

Mosquitoes suck blood	Mosquitoes are parasitic
Mothers are hardworking	Mothers are trustworthy
Muscles are strong	Muscles are unbreakable
Music is soothing	Music is pleasant
News are shocking	News are immediate
Paparazzi are ever-present	Paparazzi are worthless
Peppers are hot	Peppers are unpleasant
Professors are mean	Professors are ugly
Reassurance is temporary	Reassurance is comforting
Relationships are bidirectional	Relationships involve fighting
Relationships are long-lasting	Relationships are adventurous
Sarcasm covers things	Sarcasm is uncomfortable
Saunas are hot	Saunas are closed-in
Secretaries are unappreciated	Secretaries are disposable
Sisters are loud	Sisters are useful
Skin is smooth	Skin is breathable
Slums grow fast	Slums are problematic
Smiles are attractive	Smiles are powerful
Society is strong	Society is breakable
Solutions fix things	Solutions are practical
Spas are peaceful	Spas are friendly
Stomachs are hollow	Stomachs are spacious
Students absorb content	Students are versatile
Surgeons cut flesh	Surgeons are bloody
Teachers are knowledgeable	Teachers are organized
Temper is dangerous	Temper is volatile
The mind is open	The mind is sprawling
Thoughts are instantaneous	Thoughts are the beginning of something
Time is always moving	Time is unidirectional
Tobacco is deadly	Tobacco is ingestible
Toddlers are wild	Toddlers are noisy
Traffic is dangerous	Traffic is inconvenient
Tumor is deadly	Tumor is scary
Unemployment is tough	Unemployment is hopeless
Wealth is difficult	Wealth goes both ways
Wind is strong	Wind is quick
Wisdom is rare	Wisdom is earned

2.9 Appendix B

Experimental Items Presented in Experiment 2

Noun-noun metaphor	Constituent that is figurative
anger eruption	Head
argument journey	Head
attention beggar	Head
bribe trap	Head
campaign circus	Head
civilization cradle	Head
company slave	Head
corruption soil	Head
creativity blender	Head
crowd sea	Head
development stairs	Head
disappointment waves	Head
divorce tornado	Head
economy storm	Head
elections hurricane	Head
email flood	Head
food paradise	Head
forgiveness path	Head
friendship bridge	Head
grief abyss	Head
hair mountain	Head
history mirror	Head
hope field	Head
humour cure	Head
knowledge ocean	Head
labour fruit	Head
life wind	Head
loneliness desert	Head
love desert	Head
marriage leash	Head
music medicine	Head
news bomb	Head
problem root	Head
romance bud	Head
society pillar	Head
soul patch	Head
stocks pulse	Head
thought spark	Head
traffic artery	Head
unemployment drought	Head
wealth road	Head

word scars	Head
antenna ears	Modifier
armour persona	Modifier
bandaid solution	Modifier
barrel stomach	Modifier
barter relationship	Modifier
black day	Modifier
boulder bed	Modifier
caress melody	Modifier
cloud pillows	Modifier
crater face	Modifier
earthquake jump	Modifier
filter exam	Modifier
fire pepper	Modifier
gem husband	Modifier
gold advice	Modifier
honey compliment	Modifier
ivory smile	Modifier
monkey humour	Modifier
ogre professor	Modifier
owl wisdom	Modifier
panda look	Modifier
parasite paparazzi	Modifier
pig hunger	Modifier
plastic body	Modifier
poison job	Modifier
rainbow equality	Modifier
sailor language	Modifier
shark lawyers	Modifier
sheep character	Modifier
sloth comprehension	Modifier
snow hair	Modifier
steel mind	Modifier
straw legs	Modifier
swan dance	Modifier
symbiosis friendship	Modifier
torture midterm	Modifier
trophy girl	Modifier
turtle steps	Modifier
velvet lips	Modifier
vulture bankers	Modifier
waterfall bleed	Modifier
yawn lecture	Modifier

2.10 Appendix C

Experimental Items Presented in Experiment 3

Target	Literal prime	Figurative prime
anger eruption	volcano eruption	generosity eruption
argument journey	car journey	retirement journey
attention beggar	money beggar	justice beggar
bribe trap	bear trap	alcohol trap
campaign circus	animal circus	courtship circus
civilization cradle	baby cradle	talent cradle
company slave	child slave	popularity slave
corruption soil	plant soil	innovation soil
creativity blender	fruit blender	race blender
crowd sea	coral sea	information sea
development stairs	house stairs	success stairs
disappointment waves	sound waves	trend waves
divorce tornado	sand tornado	crime tornado
economy storm	thunder storm	discount storm
elections hurricane	tropical hurricane	party hurricane
email flood	water flood	refugee flood
food paradise	bible paradise	cat paradise
forgiveness path	beach path	wellness path
friendship bridge	suspension bridge	prosperity bridge
grief abyss	ocean abyss	debt abyss
hair mountain	rock mountain	bills mountain
hope field	corn field	discrimination field
humour cure	disease cure	cuddle cure
knowledge ocean	blue ocean	vanity ocean
labour fruit	exotic fruit	flattery fruit
loneliness desert	sand desert	indecision desert
marriage leash	dog leash	mortgage leash
music medicine	cold medicine	cuteness medicine
news bomb	terrorist bomb	truth bomb
problem root	plant root	success root
romance bud	flower bud	resentment bud
society pillar	stone pillar	religion pillar
soul patch	jean patch	bankruptcy patch
thought spark	light spark	affinity spark
traffic artery	body artery	communication artery
unemployment drought	desert drought	celibacy drought
wealth road	concrete road	revenge road
word scars	war scars	rejection scars
armour persona	armour metal	armour makeup
bandaid solution	bandaid box	bandaid compensation
barrel stomach	barrel lid	barrel memory

barter relationship	barter system	barter conversation
black day	black colour	black personality
boulder bed	boulder weight	boulder thoughts
caress melody	caress care	caress smile
crater face	crater depth	crater cheese
earthquake jump	earthquake recorder	earthquake dispute
filter exam	filter paper	filter interview
fire pepper	fire alarm	fire lust
gem husband	gem stone	gem words
gold advice	gold bar	gold achievement
honey compliment	honey jar	honey kiss
ivory smile	ivory products	ivory hair
monkey humour	monkey cage	monkey charm
ogre professor	ogre swamp	ogre stepmother
owl wisdom	owl feather	owl lifestyle
panda look	panda fur	panda laziness
parasite paparazzi	parasite cleanse	parasite girlfriend
pig hunger	pig meat	pig manners
plastic body	plastic bag	plastic beauty
poison job	poison bottle	poison habits
rainbow equality	rainbow colours	rainbow pride
sailor language	sailor boat	sailor drinking
shark lawyers	shark fin	shark president
sheep character	sheep wool	sheep followers
sloth comprehension	sloth claws	sloth driving
snow hair	snow removal	snow look
steel mind	steel pan	steel determination
straw legs	straw hat	straw hair
swan dance	swan lake	swan pose
torture midterm	torture device	torture job
trophy girl	trophy shelf	trophy mistress
turtle steps	turtle eggs	turtle grandma
velvet lips	velvet dress	velvet song
vulture bankers	vulture wings	vulture relatives
waterfall bleed	waterfall pictures	waterfall crying

Chapter 3

Is inhibition involved in the processing of opaque compound words?

A study of individual differences

3.1. Abstract

We examined whether inhibition skills were recruited during the processing of compound words. Using an individual differences perspective, we analyzed whether participants' scores on the Stroop test predicted performance on lexical decision tasks involving compound words varying in their level of semantic opacity. The results show that inhibition is involved in the comprehension of fully opaque (e.g., *hogwash*) and fully transparent (e.g., *blueberry*) compound words, but we found no evidence for such an effect in the comprehension of partially opaque compound words (e.g., *strawberry*, *jailbird*).

Keywords: compound words, opaque, inhibition, individual differences, semantic transparency

3.2. Introduction

In English, compound words (e.g., *blueberry*) consist of two unbound morphemes, the second being referred to as the head (e.g., *berry*) and the first being referred to as the modifier (e.g., *blue*). Compound words vary in semantic transparency (i.e., the degree to which the meanings of the constituents contribute to the meaning of the overall word). Depending on whether both, only one, or none of the constituents is semantically transparent, compound words can be classified into three categories: fully transparent (e.g., *blueberry*), partially transparent (e.g., *jailbird*, *strawberry*) or fully opaque (e.g., *hogwash*). This classification of the subtypes of compound words has led to the discovery of one of the most well-established findings in the compound word literature: namely, that opaque compound words are processed differently from transparent compounds. In a key study, Sandra (1990) demonstrated that transparent compounds were processed more quickly when they were preceded by a semantically related rather than by an unrelated prime matched in length and frequency (e.g., people responded more quickly to *blueberry* if it was preceded by *red* versus *eye*). In contrast, opaque compounds did not benefit from the presence of a semantically related prime (e.g., people did not respond faster to *hogwash* if it was preceded by *pig* versus *lip*). Several subsequent studies have also shown that transparent compounds are responded to more quickly than opaque compounds (e.g., Ji, Gagné, & Spalding 2011; Libben, Gibson, Yoon, & Sandra, 2003). This need for additional processing time has also been supported by eye-tracking data, which indicate that opaque compounds receive longer gazes than transparent compounds (Juhasz, 2007), as well as by typing data, which suggest that opaque constituents are typed more slowly on the computer keyboard than transparent constituents (Gagné & Spalding, 2014). A recent study using magnetoencephalography (Brooks & Cid del Garcia, 2015) indicated that the brain-response patterns for transparent and opaque compounds are different: Only transparent compounds show increased activity from 250 to 470 ms in the left anterior temporal lobe—a region that seems to be involved in morphological composition. Finally, encephalography data (MacGregor & Shtyrov, 2013) showed that only high-frequency opaque compounds are associated with larger MMN (Mismatch Negativity), which is interpreted as an indication that frequently used opaque compounds are accessed as a unitary representation from a lexical storage, rather than being computed via combinatorial mechanisms. Despite the abundance of studies showing the differences in processing times between transparent and opaque compound words, there is relatively little work that explores the cognitive mechanisms that cause this difference. Thus, the primary objective of this study is to address this matter that has largely been underexamined, and specifically investigate whether cognitive inhibition is a factor that could explain why opaque compounds need extra processing time.

As an initial attempt to explain the origin of the processing time difference between opaque and transparent compounds, Libben (2005) advanced the hypothesis that "the effects of semantic opacity, when they do occur, are related to the extra processing that is required to deactivate spuriously activated constituents" (p. 276). In other words, Libben suggests that opaque compound words require *cognitive inhibition* (i.e., the ability to suppress stimuli that are irrelevant to the task at hand), a capacity that ensures the efficient functioning of the working memory, which, otherwise, would be constantly overwhelmed by distracting information that would impede people from reaching their goals (Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999). This cognitive process is essential for people's good adjustment to everyday life; for instance, deficits in inhibition are associated with memory problems (Engle, Kane, & Tuholski, 1999), reckless driving (Sani, Tabibi, Fadardi, & Stavrinos, 2017), drug abuse (Monterosso, Aron, Cordova, Xu, & London, 2005), Attention Deficit Disorder (Bjorklund & Harnishfeger, 1990), Obsessive-Compulsive Disorder (Enright & Beech, 1990), schizophrenia (Frith, 1979) and depression (Joormann, Yoon, & Zetsche, 2007).

In the field of psycholinguistics, inhibition has been shown to be involved in the comprehension of polysemous words (i.e., words that have more than one meaning) and figurative language, such as metaphors and idioms. In the case of sentences including polysemous words (e.g., *The dog gave a loud* ***bark***), people need to inhibit the alternative context-inappropriate meanings of the ambiguous word (i.e., *layer of stems and roots of woody plants*) (Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982). Similarly, when people encounter a piece of figurative language such as *Lawyers are sharks*, they need to inhibit the irrelevant literal meaning *fish with cartilaginous skeleton* to compute the real intended meaning of the metaphor (Glucksberg, Newsome, & Goldvarg, 2001). When this inhibition fails as a consequence of disorders such as schizophrenia or Alzheimer's disease, people provide literal interpretations for figurative language (Iakimova, Passerieux, & Hardy-Bayle, 2006).

Given that, by definition, opaque compound words have constituents whose meanings are irrelevant to the computation of the whole word's meaning, Libben's (2005) assumption appears to be valid. It is logical to think that people have to inhibit the meanings of *hog* and *wash* to access the real meaning of *hogwash*. Furthermore, his claim is indirectly confirmed by the fact that when inhibition fails in patients suffering from aphasia, they tend to paraphrase opaque compound words as if they were transparent (e.g., *strawberry* might be incorrectly paraphrased as *a berry that has a straw*) (Libben, 1993). In support of Libben's inference, Ji et al. advanced the following explanation:

> The absence of links between the opaque constituent and the compound (e.g., between *straw* and *berry*) is assumed to result in inhibition . . ., and this inhibition . . . prevents the meaning of the opaque constituent from interfering with the interpretation of the compound (e.g., the meaning of *straw* is inhibited). As a result, transparent compounds should receive more activation from their constituents (both at the lexical and semantic level) than would opaque compounds (2011, p. 412).

Given that Libben's (2005) claim has not yet been directly tested, there is to date a lack of direct evidence that could support his idea that, indeed, inhibition is necessary for comprehending opaque compound words. Thus, the goal of this study is to examine whether the language system needs to recruit inhibition when processing opaque compound words in order to deal with the interference originating from the irrelevant meanings of their constituents. To address this issue, we conducted two individual-difference experiments, in which we measured participants' scores on an inhibition task and analyzed whether these scores predicted their performance on lexical decision tasks that involved the comprehension of different types of compound words. The individual-difference methodology allows us to analyze the entire range of the sample variability across the spectrum, which is often ignored by the flattening effects of working only with group means. It is also worth noting that this methodology, although seldom used in the compound word literature, has revealed previously ignored variables that influence the processing of compounds. For instance, Schmidtke, Van Dyke and Kuperman (2018) revealed that people's reading experience (i.e., amount of exposure to printed materials) and vocabulary size interact with semantic transparency to influence the pattern of eye movements when reading compound words. In addition, Kuperman and Van Dyke (2011) also showed that the profile of a person's verbal abilities (e.g., his or her ability to segment words and his or her level of reading comprehension) affects the recognition of a morphologically complex word (e.g., *trucker*) as a whole and via its decomposed morphemes (e.g., *truck* + *er*). It is worth pointing out, however, that these few individual-difference studies on compound words share one limitation: they are focused specifically on language-related skills and neglect more general cognitive abilities (e.g., memory or executive functions).

The current investigation consists of two experiments. In Experiment 1, participants performed an inhibition test and a lexical decision task with fully opaque (e.g., *hogwash*) and fully transparent (e.g., *cheekbone*) compound words. In Experiment 2, participants performed an inhibition test and a lexical decision task with partially opaque (e.g., *jailbird*, *strawberry*) compound words. We hypothesized that participants who experience difficulties (i.e., slow reaction times or low accuracy) when doing the inhibition task would also show difficulties specifically when understanding fully or partially opaque compound words, but not when understanding fully transparent compounds.

3.3 Experiment 1

The goal of Experiment 1 is to determine whether inhibition is involved in the comprehension of fully opaque, but not fully transparent compound words. Recall that the constituents of opaque compounds (e.g., *hum* and *bug*) do not contribute the meaning of the compound (e.g., *humbug*) and, thus, any meaning constructed for these constituents would be in conflict with the true meaning of the compound. Participants performed two tasks: a language task in which they had to comprehend fully opaque and fully transparent compounds, and an inhibition task in which they had to respond to visual stimuli, ignoring surrounding irrelevant information. If only opaque compounds require inhibition, participants who obtain low scores on the inhibition task will perform poorly only when responding to fully opaque compounds, but not when responding to fully transparent compounds.

3.3.1 Methods

3.3.1.1 Materials

3.3.1.1.1 Lexical decision task. The stimuli consisted of twenty-two fully transparent compound words (e.g., *cheekbone*), twenty-two fully opaque compound words (e.g., *hogwash*) and a total of one hundred and thirty-two fillers. We used three types of fillers. The first type of fillers consisted of forty-four monomorphemic words (e.g., *gratitude*) that were matched to the compound words in length and frequency[2] using SUBTLEX-US corpus (Brysbaert & New, 2009). The second type of fillers consisted of forty-four non-words that emulated a monomorphemic structure and that matched the compound words in length (e.g., *terisma*). The third type of fillers consisted of forty-four non-words that emulated a compound-like structure (i.e., they seemed to have two constituents) and that matched the compound words in length (e.g., *sidewolf*). To make sure that these eighty-eight non-word fillers were phonologically legal, they were created by combining syllables from words that appeared in English short stories. Each participant saw all the items, which are presented in Appendix A.

3.3.1.1.2 Inhibition task. A version of the Stroop test, which is a widely used measure of automatic inhibition (Stroop, 1935), was created in Supercard. The names of eleven colors (red, green, yellow, black, blue, orange, purple, pink, brown, gray and white) were displayed in ten different font colors (red, green, yellow, black, blue, orange, purple, pink, brown and gray). The test had a total of 200 trials: for half of them, the name of the color and its font matched

[2] There were two words (*swansong* and *poppyseed)* whose frequency did not appear in SUBTLEX-US. We re-ran all the analyses presented in this article after removing these two items and we confirmed that none of results was impacted.

(congruent items), and for the other half, the name of the color and its font did not match (incongruent items).

3.3.1.2 Procedure

All participants performed both the lexical decision task and the Stroop test. The order of the tasks was counterbalanced. The reaction times for each task were automatically collected by the computer timer, which measured the number of milliseconds elapsed between the stimulus appearance on the screen until the moment the participant responded with the key stroke.

3.3.1.2.1 Lexical decision task. Participants indicated, as quickly as possible, whether an item was an English word or not. They pressed the key "j" if the item was a word, or the key "f" if it was a non-word. The order of the items was randomized for each participant. The items were presented one at a time at the center of the screen. Each trial began with the message "Ready?" and the participants had to press the spacebar on the keyboard to see each item.

3.3.1.2.2 Inhibition task. Participants indicated, as quickly as possible, whether the name and font of the color were the same or not. They pressed the key "j" if they were the same, or the key "f" if they were different. This variation of the Stroop task has several advantages over the standard version: First, it is easier to administer because it does not require recording vocal responses; second, it is not affected by certain conscious strategies that participants who are familiar with the task may use to avoid interference (Bugg, Jacoby, & Toth, 2008; Logan, Zbrodoff, & Williamson, 1984), such as looking at the edge of each word to avoid reading it and to be able to focus solely on the color; and third, this variation yields the same type of interference as the standard Stroop task (Durgin, 2000; Treisman & Fearnley, 1969). The order of the items was randomized for each participant. The items were presented one at a time at the center of the screen. The experiment began with the message "Ready?" and the participants pressed the spacebar on the keyboard to see the first item.

3.3.1.3 Participants

Forty-one participants were recruited from Introductory Psychology classes in exchange for partial course credit. All participants were native speakers of English. Two participants were removed from all analyses: one due to low accuracy rate (less than 75%) on the lexical decision task and the other due to highly fluctuating reaction times (from 361 to 27,021 ms) on the Stroop test.

3.3.2 Results and discussion

3.3.2.1 Lexical decision task

Responses with reaction times that were more than 2.5 standard deviations greater than each participant's mean were removed. Additionally, reaction times greater than 2500 ms were removed. The total number of observations removed represented 0.86% of the original data set. Inverse response time (i.e., −1000/RT) was used for the reaction time analysis because the Q-Q plots revealed that the inverse transformation was better at correcting for skewness in the residuals than was the log transformation. The response time analysis was based on correct trials only.

Separate analyses for the response time and accuracy data were conducted using linear mixed-effect (LME) analyses (Pinheiro & Bates, 2000) in Stata 13 using the function *mixed* for reaction time data and the function *meqrlogit* for the binary (correct vs. incorrect) accuracy data. Because these functions use dummy coding for categorical variables, the coefficients (i.e., estimates) from these models correspond to simple effects, rather than to main effects. Therefore, the *contrast* function in Stata was used to test the main effects and interactions. The results of these tests are Wald tests and are reported as a chi-square. A Wald test is an approximation of a likelihood ratio test, but is more generalizable (i.e., it can be used in more situations than a likelihood ratio test) and indicates whether the factor (in the case of a main effect) or the interaction improves the fit of the model relative to a model that does not include that factor or interaction.

Type of compound (TT vs. OO), frequency of the compound and length of the compound word were entered as fixed effects and participant and item were included in the models as random effects. Neither the response time analysis nor the accuracy analysis showed an influence of compound type. Participants were as fast when responding to opaque-opaque compounds (M = 818 ms, SE = 10) as when responding to transparent-transparent compounds (M = 795 ms, SE = 9), $X^2(1) = 0.71$, $p = .40$. Also, they were equally accurate when responding to opaque-opaque compounds (M = 87%, SE = 1.1) as when responding to transparent-transparent compounds (M = 96%, SE = 0.6), $X^2(1) = 1.75$, $p = .19$.

3.3.2.2 Inhibition task

Responses with reaction times that were more than 2.5 standard deviations greater than each participant's mean (2.6% of the original data set) were removed. Inverse response time (i.e., −1000/RT) was used for the reaction time analysis because the Q-Q plots revealed that the inverse transformation was better at correcting for skewness in the residuals than was the log transformation. The response time analysis was based on correct trials only.

The data were analyzed using linear mixed effects regression models. Participant and item (i.e., color of the text) were included in the models as random effects, and congruency between the name of the color and its font as a fixed effect.

Surprisingly, participants were more accurate when responding to incongruent trials (*M* = 98%, *SE* = 2.5) than responding to congruent trials (*M* = 95%, *SE* = 3.4), $X^2(1) = 32.69$, $p < .0001$. Participants were slower when responding to incongruent trials (*M* = 688 ms, *SE* = 3.25), compared to congruent trials (*M* = 651 ms, *SE* = 2.90), $X^2(1) = 141.69$, $p < .0001$. These results suggest that participants might have engaged in a speed-accuracy trade-off, favouring accuracy over speed.

3.3.2.3 Lexical decision and inhibition task

For each participant, we computed the mean reaction time on congruent trials and on incongruent trials on the inhibition task. Then, for each participant we created two scores: an *inhibition score* and an *inhibition ratio*. The inhibition score was calculated by subtracting the mean reaction time on congruent trials from the mean reaction time on incongruent trials. The inhibition score, also called Stroop interference, has traditionally been used in the literature (MacLeod, 1991) as a measure of the ability to suppress goal-irrelevant information. However, this measure has received criticism lately (Knight & Heinrich, 2017) because it may not account for generalized slowness and thus may not provide a pure interference measure. For instance, the absolute difference of 10 ms coming from a participant who took 110 ms on the incongruent trial and 100 ms on the congruent trial is more important than the same absolute difference between 2510 ms and 2500 ms coming from a participant who is generally slower. Therefore, in order to adjust the comparison and take into account the proportion of the difference, we also calculated the inhibition ratio by dividing each participant's mean reaction time on incongruent trials by the mean reaction time on congruent trials. The data were analyzed using LME analyses using the function *mixed* for reaction time data on Stata 13. The response time analysis was based on correct trials only.

3.3.2.3.1 Inhibition scores and reaction times on the lexical decision task. Participant and item were included in the models as random effects, and inhibition scores, type of compound (TT vs OO), frequency of the compound and length of the compound word as fixed effects. Figure 1 shows the distribution of the inhibition scores used to predict performance on the lexical decision task. The standardized regression coefficients, standard errors, tests of slopes, and confidence intervals for the model are shown in Table 1. The term "Constant" refers to the y-intercept.

Compound type and inhibition scores did not interact, $X^2(1) < 1$. Instead, there was a main effect of inhibition scores, $z = 2.25$, $p = .025$. Participants who had strong inhibition skills (i.e., participants who showed smaller differences between the time they took to respond to incongruent trials and congruent trials on the Stroop task) responded more quickly to both opaque and transparent compounds, compared to participants who had poor inhibition skills. In terms of the accuracy analysis, compound type and inhibition scores did not interact, $X^2(1) < 1$ and, unlike in the response time analysis, there was no influence of inhibition scores, $z = 0.90$, $p = .367$.

In summary, the lack of interaction between the type of compound word and the inhibition scores is contrary to our initial hypothesis that inhibition would be involved exclusively in the processing of opaque but not in the processing of transparent compound words. This matter will be further discussed in the General Discussion.

3.3.2.3.2 Inhibition ratio and reaction times on the lexical decision task. Participant and item were included in the models as random effects, and inhibition ratio, type of compound, frequency and length of the compound word as fixed effects. Figure 1 shows the distribution of the inhibition ratios used to predict performance on the lexical decision task. The standardized regression coefficients, standard errors, tests of slopes, and confidence intervals for the model are shown in Table 2. Compound type and inhibition ratio did not interact, $X^2(1) < 1$. However, there was a main effect of inhibition ratio, $z = 2.02$, $p = .043$; participants who had strong inhibition skills (i.e., participants who showed smaller inhibition ratios on the Stroop task) responded more quickly compared to participants who had poor inhibition skills. In terms of the accuracy analysis, compound type and inhibition scores did not interact, $X^2(1) < 1$ and, unlike in the response time analysis, there was no influence of inhibition scores, $z = 0.57$, $p = .57$.

In summary, we found no evidence to suggest that inhibition is involved exclusively in the processing of opaque but not in the processing of transparent compound words. We will return to this issue in the General Discussion.

3.4 Experiment 2

Given that there is evidence that suggests that the processing of transparent-opaque and opaque-transparent compound words differs from the processing of fully opaque and fully transparent compounds (El-Bialy, Gagné, & Spalding, 2013), we investigated whether inhibition is involved in partially opaque compounds. In the current experiment, participants performed the same two tasks as in Experiment 1, but with partially opaque compound words.

3.4.1 Methods

3.4.1.1 Materials

3.4.1.1.1 Lexical decision task. The stimuli[3] consisted of twenty-two transparent-opaque compound words (e.g., *jailbird*), twenty-two opaque-transparent compound words (e.g., *strawberry*) and three types of fillers. The one hundred and thirty-two filler items were created following the same method used in Experiment 1. The items used are presented in Appendix B.

[3] There were five words (*catcall*, *bobbypin*, *pipedream*, *snailmail* and *knucklesandwich*) whose frequency did not appear in SUBTLEX-US. We re-ran all the analyses presented in this article after removing these five items and we confirmed that none of results was impacted.

3.4.1.1.2 Inhibition task. The inhibition task was identical to the one used in Experiment 1.

3.4.1.2 Procedure

The procedures for both tasks were identical to the ones used in Experiment 1.

3.4.1.3 Participants

Forty-six participants, who had not participated in Experiment 1, were recruited from introductory psychology classes in exchange of partial course credit. All participants were native speakers of English. Three participants were removed from all analyses due to low accuracy rate (less than 75%) on the lexical decision task.

3.4.2 Results and discussion

3.4.2.1 Lexical decision task

Responses with reaction times that were more than 2.5 standard deviations greater than each participant's mean were removed. Additionally, reaction times greater than 2500 ms or smaller than 300 ms were also removed to eliminate the remaining outliers on the Q-Q plot. The total number of observations removed represented 1.26% of the original data set. Inverse response time (i.e., −1000/RT) was used for the reaction time analysis because the Q-Q plots revealed that the inverse transformation was better at correcting for skewness in the residuals than was the log transformation. The response time analysis was based on correct trials only.

The response time and accuracy data were analyzed separately using linear mixed-effect analyses. Participant and item were included in the models as random effects, and compound type, frequency of the compound, and length of the compound word were entered as fixed effects. Opaque-transparent compounds were more difficult to process than were the transparent-opaque compounds. The response time analysis indicated that participants were slower when responding to opaque-transparent compound words (M = 968 ms, SE = 13) than when responding to transparent-opaque compound words (*M* = 916 ms, *S*E= 11), $X^2(1) = 6.52$, $p = .01$. The accuracy analysis revealed that participants were less accurate when responding to opaque-transparent compound words (*M* = 80%, *SE* = 1.3) than when responding to transparent-opaque compound words (*M* = 88%, *SE* = 1.1), $X^2(1) = 7.33$, $p = .007$.

3.4.2.2 Inhibition task

Responses with reaction times that were more than 2.5 standard deviations greater than each participant's mean were removed. Additionally, reaction times greater than 2500 ms or smaller than 300 ms were also removed to eliminate the remaining outliers on the Q-Q plot. The total number of observations removed represented 2.86% of the original data set. Inverse response time (i.e., −1000/RT) was used for the reaction time analysis because the Q-Q plots revealed that the inverse transformation was better at correcting for skewness in the residuals than was the log transformation. The response time analysis was based on correct trials only.

The data were analyzed using LME analyses. Participant and item (i.e., color of the text) were included in the models as random effects, and congruency between the name of the color and its font as fixed effect. As in Experiment 1, participants were more accurate when responding to incongruent trials (*M* = 98%, *SE* = 2.3) compared to congruent trials (*M* = 96%, *SE* = 3.0), $X^2(1) = 17.74$, $p <.0001$. Participants were significantly slower when responding to incongruent trials (*M* = 763 ms, *SE* = 3.69), compared to congruent trials (*M* = 703 ms, *SE* = 3.58), $X^2(1) = 345.20$, $p <.0001$. These results suggest that congruency influenced processing, but participants engaged in a speed-accuracy trade-off, as in Experiment 1.

3.4.2.3 Lexical decision and inhibition task

As in Experiment 1, we created an *inhibition score* and an *inhibition ratio* for each participant. The response time analysis was based on correct trials only. Figure 2 shows the distribution of the inhibition scores used to predict performance on the lexical decision task.

3.4.2.3.1 Inhibition scores and reaction times on the lexical decision task. Separate analyses for the response time and accuracy data were conducted using linear mixed-effect (LME) analyses. Participant and item were included in the models as random effects, and inhibition scores, compound type, frequency and length were entered as fixed effects. The standardized regression coefficients, standard errors, tests of slopes, and confidence intervals for the model predicting response times are shown in Table 3. Compound type and the inhibition scores did not interact, $X^2(1) < 1$. Participants' inhibition skills were not related to their ability to process partially opaque compound words; inhibition score was not a valid predictor, $z = 0.22$, $p = .82$[4]. In terms of the accuracy analysis, we also did not observe an interaction between compound type and inhibition score, $X^2(1) < 1$, nor did we observe an influence of inhibition ratio, $z = -1.21$, $p = .228$. Thus, there is no evidence that suggests that individual differences in inhibition skills influence the processing of partially opaque compound words.

3.4.2.3.2 Inhibition ratio and reaction times on the lexical decision task. Figure 2 shows the distribution of the inhibition ratios used to predict performance on the lexical decision task. Participant and item were included in the models as random effects, and inhibition ratio, type of compound word and frequency of length of the compound word as fixed effects. The standardized regression coefficients, standard errors, tests of slopes, and confidence intervals for the model predicting response times are shown in Table 4. We did not find any evidence to

[4] We tried fitting the model without the interaction term to verify whether the main effect of inhibition scores becomes significant. After removing the interaction term, the results did not change: There was still no main effect of inhibition scores across all levels of type of compounds, $z = 0.23$, $p = .82$.

suggests that individual differences in inhibition skills influenced the processing of partially opaque compound words. Compound type and inhibition ratio did not interact, $X^2(1) = 1.41$, $p = .24$. Participants' inhibition skills were not related to their ability to process partially opaque compound words; inhibition ratio was not a successful predictor, $z = -0.62$, $p = .53$[5]. In terms of the accuracy analysis, we also did not observe an interaction between compound type and inhibition ratio, $X^2(1) < 1$, nor did we observe an influence of inhibition ratio, $z = -1.40$, $p = .16$.

3.5 Comparing Experiment 1 and Experiment 2

The finding that in Experiment 1 the processing of fully opaque and fully transparent compounds was predicted by the performance on the inhibition task, whereas in Experiment 2 the processing of partially opaque compounds was not predicted by the performance on the inhibition task motivated us to further investigate the underlying causes of this difference. One possible explanation for these very different patterns of results is that participants performed more poorly on the lexical decision task of Experiment 2, compared to Experiment 1, which created a floor effect, leaving a smaller margin for the inhibition scores or rates to predict the performance on the lexical decision task.

To investigate whether partially opaque compound words (Experiment 1) are indeed more difficult to process than fully opaque or fully transparent compounds (Experiment 2), we combined the data sets from Experiment 1 and Experiment 2 and fit a linear mixed effects regression model using experiment, frequency and length of the compound word as fixed effects and participant and item as random effects. The reaction time analysis showed that participants were slower when responding to the partially opaque compound words from Experiment 2 (*M* =

[5] We tried fitting the model without the interaction term to verify whether the main effect of inhibition ratio becomes significant. After removing the interaction term, our results have not changed: There was still no main effect of inhibition ratio across all levels of type of compounds, $z = -0.61$, $p = .54$

942 ms, *SE* = 8), than to the fully opaque and the fully transparent compounds from Experiment 1 (*M* = 806 ms, *SE* = 7), $X^2(1) = 7.96$, *p* = .005. In terms of the control variables, word frequency influenced response time, *z* = -4.03, *p* < .0001, but length did not, *z* < 1. The accuracy analysis showed that participants were significantly less accurate when responding to the partially opaque compound words from Experiment 2 (*M* = 84%, *SE* = 0.87), than the fully opaque and the fully transparent compounds from Experiment 1 (*M* = 91%, *SE* = .69), $X^2(1) = 5.46$, *p* = .02. Word frequency influenced accuracy, *z* = 2.27, *p* < .02, but length did not, *z* < 1. Thus, both the response time and accuracy analyses indicated that partially opaque compounds were more difficult to process than compounds for which the transparency of the two constituents were consistent (i.e., fully opaque and fully transparency compounds).

To further explore the role of constituent transparency, we fit a model with the semantic transparency of the first constituent, semantic transparency of the second constituent, interaction of the semantic transparency of the first constituent and the semantic transparency of the second constituent, word frequency of the compound and length of the compound word as fixed effects. Table 5 shows the standardized regression coefficients, standard errors, tests of slopes, and confidence intervals model for the model predicting response times and Table 6 shows the same information but for the model predicting the accuracy data.

For the response time analysis, the impact of a constituent's semantic transparency was influenced by the semantic transparency of the other constituent; semantic transparency of the first constituent and the semantic transparency of the second constituent interacted, $X^2(1) = 8.32$, *p* = .004. We followed up on this interaction by examining the simple effect of the first constituent's transparency at each level of the second constituent's transparency. We observed an influence of the first constituent's semantic transparency only when the second constituent was transparent. When the second constituent was transparent, responses were slower when the first constituent was opaque (OT) than when the first constituent was transparent (TT), $X^2(1) = 13.23$, $p < .001$. However, when the second constituent was opaque, response times for compounds with transparent first constituents (TO) did not differ from compounds with opaque first constituents (OO), $X^2(1) = 1.77$, $p < .18$.

An alternative way to break-down the interaction is to examine the simple effect of the second constituent's transparency at each level of the first constituent's transparency. The influence of the second constituent's transparency depended on the semantic transparency of the first constituent. When the first constituent was transparent, responses were slower when the second constituent was opaque (TO) than when the second constituent was transparent (TT), $X^2(1) = 6.14$, $p < .013$. However, when the first constituent was opaque, responses were faster when the second constituent was opaque (OO) than when the second constituent was transparent (OT), $X^2(1) = 6.58$, $p < .010$.

In terms of the analysis of the accuracy data, we also found a significant interaction between the semantic transparency of the first constituent of the compound and the semantic transparency of the second constituent of the compound, $X^2(1) = 6.03$, $p = .01$. The analysis of the simple effect of the first constituent's transparency at each level of the second constituent's transparency, revealed that when the second constituent was transparent, responses were less accurate when the first constituent was opaque (OT) than when the first constituent was transparent (TT), $X^2(1) = 13.67$, $p < .001$. However, when the second constituent was opaque, accuracy did not differ for compounds with opaque first constituents (OO) and compounds with transparent first constituents (TO), $X^2(1) < 1$. In terms of the analysis of the simple effect of the second constituent's transparency at each level of the first constituent's transparency, when the first constituent was transparent, responses were less accurate when the first constituent was opaque (TO) than when the first constituent was transparent (TT), $X^2(1) = 4.04$, $p < .04$. When the first constituent was opaque, accuracy did not differ for compounds with opaque first constituents (OO) and compounds with transparent first constituents (OT), $X^2(1) < 2.86$, p = .09.

In summary, our first set of models indicated that partially opaque compound words are more difficult to process than fully transparent or fully opaque compounds. Therefore, the absence of an association between inhibition skills and the processing of partially opaque compounds reflected in Experiment 2 could be interpreted as a consequence of the additional processing challenges that opaque-transparent and transparent-opaque compounds pose. In fact, it is possible that this added processing difficulty overrides the influence of inhibition. However, even though these results are informative, they should certainly be taken with caution because, given that we tested two different groups of participants across our two experiments, it is possible that participants of Experiment 2 performed inherently worse than participants of Experiment 1, instead of partially opaque being more difficult to process than fully opaque and fully transparent compound words. For instance, the two groups of participants could significantly differ in terms of reading ability, motivation or other characteristics that could affect their performance (although it would be unusual for samples of participants this large to differ markedly enough in their characteristics to account for the magnitude of differences that we observed between Experiment 1 and Experiment 2). Moreover, it is also possible that differing sets of items across experiments could be differentially easy or hard to discriminate from non-words, which could lead to the participants setting different response thresholds.

Our second set of analyses provided a more fine-grained analysis of the role of constituent transparency on processing and also revealed that partially opaque compounds were more difficult to process. In particular, responses to opaque-transparent compounds were slower than responses to either transparent-transparent or opaque-opaque compounds and responses to transparent-opaque compounds were slower than responses to transparent-transparent compounds but did not differ from opaque-opaque compounds. In addition, these analyses revealed both the response time and accuracy data indicated that the semantic transparency of the first constituent influenced ease of processing only when the second constituent was semantically transparent; that is, opaque-transparent compounds were more difficult to process than transparent-transparent compounds, but opaque-transparent compounds were not more difficult than opaque-opaque compounds.

3.6 General Discussion

The results of Experiment 1 suggest that inhibition is involved in the comprehension of not only fully opaque, but also fully transparent compound words. Experiment 2, on the other hand, suggests that partially opaque compound words are inherently more difficult to process, compared to fully opaque and fully transparent compounds, and that this additional difficulty may override the influence of inhibition scores, which then stop being good predictors of the lexical decisions.

The association between inhibition skills and the processing of both fully opaque and fully transparent compound words found in Experiment 1 may have two different explanations. On one hand, as Libben (2005) stated, processing fully opaque compounds require inhibition in order to suppress the irrelevant meanings of both constituents, which interferes with the computation of the overall meaning. On the other hand, processing fully transparent compounds may require inhibition not because the meanings of their constituents are semantically opaque and need to be suppressed, but rather because fully transparent compounds are similar to polysemous words in the sense that readers need to decide which of the different possible meanings needs to be selected. For instance, in the same way that readers have to decide whether the polysemous word *bark* means *layer of stems and roots of woody plant* or *sharp sound a dog makes*, they have to choose the right relation that connects the two constituents of a fully transparent compound word (e.g., *snowball* as *ball MADE OF snow*, as *ball that IS snow* or as *ball that HAS snow*) and suppress the other possible relations. This hypothesis agrees with an idea that had already been suggested previously, namely that the comprehension of transparent compound words involves meaning computation and selection of relations (Gagné & Spalding, 2009). It is worth pointing out, however, that future research needs to determine whether inhibition per se modulates compound word processing or whether other verbal and non-verbal cognitive abilities that may covary with inhibition, such as general intelligence (Imbrosciano & Berlach, 2006), creativity (Benedek, Franz, Heene, & Neubauer, 2012) or spatial and verbal working memory (Traverso, Mantini, Usai, & Viterbori, 2015) are involved as well.

Findings from Experiment 2 indicate that there is not enough evidence to state that individual differences in inhibition skills are good predictors of the processing of partially opaque compound words. The analysis that compared Experiment 1 and Experiment 2 suggested that partially opaque compounds are inherently more difficult to process than fully transparent and fully opaque compounds. Therefore, it is possible that the lexical decision task with partially opaque compounds was too difficult to let the inhibition effect show. The idea that partially opaque compounds are more difficult to process than fully opaque compounds may seem counterintuitive: The question that arises is why having one constituent that is transparent does not help the comprehension of the whole word. However, it is worth noting that previous research has already suggested that partially transparent compound words present a pattern of results that are different from fully transparent compounds. For instance, El-Bialy et al. (2013) have shown that the ease of processing a compound word depends not only on the opacity of the constituents, but also on whether the constituents have similar levels of semantic transparency. These authors found that a semantically related prime facilitated the processing of a compound when the transparency of the first and second constituents matched (i.e., when both were transparent or when both were opaque), but not when the transparency of the constituents differed, as in the case of partially opaque compounds (e.g., presenting *ear* helped the processing of *eyesight*, but not *eyetooth*). The authors explained these puzzling results as follows: When a semantically related prime is presented, a lexical activation of the constituents of the compound word occurs, and the language system attempts to construct a meaning; if the compound is fully transparent, the constructed meaning derived from the constituents is congruent with the real meaning, so it benefits from the presence of the prime; if the compound is fully opaque, there is a conflict between the meaning derived from the constituents and the real meaning of the compound, but given that these two meanings are so unrelated to each other the conflict is resolved easily and the benefit from the prime is not offset; however, if the compound is partially transparent, the meaning derived from the constituents partially overlaps with the real meaning of the whole word, which creates a more difficult conflict that requires additional time to be resolved, which results in the advantage from the prime being offset. Moreover, the fact that partially opaque behave differently than fully opaque or fully transparent compounds has been noted not only during comprehension tasks, but also during written production tasks. For instance, Gagné and Spalding (2016) showed that it is more difficult to start typing the second constituent of fully transparent compounds (e.g., *eggbeater*) than opaque-transparent compounds (e.g., *eggplant*). The authors explained this phenomenon as follows: When typing the second constituent of a compound word, participants' language system has to shift the attention from the first constituent and suppress it; when the compound is fully transparent, the meaning of the first constituent, which is related to the meaning of the whole word, is still strongly available when starting to type the second constituent, and this delays the typing process. Gagné and Spalding (2014) also showed that participants took longer to initiate the typing process when the compound was opaque-transparent, compared to when it was fully transparent, and when the compound was fully opaque, compared to when it was transparent-opaque. In other words, our study has confirmed the idea revealed by previous research using partially opaque compounds that the language system is sensitive not only to the level of transparency of each of the constituents of a compound word, but also to whether the first and the second constituent have matching levels of semantic transparency. To summarize, we suggest that the semantic distance between the stored representation of a compound and the meanings that might be initially computed from the constituents affects the ease with which a person can settle on the actual meaning of the whole word. Thus, the computed meanings of fully opaque compounds might be so semantically distant from the stored meaning that there is relatively little competition, while the computed meanings of partially opaque (i.e., opaque-transparent and transparent-opaque) compounds will have some overlap because of the modifier and head respectively, which might make them semantically close enough to interfere with the stored meaning.

In both experiments, congruent trials are faster but less accurate than incongruent trials for the inhibition task. We suggest that this reflects a speed-accuracy trade-off. However, an alternative explanation might be due to hand dominance; the left hand is slower than the right hand, which should cause left-handed responses (i.e., incongruent trials) to be slower but more accurate than right-handed responses (i.e., congruent trials) because the participant has more time to correct his/her left-handed response. According to this explanation, hand dominance might explain why we found that there are more errors in the congruent condition (right-handed responses) than in incongruent conditions (left-handed responses). However, there are several reasons why hand dominance might not be a good explanation for the fact that congruent trials are faster but less accurate than incongruent trials. First, the congruency effect in tasks such as the Stroop task or the Simon task, is well-established and tends to be large (our congruency effect is approximately 60 ms). Handedness effects are generally small (approximately 10 ms or less) in simple tasks involving reaction time, and often not significant in more complex tasks; sometimes, reaction times can even be faster for the non-dominant hand (Bisiach, Mini, Sterzi, & Vallar, 1982; Gignac & Vernon, 2004). Furthermore, if the differences we observed in our experiments were due to hand dominance, the errors made by the faster right hand should correspond to the incongruent condition, not the congruent condition. This would occur because we must take into account that if an error is made in the congruent condition, the hand that responds is not the right hand, but the left (slower) one.

One additional issue is that Stroop tasks are sometimes taken to involve primarily conscious attempts at inhibition of the incorrect response, whereas the inhibition that could be involved in dealing with potential conflict between or among compound word meanings and the constituents would be primarily unconscious. This is particularly true of the standard Stroop paradigm, where one can “feel” oneself attempting to stop the incorrect response, and indeed in some sense to stop reading the word. This contrasts strongly with the intuitive feel of competition among compound meanings and constituents, which seems more or less non-existent. However, there is also some reason to believe that even the standard Stroop paradigm might involve both conscious and unconscious inhibition, and the variation of the Stroop paradigm that we adopted, in which one is directly asked to say whether the word form and the color match or mismatch, avoids the more conscious aspects of the standard Stroop paradigm. In particular, one is not presented with the response conflict, and one cannot do the task by attempting not to read the word. In addition, much previous research has suggested the idea that there may not be a clear-cut distinction between "conscious" (controlled, voluntary or willful) and "unconscious" inhibition. For instance, in a study using fMRI, Horga and Maia (2012) have suggested that unconscious and conscious processes share many characteristics and, in particular, that even processes such as subliminal priming can affect cognitive control mechanisms. Nevertheless, it is possible that the variant of the Stroop task that we have chosen still depends to some degree on conscious inhibition, and this would tend to suggest that our data might be underestimating the effect of individual differences in inhibition skill on compound word processing.

In conclusion, we can state that the field that relates specific executive functions to the comprehension of different types of compound words remains relatively unexplored. However, this study has contributed to an initial understanding of this matter by pointing out two facts: on one hand, that inhibition skills may be a key factor in the processing of this type of complex words, and, on the other hand, that the reasons why the language system needs to recruit inhibition may depend on the level of semantic transparency of the compound: Fully opaque compound words seem to involve inhibition in order to suppress the semantically irrelevant meaning of the constituents, whereas fully transparent compounds seem to involve inhibition in order to decide which relation that connects the two constituents is the best.

3.7 References

Benedek, M., Franz, F., Heene, M., & Neubauer, A. C. (2012). Differential effects of cognitive inhibition and intelligence on creativity. *Personality and Individual Differences, 53*(4), 480–485.

Bjorklund, D. F., & Harnishfeger, K. K. (1990). The resources construct in cognitive development: Diverse sources of evidence and a theory of inefficient inhibition. *Developmental Review, 10*(1), 48-71.

Bisiach, E., Mini, M., Sterzi, R., & Vallar, G. (1982). Hemispheric lateralization of the decisional stage in choice reaction times to visual unstructured stimuli. *Cortex, 18*(2), 191-197. https://doi.org/https://doi.org/10.1016/S0010-9452(82)80002-6

Brooks, T. L., & Cid de Garcia, D. (2015) Evidence for morphological composition in compound words using MEG. *Frontiers in Human Neuroscience*. 9:215. doi: 10.3389/fnhum.2015.00215

Brysbaert, M., & New, B. (2009). Moving beyond Kuçera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods*, *41*(4), 977–990.

Bugg, J. M., Jacoby, L. L., & Toth, J. P. (2008). Multiple levels of control in the Stroop task. *Memory & Cognition, 36*(8), 1484–1494.

Durgin, F. H. (2000). The reverse Stroop effect. *Psychonomic Bulletin & Review, 7*(1), 121–125.

El-Bialy, Rowan, Gagné, C. L. & Spalding, T. L. 2013. Processing of English compounds is sensitive to the constituents' semantic transparency. *The Mental Lexicon* 8. 75–95.

Engle, Kane & Tuholski (1999). Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence and functions of the prefrontal cortex. In Miyake, A. & Shah, P. (Eds.), *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control* (pp.102-134). London: Cambridge Press.

Enright, S. J., & Beech, A. R. (1990). Obsessional states: Anxiety disorders or schizotypes? An information processing and personality assessment. *Psychological Medicine, 20*(3), 621-627.

Frith, C. D. (1979). Consciousness, information processing, and schizophrenia. *British Journal of Psychiatry*, *134*, 225–35.

Gagné, C. L., & Spalding, T. L. (2009). Constituent integration during the processing of compound words: Does it involve the use of relational structures? *Journal of Memory and Language, 60*(1), 20-35.

Gagné, C. L., & Spalding, T. L. (2014). Typing time as an index of morphological and semantic effects during English compound processing. *Lingue e Linguaggio*, *13*(2), 241-262.

Gagné, C. L., & Spalding, T. L. (2016). Written production of English compounds: effects of morphology and semantic transparency. *Morphology*, *26*(2), 133-155. doi:10.1007/s11525-015-9265-0

Gignac, G. E., & Vernon, P. A. (2004). Reaction time and the dominant and non-dominant hands: An extension of Hick's Law. *Personality and Individual Differences, 36*(3), 733-739. https://doi.org/10.1016/s0191-8869(03)00133-8

Glucksberg, S., Newsome, M., & Goldvarg, Y. (2001). Inhibition of the literal: Filtering metaphor-irrelevant information during metaphor comprehension. *Metaphor and Symbol, 16*, 277–293.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The Psychology of Learning and Motivation, Vol. 22* (pp. 193-225). New York, NY: Academic Press.

Hasher, L., Zacks, R. T., & May, C. P. (1999). Inhibitory control, circadian arousal, and age. In D. Gopher & A. Koriat (Eds.), *Attention & Performance, XVII, Cognitive Regulation of Performance: Interaction of Theory and Application* (pp. 653-675). Cambridge, MA: MIT Press.

Horga, G., & Maia, T. V. (2012). Conscious and unconscious processes in cognitive control: a theoretical perspective and a novel empirical approach. *Frontiers in Human Neuroscience, 6*.

Iakimova, G., Passerieux, C., & Hardy-Bayle, M. C. (2006). The understanding of metaphors in schizophrenia and depression. An experimental approach. *Encephale*, *32*, 995-1002.

Imbrosciano, A., & Berlach, R. (2006). The Stroop test and its relationship to academic performance and general behaviour of young students. *Teacher Development*, *9*, 131-144.

Ji, H., Gagné, C. L., & Spalding, T. L. (2011). Benefits and costs of lexical decomposition and semantic integration during the processing of transparent and opaque English compounds. *Journal of Memory and Language, 65,* 406-430.

Joormann, J., Yoon, K. L., Zetsche, U. (2007). Cognitive inhibition in depression. *Applied and Preventive Psychology*, *12*, 128–139.

Juhasz, B. J. (2007). The influence of semantic transparency on eye movements during English compound word recognition. In R. von Gompel, W. Murray, & M. Fischer (Eds.), *Eye movements: A window on mind and brain* (pp. 373–389). Boston, MA: Elsevier.

Knight, S., & Heinrich, A. (2017). Different measures of auditory and visual stroop interference and their relationship to speech intelligibility in noise. *Frontiers in Psychology*, *8*, 230.

doi:10.3389/fpsyg.2017.00230

Kuperman, V., & Van Dyke, J.A. (2011). Individual differences in visual comprehension of morphological complexity. In L. Carlson, C. Hoelscher, & T. Shipley (Eds.), *Proceedings of the 33rd Annual Meeting of the Cognitive Science Society* (pp. 1643-1648). Austin, TX: Cognitive Science Society.

Libben, G. (1993). A Case of obligatory access to morphological constituents. *Nordic Journal of Linguistics*, *16*, 111-12.

Libben, G. (2005). Everything is psycholinguistics: Material and methodological considerations in the study of compound processing. *The Canadian Journal of Linguistics / La revue canadienne de linguistique*. *50*. 267-283.

Libben, G., Gibson, M., Yoon, Y. B., & Sandra, D. (2003). Compound fracture: The role of semantic transparency and morphological headedness. *Brain and Language, 84*, 50–64.

Logan, G. D., Zbrodoff, N. J., & Williamson, J. (1984). Strategies in the color-word Stroop task. *Bulletin of the Psychonomic Society, 22*(2), 135–138.

MacGregor, L., & Shtyrov, Y. (2013). Multiple routes for compound word processing in the brain: Evidence from EEG. *Brain & Language*, *126*, 217–229.

MacLeod C. M. (1991). Half a century of research on the Stroop effect: An integrative review. Psychol. Bull. 109, 163–203. 10.1037/0033-2909.109.2.163

Monterosso, J. R., Aron, A. R., Cordova, X., Xu, J., & London, E. D. (2005). Deficits in response inhibition associated with chronic methamphetamine abuse. *Drug and Alcohol Dependence, 79*(2), 273-277.

Pinheiro, J. C., & Bates, D. M. (2000). *Mixed-effects models in S and S-PLUS*. New York, NY: Springer.

Sandra, D. (1990). On the representation and processing of compound words: Automatic access to constituent morphemes does not occur. *Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 42*, 529–567.

Sani, S.R., Tabibi, Z., Fadardi, J.S., & Stavrinos, D. (2017). Aggression, emotional self-regulation, attentional bias, and cognitive inhibition predict risky driving behavior. *Accident; analysis and prevention, 109*, 78-88.

Seidenberg, M. S., Tanenhaus, M. K., Leiman, J. M., & Bienkowski, M. (1982). Automatic access of the meanings of ambiguous words in context: Some limitations on knowledge-based processing. *Cognitive Psychology*, *14*, 489-532.

Schmidtke, D., Van Dyke, J. A., & Kuperman, V. (2018). Individual variability in the semantic processing of English compound words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 44*(3), 421-439.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*, 643-662.

Traverso, L., Mantini, C., Usai, M.C., & Viterbori, P. (2015). The relationship between inhibition and working memory in preschoolers: Evidence for different inhibitory abilities. In G. Airenti, B. Bara, G. Sandini, & M. Cruciani (Eds.). *Proceedings of the EuroAsianPacific Joint Conference on Cognitive Science / 4th European Conference on Cognitive Science / 11th International Conference on Cognitive Science* (pp. 48-53). Torino, Italy.

Treisman, A., & Fearnley, S. (1969). The Stroop test: Selective attention to colours and words. *Nature*, *222*, 437-439.

3.8 Tables

3.8.1 Table 1

Standardized regression coefficients, standard errors, tests of slopes, and confidence intervals from the model using compound type, inhibition scores, frequency, and length to predict inverse-transformed reaction times from the lexical decision task in Experiment 1

					95% confidence interval	
	b	SE	z	p	lower bound	upper bound
Compound type	-0.025	0.038	-0.65	0.513	-0.098	0.049
Inhibition score	0.001	0.001	2.31	0.021	0.000	0.002
Compound type x Inhibition score	-0.000	0.000	-0.56	0.578	-0.001	. 0004
Frequency	-0.019	0.007	-2.89	0.004	-0.032	-0.006
Length	-0.025	0.016	-1.59	0.112	-0.055	0.006
Constant	-1.150	0.138	-8.35	0.000	-1.420	-0.880

3.8.2 Table 2

Standardized regression coefficients, standard errors, tests of slopes, and confidence intervals from the model using compound type, inhibition ratio, frequency, and length to predict inverse-transformed reaction times from the lexical decision task in Experiment 1

					95% confidence interval	
	b	SE	z	p	lower bound	upper bound
Compound type	0.163	0.227	0.72	0.472	-0.282	0.609
Inhibition ratio	0.939	0.433	2.17	0.030	0.091	1.788
Compound type x Inhibition ratio	-0.184	0.212	-0.86	0.387	-0.600	0.233
Frequency	-0.019	0.007	-2.89	0.004	-0.032	-0.006
Length	-0.025	0.016	-1.59	0.112	-0.055	0.006
Constant	-2.094	0.478	-4.38	0.000	-3.030	-1.158

3.8.3 Table 3

Standardized regression coefficients, standard errors, tests of slopes, and confidence intervals from the model using compound type, inhibition scores, frequency, and length to predict inverse-transformed reaction times from the lexical decision task in Experiment 2

					95% confidence interval	
	b	SE	z	p	lower bound	upper bound
Compound type	-0.110	0.044	-2.53	0.012	-0.195	-0.025
Inhibition score	-0.000	0.001	-0.02	0.981	-0.001	0.001
Compound type x Inhibition score	0.000	0.000	0.74	0.459	-0.001	0.001
Frequency	-0.063	0.013	-4.89	0.000	-0.088	-0.037
Length	0.015	0.012	1.23	0.221	-0.009	0.039
Constant	-1.237	0.115	-10.80	0.000	-1.462	-1.013

3.8.4 Table 4

Standardized regression coefficients, standard errors, tests of slopes, and confidence intervals from the model using compound type, inhibition ratio, frequency, and length to predict inverse-transformed reaction times from the lexical decision task in Experiment 2

					95% confidence interval	
	b	SE	z	p	lower bound	upper bound
Compound type	-0.464	0.316	-1.47	0.142	-1.083	0.155
Inhibition ratio	-0.491	0.507	-0.97	0.333	-1.485	0.503
Compound type x Inhibition ratio	0.343	0.289	1.19	0.236	-0.224	0.910
Frequency	-0.062	0.013	-4.89	0.000	-0.087	-0.037
Length	0.015	0.012	1.23	0.220	-0.009	0.039
Constant	-0.705	0.561	-1.26	0.209	-1.804	0.394

3.8.5 Table 5

Standardized regression coefficients, standard errors, tests of slopes, and confidence intervals effects from the model using semantic transparency of the first constituent (semtransC1), semantic transparency of the second constituent (semtransC2), frequency, and length to predict inverse-transformed reaction times from the lexical decision task in Experiments 1 and 2 combined

					95% confidence interval	
	b	SE	z	p	lower bound	upper bound
SemtransC1	0.199	0.055	3.64	0.000	0.092	0.306
SemtransC2	0.131	0.053	2.48	0.013	0.027	0.234
SemtransC1 x SemtransC2	-0.270	0.094	-2.88	0.004	-0.454	-0.087
Frequency	-0.028	0.006	-4.52	0.000	-0.040	-0.016
Length	-0.001	0.010	-0.15	0.885	-0.022	0.019
Constant	-1.336	0.100	-13.30	0.000	-1.533	-1.139

3.8.6 Table 6

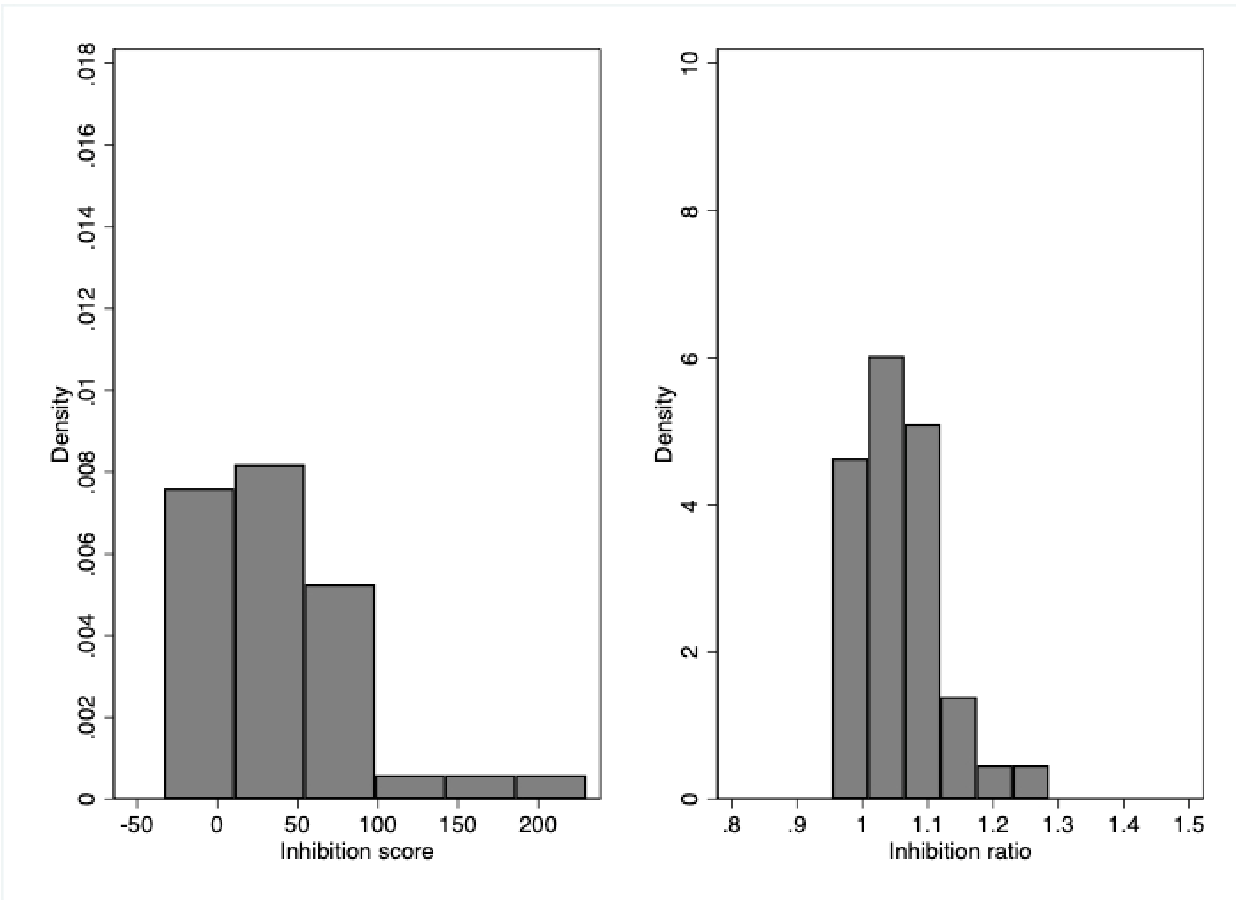
Standardized regression coefficients, standard errors, tests of slopes, and confidence intervals from the model using semantic transparency of the first constituent (semtransC1), semantic transparency of the second constituent (semtransC2), frequency, and length to predict accuracy (correct vs. incorrect) from the lexical decision task in Experiments 1 and 2 combined

					95% confidence interval	
	b	SE	z	p	lower bound	upper bound
SemtransC1	-2.187	0.592	-3.70	0.000	-3.347	-1.028
SemtransC2	-1.141	0.568	-2.01	0.044	-2.254	-0.028
SemtransC1 x SemtransC2	2.109	0.859	2.46	0.014	0.426	3.792
Frequency	0.301	0.106	2.84	0.005	0.093	0.509
Length	-0.037	0.146	-0.26	0.798	-0.323	0.249
Constant	4.209	1.395	3.02	0.003	1.476	6.943

3.9 Figures

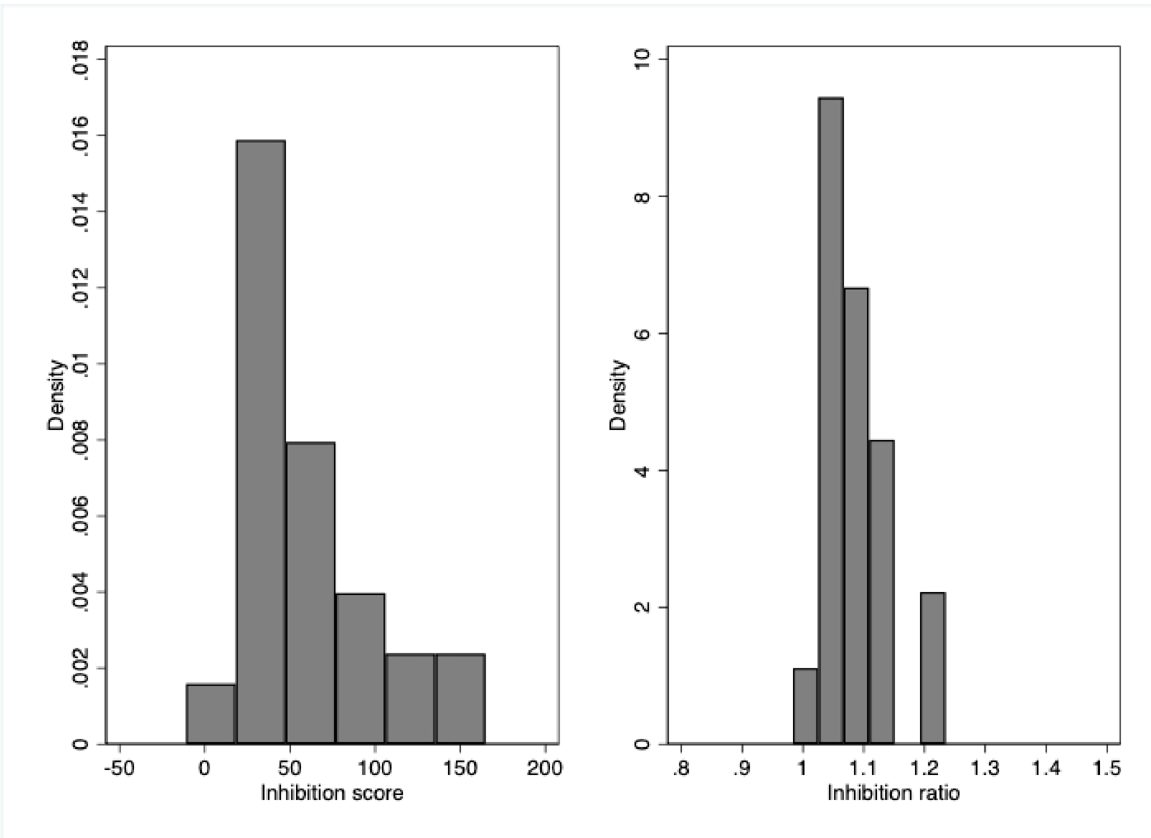
3.9.1 Figure 1

Histogram of inhibition scores and inhibition ratios used to predict performance on the lexical decision task of Experiment 1



3.9.2 Figure 2

Histogram of inhibition scores and inhibition ratios used to predict performance on the lexical decision task of Experiment 2



3.10 Appendix A

Stimuli Presented in the Lexical Decision Task in Experiment 1

String of letters presented	Type of stimulus
bandwagon	Fully opaque compound
blackmail	Fully opaque compound
blockbuster	Fully opaque compound
bootleg	Fully opaque compound
busybody	Fully opaque compound
buttercup	Fully opaque compound
dingbat	Fully opaque compound
dumbbell	Fully opaque compound
fanfare	Fully opaque compound
hedgehog	Fully opaque compound
highlight	Fully opaque compound
hogwash	Fully opaque compound
honeymoon	Fully opaque compound
jackpot	Fully opaque compound
marshmallow	Fully opaque compound
mushroom	Fully opaque compound
nutcase	Fully opaque compound
scapegoat	Fully opaque compound
snapdragon	Fully opaque compound
stalemate	Fully opaque compound
swansong	Fully opaque compound
tightwad	Fully opaque compound
cheekbone	Fully transparent compound
clamshell	Fully transparent compound
cloverleaf	Fully transparent compound
corkscrew	Fully transparent compound
fingertip	Fully transparent compound
gunpowder	Fully transparent compound
hailstorm	Fully transparent compound
hairnet	Fully transparent compound
lampshade	Fully transparent compound
mincemeat	Fully transparent compound
molehill	Fully transparent compound
nosebleed	Fully transparent compound
paintbrush	Fully transparent compound
poppyseed	Fully transparent compound
racehorse	Fully transparent compound
rosebud	Fully transparent compound
snakeskin	Fully transparent compound
thumbnail	Fully transparent compound

toothpick	Fully transparent compound
wastebasket	Fully transparent compound
windowpane	Fully transparent compound
wristwatch	Fully transparent compound
dominican	Non compound word filler
gratitude	Non compound word filler
realization	Non compound word filler
monarch	Non compound word filler
glaucoma	Non compound word filler
franchise	Non compound word filler
anchovy	Non compound word filler
literacy	Non compound word filler
nirvana	Non compound word filler
advocacy	Non compound word filler
vandalism	Non compound word filler
lactose	Non compound word filler
procedure	Non compound word filler
amnesia	Non compound word filler
electrician	Non compound word filler
diplomat	Non compound word filler
prodigy	Non compound word filler
diversity	Non compound word filler
conformism	Non compound word filler
actuality	Non compound word filler
tubercle	Non compound word filler
allegory	Non compound word filler
alchemist	Non compound word filler
trapezoid	Non compound word filler
allocation	Non compound word filler
retrieval	Non compound word filler
emergence	Non compound word filler
itinerary	Non compound word filler
symbiosis	Non compound word filler
hipster	Non compound word filler
blaspheme	Non compound word filler
phosphate	Non compound word filler
affluent	Non compound word filler
meteorite	Non compound word filler
memorandum	Non compound word filler
mysticism	Non compound word filler
recipient	Non compound word filler
reptile	Non compound word filler
symposium	Non compound word filler
monograph	Non compound word filler
detergent	Non compound word filler
testimonial	Non compound word filler

recompense	Non compound word filler
attachment	Non compound word filler
ansition	Nonword filler with monomorphemic-like structure
vangeliss	Nonword filler with monomorphemic-like structure
untertracts	Nonword filler with monomorphemic-like structure
trovers	Nonword filler with monomorphemic-like structure
tronomic	Nonword filler with monomorphemic-like structure
ricultrur	Nonword filler with monomorphemic-like structure
megatlo	Nonword filler with monomorphemic-like structure
ervation	Nonword filler with monomorphemic-like structure
cologic	Nonword filler with monomorphemic-like structure
sourcest	Nonword filler with monomorphemic-like structure
gisticoat	Nonword filler with monomorphemic-like structure
diamint	Nonword filler with monomorphemic-like structure
ervolemia	Nonword filler with monomorphemic-like structure
terisma	Nonword filler with monomorphemic-like structure
quenciality	Nonword filler with monomorphemic-like structure
trophims	Nonword filler with monomorphemic-like structure
assiert	Nonword filler with monomorphemic-like structure
milatiocy	Nonword filler with monomorphemic-like structure
complishly	Nonword filler with monomorphemic-like structure
phenylmon	Nonword filler with monomorphemic-like structure
dosteron	Nonword filler with monomorphemic-like structure
descenss	Nonword filler with monomorphemic-like structure
framplist	Nonword filler with monomorphemic-like structure
pressdite	Nonword filler with monomorphemic-like structure
tantaneous	Nonword filler with monomorphemic-like structure
tommutals	Nonword filler with monomorphemic-like structure
texteenex	Nonword filler with monomorphemic-like structure
niversiof	Nonword filler with monomorphemic-like structure
elfilment	Nonword filler with monomorphemic-like structure
plicits	Nonword filler with monomorphemic-like structure
mollgrass	Nonword filler with monomorphemic-like structure
tatchwors	Nonword filler with monomorphemic-like structure
effinoil	Nonword filler with monomorphemic-like structure
eartfulls	Nonword filler with monomorphemic-like structure
erfeinting	Nonword filler with monomorphemic-like structure
tractivis	Nonword filler with monomorphemic-like structure
tionwider	Nonword filler with monomorphemic-like structure
precial	Nonword filler with monomorphemic-like structure
ronitally	Nonword filler with monomorphemic-like structure
quelfiort	Nonword filler with monomorphemic-like structure
wrismatic	Nonword filler with monomorphemic-like structure
ellitatious	Nonword filler with monomorphemic-like structure
letrerolit	Nonword filler with monomorphemic-like structure
mertractor	Nonword filler with monomorphemic-like structure

ragefiber	Nonword filler with compound-like structure
wittymain	Nonword filler with compound-like structure
womenswitch	Nonword filler with compound-like structure
postsoy	Nonword filler with compound-like structure
sidewolf	Nonword filler with compound-like structure
peopleraw	Nonword filler with compound-like structure
roadbud	Nonword filler with compound-like structure
vibewear	Nonword filler with compound-like structure
wigmale	Nonword filler with compound-like structure
agonygem	Nonword filler with compound-like structure
openlarva	Nonword filler with compound-like structure
vanring	Nonword filler with compound-like structure
flirtpoor	Nonword filler with compound-like structure
clogpaw	Nonword filler with compound-like structure
crestarctic	Nonword filler with compound-like structure
geekdawn	Nonword filler with compound-like structure
cowfrog	Nonword filler with compound-like structure
tractwrap	Nonword filler with compound-like structure
mildcounty	Nonword filler with compound-like structure
civilfull	Nonword filler with compound-like structure
lacegolf	Nonword filler with compound-like structure
drillfox	Nonword filler with compound-like structure
juiceloan	Nonword filler with compound-like structure
jeanmedal	Nonword filler with compound-like structure
devourheck	Nonword filler with compound-like structure
beanmoral	Nonword filler with compound-like structure
gospelear	Nonword filler with compound-like structure
anytechno	Nonword filler with compound-like structure
ponypinky	Nonword filler with compound-like structure
limebeg	Nonword filler with compound-like structure
ovenlimbs	Nonword filler with compound-like structure
porchfolk	Nonword filler with compound-like structure
bondjude	Nonword filler with compound-like structure
clawalign	Nonword filler with compound-like structure
chartsense	Nonword filler with compound-like structure
dozerjust	Nonword filler with compound-like structure
hempopera	Nonword filler with compound-like structure
diveran	Nonword filler with compound-like structure
indexhonk	Nonword filler with compound-like structure
gloveyawn	Nonword filler with compound-like structure
smileeuro	Nonword filler with compound-like structure
worstsilica	Nonword filler with compound-like structure
gossipmaze	Nonword filler with compound-like structure
igloosuave	Nonword filler with compound-like structure

3.11 Appendix B

Stimuli Presented in the Lexical Decision Task in Experiment 2

String of letters presented	Type of stimulus
mayfly	Opaque-transparent compound
bobtail	Opaque-transparent compound
jaywalk	Opaque-transparent compound
beeline	Opaque-transparent compound
warthog	Opaque-transparent compound
crowbar	Opaque-transparent compound
catcall	Opaque-transparent compound
clubfoot	Opaque-transparent compound
joystick	Opaque-transparent compound
wormwood	Opaque-transparent compound
alderman	Opaque-transparent compound
smallpox	Opaque-transparent compound
bobbypin	Opaque-transparent compound
crabgrass	Opaque-transparent compound
flagstone	Opaque-transparent compound
horseplay	Opaque-transparent compound
buckwheat	Opaque-transparent compound
butterfly	Opaque-transparent compound
pipedream	Opaque-transparent compound
snailmail	Opaque-transparent compound
strawberry	Opaque-transparent compound
frankincense	Opaque-transparent compound
hotdog	Transparent-opaque compound
inkwell	Transparent-opaque compound
oddball	Transparent-opaque compound
boldface	Transparent-opaque compound
sideburn	Transparent-opaque compound
typeface	Transparent-opaque compound
slowpoke	Transparent-opaque compound
jailbird	Transparent-opaque compound
sidekick	Transparent-opaque compound
doughnut	Transparent-opaque compound
blackhead	Transparent-opaque compound
lazybones	Transparent-opaque compound
turntable	Transparent-opaque compound
honeycomb	Transparent-opaque compound
gingersnap	Transparent-opaque compound
spoilsport	Transparent-opaque compound
chatterbox	Transparent-opaque compound
cheapskate	Transparent-opaque compound

lumberjack	Transparent-opaque compound
doubleheader	Transparent-opaque compound
butterscotch	Transparent-opaque compound
knucklesandwich	Transparent-opaque compound
marmot	Non compound word filler
opiate	Non compound word filler
syrians	Non compound word filler
slavish	Non compound word filler
chicory	Non compound word filler
migrant	Non compound word filler
adrenal	Non compound word filler
hospice	Non compound word filler
refusal	Non compound word filler
polygon	Non compound word filler
modality	Non compound word filler
ganglion	Non compound word filler
nepotism	Non compound word filler
meteoric	Non compound word filler
aberrant	Non compound word filler
gluttony	Non compound word filler
asterisk	Non compound word filler
monarchy	Non compound word filler
symmetry	Non compound word filler
maternal	Non compound word filler
opposing	Non compound word filler
petition	Non compound word filler
ontology	Non compound word filler
doctrinal	Non compound word filler
amplitude	Non compound word filler
moderator	Non compound word filler
rheumatic	Non compound word filler
quotation	Non compound word filler
extremist	Non compound word filler
enclosure	Non compound word filler
actuality	Non compound word filler
orchestra	Non compound word filler
secretion	Non compound word filler
intestine	Non compound word filler
odontology	Non compound word filler
convulsion	Non compound word filler
expressive	Non compound word filler
saturation	Non compound word filler
hemoglobin	Non compound word filler
psychology	Non compound word filler
oceanography	Non compound word filler
nutritionist	Non compound word filler

purification	Non compound word filler
procastinators	Non compound word filler
niesof	Nonword filler with monomorphemic-like structure
runtly	Nonword filler with monomorphemic-like structure
megatlo	Nonword filler with monomorphemic-like structure
terisma	Nonword filler with monomorphemic-like structure
trovers	Nonword filler with monomorphemic-like structure
plicits	Nonword filler with monomorphemic-like structure
assiert	Nonword filler with monomorphemic-like structure
precial	Nonword filler with monomorphemic-like structure
diamint	Nonword filler with monomorphemic-like structure
cologic	Nonword filler with monomorphemic-like structure
effinoil	Nonword filler with monomorphemic-like structure
tatchwor	Nonword filler with monomorphemic-like structure
sourcest	Nonword filler with monomorphemic-like structure
tionider	Nonword filler with monomorphemic-like structure
trophims	Nonword filler with monomorphemic-like structure
tractivi	Nonword filler with monomorphemic-like structure
descenss	Nonword filler with monomorphemic-like structure
molgrass	Nonword filler with monomorphemic-like structure
tronomic	Nonword filler with monomorphemic-like structure
dosteron	Nonword filler with monomorphemic-like structure
eartfull	Nonword filler with monomorphemic-like structure
elfilmen	Nonword filler with monomorphemic-like structure
ervation	Nonword filler with monomorphemic-like structure
framplist	Nonword filler with monomorphemic-like structure
ricultrur	Nonword filler with monomorphemic-like structure
gisticoat	Nonword filler with monomorphemic-like structure
tommutals	Nonword filler with monomorphemic-like structure
texteenex	Nonword filler with monomorphemic-like structure
ervolemia	Nonword filler with monomorphemic-like structure
pressdite	Nonword filler with monomorphemic-like structure
pansition	Nonword filler with monomorphemic-like structure
vangeliss	Nonword filler with monomorphemic-like structure
milatiocy	Nonword filler with monomorphemic-like structure
phenylmon	Nonword filler with monomorphemic-like structure
letrerolit	Nonword filler with monomorphemic-like structure
wrismatics	Nonword filler with monomorphemic-like structure
tantaneous	Nonword filler with monomorphemic-like structure
erfeinting	Nonword filler with monomorphemic-like structure
mertractor	Nonword filler with monomorphemic-like structure
complishly	Nonword filler with monomorphemic-like structure
ellirtatious	Nonword filler with monomorphemic-like structure
unttertracts	Nonword filler with monomorphemic-like structure
quenciallity	Nonword filler with monomorphemic-like structure
quiellfiortress	Nonword filler with monomorphemic-like structure

anycup	Nonword filler with compound-like structure
sinpig	Nonword filler with compound-like structure
roadbud	Nonword filler with compound-like structure
clogpaw	Nonword filler with compound-like structure
postsoy	Nonword filler with compound-like structure
limebeg	Nonword filler with compound-like structure
cowfrog	Nonword filler with compound-like structure
diveran	Nonword filler with compound-like structure
vanring	Nonword filler with compound-like structure
wigmale	Nonword filler with compound-like structure
bondjude	Nonword filler with compound-like structure
porchfar	Nonword filler with compound-like structure
agonygem	Nonword filler with compound-like structure
hipopera	Nonword filler with compound-like structure
geekdawn	Nonword filler with compound-like structure
dozerjar	Nonword filler with compound-like structure
drillfox	Nonword filler with compound-like structure
ovenlimb	Nonword filler with compound-like structure
sidewolf	Nonword filler with compound-like structure
lacegolf	Nonword filler with compound-like structure
clawline	Nonword filler with compound-like structure
ponypink	Nonword filler with compound-like structure
vibewear	Nonword filler with compound-like structure
juiceloan	Nonword filler with compound-like structure
peopleraw	Nonword filler with compound-like structure
openlarva	Nonword filler with compound-like structure
beanmoral	Nonword filler with compound-like structure
gospelear	Nonword filler with compound-like structure
flirtpoor	Nonword filler with compound-like structure
jeanmedal	Nonword filler with compound-like structure
ragefiber	Nonword filler with compound-like structure
wittymain	Nonword filler with compound-like structure
tractwrap	Nonword filler with compound-like structure
civilfull	Nonword filler with compound-like structure
gossipmaze	Nonword filler with compound-like structure
smileeuros	Nonword filler with compound-like structure
devourheck	Nonword filler with compound-like structure
chartsense	Nonword filler with compound-like structure
igloosuave	Nonword filler with compound-like structure
mildcounty	Nonword filler with compound-like structure
bettersilica	Nonword filler with compound-like structure
womenswitchs	Nonword filler with compound-like structure
frencharctic	Nonword filler with compound-like structure
princessyawning	Nonword filler with compound-like structure

Chapter 4

Are analogical thinking and general intelligence involved in the comprehension of novel and conventional metaphors?

A study of individual differences

4.1.Abstract

A nominal metaphor (e.g., *Lawyers are sharks*) is usually composed of two nouns: a topic (i.e., main referent of the statement; here, *lawyers*) and a vehicle (i.e., term that possesses the properties that are relevant for the figurative meaning; here, *sharks*). Metaphors vary in their level of conventionality, ranging from novel to conventionalized. The career of metaphor hypothesis (Bowdle & Gentner, 2005) claims that novel metaphors are comprehended by comparing the properties of the vehicle and the topic, whereas conventional metaphors are comprehended by including the topic inside the category that is represented by the vehicle (e.g., *shark* represents the category of predators). We tested this claim using an individual-differences perspective: Participants' scores on a sense/nonsense task that involved novel and conventional metaphors were related to their scores on the subtest Similarities of the WAIS-IV, which measures the ability to identify analogies between two concepts. According to the career of metaphor hypothesis, the scores obtained on the subtest Similarities should predict performance on the sense/nonsense task only for novel metaphors, but not for conventional metaphors; however, contrary to what this hypothesis would have predicted, scores on the subtest Similarities predicted accuracy on the sense/nonsense task for both novel and conventional metaphors, suggesting that metaphor comprehension always requires comparison and matching processes, regardless of the level of conventionality. The scores obtained on the subtest Matrix of the WAIS-IV, which measures general fluid intelligence, did not predict performance on the sense/nonsense task.

Keywords: metaphor, conventionality, individual differences, similarities, intelligence

4.2.Introduction

Nominal metaphors (i.e., metaphors whose main constituents are nouns) are typically presented in the form *X is Y*: *X* is the topic (i.e., the concept the speaker wants to describe, such as *lawyers* in *Lawyers are sharks*), and *Y* is the vehicle (i.e., the concept that possesses the properties the speaker wants to attribute to the topic, such as being aggressive, conveyed by the word *sharks* in the previous example). Given that correctly understanding a metaphor requires the coordination of many types of information (e.g., the intention of the speaker and cultural knowledge), it has been assumed that metaphor comprehension involves many different cognitive functions. In fact, several studies have tried to elucidate which specific cognitive functions (e.g., working memory, inhibition, attention) are needed for the comprehension of this type of metaphor (Benedek, Beaty, Jauk, Koschutnig, Fink, Silvia, Dunst, & Neubauer, 2013; Mashal, 2013). One method that has been frequently used to address this question is the individual-differences perspective, in which participants' scores on cognitive tests are used to predict how quickly or accurately they understand metaphors. The goal of this study is to contribute to the growing literature on the relationship between cognitive skills and metaphor processing by examining specifically whether individuals' analogical thinking skills and general intelligence are involved in the comprehension of novel and conventional metaphors.

The research on the involvement of different cognitive functions in metaphor interpretation is vast. One of the cognitive functions that has been most studied in relation to metaphor processing is working memory. For instance, Chiappe and Chiappe (2007) found that working memory and inhibition skills correlate with speed and quality of metaphor interpretation. In addition, Olkoniemi, Ranta, and Kaakinen (2016) showed that working memory capacity is also related to how the pattern of eye movements change during an experimental session involving metaphors: In general, most readers tend to initiate progressively fewer look-backs (i.e., eye-movements returning to a previous sentence from other parts of the text after the first-pass reading) as the experiment progresses; however, low working memory readers do not show a decrease in the probability of looking back to metaphorical sentences throughout the experiment. The authors interpreted these results as a confirmation of Giora's (1999) hypothesis that readers with low working memory capacity have difficulties with suppressing the salient literal meanings, which results in needing to look back at the metaphorical sentences to refresh the figurative interpretation in their working memory. Moreover, there is also evidence of the involvement of executive functions (i.e., processes necessary for the cognitive control of behavior, such as inhibition, information update, attentional control, and cognitive flexibility) in the comprehension of metaphors (Columbus, Sheikh, Côté-Lecaldare, Häuser, Baum, & Titone, 2015). Using an individual-differences perspective during an eye-tracking study that measured participants' executive control, it was found that readers with high but not low executive control spend more time reading metaphorical verbs when the prior context forces a figurative interpretation (e.g., *The fickle model* ***flitted*** *between hair colors all the time*), which can be interpreted as a sign that readers try "presumably to semantically commit to the contextually appropriate interpretation" (Columbus et al., 2015, p. 7). Furthermore, readers with low executive control are more likely to regress back to the context words, compared to readers with high executive control, which can be interpreted as a sign that individuals with poor executive control need to work harder to fully understand a figurative sentence because they are less efficient at integrating contextual cues. The hypothesis of the importance of executive functions in metaphor comprehension has been supported by a developmental study that demonstrated that there is a clear progression in metaphor comprehension between ages 11 and 15: At age 11, only verbal reasoning skills –measured using analogical and class-inclusion reasoning tasks—predict metaphor interpretation, whereas at age 15, when executive functioning is sufficiently consolidated, the ability to update information and cognitive inhibition also predict metaphor interpretation (Carriedo, Corral, Montoro, Herrero, Ballestrino, & Sebastián, 2016).

It is imperative to note, however, that despite the abundance of studies in metaphor processing, there is a problem that still needs to be addressed: Most research in metaphor comprehension has been conducted with a focus on either the characteristics of the stimuli presented, such as familiarity and aptness, or on the characteristics of the participants, such as intelligence and executive functions. There are very few studies on metaphor comprehension that integrate both aspects at the same time by analyzing the interaction between the properties of the metaphors and the cognitive profile of the readers. Trick and Katz (1986) were the first to find a relationship between metaphor characteristics and people's analogical reasoning skills (i.e., the ability to perceive and use relational similarities between two situations or events) during metaphor comprehension: They showed that individuals with high analogical reasoning scores understand better, and appreciate more, metaphors whose topic and vehicle come from very semantically distant domains.

Thus, the goal of this study is to contribute to the so far very limited research about the interaction between metaphor characteristics and individuals' cognitive abilities. More specifically, we want to examine whether analogical reasoning skills can predict the performance on a metaphor comprehension task that involves metaphors with varying levels of conventionality—the strength of association between the vehicle and its figurative property (e.g., how strongly associated is *shark* in *Lawyers are sharks* to the property of being aggressive). The reason that motivated us to specifically focus on participants' analogical thinking skills and metaphors' conventionality is the fact that by doing this we could test the career of metaphor hypothesis (Bowdle & Gentner, 2005), which, despite being one of the most well-known theories of metaphor comprehension, has received relatively little direct supporting evidence (Holyoak & Stamenković, 2018).

In fact, despite decades of research, scientists have not yet found a definite answer to the question of which exact cognitive mechanisms underlie the comprehension of metaphors. On one hand, the alignment model (Gentner, 1983; Gentner & Wolff, 1997; Wolff & Gentner, 2000) states that metaphors function like literal analogies (e.g., *An atom is like the solar system*) and that, in order to be comprehended, the topic and the vehicle are aligned so that the reader can detect similarities between them (e.g., the concepts of *lawyer* and *shark* are mapped onto each other until the commonality *being aggressive* is highlighted and the reader realizes that, in the same way that sharks are aggressive on their prey, lawyers are also aggressive when defending their clients). On the other hand, in contrast to the alignment model, the class-inclusion model (Glucksberg, 2003; Glucksberg & Keysar, 1990), claims that metaphors function like categorical assertions, in the sense the topic designates an ad-hoc category of which the vehicle is a prototypical member. According to this view, for a metaphor to be comprehended, the topic has to be assigned to a metaphorical category represented and named after the vehicle, and once the topic is classified as part of that category, the properties of that class are attributed to the topic (e.g., when people hear *Lawyers are sharks*, they realize that lawyers are members of a category of beings that are aggressive and scary). Finally, the career of metaphor hypothesis (Bowdle & Gentner, 2005) conciliates both the alignment model and the class-inclusion model by stating that both analogy and categorization are required for comprehending metaphors, depending on the level of conventionality of the metaphor that is being interpreted: If the metaphor is conventional, it will be interpreted through categorization; in contrast, if the metaphor is novel, it will be interpreted through analogy. Therefore, for instance, a metaphor such as *Lawyers are sharks*, which is conventional because most people associate sharks with being aggressive, involves a categorization in which the topic *lawyers* is placed inside the category of aggressive things, represented and named after *sharks*; on the opposite, a metaphor such as *Science is a glacier*, which is novel because most people do not associate a glacier with the property of moving slowly and steadily, but rather they associate it with the property of being big and cold, will require an alignment in which *science* and *glacier* are structurally matched and compared, until the property *moving slowly but steadily*, which is common to both entities, is selected.

If the career of metaphor is correct, the specific ability to find analogies between two concepts, and not merely general intelligence, would be related to the comprehension of novel, but not conventional metaphors. In other words, we can test the career of metaphor hypothesis by analyzing whether people's scores on a task that measures precisely the ability to compare two entities is associated to their ability to comprehend novel, but not conventional metaphors. For this purpose, we analyzed whether participants' scores on the subtest Similarities (which measures the ability to identify analogies between two concepts), but not the subtest Matrix Reasoning (which measures pure general non-verbal intelligence) of the Wechsler Adult Intelligence Scale (WAIS-IV) (Wechsler, 2008) predicted accuracy or reaction times during the comprehension of novel but not conventional metaphors.

4.3. Methods

4.3.1 Participants

Forty-three participants were recruited from Introductory Psychology classes in exchange for partial course credit. All participants were native speakers of English.

4.3.2 Tests/Tasks

All participants completed three tasks: the subtests Similarities and Matrix Reasoning of the Wechsler Adult Intelligence Scale (WAIS-IV) (Wechsler, 2008), and a sense/nonsense task involving metaphors. All participants performed the Matrix Reasoning subtest, which involves non-verbal abstract visual stimuli, at the end of the experimental session. The order of the remaining two tasks, which involve verbal stimuli, was counterbalanced.

4.3.2.1 Subtest Similarities

Analogical thinking skills was measured using the subtest Similarities of the WAIS-IV. This subtest, which requires participants to identify the qualitative relationship between two words to find similarities between two concepts that may not appear to be related on the surface, was designed to assess analogical verbal reasoning. This subtest consists of eighteen pairs of words (e.g., *fork-spoon*), arranged in increasing order of difficulty. Participants were verbally asked to explain in what way the two members of each pair of words were alike (e.g., the participant was asked to give a verbal answer to the question *In what way are a fork and a spoon similar?*). The experimenter recorded the participant's answer in the Record Form provided with the WAIS-IV. Later, the experimenter scored this subtest using the Administration and Scoring Manual provided with the WAIS-IV. According to this manual, participants could receive 0, 1 or 2 points for each response, depending on the quality of the answer. For instance, when asked how a fork and a spoon are similar, the answer *They are both metallic* would receive 0 points because it does not capture the main similarity between the two objects and it is not necessarily true; the answer *They both go in the mouth* would receive 1 point because it points out a relevant but less important similarity; and the answer *They are both utensils* would receive 2 points because it states the most essential similarity between a fork and a spoon.

4.3.2.2 Subtest Matrix Reasoning

General fluid intelligence was measured using the subtest Matrix Reasoning of the WAIS-IV. This subtest, presented in a visual format, measures non-verbal problem-solving skills, inductive reasoning, perceptual organization skills and spatial reasoning ability, and is usually used as a broad measure of non-verbal intelligence. This subtest consists of twenty-six matrices of abstract images in which there is one picture missing. Participants were asked to identify patterns in the design and choose, among a number of possible options, the missing picture that completed the design. Participants could give the answer verbally or simply point at the option they chose. The experimenter recorded each participant's answer in the Record Form provided with the WAIS-IV. As detailed in the Administration and Scoring Manual provided with the WAIS-IV, each answer could receive 1 point (if the participant chose the right missing picture) or 0 points (if the participant chose any other option that was not the right answer).

4.3.2.3 Sense/nonsense task

After creating an initial list of many *X is Y* metaphors (e.g., *My sister is a megaphone*), we selected seventy-eight that had been rated as apt by nine research assistants, and we presented them to fifty-one participants in a pilot study, with instructions to rate, on a scale of 1 to 7, how strongly associated the vehicle was to the figurative property that was conveyed in each sentence (e.g., *How strongly associated is "megaphone" to the property "being loud" in the sentence "My sister is a megaphone"?*). Finally, we selected the twenty-three metaphors that had received the highest ratings in the pilot study (i.e., mean ratings ranging from 5.47 to 6.50) and the twenty-three that had received the lowest ratings (i.e., mean ratings ranging from 3.67 to 5.43). We used the former as our conventional metaphors, and the latter as our novel metaphors. Additionally, we also created three types of fillers: forty-six literally true sentences (e.g., *Blood is a fluid*), forty-six literally false sentences (e.g., *A curtain is a machine*), and forty-six non-sense sentences (e.g., *Beavers are umbrellas*). For each sentence that was presented, participants had to make a sense/nonsense judgment by indicating, as quickly as possible, whether the sentence had any sensible interpretation or not. Literally true sentences and novel and conventional metaphors were expected to elicit a "yes" answer, whereas literally false and non-sense sentences were expected to elicit a "no" answer. To avoid participants from being biased towards figurative language, they were told that we wanted to investigate how people understood language and that they would see statements like *Blood is a fluid* or *A curtain is a machine*, and that they should say whether these statements made sense or not. Participants were also told that they would sometimes be shown statements, such as *My sister is a megaphone*, that made sense if they were interpreted metaphorically. As in Wolff and Gentner (2011), participants were instructed to classify such statements as being sensical. Participants were instructed to press the key "j" if the sentence could be interpreted literally or metaphorically, or the key "f" if it did not make sense. The items were presented one at a time at the center of the screen. Each trial began with the message "Ready?" and the participants had to press the spacebar on the keyboard to see each item. The reaction times were automatically collected by the computer timer, which measured the number of milliseconds elapsed between the stimulus appearance on the screen until the moment the participant responded with the key stroke. The order of the items was randomized for each participant. The items presented in the sense/nonsense task are included in the Appendix.

4.4 Results

4.4.1 Sense/Nonsense Task

Separate analyses for the response time and accuracy data were conducted using linear mixed-effect (LME) analyses (Pinheiro & Bates, 2000) in Stata 13 using the function *mixed* for reaction time data and the function *meqrlogit* for the binary (correct vs. incorrect) accuracy data. Because these functions use dummy coding for categorical variables, the coefficients (i.e., estimates) from these models correspond to simple effects, rather than to main effects. Therefore, the *contrast* function in Stata was used to test the main effects and interactions. The results of these tests are Wald tests and are reported as a chi-square. A Wald test is an approximation of a likelihood ratio test, but is more generalizable (i.e., it can be used in more situations than a likelihood ratio test) and indicates whether the factor (in the case of a main effect) or the interaction improves the fit of the model relative to a model that does not include that factor or interaction. Participant and item were included in the models as random effects, and type of metaphor (novel or conventional) as a fixed effect. Trials with reaction times that were more than 2.5 standard deviations greater than the mean were removed. Additionally, outliers (i.e., reaction times equal or smaller than 700 ms, or equal or greater than 4250 ms) that were visualized with the help of a Q-Q plot were removed. The total number of observations removed represented 0.91% of the original data set. Log-transformed response time was used for the reaction time analysis because the Q-Q plots revealed that this transformation was better at correcting for skewness in the residuals than was the inverse transformation. The response time analysis was based on correct trials only.

In agreement with previous literature (Arzouan, Goldstein, & Faust, 2007), metaphor conventionality influenced the ease of processing during metaphor comprehension. Participants were slower when responding to novel metaphors (M = 1736 ms, SD = 737), compared to conventional metaphors (M = 1593 ms, SD = 713), $X^2(1)$ = 18.16, p <.001. The standardized regression coefficients, standard errors, tests of slopes, and confidence intervals for the model are shown in Table 1. The term “Constant” refers to the y-intercept. Participants were also less accurate when responding to novel metaphors (M = 56%, SD = 50), compared to conventional metaphors (M =75%, SD =

43), $X^2(1) = 16.88$, $p <.001$. The standardized regression coefficients, standard errors, tests of slopes, and confidence intervals for the model are shown in Table 2.

4.4.2 Sense/Nonsense Task, Subtest Matrix Reasoning and Subtest Similarities

To examine whether metaphor comprehension is associated with general intelligence or analogical thinking skills, we tested whether the scores obtained on the subtest Matrix Reasoning or on the subtest Similarities could predict reaction times or accuracy on the sense/nonsense task involving metaphors. Separate analyses for the response time and accuracy data were conducted using linear mixed-effect (LME) analyses in Stata 13 using the function *mixed* for reaction time data and the function *meqrlogit* for the binary (correct vs. incorrect) accuracy data. The response time analysis was based on correct trials only. Participant and item were included in the models as random effects, and type of metaphor (novel or conventional), scores obtained on the subtest Matrix Reasoning and scores obtained on the subtest Similarities as fixed effects. Figure 1 and 2 show, respectively, the distribution of the scores obtained on the subtest Matrix Reasoning and the subtest Similarities, used to predict performance on the sense/nonsense task.

In terms of reaction time, type of metaphor (novel or conventional), scores obtained on the Matrix Reasoning subtest and scores obtained on the Similarities subtest did not interact, $X^2(1) = 2.24$, $p = .13$, nor did type of metaphor and scores obtained on the Matrix Reasoning subtest, $X^2(1) = 2.60$, $p = .11$. There was no main effect of Matrix Reasoning scores, $z = -0.70$, $p = .20$. Type of metaphor and scores obtained on the Similarities subtest did not interact, $X^2(1) = 2.45$, $p = .12$. There was no main effect of Similarities scores, $z = -1.14$, $p = .35$. There was a main effect of type of metaphor, $X^2(1)$

= 3.93, p = .047. The standardized regression coefficients, standard errors, tests of slopes, and confidence intervals for the model are shown in Table 3.

In terms of accuracy, type of metaphor, scores obtained on the Matrix Reasoning subtest and scores obtained on the Similarities subtest did not interact, $X^2(1) = 0.08$, p = .78, nor did Type of metaphor and scores obtained on the Matrix Reasoning subtest, $X^2(1) = 0.07$, p = .79. There was no main effect of Matrix Reasoning scores, z = -0.98, p = .25. Type of metaphor and scores obtained on the Similarities subtest did not interact, $X^2(1) = 0.08$, p = .77. There was a main effect of Similarities scores, z = -0.77, p = .035. There was no main effect of type of metaphor, $X^2(1) = 0.01$, p = .91. The standardized regression coefficients, standard errors, tests of slopes, and confidence intervals for the model are shown in Table 4.

Together, these results suggest that analogical thinking skills, but not general non-verbal intelligence, might be involved in accurately interpreting both novel and conventional metaphors. We will discuss the implications of our results in the General Discussion.

4.5 General Discussion

This study has revealed several interesting results. First, we found that participants took longer and were less accurate when interpreting novel metaphors, in comparison to conventional metaphors. This confirms the idea, already suggested by other researchers (Arzouan et al., 2007), that novel metaphors are more difficult to process than conventional metaphors. This finding is not surprising if we take into account that, by definition, the vehicle (e.g., *sharks* in *Lawyers are sharks*) and the relevant property (e.g., being aggressive) of conventional metaphors are strongly associated, which means that less time is needed to connect the two already semantically closely related concepts. On the other hand, it seems logical that novel metaphors require more effort because, given that the vehicle and the relevant property are more distant, establishing mapping between both concepts is more time-consuming and it probably involves the activation of more background knowledge.

Second, we found that pure non-verbal intelligence is not a good predictor of how quickly or accurately metaphors are comprehended. This suggests that that having high fluid intelligence is not enough to comprehend metaphors: Individuals with high fluid intelligence, who may actually show varying levels of other cognitive skills, do not necessarily perform well in metaphor interpretation tasks. This result is consistent with what other authors have previously found (Beaty & Silvia, 2013; Stamenkovic, Ichien, & Holyoak, 2019), that is, that fluid intelligence is only associated with the processing of much more complex and creative metaphors, such as those that appear in poetry and other literary sources.

Moreover, the most important finding of this study is the fact that our results suggest that specifically the ability to detect analogies between concepts is associated with how accurately a reader can understand both novel and conventional metaphors. This has a very important theoretical implication: It seems to be inconsistent with the career of metaphor hypothesis, which states that only novel metaphors are understood through analogy, and the class-inclusion model, which states that metaphors are comprehended through categorization, not analogy. Instead, our results are more consistent with the alignment model (Gentner, 1983; Gentner & Wolff, 1997; Wolff & Gentner, 2000), which sustains that the first step to accurately interpret any metaphor, regardless of its level of conventionality, consists in highlighting commonalities between the topic and the vehicle (e.g., to interpret the metaphor *Some suburbs are parasites*, the reader first needs to align *suburbs* and *parasites* and realize that both concepts possess the quality of depending on a host and harming it). In that sense, our data shows that individuals' ability to detect analogies between two concepts can be used as a predictor of how well they will interpret a wide range of metaphors that vary in their level of conventionality. Thus, this confirms that all metaphors need mapping and the detection of commonalities between the topic and the vehicle.

Finally, it is worth noting that we can draw a parallelism between our results and what is already known in the field of conceptual combination: In fact, Gagné and Spalding (2006) have found that both conventional (i.e., lexicalized) noun-noun phrases (e.g., *coffee cup*) and novel noun-noun phrases (e.g., *unicorn nest*) involve the same cognitive processes (i.e., both conventional and novel noun-noun phrases seem to require combination and computation of meaning, in the same way that both conventional and novel metaphors seem to require analogical thinking. Indeed, it seems logical that our data show that novel and conventional metaphors share underlying cognitive mechanisms, similarly to what occurs with novel and lexicalized noun-noun phrases because, at least during the initial stages of processing, it is impossible for the language system to distinguish between novel and lexicalized noun-noun combinations, or between conventional and novel metaphors. The parallelism between analogy being involved in the comprehension of both novel and conventional metaphors, and decomposition and meaning construction being involved in both novel and lexicalized noun-noun phrases becomes more evident when we take into account two pieces of evidence. First, the reason that pushed Gagné and Spalding (2006) to propose that the comprehension of even lexicalized noun-noun phrases involves an obligatory conceptual combination process was the fact that transparent compound words (i.e., established noun-noun phrases whose overall meaning is clearly related to the meaning of the constituents, such as *snowball*) are usually faster to process than opaque compound words (i.e., established noun-noun phrases whose overall meaning is unrelated to the meaning of the constituents, such as *hogwash*), which suggests that computing the whole compound's meaning taking into account the automatically activated meaning of the constituents facilitates the processing of transparent compounds, but creates interference during the interpretation of opaque compounds. Analogously, the well-established phenomenon called *metaphor interference effect* (Pierce, MacLaren, & Chiappe, 2010), that is, the fact that people take longer to judge that metaphors are literally false than to judge that control nonsense *X is Y* sentences (e.g., *An insult is a warehouse*) are false, suggests that metaphor processing is automatic, even for novel metaphors (Chouinard, Volden, Hollinger, & Cummine, 2019). Second, it has been demonstrated that when the language system fails due to brain abnormalities (e.g., aphasia, schizophrenia, autism, Alzheimer's disease), patients are unable to inhibit irrelevant meanings that interfere with the meaning computation of opaque compound words and metaphors. For instance, aphasic patients may interpret an opaque compound such as *hogwash* as something related to washing pigs because the they are unable to inhibit the irrelevant meanings of *hog* and *wash* during the interpretation of the overall word (Jarema, 2006; Libben, 1993; Libben, 1998); similarly, patients suffering from Alzheimer's disease (Maki, Yamaguchi, Koeda, & Yamaguchi, 2013), schizophrenia (Iakimova, Passerieux, & Hardy-Bayle, 2006) or autism (Adachi, Koeda, Hirabayashi, Maeoka, Shiota, Wright, & Wada, 2004; Baron-Cohen, 1997; Cohen & Rémillard, 2006; Happé, 1993, 1994, 1995; Kaland, Møller-Nielsen, Callesen, Mortensen, Gottlieb, & Smith, 2002; Martin & McDonald, 2004; Ozonoff & Miller; 1996; Tantam, 1991) may interpret literally a metaphorical sentence such as *Surgeons are butchers*, stating, for example, that it means that surgeons work in stores selling meat.

In conclusion, this study has contributed to the discussion about the specific cognitive mechanisms involved in the comprehension of metaphors that differ in their level of conventionality and has revealed the key role of analogy in the rightful interpretation of both novel and conventional metaphors. This is consistent with the alignment model of metaphor comprehension and inconsistent with the career of metaphor and the class-inclusion model.

4.6 References

Adachi, T., Koeda, T., Hirabayashi, S., Maeoka, Y., Shiota, M., Wright, C. E., & Wada, A. (2004). The metaphor and sarcasm scenario test: A new instrument to help differentiate high functioning pervasive developmental disorder from attention deficit/hyperactivity disorder. *Brain & Development*, *26*, 301–306.

Arzouan, Y., Goldstein, A., & Faust, M. (2007). Brainwaves are stethoscopes: ERP correlates of novel metaphor comprehension. *Brain Research, 1160*, 69-81.

Beaty, R. E., & Silvia, P. J. (2013). Metaphorically speaking: Cognitive abilities and the production of figurative language. *Memory & Cognition, 41*(2), 255-267.

Benedek, M., Beaty, R.E., Jauk, E., Koschutnig, K., Fink, A., Silvia, P.J., Dunst, B., & Neubauer, A.C. (2013). Creating metaphors: The neural basis of figurative language production. *NeuroImage*, *90*, 99-106.

Bowdle, B. F., & Gentner, D. (2005). The Career of Metaphor. *Psychological Review, 112*(1), 193-216.

Carriedo, N., Corral, A., Montoro, P. R., Herrero, L., Ballestrino, P., & Sebastián, I. (2016). The development of metaphor comprehension and its relationship with relational verbal reasoning and executive function. *PLoS ONE, 11*(3). Article ID e0150289.

Chiappe, D. L., & Chiappe, P. (2007). The role of working memory in metaphor production and comprehension. *Journal of Memory and Language, 56*(2), 172-188.

Chouinard, B., Volden, J., Hollinger, J., & Cummine, J. (2019). Spoken metaphor comprehension: Evaluation using the metaphor interference effect. *Discourse*

Processes, *56*(3), 1-18.

Cohen, H., & Rémillard, S. (2006). Autism and Asperger Syndrome: A spectrum of disability. In K. Brown (Ed.), *Encyclopedia of Language and Linguistics* (2nd ed., pp. 617–621). Oxford, UK: Elsevier.

Columbus, G., Sheikh, N. A., Côté-Lecaldare, M., Häuser, K., Baum, S. R., & Titone, D. (2015). Individual differences in executive control relate to metaphor processing: An eye movement study of sentence reading. *Frontiers in Human Neuroscience, 8,* Article ID 1057.

Gagné, C. L., & Spalding, T. L. (2006). Using conceptual combination research to better understand novel compound words. *SKASE Journal of Theoretical Linguistics, 3*(2), 9-16.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science, 7*(2), 155-170.

Gentner, D., & Wolff, P. (1997). Alignment in the processing of metaphor. *Journal of Memory and Language, 37,* 331-355.

Giora, R. (1995). On irony and negation. *Discourse Processes, 19*(2), 239-264.

Glucksberg, S. (2003). The psycholinguistics of metaphor. *Trends in Cognitive Sciences, 7*(2), 92-96.

Glucksberg, S., & Keysar, B. (1990). Understanding metaphorical comparisons: Beyond similarity. *Psychological Review, 97*(1), 3-18.

Happé, F. G. E. (1993). Communicative competence and theory of mind in autism: A test of relevance theory. *Cognition*, *48*, 101–119.

Happé, F. G. E. (1994). An advanced test of theory of mind: Understanding of story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. *Journal of Autism and Developmental Disorders*, *24*, 129–154.

Happé, F. G. E. (1995). The role of age and verbal ability in the theory of mind task performance of subjects with autism. *Child Development*, *66*, 843–855.

Holyoak, K. J., & Stamenković, D. (2018). Metaphor comprehension: A critical review of theories and evidence. *Psychological Bulletin, 144*(6), 641-671.

Iakimova, G., Passerieux, C., & Hardy-Bayle, M. C. (2006). The understanding of metaphors in schizophrenia and depression. An experimental approach. *Encephale*, *32*, 995-1002.

Jarema, G. (2006). Compound representation and processing: A cross-language perspective. In G. Libben & G. Jarema (Eds.), *The representation and processing of compound words* (pp. 45-70). Oxford University Press.

Kaland, N., Møller-Nielsen, A., Callesen, K., Mortensen, E. L., Gottlieb, D., & Smith, L. (2002). An 'advanced' test of theory of mind: Evidence from children and adolescents with Asperger syndrome. *Journal of Child Psychology and Psychiatry*, *43*, 517–528.

Kazmerski, V. A., Blasko, D. G., & Dessalegn, B. G. (2003). ERP and behavioral evidence of individual differences in metaphor comprehension. *Memory & Cognition, 31*(5), 673-689.

Libben, G. (1993). A Case of obligatory access to morphological constituents. *Nordic Journal of Linguistics*, *16*, 111-12.

Libben, G. (1998). Semantic transparency in the processing of compounds:

Consequences for representation, processing, and impairment. *Brain and Language, 61*(1), 30-44.

Maki, Y., Yamaguchi, T., Koeda, T., & Yamaguchi, H. (2013). Communicative competence in Alzheimer's disease: Metaphor and sarcasm comprehension. *American Journal of Alzheimer's Disease and Other Dementias, 28*(1), 69–74.

Martin, I., & McDonald, S. (2004). An exploration of causes of non-literal language problems in individuals with Asperger syndrome. *Journal of Autism and Developmental Disorders*, *34*, 311–328.

Mashal, N. (2013). The role of working memory in the comprehension of unfamiliar and familiar metaphors. *Language and Cognition*, *5*, 409-436.

Olkoniemi, H., Ranta, H., & Kaakinen, J. K. (2016). Individual differences in the processing of written sarcasm and metaphor: Evidence from eye movements. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 42*(3), 433-450.

Ozonoff, S., & Miller, J. N. (1996). An exploration of right-hemisphere contribution to the pragmatic impairments of autism. *Brain and Language*, *52*, 411–434.

Pierce, R. S., MacLaren, R., & Chiappe, D. L. (2010). The role of working memory in the metaphor interference effect. *Psychonomic Bulletin & Review, 17*(3), 400–404.

Pinheiro, J. C., & Bates, D. M. (2000). *Mixed-effects models in S and S-PLUS*. New York, NY: Springer.

Stamenkovic, D., Ichien, N., & Holyoak, K. (2019). Metaphor comprehension: An individual-differences approach. *Journal of Memory and Language*, *105*, 108-118.

Tantam, D. (1991). Asperger syndrome in adulthood. In U. Frith (Ed.), *Autism & Asperger syndrome* (pp. 145–183). Cambridge, UK: Cambridge University Press.

Trick, L., & Katz, A. N. (1986). The domain interaction approach to metaphor processing: Relating individual differences and metaphor characteristics. *Metaphor & Symbolic Activity, 1*(3), 185-213.

Wechsler D. (2008). WAIS-IV administration and scoring manual. San Antonio, TX: Psychological Corporation.

Wolff, P., & Gentner, D. (2000). Evidence for role-neutral initial processing of metaphors. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*(2), 529-541.

Wolff, P., & Gentner, D. (2011). Structure-mapping in metaphor comprehension. *Cognitive science*, *35*(8). 1456-1488.

4.7 Tables

4.7.1 Table 1

Fixed effects from the linear mixed effect model using type of metaphor to predict reaction time on the sense/nonsense task

					95% confidence interval	
	b	SE	z	p	lower bound	upper bound
Type of metaphor	.143	.033	4.26	< 0.0001	.077	.208
Constant	7.287	.042	174.23	<0.0001	7.205	7.369

4.7.2 Table 2

Fixed effects from the linear mixed effect model using type of metaphor to predict accuracy on the sense/nonsense task

					95% confidence interval	
	b	SE	z	p	lower bound	upper bound
Metaphor type	-1.058	.257	-4.11	<0.0001	-1.562	-.553
Constant	1.425	.242	5.88	<0.0001	.950	1.901

4.7.3 Table 3

Fixed effects from the linear mixed effect model using type of metaphor, and scores obtained on the Matrix Reasoning subtest and the Similarities subtest to predict reaction time on the sense/nonsense task

					95% confidence interval	
	b	SE	z	p	lower bound	upper bound
Metaphor type	.928	.468	1.98	0.047	.011	1.846
Matrix	-.038	.055	-0.70	0.487	-.146	.070
Metaphor type x Matrix	-.048	.030	-1.61	0.107	-.107	.010
Similarities	-.039	.034	-1.14	0.256	-.106	.028
Metaphor type x Similarities	-.029	.018	-1.56	0.118	-.065	.007
Matrix x Similarities	.002	.002	0.94	0.345	-.002	.006
Metaphor type x Matrix x Similarities	.002	.001	1.50	0.134	-.001	.004
Constant	8.041	.856	9.40	0.000	6.364	9.718

Note. Model allows type of metaphor, and scores on the Matrix Reasoning subtest and the Similarities subtest to interact.

4.7.4 Table 4

Fixed effects from the linear mixed effect model using type of metaphor, and scores obtained on the Matrix Reasoning subtest and the Similarities subtest to predict accuracy on the sense/nonsense task

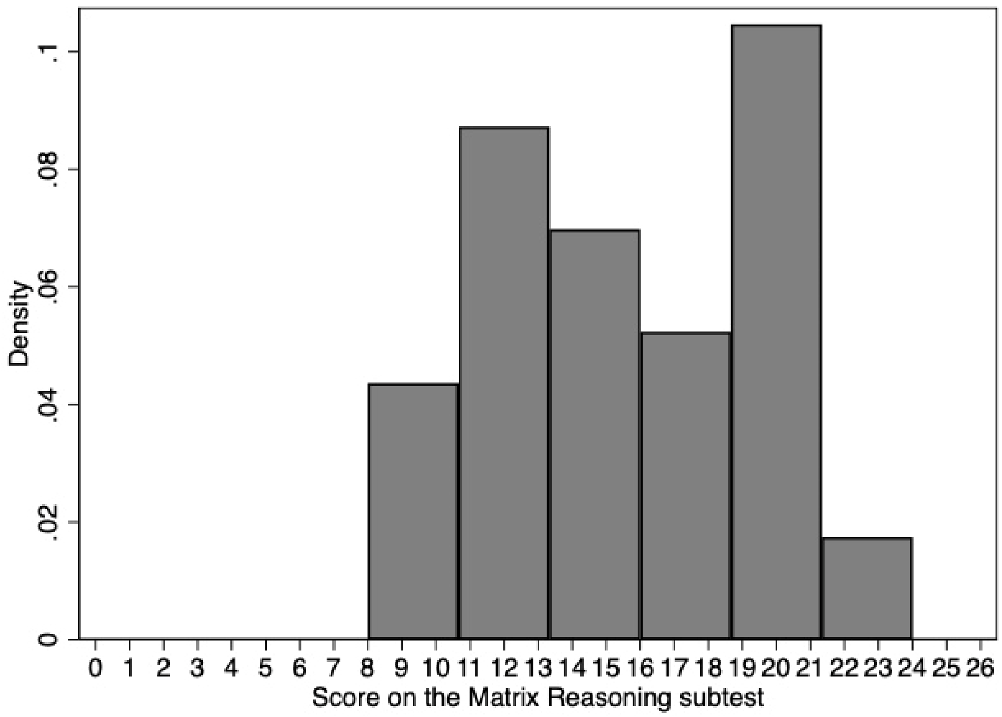
					95% confidence interval	
	b	SE	z	p	lower bound	upper bound
Metaphor type	-.313	2.674	-0.12	0.907	-5.554	4.928
Matrix	-.248	.253	-0.98	0.326	-.744	.247
Metaphor type x Matrix	-.047	.173	-0.27	0.787	-.386	.293
Similarities	-.120	.157	-0.77	0.444	-.427	.187
Metaphor type x Similarities	-.031	.107	-0.29	0.772	-.240	.178
Matrix x Similarities	.012	.010	1.19	0.236	-.008	.032
Metaphor type x Matrix x Similarities	.002	.007	0.28	0.780	-.012	.016
Constant	3.656	3.916	0.93	0.350	-4.019	11.332

Note. Model allows type of metaphor, and scores on the Matrix Reasoning subtest and the Similarities subtest to interact.

4.8 Figures

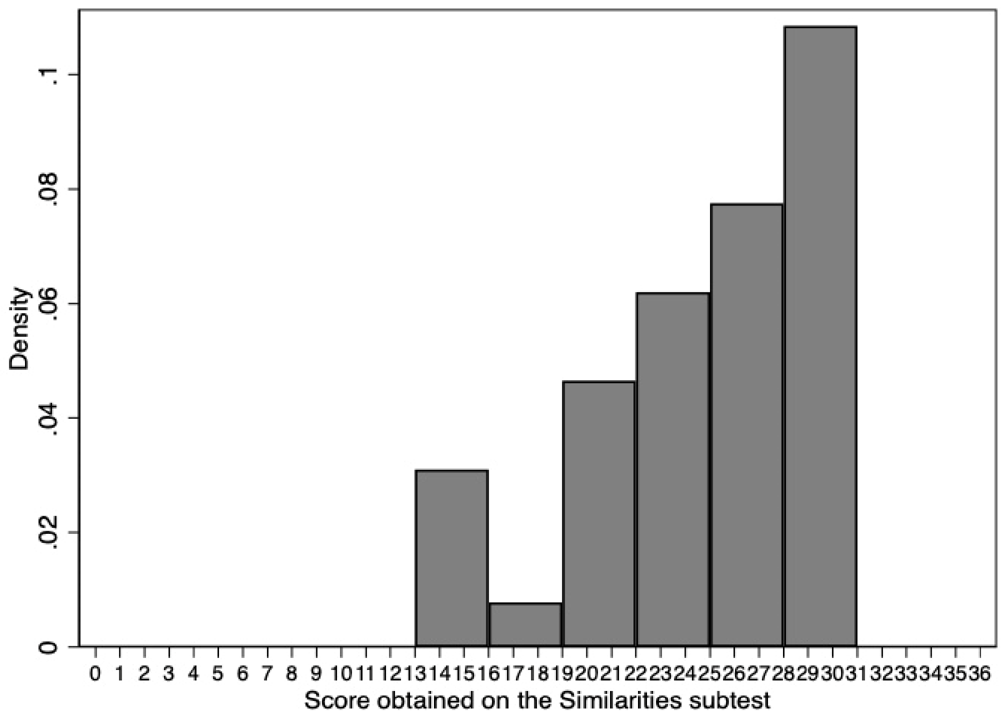
4.8.1 Figure 1

Histogram of scores obtained on the Matrix Reasoning subtest used to predict performance on the sense/nonsense task



4.8.2 Figure 2

Histogram of scores obtained on the Similarities subtest used to predict performance on the sense/nonsense task



4.9 Appendix

Experimental Items Presented in the Sense/Nonsense Task

Type of sentence	Sentence
Conventional metaphor	His arms are steel
Conventional metaphor	A lie is a dagger
Conventional metaphor	A marriage is a leash
Conventional metaphor	Teachers are encyclopedias
Conventional metaphor	A friend is an anchor
Conventional metaphor	Love is an antidote
Conventional metaphor	A diploma is a doorway
Conventional metaphor	Paparazzi are parasites
Conventional metaphor	A worker is a robot
Conventional metaphor	Divorces are storms
Conventional metaphor	Music is a medicine
Conventional metaphor	Smiles are magnets
Conventional metaphor	Exams are torture
Conventional metaphor	My skin is silk
Conventional metaphor	Tobacco is poison
Conventional metaphor	Memory is a warehouse
Conventional metaphor	My room is a dump
Conventional metaphor	Clouds are pillows
Conventional metaphor	Anger is a volcano
Conventional metaphor	Loneliness is a desert
Conventional metaphor	The casino is a drug
Conventional metaphor	My husband is a gem
Conventional metaphor	The spa is heaven
Novel metaphor	An argument is a journey
Novel metaphor	Death is a cave
Novel metaphor	Creativity is a blender
Novel metaphor	An exam is a filter
Novel metaphor	An accountant is a juggler
Novel metaphor	A campaign is a circus
Novel metaphor	Our planet is a ball
Novel metaphor	Athletes are cheetahs
Novel metaphor	Surgeons are butchers
Novel metaphor	Tumor is a plague
Novel metaphor	Bankers are vultures
Novel metaphor	History is a mirror
Novel metaphor	The mind is an arena
Novel metaphor	Education is a lantern
Novel metaphor	Dancers are butterflies
Novel metaphor	A judge is a balance
Novel metaphor	Cheaters are snakes
Novel metaphor	Alcohol is a crutch

Novel metaphor	A bribe is a trap
Novel metaphor	Peppers are fire
Novel metaphor	Genes are a lottery
Novel metaphor	Ideas are diamonds
Novel metaphor	Humour is a cure
Literally true	Canada is a country
Literally true	A dog is a pet
Literally true	Obama is a politician
Literally true	Robins are birds
Literally true	Water is a necessity
Literally true	Stealing is a crime
Literally true	Physics is a science
Literally true	Cocaine is a drug
Literally true	Fear is an emotion
Literally true	Coffee is a drink
Literally true	Cancer is a disease
Literally true	The kidney is an organ
Literally true	London is a city
Literally true	News is information
Literally true	Blood is a fluid
Literally true	Testosterone is a hormone
Literally true	Waving is a gesture
Literally true	Twins are siblings
Literally true	Pictures are images
Literally true	Dollars are money
Literally true	The Bible is a book
Literally true	A contract is an agreement
Literally true	The Earth is a planet
Literally true	A tower is a building
Literally true	A leg is a limb
Literally true	Christianity is a religion
Literally true	Sushi is food
Literally true	Wine is a beverage
Literally true	Walmart is a brand
Literally true	McDonald's is a restaurant
Literally true	Winter is a season
Literally true	A fight is a dispute
Literally true	Dinner is a meal
Literally true	Grandparents are adults
Literally true	Hairdressing is a profession
Literally true	A toddler is a child
Literally true	Reading is a skill
Literally true	Christmas is a holiday
Literally true	A lotion is a moisturizer
Literally true	Pines are trees
Literally true	Chess is a game

Literally true	A fridge is an appliance
Literally true	Milk is dairy
Literally true	Boxes are containers
Literally true	A square is a shape
Literally true	Roses are flowers
Literally false	A banana is a kangaroo
Literally false	Stilettos are cookies
Literally false	Potatoes are antlers
Literally false	An owl is a mammal
Literally false	A pantry is a buckle
Literally false	Shoulders are tissues
Literally false	Tunnels are cereals
Literally false	Knees are kettles
Literally false	A clarinet is a bucket
Literally false	A bow is a tremor
Literally false	Salt is gas
Literally false	A cabin is jewelry
Literally false	A ranch is a dress
Literally false	A snake is a cup
Literally false	A basket is a pencil
Literally false	A book is a vegetable
Literally false	A bridge is a fruit
Literally false	A curtain is a machine
Literally false	Diapers are noodles
Literally false	A document is a cucumber
Literally false	A drawer is a stone
Literally false	A leaf is a hammer
Literally false	A lemon is a utensil
Literally false	A piano is a mammal
Literally false	A ruler is a battery
Literally false	A vacuum is a drink
Literally false	A whistle is an animal
Literally false	Bats are plants
Literally false	Brooms are clothing
Literally false	Candles are shoes
Literally false	Meat is technology
Literally false	Squirrels are minerals
Literally false	A stallion is an atrium
Literally false	An attic is a trumpet
Literally false	A wheel is a cube
Literally false	A kidney is a powder
Literally false	Chickens are phones
Literally false	Sticks are crabs
Literally false	A towel is a cork
Literally false	An almond is a sandal
Literally false	Whiskers are cabbages

Literally false	An armour is liquor
Literally false	Zucchinis are predators
Literally false	Candles are collars
Literally false	A lobster is a gun
Literally false	A possum is a heater
Nonsense	Suburbs are eagles
Nonsense	Deception is an angel
Nonsense	A lawyer is a door
Nonsense	The baby is a map
Nonsense	The librarian is a cork
Nonsense	A desk is an oven
Nonsense	A forest is a mouse
Nonsense	A hippopotamus is a dessert
Nonsense	A sauna is a fish
Nonsense	A giraffe is a fountain
Nonsense	A ferry is a spider
Nonsense	A canary is truth
Nonsense	Horoscopes are bulldozers
Nonsense	Auditions are blimps
Nonsense	Mosquitoes are dinosaurs
Nonsense	A ballerina is a war
Nonsense	The camel is a ferret
Nonsense	The toaster is a sponge
Nonsense	A slum is a rocket
Nonsense	The coach is a dart
Nonsense	A seller is research
Nonsense	The genius is a top
Nonsense	Islands are boomerangs
Nonsense	A groupie is a cactus
Nonsense	A boat is a tumor
Nonsense	The casino is a cat
Nonsense	A stick is a boxer
Nonsense	The moat is a bridge
Nonsense	Detectives are fertilizers
Nonsense	A dragster is a fence
Nonsense	The submarine is a violin
Nonsense	Respect is a vampire
Nonsense	Beavers are umbrellas
Nonsense	Crime is an ambassador
Nonsense	A certificate is a virus
Nonsense	A cousin is thunder
Nonsense	Temper is a lamp
Nonsense	A leech is an egg
Nonsense	Hunters are shackles
Nonsense	A cigar is a beach
Nonsense	Diapers are teachers

Nonsense	An aristocrat is a jungle
Nonsense	A blizzard is a beard
Nonsense	Arrows are weeds
Nonsense	A plague is a hawk
Nonsense	An acid is a statue

Chapter 5

General Discussion

5.1 Summary of Projects

This dissertation included three sets of studies, which aimed at testing the possibility that the fields of conceptual combination and metaphor comprehension may be more connected than was previously thought. The premise was to apply theoretical points of view and methodological strategies from one field to the other, building bridges between these two areas that have traditionally been studied separately. The first set of studies focused on noun-noun metaphors; the second set of studies analyzed the relationship between compound word processing and cognitive inhibition; and the third study investigated the relationship between analogical thinking skills and intelligence and metaphor comprehension.

5.1.1 Project 1: Applying What is Known About Compound Words to the Study of Noun-Noun Metaphors

The first set of experiments, which analyzed the processing of noun-noun metaphors (e.g., *helicopter parents*), had three different objectives. The first goal of this study was to investigate whether noun-noun metaphors were semantically equivalent to *X is Y* metaphors (e.g., *Lawyers are sharks*), in the sense that an *X is Y* metaphor can be transformed into its corresponding noun-noun (e.g., *His parents are helicopters* can be transformed into *He has **helicopter parents***) without losing intensity in its figurative meaning (e.g., the parents depicted in *His parents are helicopters* are as overprotective and overbearing as the parents described by saying *He has helicopter parents*). The results presented in this dissertation show that, indeed, the figurative meaning of metaphors does not change depending on the format in which they are presented; in fact, for instance, lawyers are rated as having the same level of aggressiveness regardless of whether they are referred to using the expression *shark lawyers* or the sentence *Lawyers are sharks*. This study had also a second and more important goal, that is, determining the role of the head of noun-noun metaphors (e.g., *leash* in *marriage leash*). The key finding of this study is the fact that it was revealed that the head of noun-noun metaphors plays a crucial role in the speed of processing: Noun-nouns with metaphorical heads (e.g., *marriage leash*) require more time to be comprehended than noun-nouns with literal heads and metaphorical modifiers (e.g., *helicopter parents*). Finally, the third goal of this study was to examine how noun-noun metaphors respond to primes. Knowing that it had previously been established that an *X is Y* metaphor (e.g., *My lawyer is a shark*) that was preceded by a literal prime (e.g., *Sharks can swim*) takes longer to be interpreted, compared to when it is presented alone (Glucksberg, McGlone, & Manfredi, 1997), it seemed logical to examine whether it was more difficult to process a noun-noun metaphor if one of the constituents had previously been used literally (e.g., the hypothesis was that the literal prime *jean patch* would slow down the processing of the figurative expression *soul patch*). Indeed, the results confirmed that noun-noun metaphors respond to literal primes in the same way as *X is Y* metaphors: Giving a literal use to one of the constituents of a noun-noun metaphor slows down the subsequent processing of the noun-noun metaphor itself.

5.1.2 Project 2: Applying What is Known About Metaphor Comprehension to the Study of Compound Words

In the figurative language processing literature, it is well-established that the comprehension of metaphors requires cognitive inhibition because the reader needs to suppress the literal meaning of the vehicle (e.g., to understand *Lawyers are shark*, the reader has to inhibit the definition *marine fish with a cartilaginous skeleton*) (Galinsky & Glucksberg, 2000; George & Wiley, 2016). Given that metaphors and opaque compound words are both considered to be semantically opaque (i.e., the encyclopedic definitions of their constituent parts do not always completely overlap with the intended overall meaning) the second set of experiments presented in this dissertation aimed at investigating whether cognitive inhibition is also involved in the processing of opaque compound words, similarly to what occurs with figurative language. Using an individual differences perspective, it was revealed in this study that readers with high inhibition skills are better at processing both fully opaque (e.g., *hogwash*) and fully transparent (e.g., *birdhouse*) compounds, compared to readers with poor inhibition skills. The involvement of inhibition in the comprehension of both types of compounds was explained as follows: Opaque compounds require inhibition because readers need to suppress the interference coming from the irrelevant meanings of their constituents (e.g., people need to inhibit the meanings of *hog* and *wash* to get to the real meaning of hogwash); on the other hand, transparent compounds require inhibition because their transparency allows for their constituents to contribute to the word's overall meaning in different ways, depending on the relation that connects both elements, so the language system has to decide which relation between the two morphemes to select and which to suppress (e.g., the correct interpretation of *birdhouse* requires the language system to choose the relation *house that is FOR birds* and suppress the other possible relations, such as *house that HAS birds* or *house that IS like a bird*).

5.1.3 Project 3: Applying What is Known About Compound Words to the Study of X is Y Metaphors

In the compound word processing literature, it had historically been assumed that, depending on the level of transparency of a compound word, the cognitive mechanisms involved in accessing and processing the word would be very different. For opaque compound words (e.g., *hogwash*), it was assumed that the meaning would be directly retrieved from memory; for transparent compound words (e.g., *blueberry*), it was assumed that the meaning would be obtained via decomposition into the constituents and using them to access the representation of the compound (Sandra, 1990; Zwitserlood, 1994). However, more recent studies have found that those assumptions were wrong: In fact, all types of compounds, regardless of their level of semantic transparency, seem to involve some degree of decomposition and meaning construction (Fiorentino & Poeppel, 2007; Gagné & Spalding, 2009; Ji, Gagné, & Spalding, 2011). Similarly, in the metaphor processing literature, it has been assumed that, depending on the level of conventionality of a metaphor, the cognitive mechanisms involved would also be very different. For conventional metaphors, it was assumed that they would need categorization processes; for novel metaphors, it was assumed that they would need analogy and structure mapping (Bowdle & Gentner, 2005). However, it is possible that, in the same way that it has recently been revealed that decomposition is involved in the comprehension of all types of compounds, analogy is also involved in the comprehension of all types of metaphors, regardless of their level of conventionality. Therefore, the goal of the third study, which also used an individual differences perspective, was to analyze the involvement of analogical thinking in metaphor comprehension. The results of this study have shown that all metaphors, regardless of their level of conventionality, need analogy, and not merely general intelligence, in order to be correctly comprehended. In fact, readers with high analogical thinking skills are better at correctly interpreting both novel (e.g., *Science is an iceberg*) and conventional metaphors (e.g., *Time is money*), compared to participants with poor analogical thinking skills. It was also found that having high IQ was not related to being faster or more accurate at understanding metaphors.

5.2 How the Results of This Dissertation Contributed at Building Bridges Between the Fields of Conceptual Combination and Metaphor Processing

In the Introduction, I pointed out four commonalities that the fields of compound word processing and metaphor comprehension shared: a theoretical similarity, a structural similarity, a semantic similarity, and a cognitive similarity. In the next paragraphs, I will address again, one by one, these four commonalities and explain how the three sets of studies that are part of this dissertation have contributed to highlighting the connections between these two domains that have traditionally been studied separately.

First, from a theoretical point of view, the fields of compound word processing and metaphor comprehension were for decades dominated by debates around the dichotomy between decomposition and retrieval from memory: In the same way that researchers wondered for many years if opaque compound words (e.g., *hogwash*) were decomposed into their constituents or, on the contrary, were simply retrieved from memory (Ji et al., 2011; Libben, 1998; Libben, Gibson, Yoon, & Sandra, 2003; Sandra, 1990; Zwitserlood, 1994), psycholinguists working in the domain of figurative language were for a long time intrigued by the question of whether crystalized metaphors (e.g., *Time is money*) are understood through a word-by-word analysis of their constituents (Clark & Lucy, 1975; Glucksberg, 1998; Searle, 1979) or are retrieved from memory

(Gibbs, 1979; Gibbs, 1989; Mashal, 2013) like idioms (Libben & Titone, 2008; Titone, Columbus, Whitford, Mercier, & Libben, 2014). It is curious to note that both fields followed similar theoretical paths. Traditionally, opaque compound words were thought to involve meaning retrieval from memory, given that they are crystalized noun-noun phrases whose constituents are unrelated to the meaning of the whole word; only later, research revealed that, in fact, even opaque compound words involve decomposition into constituents and attempts at meaning computation. In other words, the history of the study of compound words can be summarized as follows: At the beginning, researchers were convinced that opaque compound words were radically different from transparent compound words in terms of the mechanisms underlying their comprehension, in the sense that scientists believed that only transparent compounds could be broken down into their constituents during comprehension; however, psycholinguists realized later that all compound words, regardless of their opacity, involve analyses of their constituents and attempts of combining them to construct an overall meaning. Analogously, for a long time it was thought that conventional and novel metaphors required radically different cognitive processes: Conventional metaphors (e.g., *Time is money*) were thought to simply require including the topic inside a general category designated by the vehicle (e.g., *time* goes inside the category of valuable things, represented by the word *money*), whereas only novel metaphors (e.g., *Science is an iceberg*) were thought to require a word-by-word analysis that involved exhaustively comparing the topic and the vehicle until finding a shared feature (Bowdle & Gentner, 2005). Once again, only later, did researchers realize that novel and conventional metaphors are more similar than previously thought and that both share underlying cognitive mechanisms (Stamenkovic, Ichien, & Holyoak, 2019). Similarly, the third set of studies presented in this dissertation established that, in the same way that decomposition and meaning computation are involved in the processing of not only transparent, but also opaque compound words, analogical thinking is necessary for the comprehension of not only novel but also conventional metaphors. In sum, the third set of studies put in evidence that the dichotomy between decomposition into constituents or words, and meaning retrieval from memory that governed the metaphor and compound word literatures is actually not valid, because it is impossible for the language system to know beforehand if a compound word or a metaphor that is encountered is transparent or opaque, or novel or conventional, respectively, before even being processed.

The second commonality between compound words and metaphors that was highlighted in the introduction is structural: Both types of phrases are composed of two key constituents, that is, a head and a modifier in the case of compound words, and a topic and a vehicle in the case of metaphors. The first set of experiments presented in this dissertation showed that there exists a type of phrase that is actually a hybrid between *X is Y* metaphors (e.g., *His parents are helicopters*) and open compound words (i.e., compound words separated by a space, such as *coffee cup*): noun-noun metaphors (e.g., *helicopter parents*), which, despite being abundant in everyday language (e.g., *tiger mom*, *gold digger*, *sugar daddy*), have been relatively understudied in the field of psycholinguistics (Ferguson, Forbus, & Gentner, 1997; Gagné, 2002; Jia, Zan, Fan, Yu, & Wang, 2014). In noun-noun metaphors, the vehicle generally becomes the modifier and the topic becomes the head. The first set of studies has established that these metaphors presented in a more compact, compound-like format, are in fact as figurative as the standard-formatted *X is Y* metaphors. More importantly, it was confirmed that noun-noun metaphors behave like compound words in the sense that their head (e.g., *leash* in *marriage leash*) determines the ease of processing of this type of phrase. In the same way that compound words with semantically opaque heads (e.g., *jailbird*) are harder to process than compound words with semantically transparent heads (e.g., *strawberry*) (Ji et al., 2011; Libben et al., 2003), noun-noun metaphors with figurative heads (e.g., *marriage leash*) are harder to process that noun-noun metaphors with literal heads and metaphorical modifiers (e.g., *tiger mom*). This leads us to the third commonality between compound words and metaphors pointed out in the introduction: semantic opacity.

The third feature shared by compound words and metaphors is semantic: Both types of phrases vary in the degree in which their constituent words are related to the overall meaning. In the case of compound words, they can be classified on a continuum of semantic transparency, depending on how easily the overall meaning of the word can be extracted from the meaning of the constituent morphemes, with fully transparent compounds (e.g., *snowball*) on one end and fully opaque compounds (e.g., *hogwash*) on the other (Libben, 1998; Gagné, Spalding, & Schmidtke, 2019). In an equivalent way, metaphors can vary in their level of conventionality, ranging from easily understandable (e.g., *Time is money*) to very ingenious and requiring more effort to be comprehended (e.g. *Universities are ladders*) (Marschark, Katz, & Paivio, 1983). In that sense, the first set of experiments of this dissertation has suggested the idea that figurativeness in metaphors is analogous to semantic opacity in compound words, in that both require additional mental effort that goes beyond simply remembering the encyclopedic definitions of their constituent parts.

The last commonality between compound words and metaphors that was introduced in this dissertation is related to the cognitive skills involved in the processing of these two types of phrases. More specifically, I suggested that, in the same way that it has been widely demonstrated that figurative language processing requires cognitive inhibition in order to suppress the irrelevant literal meanings from the individual words composing the figurative expression (Glucksberg, Newsome, & Goldvarg, 2001; Iakimova, Passerieux, & Hardy-Bayle, 2006), it was possible that opaque compound words, given that they are not semantically transparent either and also require suppression of the irrelevant meanings of the constituents, require inhibition too. Interestingly, the results of the second set of studies demonstrated that the processing of not only opaque but also transparent compounds require inhibition skills. Indeed, opaque compound words need inhibition to be comprehended because the reader needs to suppress the irrelevant meaning of the constituents (e.g., *hog* and *wash* in *hogwash*) to get to the word's real meaning (e.g., *nonsense*); on the other hand, transparent compounds need inhibition because the reader has to decide the relation that would correctly connect the two constituents that do contribute to the word's overall meaning (e.g., *pot FOR tea* in *teapot*, and not *pot MADE OF tea* or *pot that HAS tea*). The results of the second set of experiments of this dissertation seem to indicate that, whenever there are several meanings that arise and compete, and the language system has to make a decision to choose the correct interpretation, inhibition is recruited, and this is the case not only for figurative language such as metaphors, but also for "regular" literal language such as compound words.

5.3 The Theoretical Implications of This Dissertation

The findings introduced in this dissertation have several theoretical implications. In the next paragraphs I will explain how these studies have helped understand that the fields of metaphor comprehension and conceptual combination should be more mutually influenced.

5.3.1 How Could the Field of Metaphor Comprehension Benefit From Findings in the Field of Conceptual Combination?

The first implication that these studies have for the field of metaphor comprehension is related to the fact that it was revealed that figurativeness is a type of semantic opacity and that knowledge about the role of the head in literal noun-noun phrases can be applied to the study of noun-noun metaphors. More specifically, theories of metaphor need to start considering theories of conceptual combination. For instance, the metaphor processing literature should, in the future, incorporate the idea that the head and a modifier of a noun-noun metaphor can be connected through different relations (Gagné & Shoben, 1997) (e.g., *sugar baby* refers to a "baby" that GETS "sugar" and not to a baby that is MADE OF sugar or a baby that IS sugar; *helicopter parents* refer to parents that ARE LIKE helicopters and not to parents that HAVE helicopters).

The fact that the speed and accuracy of noun-noun metaphors depend heavily on the head's opacity, and the fact that the processing of noun-noun metaphors may involve the right selection of the relation that connects the head and the modifier suggest that metaphors and compounds may share several underlying mechanisms. This leads us to the second implication for the field of metaphor processing: the realization that, in fact, metaphors are not that "special" in the sense that they are not very different from what is considered "normal" or "literal" language. Actually, Gernsbacher, Keysar, Robertson and Werner (2001) have previously suggested that metaphor interpretation requires what they call "general comprehension mechanisms", such as suppression or inhibition of confusing information, just like in any act of understanding, including the understanding of simple literal compound words, as was demonstrated in this dissertation.

A third way in which the field of metaphor comprehension would benefit from the findings in conceptual combination literature is related to the concept of language efficiency. It is well-known that novel expressions that are used repeatedly acquire, over time, a shortened format and become crystallized for the sake of communication efficiency (Krauss & Weinheimer, 1964). This is what occurred with compound words (e.g., *the bell that is by the door* became *doorbell*). Moreover, it has also been demonstrated that when people are presented with full phrases to describe a novel concept (e.g., *the dog that is blue*), they naturally tend to refer back to it using the shortened noun-noun version (e.g., *blue dog*) (Gagné, Spalding, Burry, & Adams, 2020). It is very interesting to note that there is some evidence that this process of shortening and crystallization over time may also be behind the creation of noun-noun metaphors (e.g., at the beginning, someone may have come up with the novel comparison *His parents behave like helicopters*, which later became popular and was used so many times that it turned into the shorter version *helicopter parents*) (Sana, Park, Burry, Gagné, & Spalding, 2018). Therefore, I suggest that, in the same way that literal compound words originated once as the simplest and most efficient way to convey new meaning (e.g., *tea* and *cup* were once combined to refer more efficiently to the concept *cup that is used to serve tea*), noun-noun metaphors may have also appeared as means of communicating very complex ideas in a succinct way. In fact, in the *X is Y* metaphor processing literature, it has already been stated that metaphors, far from being purely adorning figures of style that serve poetic purposes, are actually necessary for efficient communication. This idea that metaphors are not only "nice", but rather essential for efficiently stating the intending meaning, has been referred to as the *compactness thesis* (Ortony, 1975; Katz, 1996).

5.3.2 How Could the Field of Conceptual Combination Benefit From Findings in the Field of Metaphor Comprehension?

The studies presented in this dissertation also have implications for the conceptual combination theories. First, if opacity in compound words and figurativeness in metaphors are analogous, then more in-depth analyses are necessary to study more specifically how the subtype of compound words that have constituents that are used metaphorically (e.g., *bird* in *jailbird* or *dead* in *deadline* are used figuratively) are processed. In that sense, researchers in the area of conceptual combination need to further build on Mullaly, Gagné, Spalding and Marchak's (2010) pioneering study of ambiguous adjective-noun phrases, which addressed the fact that some adjective-noun phrase (e.g., *green bus*) have double meanings: one that is literal (e.g., a bus whose colour is green) and another that is figurative (e.g., a bus that is less polluting).

Second, given that is has been suggested that noun-noun phrases and metaphors may share many underlying mechanisms, researchers working in the field of conceptual combination need to find ways of testing this idea with cognitive data. The idea that noun-noun combinations and metaphors may involve the same cognitive processes was initially introduced by Wisniewski (1997), who stated that the processing of noun-nouns require comparison and meaning construction that lead to novel feature emergence, just like metaphors. Wisniewski supported his claim providing data of participants' interpretations, whereas, in this dissertation, I have presented rating, speed and accuracy data that suggest that noun-nouns and metaphors are more similar than previously thought.

5.4 Conclusions

This dissertation has highlighted the fact that metaphors and compound words are similar from a theoretical, a structural, a semantic and a cognitive point of view, and has emphasized the importance of further connecting the fields of figurative language comprehension and conceptual combination in such a way that methods and findings originating from one area can motivate new research in the other. Actually, I have pointed out that metaphors and compound words are so similar that, in the intersection of these two areas of study, there exists a perfect hybrid: noun-noun metaphors, that is, compound-like metaphors, which truly deserve more attention from psycholinguists. I anticipate that in the near future noun-noun metaphors will inspire a new fruitful line of research that will encourage scientists from different backgrounds to join forces to further investigate this relatively unexplored land.

5.5 References

Bowdle, B. F., & Gentner, D. (2005). The career of metaphor. *Psychological Review*, *112*(1), 193-216.

Clark, H. H., & Lucy, P. (1975). Understanding what is meant from what is said: A study in conversationally conveyed requests. *Journal of Verbal Learning & Verbal Behavior, 14*(1), 56–72.

Ferguson, R., Forbus, K., & Gentner, D. (1997). On the proper treatment of noun-noun metaphor: A Critique of the Sapper model. In M. G. Shafto & P. Langley (Eds.), *Proceedings of the 19th Annual Meeting of the Cognitive Science Society* (pp. 913). Mahwah, NJ: Cognitive Science Society.

Fiorentino, R., & Poeppel, D. (2007). Compound words and structure in the lexicon. *Language and Cognitive Processes, 22*(7), 953–1000.

Gagné, C. L. (2002). Metaphoric interpretations of comparison-based combinations. *Metaphor and Symbol, 17*(3), 161-178.

Gagné, C. L., & Shoben, E. J. (1997). Influence of thematic relations on the comprehension of modifier–noun combinations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23*(1), 71–87.

Gagné, C. L., & Spalding, T. L. (2009). Constituent integration during the processing of compound words: Does it involve the use of relational structures? *Journal of Memory and Language, 60*(1), 20-35.

Gagné, C. L., Spalding, T. L., Burry, J. C., & Adams. J. T. (2020). Production of multiword referential phrases: Inclusion of over-specifying information and a preference for modifier-noun phrases. In Sabine Schulte im Walde & Eva Smolka

(Eds.), *The role of constituents in multiword expressions: An interdisciplinary, cross-lingual perspective*, 155–178. Berlin: Language Science Press.

Gagné, C.L., Spalding, T.L., & Schmidtke, D. (2019). LADEC: The Large Database of English Compounds. *Behavior Research Methods, 51,* 2152–2179.

Galinsky, A. D., & Glucksberg, S. (2000). Inhibition of the literal: Metaphors and idioms as judgmental primes. *Social Cognition, 18*(1), 35–54.

George, T., & Wiley, J. (2016). Forgetting the literal: The role of inhibition in metaphor comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 42*(8), 1324–1330.

Gernsbacher, M. A., Keysar, B., Robertson, R. R., & Werner, N. K. (2001). The role of suppression and enhancement in understanding metaphors. *Journal of Memory and Language, 45*(3), 433–450.

Gibbs, R. (1979). Contextual effects in understanding indirect requests. *Discourse Processes, 2*, 1-10.

Gibbs, R. (1989). Understanding and literal meaning. *Cognitive Science*, *13*(2), 243–251.

Glucksberg, S. (1998). Understanding metaphors. *Current Directions in Psychological Science, 7*(2), 39–43.

Glucksberg, S., McGlone, M. S., & Manfredi, D. (1997). Property attribution in metaphor comprehension. *Journal of Memory and Language, 36*(1), 50-67.

Glucksberg, S., Newsome, M., & Goldvarg, Y. (2001). Inhibition of the literal: Filtering metaphor-irrelevant information during metaphor comprehension. *Metaphor and Symbol, 16*, 277–293.

Iakimova, G., Passerieux, C., & Hardy-Bayle, M. C. (2006). The understanding of metaphors in schizophrenia and depression. An experimental approach. *Encephale*, *32*, 995-1002.

Ji, H., Gagné, C. L., & Spalding, T. L. (2011) Benefits and costs of lexical decomposition and semantic integration during the processing of transparent and opaque English compounds. *Journal of Memory and Language, 65,* 406-430.

Jia, Y., Zan, H., Fan, M., Yu, S., & Wang, Z. (2014). Word Relevance Computation for Noun-Noun Metaphor Recognition. In Su X., He T. (Eds.), *Chinese Lexical Semantics. CLSW 2014. Lecture Notes in Computer Science* (pp. 251-259). Switzerland: Springer, Cham.

Katz, A. (1996). On interpreting statements as metaphor or irony: Contextual heuristics and cognitive consequences. In J. Mio & A. Katz (Eds), *Metaphor: Implication and applications*. Mahwah, NJ: Lawrence Erlbaum.

Krauss, R. M., & Weinheimer, S. (1964). Changes in reference phrases as a function of frequency of usage in social interaction: A preliminary study. *Psychonomic Science, 1*(5), 113–114.

Libben, G. (1998). Semantic transparency in the processing of compounds: Consequence for representation, processing, and impairment. *Brain and Language, 61*(1), 30–44.

Libben, G., Gibson, M., Yoon, Y. B., & Sandra, D. (2003). Compound fracture: The role of semantic transparency and morphological headedness. *Brain and Language, 84*(1), 50–64.

Libben, M. R., & Titone, D. A. (2008). The multidetermined nature of idiom processing. *Memory & Cognition, 36*(6), 1103–1121.

Marschark. M., Katz, A., & Paivio, A. (1983). Dimensions of metaphor. *Journal of Psycholinguistic Research*, *22*, 17-40.

Mashal, N. (2013). The role of working memory in the comprehension of unfamiliar and familiar metaphors. *Language and Cognition, 5*(4), 409-436.

Mullaly, A., Gagné, C., Spalding, T., & Marchak, K. (2010). Examining ambiguous adjectives in adjective-noun phrases: Evidence for representation as a shared core-meaning with sense specialization. *The Mental Lexicon*, *5*, 87-114.

Ortony, A. (1975). Why Metaphors Are Necessary and Not Just Nice. *Educational Theory*, *25*(1), 45-53.

Sana, F., Park, J., & Burry, J.C., Gagné, C.L. & Spalding, T.L. (2018, September). *How does syntactic form and conventionality affect metaphor production?* Poster session presented at the 11th International Mental Lexicon Conference, Edmonton, AB.

Sandra, D. (1990). On the representation and processing of compound words: Automatic access to constituent morphemes does not occur. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 42*(3-A), 529–567.

Searle, J. (1979). Metaphor. In: A. Ortony (Ed.) *Metaphor and Thought* (pp. 92-123). New York: Cambridge University Press.

Stamenkovic, D., Ichien, N., & Holyoak, K. (2019). Metaphor comprehension: An individual-differences approach. *Journal of Memory and Language*, *105*, 108-118.

Titone, D., Columbus, G., Whitford, V., Mercier, J., & Libben, M. (2015). Contrasting bilingual and monolingual idiom processing. In R. R. Heredia & A. B. Cieślicka (Eds.), *Bilingual figurative language processing* (p. 171–207). Cambridge University Press.

Wisniewski, E. J. (1997) When concepts combine. *Psychonomic Bulletin & Rev*iew, *4*, 167–183.

Zwitserlood, P. (1994). The role of semantic transparency in the processing and representation of Dutch compounds. *Language and Cognitive Processes, 9*(3), 341–368.

Bibliography

Adachi, T., Koeda, T., Hirabayashi, S., Maeoka, Y., Shiota, M., Wright, C. E., & Wada, A. (2004). The metaphor and sarcasm scenario test: A new instrument to help differentiate high functioning pervasive developmental disorder from attention deficit/hyperactivity disorder. *Brain & Development*, *26*, 301–306.

Aisenman, R. A. (1999). Structure-mapping and the simile-metaphor preference. *Metaphor and Symbol, 14*(1), 45–51.

Al-Azary, H., Buchanan, L. (2017). Novel metaphor comprehension: Semantic neighbourhood density interacts with concreteness. *Memory & Cognition*, *45*, 296–307.

Al-Azary, H., McAuley, T., Buchanan, L., & Katz, A. N. (2019). Semantic processing of metaphor: A case-study of deep dyslexia. *Journal of Neurolinguistics, 51,* 297–308.

Arzouan, Y., Goldstein, A., & Faust, M. (2007). Brainwaves are stethoscopes: ERP correlates of novel metaphor comprehension. *Brain Research, 1160*, 69-81.

Baayen, R. H., Wurm, L. H., & Aycock, J. (2007). Lexical dynamics for low-frequency complex words: A regression study across tasks and modalities. *The Mental Lexicon, 2,* 419–463.

Barnes-Holmes, Y., Hayes, S. C., Barnes-Holmes, D., & Roche, B. (2001). Relational frame theory: A post-Skinnerian account of human language and cognition. In H. W. Reese & R. Kail (Eds.), *Advances in child development and behavior* (pp. 101–138). Academic Press.

Bauer, L. (1988). *Introducing linguistic morphology*. Edinburgh: Edinburgh University

Press.

Beaty, R. E., & Silvia, P. J. (2013). Metaphorically speaking: Cognitive abilities and the production of figurative language. *Memory & Cognition, 41*(2), 255-267.

Benedek, M., Beaty, R.E., Jauk, E., Koschutnig, K., Fink, A., Silvia, P.J., Dunst, B., & Neubauer, A.C. (2013). Creating metaphors: The neural basis of figurative language production. *NeuroImage*, *90*, 99-106.

Benedek, M., Franz, F., Heene, M., & Neubauer, A. C. (2012). Differential effects of cognitive inhibition and intelligence on creativity. *Personality and Individual Differences, 53*(4), 480–485.

Bisiach, E., Mini, M., Sterzi, R., & Vallar, G. (1982). Hemispheric lateralization of the decisional stage in choice reaction times to visual unstructured stimuli. *Cortex, 18*(2), 191-197. https://doi.org/https://doi.org/10.1016/S0010-9452(82)80002-6

Bjorklund, D. F., & Harnishfeger, K. K. (1990). The resources construct in cognitive development: Diverse sources of evidence and a theory of inefficient inhibition. *Developmental Review, 10*(1), 48-71.

Bowdle, B. F., & Gentner, D. (2005). The career of metaphor. *Psychological Review*, *112*(1), 193-216.

Brennan, S. E., & Clark, H. H. (1996). Conceptual pacts and lexical choice in conversation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*(6), 1482-1493.

Brooks, T. L., & Cid de Garcia, D. (2015). Evidence for morphological composition in compound words using MEG. *Frontiers in human neuroscience*, *9*, 215. https://doi.org/10.3389/fnhum.2015.00215

Brysbaert, M., & New, B. (2009). Moving beyond Kuçera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods*, *41*(4), 977–990.

Bugg, J. M., Jacoby, L. L., & Toth, J. P. (2008). Multiple levels of control in the Stroop task. *Memory & Cognition, 36*(8), 1484–1494.

Cacciari, C., & Glucksberg, S. (1991). Understanding idiomatic expressions: The contribution of word meanings. In G. B. Simpson (Ed.), *Advances in psychology, No. 77. Understanding word and sentence* (pp. 217–240). North-Holland.

Carriedo, N., Corral, A., Montoro, P. R., Herrero, L., Ballestrino, P., & Sebastián, I. (2016). The development of metaphor comprehension and its relationship with relational verbal reasoning and executive function. *PLoS ONE, 11*(3). Article ID e0150289.

Chiappe, D. L., & Chiappe, P. (2007). The role of working memory in metaphor production and comprehension. *Journal of Memory and Language, 56*(2), 172–188.

Chiappe, D., Kennedy, J., & Chiappe, P. (2003). Aptness is more important than comprehensibility in preference for metaphors and similes. *Poetics*, *31*, 51-68.

Chomsky, N. (1959). A review of B. F. Skinner's Verbal Behavior. *Language*, *35*(1), 26–58.

Chouinard, B., Volden, J., Hollinger, J., & Cummine, J. (2019). Spoken metaphor comprehension: Evaluation using the metaphor interference effect. *Discourse Processes*, *56*(3), 1-18.

Clark, H. H., & Lucy, P. (1975). Understanding what is meant from what is said: A study in conversationally conveyed requests. *Journal of Verbal Learning & Verbal Behavior, 14*(1), 56–72.

Clark, H. H., & Wilkes-Gibbs, D. (1986). Referring as a collaborative process. *Cognition*, *22*, 1-39.

Cohen, H., & Rémillard, S. (2006). Autism and Asperger Syndrome: A spectrum of disability. In K. Brown (Ed.), *Encyclopedia of Language and Linguistics* (2nd ed., pp. 617–621). Oxford, UK: Elsevier.

Colston, H. L., & Gibbs, R. W., Jr. (2007). A brief history of irony. In R. W. Gibbs, Jr. & H. L. Colston (Eds.), *Irony in language and thought: A cognitive science reader* (pp. 3–21). Lawrence Erlbaum Associates Publishers.

Columbus, G., Sheikh, N. A., Côté-Lecaldare, M., Häuser, K., Baum, S. R., & Titone, D. (2015). Individual differences in executive control relate to metaphor processing: An eye movement study of sentence reading. *Frontiers in Human Neuroscience, 8,* Article 1057.

Corballis, M. C. (1992). On the evolution of language and generativity. *Cognition, 44*(3), 197–226.

Durgin, F. H. (2000). The reverse Stroop effect. *Psychonomic Bulletin & Review, 7*(1), 121–125.

El-Bialy, Rowan, Gagné, C. L. & Spalding, T. L. 2013. Processing of English compounds is sensitive to the constituents' semantic transparency. *The Mental Lexicon* 8. 75–95.

Engle, Kane & Tuholski (1999). Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence and functions of the prefrontal cortex. In Miyake, A. & Shah, P. (Eds.), *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control* (pp.102-134). London: Cambridge Press.

Enright, S. J., & Beech, A. R. (1990). Obsessional states: Anxiety disorders or schizotypes? An information processing and personality assessment. *Psychological Medicine, 20*(3), 621-627.

Estes, Z. (2003). A tale of two similarities: Comparison and integration in conceptual combination. *Cognitive Science*, *27*(6), 911–921.

Estes, Z., & Glucksberg, S. (2000). Interactive property attribution in concept combination. *Memory & Cognition, 28*(1), 28–34.

Ferguson, R., Forbus, K., & Gentner, D. (1997). On the proper treatment of noun-noun metaphor: A Critique of the Sapper model. In M. G. Shafto & P. Langley (Eds.), *Proceedings of the 19th Annual Meeting of the Cognitive Science Society* (pp. 913). Mahwah, NJ: Cognitive Science Society.

Fiorentino, R., & Poeppel, D. (2007). Compound words and structure in the lexicon. *Language and Cognitive Processes, 22*(7), 953–1000.

Fodor, J., & Lepore, E. (1996). The red herring and the pet fish: Why concepts still can't be prototypes. *Cognition, 58*(2), 253–270.

Forgács, B., Bardolph, M. D., Amsel, B. D., DeLong, K. A., & Kutas, M. (2015). Metaphors are physical and abstract: ERPs to metaphorically modified nouns resemble ERPs to abstract language. *Frontiers in Human Neuroscience, 9,* Article 28.

Frisson, S., & Pickering, M. J. (1999). The processing of metonymy: Evidence from eye movements. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*(6), 1366–1383.

Frith, C. D. (1979). Consciousness, information processing, and schizophrenia. *British Journal of Psychiatry*, *134*, 225–35.

Gagné, C. L. (2000). Relation-based combinations versus property-based combinations: A test of the CARIN theory and the dual-process theory of conceptual combination. *Journal of Memory and Language*, *42*, 365-389.

Gagné, C. L. (2002). Metaphoric interpretations of comparison-based combinations. *Metaphor and Symbol, 17*(3), 161-178.

Gagné, C., Friedman, A., & Faries, J. (1996). Effect of priming on the comprehension of predicative metaphors. *Metaphor & Symbolic Activity, 11*(2), 125–143.

Gagné, C. L., & Shoben, E. J. (1997). Influence of thematic relations on the comprehension of modifier-noun combinations. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *23*, 71-87.

Gagné, C. L. & Spalding, T. L. (2006). Using conceptual combination research to better understand novel compound words. *SKASE Journal of Theoretical Linguistics, 3*, 9-16.

Gagné, C. L., & Spalding, T. L. (2009). Constituent integration during the processing of compound words: Does it involve the use of relational structures? *Journal of Memory and Language, 60*(1), 20–35.

Gagné, C., & Spalding, T. (2014). Typing time as an index of morphological and semantic effects during English compound processing. *Lingue e Linguaggio*, *13*(2), 241-262.

Gagné, C. L., & Spalding, T. L. (2016). Written production of English compounds: effects of morphology and semantic transparency. *Morphology*, *26*(2), 133-155. doi:10.1007/s11525-015-9265-0

Gagné, C. L., Spalding, T. L., Burry, J. C., & Adams, J. T. (2020). Production of multi-word referential phrases: Inclusion of over-specifying information and a preference for modifier-noun. In S. Schulte im Walde & E. Smolka (Eds.). *The role of constituents in multiword expressions: An interdisciplinary, cross-lingual approach* (pp. 135-158). Berlin: Language Science Press.

Gagné, C. L., Spalding, T. L., & Gorrie, M. C. (2005). Sentential Context and the Interpretation of Familiar Open-Compounds and Novel Modifier-Noun Phrases. *Language and Speech*, *48*(2), 203–219.

Gagné, C.L., Spalding, T.L., & Schmidtke, D. (2019). LADEC: The Large Database of English Compounds. *Behavior Research Methods, 51,* 2152–2179.

Gagné, C. L., Spalding, T. L., Spicer, P., Wong, D., Rubio, B., & Cruz, K. P. (2020). Is buttercup a kind of cup? Hyponymy and semantic transparency in compound words. *Journal of Memory and Language, 113*. https://doi.org/10.1016/j.jml.2020.104110

Galinsky, A. D., & Glucksberg, S. (2000). Inhibition of the literal: Metaphors and idioms as judgmental primes. *Social Cognition, 18*(1), 35–54.

Garrod, S., & Anderson, A. (1987). Saying what you mean in dialogue: A study in conceptual and semantic co-ordination. *Cognition*, *27*(2), 181-218.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive*

Science, *7*, 155-170.

Gentner, D., & Wolff, P. (1997). Alignment in the processing of metaphor. *Journal of Memory and Language, 37*(3), 331-355.

George, T., & Wiley, J. (2016). Forgetting the literal: The role of inhibition in metaphor comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 42*(8), 1324–1330.

Gernsbacher, M. A., Keysar, B., Robertson, R. R., & Werner, N. K. (2001). The role of suppression and enhancement in understanding metaphors. *Journal of Memory and Language, 45*(3), 433–450.

Gibbs, R. (1979). Contextual effects in understanding indirect requests. *Discourse Processes, 2*, 1-10.

Gibbs, R. (1989). Understanding and literal meaning. *Cognitive Science*, *13*(2), 243–251.

Gibbs, R. (2008). Metaphor and thought: The state of the art. In R. W. Gibbs, Jr. (Ed.), *The Cambridge handbook of metaphor and thought* (pp. 3–13). Cambridge University Press.

Gibbs, R. (2011). Multiple constraints in theories of metaphor. *Discourse Processes*, *48*(8), 575–584.

Gignac, G. E., & Vernon, P. A. (2004). Reaction time and the dominant and non-dominant hands: An extension of Hick's Law. *Personality and Individual Differences, 36*(3), 733-739. https://doi.org/10.1016/s0191-8869(03)00133-8

Giora, R. (1995). On irony and negation. *Discourse Processes, 19*(2), 239-264.

Glucksberg, S. (1998). Understanding metaphors. *Current Directions in Psychological Science, 7*(2), 39–43.

Glucksberg, S. (2003). The psycholinguistics of metaphor. *Trends in Cognitive Sciences, 7*(2), 92-96.

Glucksberg, S., & Keysar, B. (1990). Understanding metaphorical comparisons: Beyond similarity. *Psychological Review, 97*(1), 3-18.

Glucksberg, S., McGlone, M. S., & Manfredi, D. (1997). Property attribution in metaphor comprehension. *Journal of Memory and Language, 36*(1), 50-67.

Glucksberg, S., Newsome, M., & Goldvarg, Y. (2001). Inhibition of the literal: Filtering metaphor-irrelevant information during metaphor comprehension. *Metaphor and Symbol, 16*, 277–293.

Goldvarg, Y., & Glucksberg, S. (1998). Conceptual combinations: The role of similarity. *Metaphor and Symbol, 13*(4), 243–255.

Gottfried, G. M. (1997). Using metaphors as modifiers: Children's production of metaphoric compounds. *Journal of Child Language, 24*(3), 567–601.

Happé, F. G. E. (1993). Communicative competence and theory of mind in autism: A test of relevance theory. *Cognition*, *48*, 101–119.

Happé, F. G. E. (1994). An advanced test of theory of mind: Understanding of story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. *Journal of Autism and Developmental Disorders*, *24*, 129–154.

Happé, F. G. E. (1995). The role of age and verbal ability in the theory of mind task performance of subjects with autism. *Child Development*, *66*, 843–855.

Hasenäcker, J., & Schroeder, S. (2019). Compound reading in German: Effects of constituent frequency and whole-word frequency in children and adults. *Journal* *of Experimental Psychology: Learning, Memory, and Cognition, 45*(5), 920–933.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The Psychology of Learning and Motivation, Vol. 22* (pp. 193-225). New York, NY: Academic Press.

Hasher, L., Zacks, R. T., & May, C. P. (1999). Inhibitory control, circadian arousal, and age. In D. Gopher & A. Koriat (Eds.), *Attention & Performance, XVII, Cognitive Regulation of Performance: Interaction of Theory and Application* (pp. 653-675). Cambridge, MA: MIT Press.

Holyoak, K. J., & Stamenković, D. (2018). Metaphor comprehension: A critical review of theories and evidence. *Psychological Bulletin, 144*(6), 641-671.

Horga, G., & Maia, T. V. (2012). Conscious and unconscious processes in cognitive control: a theoretical perspective and a novel empirical approach. *Frontiers in Human Neuroscience, 6*.

Hyönä, J. (2015). Are polymorphemic words processed differently from other words during reading? In A. Pollatsek & R. Treiman (Eds.), *Oxford library of psychology. The Oxford handbook of reading* (p. 114–128). Oxford University Press.

Hyönä, J., & Pollatsek, A. (2000). Processing of Finnish compound words in reading. In A. Kennedy, R. Radach, D. Heller, & J. Pynte (Eds.), *Reading as a perceptual process* (pp. 65–87). North-Holland/Elsevier Science Publishers.

Iakimova, G., Passerieux, C., & Hardy-Bayle, M. C. (2006). The understanding of metaphors in schizophrenia and depression. An experimental approach. *Encephale*, *32*, 995-1002.

Imbrosciano, A., & Berlach, R. (2006). The Stroop test and its relationship to academic performance and general behaviour of young students. *Teacher Development*, *9*, 131-144.

Jarema, G. (2006). Compound representation and processing: A cross-language perspective. In G. Libben & G. Jarema (Eds.), *The representation and processing of compound words* (pp. 45-70). Oxford University Press.

Ji, H., Gagné, C. L., & Spalding, T. L. (2011) Benefits and costs of lexical decomposition and semantic integration during the processing of transparent and opaque English compounds. *Journal of Memory and Language, 65,* 406-430.

Jia, Y., Zan, H., Fan, M., Yu, S., & Wang, Z. (2014). Word Relevance Computation for Noun-Noun Metaphor Recognition. In: Su X., He T. (Eds.), *Chinese Lexical Semantics. CLSW 2014. Lecture Notes in Computer Science* (pp. 251-259). Switzerland: Springer, Cham.

Jones, L. L., & Estes, Z. (2005). Metaphor comprehension as attributive categorization. *Journal of Memory and Language, 53*(1), 110-124.

Jones, L. L., & Estes, Z. (2006). Roosters, robins, and alarm clocks: Aptness and conventionality in metaphor comprehension. *Journal of Memory and Language, 55*(1), 18–32.

Joormann, J., Yoon, K. L., Zetsche, U. (2007). Cognitive inhibition in depression. *Applied and Preventive Psychology*, *12*, 128–139.

Juhasz, B. J. (2007). The influence of semantic transparency on eye movements during English compound word recognition. In R. von Gompel, W. Murray, & M. Fischer (Eds.), *Eye movements: A window on mind and brain* (pp. 373–

389). Boston, MA: Elsevier.

Juhasz, B. J. (2008). The processing of compound words in English: Effects of word length on eye movements during reading. *Language and Cognitive Processes, 23*(7-8), 1057–1088.

Kaland, N., Møller-Nielsen, A., Callesen, K., Mortensen, E. L., Gottlieb, D., & Smith, L. (2002). An 'advanced' test of theory of mind: Evidence from children and adolescents with Asperger syndrome. *Journal of Child Psychology and Psychiatry*, *43*, 517–528.

Kazmerski, V. A., Blasko, D. G., & Dessalegn, B. G. (2003). ERP and behavioral evidence of individual differences in metaphor comprehension. *Memory & Cognition, 31*(5), 673–689.

Katz, A. (1996). On interpreting statements as metaphor or irony: Contextual heuristics and cognitive consequences. In J. Mio & A. Katz (Eds), *Metaphor: Implication and applications*. Mahwah, NJ: Lawrence Erlbaum.

Keysar, B., Shen, Y., Glucksberg, S., & Horton, W. S. (2000). Conventional language: How metaphorical is it? *Journal of Memory and Language, 43*(4), 576–593.

Knight, S., & Heinrich, A. (2017). Different measures of auditory and visual stroop interference and their relationship to speech intelligibility in noise. *Frontiers in Psychology*, *8*, 230. doi:10.3389/fpsyg.2017.00230

Krauss, R. M., & Weinheimer, S. (1964). Changes in the length of reference phrases as a function of social interaction: A preliminary study. *Psychonomic Science*, *1*, 113-114.

Kuperman, V., & Van Dyke, J.A. (2011). Individual differences in visual comprehension of morphological complexity. In L. Carlson, C. Hoelscher, & T. Shipley (Eds.), *Proceedings of the 33rd Annual Meeting of the Cognitive Science Society* (pp. 1643-1648). Austin, TX: Cognitive Science Society.

Lakoff, G. (2008). The neural theory of metaphor. In R. W. Gibbs, Jr. (Ed.), *The Cambridge handbook of metaphor and thought* (pp. 17–38). Cambridge University Press.

Libben, G. (1993). A Case of obligatory access to morphological constituents. *Nordic Journal of Linguistics*, *16*, 111-12.

Libben, G. (1998). Semantic transparency in the processing of compounds: Consequence for representation, processing, and impairment. *Brain and Language, 61*(1), 30–44.

Libben, G. (2005). Everything is psycholinguistics: Material and methodological considerations in the study of compound processing. *The Canadian Journal of Linguistics / La revue canadienne de linguistique*, *50*, 267–283.

Libben, G. (2010). Compound words, semantic transparency, and morphological transcendence. *Linguistische Berichte Sonderheft*, *17*, 1-14.

Libben, G., Gibson, M., Yoon, Y. B., & Sandra, D. (2003). Compound fracture: The role of semantic transparency and morphological headedness. *Brain and Language, 84*(1), 50–64.

Libben, M. R., & Titone, D. A. (2008). The multidetermined nature of idiom processing. *Memory & Cognition, 36*(6), 1103–1121.

Logan, G. D., Zbrodoff, N. J., & Williamson, J. (1984). Strategies in the color-word Stroop task. *Bulletin of the Psychonomic Society, 22*(2), 135–138.

MacGregor, L., & Shtyrov, Y. (2013). Multiple routes for compound word processing in the brain: Evidence from EEG. *Brain & Language*, *126*, 217–229.

MacLeod C. M. (1991). Half a century of research on the Stroop effect: An integrative review. Psychol. Bull. 109, 163–203. 10.1037/0033-2909.109.2.163

Maki, Y., Yamaguchi, T., Koeda, T., & Yamaguchi, H. (2013). Communicative competence in Alzheimer's disease: Metaphor and sarcasm comprehension. *American Journal of Alzheimer's Disease and Other Dementias, 28*(1), 69–74.

Marschark. M., Katz, A., & Paivio, A. (1983). Dimensions of metaphor. *Journal of Psycholinguistic Research*, *22*, 17-40.

Martin, I., & McDonald, S. (2004). An exploration of causes of non-literal language problems in individuals with Asperger syndrome. *Journal of Autism and Developmental Disorders*, *34*, 311–328.

Mashal, N. (2013). The role of working memory in the comprehension of unfamiliar and familiar metaphors. *Language and Cognition*, *5*, 409-436.

McGlone, M.S., & Manfredi, D.A. (2001). Topic-vehicle interaction in metaphor comprehension. *Memory & Cognition*, *29*(8), 1209-1219.

Metzing, C., & Brennan, S. E. (2003). When conceptual pacts are broken: Partner-specific effects on the comprehension of referring expressions. *Journal of Memory and Language*, *49*(2), 201-213.

Monterosso, J. R., Aron, A. R., Cordova, X., Xu, J., & London, E. D. (2005). Deficits in response inhibition associated with chronic methamphetamine abuse. *Drug and Alcohol Dependence, 79*(2), 273-277.

Mullaly, A., Gagné, C., Spalding, T., & Marchak, K. (2010). Examining ambiguous adjectives in adjective-noun phrases: Evidence for representation as a shared core-meaning with sense specialization. *The Mental Lexicon*, *5*, 87-114.

Murphy, G. L. (1990). Noun phrase interpretation and conceptual combination. *Journal of Memory and Language, 29*(3), 259–288.

Myers, J. (2007). Generative morphology as psycholinguistics. In G. Jarema & G. Libben (Eds.), *The mental lexicon: Core perspectives* (pp. 105-128). Amsterdam: Elsevier.

Olkoniemi, H., Ranta, H., & Kaakinen, J. K. (2016). Individual differences in the processing of written sarcasm and metaphor: Evidence from eye movements. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 42*(3), 433-450.

Ortony, A. (1975). Why Metaphors Are Necessary and Not Just Nice. *Educational Theory*, *25*(1), 45-53.

Ortony, A., Reynolds, R. E., & Arter, J. A. (1978). Metaphor: Theoretical and empirical research. *Psychological Bulletin, 85*(5), 919–943.

Ozonoff, S., & Miller, J. N. (1996). An exploration of right-hemisphere contribution to the pragmatic impairments of autism. *Brain and Language*, *52*, 411–434.

Park, J., Sana, F., Gagné, C. L., & Spalding, T. L. (accepted). Is inhibition involved in the processing of opaque compound words? A study of individual difference. *The Mental Lexicon*.

Pierce, R. S., MacLaren, R., & Chiappe, D. L. (2010). The role of working memory in the metaphor interference effect. *Psychonomic Bulletin & Review, 17*(3), 400–404.

Pinheiro, J. C., & Bates, D. M. (2000). *Mixed-effects models in S and S-PLUS*. New York, NY: Springer.

Plag, I. (2003). *Word-formation in English*. Cambridge, England: Cambridge University Press.

Rubio-Fernández, P. (2007) Suppression in metaphor interpretation: Differences between meaning selection and meaning construction. *Journal of Semantics*, *24*(4), 345-371.

Sakamoto, M., & Utsumi, A. (2014). Adjective metaphors evoke negative meanings. *PloS one*, *9*(2), e89008.

Sana, F., Park, J., & Burry, J.C., Gagné, C.L. & Spalding, T.L. (2018, September). *How does syntactic form and conventionality affect metaphor production?* Poster session presented at the 11th International Mental Lexicon Conference, Edmonton, AB.

Sandra, D. (1990). On the representation and processing of compound words: Automatic access to constituent morphemes does not occur. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 42*(3-A), 529–567.

Sani, S.R., Tabibi, Z., Fadardi, J.S., & Stavrinos, D. (2017). Aggression, emotional self-regulation, attentional bias, and cognitive inhibition predict risky driving behavior. *Accident; analysis and prevention, 109*, 78-88.

Santoro, Mirko. (2019). Compounds in sign languages: The case of Italian and French Sign Language. *Sign Language & Linguistics*, *22*, 291–297.

Schmidtke, D., Gagné, C. L., Kuperman, V., Spalding, T. L., & Tucker, B. V. (2018).

Conceptual relations compete during auditory and visual compound word recognition. *Language, cognition and neuroscience*, *33*(7), 923–942.

Schmidtke, D., Kuperman, V., Gagné, C. L., & Spalding, T. L. (2016). Competition between conceptual relations affects compound recognition: the role of entropy. *Psychonomic bulletin & review*, *23*(2), 556–570.

Schmidtke, D., Van Dyke, J. A., & Kuperman, V. (2018). Individual variability in the semantic processing of English compound words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 44*(3), 421–439.

Searle, J. (1979). Metaphor. In: A. Ortony (Ed.) *Metaphor and Thought* (pp. 92-123). New York: Cambridge University Press.

Seidenberg, M. S., Tanenhaus, M. K., Leiman, J. M., & Bienkowski, M. (1982). Automatic access of the meanings of ambiguous words in context: Some limitations on knowledge-based processing. *Cognitive Psychology*, *14*, 489-532.

Spalding, T. L., & Gagné, C. L. (2007). Semantic property activation during the interpretation of combined concepts. *The Mental Lexicon*, *2*(1), 25-47.

Spalding, T. L., & Gagné, C. L. (2015). Property attribution in combined concepts. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41*(3), 693–707.

Spalding, T. L., Gagné, C. L., Mullaly, A. C., & Ji, H. (2010). Relation-based interpretations of noun–noun phrases: A new theoretical approach. *Linguistische Berichte Sonderheft, 17,*283–315.

Stamenkovic, D., Ichien, N., & Holyoak, K. (2019). Metaphor comprehension: An individual-differences approach. *Journal of Memory and Language*, *105*, 108-

118.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*, 643-662.

Tantam, D. (1991). Asperger syndrome in adulthood. In U. Frith (Ed.), *Autism & Asperger syndrome* (pp. 145–183). Cambridge, UK: Cambridge University Press.

Thibodeau, P., & Durgin, F. H. (2008). Productive figurative communication: Conventional metaphors facilitate the comprehension of related novel metaphors. *Journal of Memory and Language, 58*(2), 521–540.

Titone, D., Columbus, G., Whitford, V., Mercier, J., & Libben, M. (2015). Contrasting bilingual and monolingual idiom processing. In R. R. Heredia & A. B. Cieślicka (Eds.), *Bilingual figurative language processing* (p. 171–207). Cambridge University Press.

Traverso, L., Mantini, C., Usai, M.C., & Viterbori, P. (2015). The relationship between inhibition and working memory in preschoolers: Evidence for different inhibitory abilities. In G. Airenti, B. Bara, G. Sandini, & M. Cruciani (Eds.). *Proceedings of the EuroAsianPacific Joint Conference on Cognitive Science / 4th European Conference on Cognitive Science / 11th International Conference on Cognitive Science* (pp. 48-53). Torino, Italy.

Treisman, A., & Fearnley, S. (1969). The Stroop test: Selective attention to colours and words. *Nature*, *222*, 437-439.

Trick, L., & Katz, A. N. (1986). The domain interaction approach to metaphor processing: Relating individual differences and metaphor characteristics. *Metaphor & Symbolic Activity, 1*(3), 185-213.

Tse, C.-S., Yap, M. J., Chan, Y.-L., Sze, W. P., Shaoul, C., & Lin, D. (2017). The Chinese Lexicon Project: A megastudy of lexical decision performance for 25,000+ traditional Chinese two-character compound words. *Behavior Research Methods, 49*(4), 1503–1519.

Vercellotti, M. L., & Mortensen, D. R. (2012). A classification of compounds in American Sign Language: An evaluation of the Bisetto and Scalise framework. *Morphology*, *22*, 545–579.

Wechsler D. (2008). WAIS-IV administration and scoring manual. San Antonio, TX: Psychological Corporation.

Weiland, H., Bambini, V., & Schumacher, P. B. (2014). The role of literal meaning in figurative language comprehension: Evidence from masked priming ERP. *Frontiers in Human Neuroscience, 8,* Article 583.

Wilkes-Gibbs, D., & Clark, H. H. (1992). Coordinating beliefs in conversation. *Journal of Memory and Language*, *31*, 183–194.

Wisniewski, E. J. (1996). Construal and similarity in conceptual combination. *Journal of Memory and Language, 35*(3), 434–453.

Wisniewski, E. J. (1997). When concepts combine. *Psychonomic Bulletin & Review, 4*(2), 167–183.

Wisniewski, E. J., & Love, B. C. (1998). Relations versus properties in conceptual combination. *Journal of Memory and Language, 38*(2), 177–202.

Wolff, P., & Gentner, D. (2000). Evidence for role-neutral initial processing of metaphors. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 529-541.

Wolff, P., & Gentner, D. (2011). Structure-mapping in metaphor comprehension. *Cognitive science*, *35*(8). 1456-1488.

Xun, Z., & Hee, Y. E. (2016). Comparative study on the structures of Chinese and Korean compound words. *Lingua Cultura*, *10*(1), 7–12.

Zharikov, S., & Gentner, D. (2002). Why do metaphors seem deeper than similes? In W. D. Gray & C. D. Schunn (Eds.), *Proceedings of the Twenty-Fourth Annual Conference of the Cognitive Science Society* (pp. 976-981). Fairfax, VA: George Mason University.

Zwitserlood, P. (1994). The role of semantic transparency in the processing and representation of Dutch compounds. *Language and Cognitive Processes, 9*(3), 341–368.

Appendix 1

Experimental Items Presented in Experiment 1 of Chapter 2

X is Y	Noun-noun	Simile
A bed is a boulder	boulder bed	A bed is like a boulder
A business is an organism	business organism	A business is like an organism
A campaign is a circus	campaign circus	A campaign is like a circus
A crowd is a sea	crowd sea	A crowd is like a sea
A divorce is a tornado	divorce tornado	A divorce is like a tornado
A friend is an anchor	anchor friend	A friend is like an anchor
A giraffe is a skyscraper	skyscraper giraffe	A giraffe is like a skyscraper
A granny is a turtle	turtle granny	A granny is like a turtle
A husband is a gem	gem husband	A husband is like a gem
A job is poison	poison job	A job is like poison
A judge is a balance	balance judge	A judge is like a balance
A jump is an earthquake	earthquake jump	A jump is like an earthquake
A librarian is a mouse	mouse librarian	A librarian is like a mouse
A persona is an armour	armour persona	A persona is like an armour
A pillow is a cloud	cloud pillow	A pillow is like a cloud
A smile is radiance	radiance smile	A smile is like radiance
A wife is a trophy	trophy wife	A wife is like a trophy
Adventure is spice	adventure spice	Adventure is like spice
Advices are gold	gold advices	Advices are like gold
An accountant is a juggler	juggler accountant	An accountant is like a juggler
Anger is a volcano	volcano anger	Anger is like a volcano
Arguments are journeys	argument journey	Arguments are like journeys
Arguments are wars	argument war	Arguments are like wars
Babies are angels	angel baby	Babies are like angels
Bankers are vultures	vulture bankers	Bankers are like vultures
Betrayal is a toxin	betrayal toxin	Betrayal is like a toxin
Bribes are traps	bribe trap	Bribes are like traps
Buffets are paradise	buffet paradise	Buffets are like paradise
Canaries are violins	violin canaries	Canaries are like violins
Cheaters are snakes	snake cheaters	Cheaters are like snakes
Corruption is a virus	corruption virus	Corruption is like a virus
Creativity is a blender	creativity blender	Creativity is like a blender
Crime is a disease	crime disease	Crime is like a disease
Crowds are thunder	thunder crowd	Crowds are like thunder
Dancers are butterflies	butterfly dancers	Dancers are like butterflies

Development is a tree	development tree	Development is like a tree
Disappointment is a stumble	disappointment stumble	Disappointment is like a stumble
Drivers are sloths	sloth driver	Drivers are like sloths
Duties are mountains	duty mountain	Duties are like mountains
The economy is a machine	economy machine	The economy is like a machine
Education is a lantern	education lantern	Education is like a lantern
Elections are hurricanes	election hurricane	Elections are like hurricanes
Emails are a flood	email flood	Emails are like a flood
Exams are filters	filter exams	Exams are like filters
Faces are cookies	cookie face	Faces are like cookies
Followers are sheep	sheep followers	Followers are like sheep
Forgiveness is a path	forgiveness path	Forgiveness is like a path
Friendship is a bridge	friendship bridge	Friendship is like a bridge
Friendship is a symbiosis	symbiosis friendship	Friendship is like a symbiosis
Genes are lottery	lottery genes	Genes are like lottery
Grief is an abyss	grief abyss	Grief is like an abyss
Hairs are noodles	noodle hairs	Hairs are like noodles
History is a mirror	history mirror	History is like a mirror
History is footprints	history footprints	History is like footprints
Humour is a cure	humour cure	Humour is like a cure
Hunger is an avalanche	avalanche hunger	Hunger is like an avalanche
Ideas are diamonds	diamond ideas	Ideas are like diamonds
Indecision is paralysis	indecision paralysis	Indecision is like paralysis
Insults are scars	insult scars	Insults are like scars
Judges are dinosaurs	dinosaur judge	Judges are like dinosaurs
Knowledge is an ocean	knowledge ocean	Knowledge is like an ocean
Language is a river	river language	Language is like a river
Lawyers are sharks	shark lawyers	Lawyers are like sharks
Legs are straws	straw legs	Legs are like straws
Lies are daggers	dagger lie	Lies are like daggers
Life is a game	life game	Life is like a game
Life is wind	life wind	Life is like wind
Lips are velvet	velvet lips	Lips are like velvet
Loneliness is a desert	loneliness desert	Loneliness is like a desert
Love is a drug	love drug	Love is like a drug
Love is an antidote	love antidote	Love is like an antidote
Love is madness	madness love	Love is like madness
Marriage is a leash	marriage leash	Marriage is like a leash
Melodies are hugs	hug melody	Melodies are like hugs
Memory is a warehouse	memory warehouse	Memory is like a warehouse

Midterms are torture	torture midterm	Midterms are like torture
Mosquitoes are darts	dart mosquitoes	Mosquitoes are like darts
Mosquitoes are vampires	vampire mosquito	Mosquitoes are like vampires
Mothers are mules	mule mother	Mothers are like mules
Muscles are steel	steel muscles	Muscles are like steel
Music is medicine	music medicine	Music is like medicine
News are bombs	news bombs	News are like bombs
Paparazzi are parasites	parasite paparazzi	Paparazzi are like parasites
Peppers are fire	fire pepper	Peppers are like fire
Professors are ogres	ogre professor	Professors are like ogres
Reassurance is a patch	reassurance patch	Reassurance is like a patch
Relationships are barter	barter relationship	Relationships are like barter
Relationships are journeys	relationship journey	Relationships are like journeys
Sarcasm is a veil	sarcasm veil	Sarcasm is like a veil
Saunas are ovens	oven sauna	Saunas are like ovens
Secretaries are slaves	slave secretary	Secretaries are like slaves
Sisters are megaphones	megaphone sister	Sisters are like megaphones
Skin is silk	silk skin	Skin is like silk
Slums are tumors	tumor slums	Slums are like tumors
Smiles are magnets	magnet smile	Smiles are like magnets
Society is a pillar	society pillar	Society is like a pillar
Solutions are a bandaid	bandaid solution	Solutions are like a bandaid
Spas are heaven	heaven spa	Spas are like heaven
Stomachs are barrels	barrel stomach	Stomachs are like barrels
Students are sponges	sponge student	Students are like sponges
Surgeons are butchers	butcher surgeons	Surgeons are like butchers
Teachers are encyclopedias	encyclopedia teacher	Teachers are like encyclopedias
Temper is gasoline	gasoline temper	Temper is like gasoline
The mind is a field	mind field	The mind is like a field
Thoughts are sparks	thought spark	Thoughts are like sparks
Time is an escalator	escalator time	Time is like an escalator
Tobacco is poison	tobacco poison	Tobacco is like poison
Toddlers are monkeys	monkey toddler	Toddlers are like monkeys
Traffic is a tumor	traffic tumor	Traffic is like a tumor
Tumor is a plague	plague tumor	Tumor is like a plague
Unemployment is a drought	unemployment drought	Unemployment is like a drought
Wealth is a road	wealth road	Wealth is like a road
Wind is a wrestler	wrestler wind	Wind is like a wrestler
Wisdom is a gift	gift wisdom	Wisdom is like a gift

Appendix 2

Experimental Items Presented in Experiment 1 of Chapter 2

Dominant figurative interpretation	Non-dominant figurative interpretation
A bed is uncomfortable	A bed is durable
A business can grow	A business is autonomous
A campaign is funny	A campaign requires coordination
A crowd is vast	A crowd moves slowly
A divorce is destructive	A divorce is painful
A friend is supportive	A friend is stable
A giraffe is tall	A giraffe is noticeable
A granny is slow	A granny is wise
A husband is valuable	A husband is beautiful
A job kills you	A job is dangerous
A judge is fair	A judge makes decisions
A jump is shaking	A jump hits the ground
A librarian is quiet	A librarian is usually disregarded
A persona is protective	A persona is defining
A pillow is soft	A pillow is fluffy
A smile is bright	A smile is attractive
A wife is something people are proud of	A wife is aesthetically pleasing
Adventure is exciting	Adventure is intense
Advices are valuable	Advices are rare
An accountant multitasks	An accountant is talented
Anger is destructive	Anger is unexpected
Arguments are time-consuming	Arguments allow learning
Arguments last long	Arguments are aggressive
Babies are innocent	Babies are peaceful
Bankers are ruthless	Bankers are persistent
Betrayal is deadly	Betrayal is vicious
Bribes are deceiving	Bribes are unexpected
Buffets cause pleasure	Buffets involve abundance
Canaries are musical	Canaries evoke emotion
Cheaters are sneaky	Cheaters are not trustworthy
Corruption is contagious	Corruption is weakening
Creativity is a mixture	Creativity is changing
Crime is dangerous	Crime is treatable
Crowds are loud	Crowds are powerful

Dancers are graceful	Dancers move
Development involves growth	Development requires nurturing
Disappointment is something people can get over	Disappointment is sad
Drivers are slow	Drivers are patient
Duties are daunting	Duties are immovable
The economy is always working	The economy is powerful
Education is guiding	Education is a tool
Elections are messy	Elections are unpredictable
Emails are overwhelming	Emails are sudden
Exams are selective	Exams are a process
Faces are enticing	Faces come in different forms
Followers are dependant	Followers are weak
Forgiveness takes a lot of time	Forgiveness is a process
Friendship connects people	Friendship is strong
Friendship is mutually beneficial	Friendship involves sharing
Genes are related to luck	Genes are unpredictable
Grief is endless	Grief is difficult to escape from
Hairs are long	Hairs are fragile
History reflects things about us	History is informative
History is traceable	History is directive
Humour gives happiness	Humour is rejuvenating
Hunger is uncontrollable	Hunger causes rumbling sounds
Ideas are valuable	Ideas are profitable
Indecision makes people get stuck	Indecision is stressful
Insults are damaging	Insults are unforgettable
Judges are old	Judges are intimidating
Knowledge is vast	Knowledge is fluid
Language flows	Language is endless
Lawyers are aggressive	Lawyers are scary
Legs are thin	Legs are cylindrical
Lies cause pain	Lies are useful sometimes
Life involves decisions	Life is fun
Life is always changing	Life is unpredictable
Lips are soft	Lips are beautiful
Loneliness gives people a feeling of emptiness	Loneliness is harsh
Love is addictive	Love is pleasurable
Love is healing	Love is a solution to a problem
Love is intense	Love is uncertain
Marriage is controlling	Marriage involves ownership
Melodies are comforting	Melodies grab people's attention

Memory is a storage	Memory is compartmented
Midterms are stressful	Midterms last long
Mosquitoes make punctures	Mosquitoes target things
Mosquitoes suck blood	Mosquitoes are parasitic
Mothers are hardworking	Mothers are trustworthy
Muscles are strong	Muscles are unbreakable
Music is soothing	Music is pleasant
News are shocking	News are immediate
Paparazzi are ever-present	Paparazzi are worthless
Peppers are hot	Peppers are unpleasant
Professors are mean	Professors are ugly
Reassurance is temporary	Reassurance is comforting
Relationships are bidirectional	Relationships involve fighting
Relationships are long-lasting	Relationships are adventurous
Sarcasm covers things	Sarcasm is uncomfortable
Saunas are hot	Saunas are closed-in
Secretaries are unappreciated	Secretaries are disposable
Sisters are loud	Sisters are useful
Skin is smooth	Skin is breathable
Slums grow fast	Slums are problematic
Smiles are attractive	Smiles are powerful
Society is strong	Society is breakable
Solutions fix things	Solutions are practical
Spas are peaceful	Spas are friendly
Stomachs are hollow	Stomachs are spacious
Students absorb content	Students are versatile
Surgeons cut flesh	Surgeons are bloody
Teachers are knowledgeable	Teachers are organized
Temper is dangerous	Temper is volatile
The mind is open	The mind is sprawling
Thoughts are instantaneous	Thoughts are the beginning of something
Time is always moving	Time is unidirectional
Tobacco is deadly	Tobacco is ingestible
Toddlers are wild	Toddlers are noisy
Traffic is dangerous	Traffic is inconvenient
Tumor is deadly	Tumor is scary
Unemployment is tough	Unemployment is hopeless
Wealth is difficult	Wealth goes both ways
Wind is strong	Wind is quick
Wisdom is rare	Wisdom is earned

Appendix 3

Experimental Items Presented in Experiment 2 of Chapter 2

Noun-noun metaphor	Constituent that is figurative
anger eruption	Head
argument journey	Head
attention beggar	Head
bribe trap	Head
campaign circus	Head
civilization cradle	Head
company slave	Head
corruption soil	Head
creativity blender	Head
crowd sea	Head
development stairs	Head
disappointment waves	Head
divorce tornado	Head
economy storm	Head
elections hurricane	Head
email flood	Head
food paradise	Head
forgiveness path	Head
friendship bridge	Head
grief abyss	Head
hair mountain	Head
history mirror	Head
hope field	Head
humour cure	Head
knowledge ocean	Head
labour fruit	Head
life wind	Head
loneliness desert	Head
love desert	Head
marriage leash	Head
music medicine	Head
news bomb	Head
problem root	Head
romance bud	Head
society pillar	Head
soul patch	Head
stocks pulse	Head
thought spark	Head
traffic artery	Head
	Head

unemployment	Head
drought	Head
wealth road	Modifier
word scars	Modifier
antenna ears	Modifier
armour persona	Modifier
bandaid solution	Modifier
barrel stomach	Modifier
barter relationship	Modifier
black day	Modifier
boulder bed	Modifier
caress melody	Modifier
cloud pillows	Modifier
crater face	Modifier
earthquake jump	Modifier
filter exam	Modifier
fire pepper	Modifier
gem husband	Modifier
gold advice	Modifier
honey compliment	Modifier
ivory smile	Modifier
monkey humour	Modifier
ogre professor	Modifier
owl wisdom	Modifier
panda look	Modifier
parasite paparazzi	Modifier
pig hunger	Modifier
plastic body	Modifier
poison job	Modifier
rainbow equality	Modifier
sailor language	Modifier
shark lawyers	Modifier
sheep character	Modifier
sloth comprehension	Modifier
snow hair	Modifier
steel mind	Modifier
straw legs	Modifier
swan dance	Modifier
symbiosis friendship	Modifier
torture midterm	Modifier
trophy girl	Modifier
turtle steps	Modifier
velvet lips	Modifier
vulture bankers	Modifier
waterfall bleed	
yawn lecture	

Appendix 4

Experimental Items Presented in Experiment 3 of Chapter

Target	Literal prime	Figurative prime
anger eruption	volcano eruption	generosity eruption
argument journey	car journey	retirement journey
attention beggar	money beggar	justice beggar
bribe trap	bear trap	alcohol trap
campaign circus	animal circus	courtship circus
civilization cradle	baby cradle	talent cradle
company slave	child slave	popularity slave
corruption soil	plant soil	innovation soil
creativity blender	fruit blender	race blender
crowd sea	coral sea	information sea
development stairs	house stairs	success stairs
disappointment waves	sound waves	trend waves
divorce tornado	sand tornado	crime tornado
economy storm	thunder storm	discount storm
elections hurricane	tropical hurricane	party hurricane
email flood	water flood	refugee flood
food paradise	bible paradise	cat paradise
forgiveness path	beach path	wellness path
friendship bridge	suspension bridge	prosperity bridge
grief abyss	ocean abyss	debt abyss
hair mountain	rock mountain	bills mountain
hope field	corn field	discrimination field
humour cure	disease cure	cuddle cure
knowledge ocean	blue ocean	vanity ocean
labour fruit	exotic fruit	flattery fruit
loneliness desert	sand desert	indecision desert
marriage leash	dog leash	mortgage leash
music medicine	cold medicine	cuteness medicine
news bomb	terrorist bomb	truth bomb
problem root	plant root	success root
romance bud	flower bud	resentment bud
society pillar	stone pillar	religion pillar
soul patch	jean patch	bankruptcy patch
thought spark	light spark	affinity spark
traffic artery	body artery	communication artery
unemployment drought	desert drought	celibacy drought
wealth road	concrete road	revenge road
word scars	war scars	rejection scars
armour persona	armour metal	armour makeup
bandaid solution	bandaid box	bandaid compensation
barrel stomach	barrel lid	barrel memory

barter relationship	barter system	barter conversation
black day	black colour	black personality
boulder bed	boulder weight	boulder thoughts
caress melody	caress care	caress smile
crater face	crater depth	crater cheese
earthquake jump	earthquake recorder	earthquake dispute
filter exam	filter paper	filter interview
fire pepper	fire alarm	fire lust
gem husband	gem stone	gem words
gold advice	gold bar	gold achievement
honey compliment	honey jar	honey kiss
ivory smile	ivory products	ivory hair
monkey humour	monkey cage	monkey charm
ogre professor	ogre swamp	ogre stepmother
owl wisdom	owl feather	owl lifestyle
panda look	panda fur	panda laziness
parasite paparazzi	parasite cleanse	parasite girlfriend
pig hunger	pig meat	pig manners
plastic body	plastic bag	plastic beauty
poison job	poison bottle	poison habits
rainbow equality	rainbow colours	rainbow pride
sailor language	sailor boat	sailor drinking
shark lawyers	shark fin	shark president
sheep character	sheep wool	sheep followers
sloth comprehension	sloth claws	sloth driving
snow hair	snow removal	snow look
steel mind	steel pan	steel determination
straw legs	straw hat	straw hair
swan dance	swan lake	swan pose
torture midterm	torture device	torture job
trophy girl	trophy shelf	trophy mistress
turtle steps	turtle eggs	turtle grandma
velvet lips	velvet dress	velvet song
vulture bankers	vulture wings	vulture relatives
waterfall bleed	waterfall pictures	waterfall crying

Appendix 5

Stimuli Presented in the Lexical Decision Task in Experiment 1 of Chapter 3

String of letters presented	Type of stimulus
bandwagon	Fully opaque compound
blackmail	Fully opaque compound
blockbuster	Fully opaque compound
bootleg	Fully opaque compound
busybody	Fully opaque compound
buttercup	Fully opaque compound
dingbat	Fully opaque compound
dumbbell	Fully opaque compound
fanfare	Fully opaque compound
hedgehog	Fully opaque compound
highlight	Fully opaque compound
hogwash	Fully opaque compound
honeymoon	Fully opaque compound
jackpot	Fully opaque compound
marshmallow	Fully opaque compound
mushroom	Fully opaque compound
nutcase	Fully opaque compound
scapegoat	Fully opaque compound
snapdragon	Fully opaque compound
stalemate	Fully opaque compound
swansong	Fully opaque compound
tightwad	Fully opaque compound
cheekbone	Fully transparent compound
clamshell	Fully transparent compound
cloverleaf	Fully transparent compound
corkscrew	Fully transparent compound
fingertip	Fully transparent compound
gunpowder	Fully transparent compound
hailstorm	Fully transparent compound
hairnet	Fully transparent compound
lampshade	Fully transparent compound
mincemeat	Fully transparent compound
molehill	Fully transparent compound
nosebleed	Fully transparent compound
paintbrush	Fully transparent compound
poppyseed	Fully transparent compound
racehorse	Fully transparent compound
rosebud	Fully transparent compound
snakeskin	Fully transparent compound
thumbnail	Fully transparent compound
toothpick	Fully transparent compound

wastebasket	Fully transparent compound
windowpane	Fully transparent compound
wristwatch	Fully transparent compound
dominican	Non compound word filler
gratitude	Non compound word filler
realization	Non compound word filler
monarch	Non compound word filler
glaucoma	Non compound word filler
franchise	Non compound word filler
anchovy	Non compound word filler
literacy	Non compound word filler
nirvana	Non compound word filler
advocacy	Non compound word filler
vandalism	Non compound word filler
lactose	Non compound word filler
procedure	Non compound word filler
amnesia	Non compound word filler
electrician	Non compound word filler
diplomat	Non compound word filler
prodigy	Non compound word filler
diversity	Non compound word filler
conformism	Non compound word filler
actuality	Non compound word filler
tubercle	Non compound word filler
allegory	Non compound word filler
alchemist	Non compound word filler
trapezoid	Non compound word filler
allocation	Non compound word filler
retrieval	Non compound word filler
emergence	Non compound word filler
itinerary	Non compound word filler
symbiosis	Non compound word filler
hipster	Non compound word filler
blaspheme	Non compound word filler
phosphate	Non compound word filler
affluent	Non compound word filler
meteorite	Non compound word filler
memorandum	Non compound word filler
mysticism	Non compound word filler
recipient	Non compound word filler
reptile	Non compound word filler
symposium	Non compound word filler
monograph	Non compound word filler
detergent	Non compound word filler
testimonial	Non compound word filler
recompense	Non compound word filler

attachment	Non compound word filler
ansition	Nonword filler with monomorphemic-like structure
vangeliss	Nonword filler with monomorphemic-like structure
untertracts	Nonword filler with monomorphemic-like structure
trovers	Nonword filler with monomorphemic-like structure
tronomic	Nonword filler with monomorphemic-like structure
ricultrur	Nonword filler with monomorphemic-like structure
megatlo	Nonword filler with monomorphemic-like structure
ervation	Nonword filler with monomorphemic-like structure
cologic	Nonword filler with monomorphemic-like structure
sourcest	Nonword filler with monomorphemic-like structure
gisticoat	Nonword filler with monomorphemic-like structure
diamint	Nonword filler with monomorphemic-like structure
ervolemia	Nonword filler with monomorphemic-like structure
terisma	Nonword filler with monomorphemic-like structure
quenciality	Nonword filler with monomorphemic-like structure
trophims	Nonword filler with monomorphemic-like structure
assiert	Nonword filler with monomorphemic-like structure
milatiocy	Nonword filler with monomorphemic-like structure
complishly	Nonword filler with monomorphemic-like structure
phenylmon	Nonword filler with monomorphemic-like structure
dosteron	Nonword filler with monomorphemic-like structure
descenss	Nonword filler with monomorphemic-like structure
framplist	Nonword filler with monomorphemic-like structure
pressdite	Nonword filler with monomorphemic-like structure
tantaneous	Nonword filler with monomorphemic-like structure
tommutals	Nonword filler with monomorphemic-like structure
texteenex	Nonword filler with monomorphemic-like structure
niversiof	Nonword filler with monomorphemic-like structure
elfilment	Nonword filler with monomorphemic-like structure
plicits	Nonword filler with monomorphemic-like structure
mollgrass	Nonword filler with monomorphemic-like structure
tatchwors	Nonword filler with monomorphemic-like structure
effinoil	Nonword filler with monomorphemic-like structure
eartfulls	Nonword filler with monomorphemic-like structure
erfeinting	Nonword filler with monomorphemic-like structure
tractivis	Nonword filler with monomorphemic-like structure
tionwider	Nonword filler with monomorphemic-like structure
precial	Nonword filler with monomorphemic-like structure
ronitally	Nonword filler with monomorphemic-like structure
quelfiort	Nonword filler with monomorphemic-like structure
wrismatic	Nonword filler with monomorphemic-like structure
ellitatious	Nonword filler with monomorphemic-like structure
letrerolit	Nonword filler with monomorphemic-like structure
mertractor	Nonword filler with monomorphemic-like structure
ragefiber	Nonword filler with compound-like structure

wittymain	Nonword filler with compound-like structure
womenswitch	Nonword filler with compound-like structure
postsoy	Nonword filler with compound-like structure
sidewolf	Nonword filler with compound-like structure
peopleraw	Nonword filler with compound-like structure
roadbud	Nonword filler with compound-like structure
vibewear	Nonword filler with compound-like structure
wigmale	Nonword filler with compound-like structure
agonygem	Nonword filler with compound-like structure
openlarva	Nonword filler with compound-like structure
vanring	Nonword filler with compound-like structure
flirtpoor	Nonword filler with compound-like structure
clogpaw	Nonword filler with compound-like structure
crestarctic	Nonword filler with compound-like structure
geekdawn	Nonword filler with compound-like structure
cowfrog	Nonword filler with compound-like structure
tractwrap	Nonword filler with compound-like structure
mildcounty	Nonword filler with compound-like structure
civilfull	Nonword filler with compound-like structure
lacegolf	Nonword filler with compound-like structure
drillfox	Nonword filler with compound-like structure
juiceloan	Nonword filler with compound-like structure
jeanmedal	Nonword filler with compound-like structure
devourheck	Nonword filler with compound-like structure
beanmoral	Nonword filler with compound-like structure
gospelear	Nonword filler with compound-like structure
anytechno	Nonword filler with compound-like structure
ponypinky	Nonword filler with compound-like structure
limebeg	Nonword filler with compound-like structure
ovenlimbs	Nonword filler with compound-like structure
porchfolk	Nonword filler with compound-like structure
bondjude	Nonword filler with compound-like structure
clawalign	Nonword filler with compound-like structure
chartsense	Nonword filler with compound-like structure
dozerjust	Nonword filler with compound-like structure
hempopera	Nonword filler with compound-like structure
diveran	Nonword filler with compound-like structure
indexhonk	Nonword filler with compound-like structure
gloveyawn	Nonword filler with compound-like structure
smileeuro	Nonword filler with compound-like structure
worstsilica	Nonword filler with compound-like structure
gossipmaze	Nonword filler with compound-like structure
igloosuave	Nonword filler with compound-like structure

Appendix 6

Stimuli Presented in the Lexical Decision Task in Experiment 2 of Chapter 3

String of letters presented	Type of stimulus
mayfly	Opaque-transparent compound
bobtail	Opaque-transparent compound
jaywalk	Opaque-transparent compound
beeline	Opaque-transparent compound
warthog	Opaque-transparent compound
crowbar	Opaque-transparent compound
catcall	Opaque-transparent compound
clubfoot	Opaque-transparent compound
joystick	Opaque-transparent compound
wormwood	Opaque-transparent compound
alderman	Opaque-transparent compound
smallpox	Opaque-transparent compound
bobbypin	Opaque-transparent compound
crabgrass	Opaque-transparent compound
flagstone	Opaque-transparent compound
horseplay	Opaque-transparent compound
buckwheat	Opaque-transparent compound
butterfly	Opaque-transparent compound
pipedream	Opaque-transparent compound
snailmail	Opaque-transparent compound
strawberry	Opaque-transparent compound
frankincense	Opaque-transparent compound
hotdog	Transparent-opaque compound
inkwell	Transparent-opaque compound
oddball	Transparent-opaque compound
boldface	Transparent-opaque compound
sideburn	Transparent-opaque compound
typeface	Transparent-opaque compound
slowpoke	Transparent-opaque compound
jailbird	Transparent-opaque compound
sidekick	Transparent-opaque compound
doughnut	Transparent-opaque compound
blackhead	Transparent-opaque compound
lazybones	Transparent-opaque compound
turntable	Transparent-opaque compound
honeycomb	Transparent-opaque compound
gingersnap	Transparent-opaque compound
spoilsport	Transparent-opaque compound
chatterbox	Transparent-opaque compound
cheapskate	Transparent-opaque compound
lumberjack	Transparent-opaque compound

doubleheader	Transparent-opaque compound
butterscotch	Transparent-opaque compound
knucklesandwich	Transparent-opaque compound
marmot	Non compound word filler
opiate	Non compound word filler
syrians	Non compound word filler
slavish	Non compound word filler
chicory	Non compound word filler
migrant	Non compound word filler
adrenal	Non compound word filler
hospice	Non compound word filler
refusal	Non compound word filler
polygon	Non compound word filler
modality	Non compound word filler
ganglion	Non compound word filler
nepotism	Non compound word filler
meteoric	Non compound word filler
aberrant	Non compound word filler
gluttony	Non compound word filler
asterisk	Non compound word filler
monarchy	Non compound word filler
symmetry	Non compound word filler
maternal	Non compound word filler
opposing	Non compound word filler
petition	Non compound word filler
ontology	Non compound word filler
doctrinal	Non compound word filler
amplitude	Non compound word filler
moderator	Non compound word filler
rheumatic	Non compound word filler
quotation	Non compound word filler
extremist	Non compound word filler
enclosure	Non compound word filler
actuality	Non compound word filler
orchestra	Non compound word filler
secretion	Non compound word filler
intestine	Non compound word filler
odontology	Non compound word filler
convulsion	Non compound word filler
expressive	Non compound word filler
saturation	Non compound word filler
hemoglobin	Non compound word filler
psychology	Non compound word filler
oceanography	Non compound word filler
nutritionist	Non compound word filler
purification	Non compound word filler

procastinators	Non compound word filler
niesof	Nonword filler with monomorphemic-like structure
runtly	Nonword filler with monomorphemic-like structure
megatlo	Nonword filler with monomorphemic-like structure
terisma	Nonword filler with monomorphemic-like structure
trovers	Nonword filler with monomorphemic-like structure
plicits	Nonword filler with monomorphemic-like structure
assiert	Nonword filler with monomorphemic-like structure
precial	Nonword filler with monomorphemic-like structure
diamint	Nonword filler with monomorphemic-like structure
cologic	Nonword filler with monomorphemic-like structure
effinoil	Nonword filler with monomorphemic-like structure
tatchwor	Nonword filler with monomorphemic-like structure
sourcest	Nonword filler with monomorphemic-like structure
tionider	Nonword filler with monomorphemic-like structure
trophims	Nonword filler with monomorphemic-like structure
tractivi	Nonword filler with monomorphemic-like structure
descenss	Nonword filler with monomorphemic-like structure
molgrass	Nonword filler with monomorphemic-like structure
tronomic	Nonword filler with monomorphemic-like structure
dosteron	Nonword filler with monomorphemic-like structure
eartfull	Nonword filler with monomorphemic-like structure
elfilmen	Nonword filler with monomorphemic-like structure
ervation	Nonword filler with monomorphemic-like structure
framplist	Nonword filler with monomorphemic-like structure
ricultrur	Nonword filler with monomorphemic-like structure
gisticoat	Nonword filler with monomorphemic-like structure
tommutals	Nonword filler with monomorphemic-like structure
texteenex	Nonword filler with monomorphemic-like structure
ervolemia	Nonword filler with monomorphemic-like structure
pressdite	Nonword filler with monomorphemic-like structure
pansition	Nonword filler with monomorphemic-like structure
vangeliss	Nonword filler with monomorphemic-like structure
milatiocy	Nonword filler with monomorphemic-like structure
phenylmon	Nonword filler with monomorphemic-like structure
letrerolit	Nonword filler with monomorphemic-like structure
wrismatics	Nonword filler with monomorphemic-like structure
tantaneous	Nonword filler with monomorphemic-like structure
erfeinting	Nonword filler with monomorphemic-like structure
mertractor	Nonword filler with monomorphemic-like structure
complishly	Nonword filler with monomorphemic-like structure
ellirtatious	Nonword filler with monomorphemic-like structure
unttertracts	Nonword filler with monomorphemic-like structure
quenciallity	Nonword filler with monomorphemic-like structure
quiellfiortress	Nonword filler with monomorphemic-like structure
anycup	Nonword filler with compound-like structure

sinpig	Nonword filler with compound-like structure
roadbud	Nonword filler with compound-like structure
clogpaw	Nonword filler with compound-like structure
postsoy	Nonword filler with compound-like structure
limebeg	Nonword filler with compound-like structure
cowfrog	Nonword filler with compound-like structure
diveran	Nonword filler with compound-like structure
vanring	Nonword filler with compound-like structure
wigmale	Nonword filler with compound-like structure
bondjude	Nonword filler with compound-like structure
porchfar	Nonword filler with compound-like structure
agonygem	Nonword filler with compound-like structure
hipopera	Nonword filler with compound-like structure
geekdawn	Nonword filler with compound-like structure
dozerjar	Nonword filler with compound-like structure
drillfox	Nonword filler with compound-like structure
ovenlimb	Nonword filler with compound-like structure
sidewolf	Nonword filler with compound-like structure
lacegolf	Nonword filler with compound-like structure
clawline	Nonword filler with compound-like structure
ponypink	Nonword filler with compound-like structure
vibewear	Nonword filler with compound-like structure
juiceloan	Nonword filler with compound-like structure
peopleraw	Nonword filler with compound-like structure
openlarva	Nonword filler with compound-like structure
beanmoral	Nonword filler with compound-like structure
gospelear	Nonword filler with compound-like structure
flirtpoor	Nonword filler with compound-like structure
jeanmedal	Nonword filler with compound-like structure
ragefiber	Nonword filler with compound-like structure
wittymain	Nonword filler with compound-like structure
tractwrap	Nonword filler with compound-like structure
civilfull	Nonword filler with compound-like structure
gossipmaze	Nonword filler with compound-like structure
smileeuros	Nonword filler with compound-like structure
devourheck	Nonword filler with compound-like structure
chartsense	Nonword filler with compound-like structure
igloosuave	Nonword filler with compound-like structure
mildcounty	Nonword filler with compound-like structure
bettersilica	Nonword filler with compound-like structure
womenswitchs	Nonword filler with compound-like structure
frencharctic	Nonword filler with compound-like structure
princessyawning	Nonword filler with compound-like structure

Appendix 7

Experimental Items Presented in the Sense/Nonsense Task of Chapter 4

Type of sentence	Sentence
Conventional metaphor	His arms are steel
Conventional metaphor	A lie is a dagger
Conventional metaphor	A marriage is a leash
Conventional metaphor	Teachers are encyclopedias
Conventional metaphor	A friend is an anchor
Conventional metaphor	Love is an antidote
Conventional metaphor	A diploma is a doorway
Conventional metaphor	Paparazzi are parasites
Conventional metaphor	A worker is a robot
Conventional metaphor	Divorces are storms
Conventional metaphor	Music is a medicine
Conventional metaphor	Smiles are magnets
Conventional metaphor	Exams are torture
Conventional metaphor	My skin is silk
Conventional metaphor	Tobacco is poison
Conventional metaphor	Memory is a warehouse
Conventional metaphor	My room is a dump
Conventional metaphor	Clouds are pillows
Conventional metaphor	Anger is a volcano
Conventional metaphor	Loneliness is a desert
Conventional metaphor	The casino is a drug
Conventional metaphor	My husband is a gem
Conventional metaphor	The spa is heaven
Novel metaphor	An argument is a journey
Novel metaphor	Death is a cave
Novel metaphor	Creativity is a blender
Novel metaphor	An exam is a filter
Novel metaphor	An accountant is a juggler
Novel metaphor	A campaign is a circus
Novel metaphor	Our planet is a ball
Novel metaphor	Athletes are cheetahs
Novel metaphor	Surgeons are butchers
Novel metaphor	Tumor is a plague
Novel metaphor	Bankers are vultures
Novel metaphor	History is a mirror
Novel metaphor	The mind is an arena
Novel metaphor	Education is a lantern
Novel metaphor	Dancers are butterflies
Novel metaphor	A judge is a balance
Novel metaphor	Cheaters are snakes
Novel metaphor	Alcohol is a crutch

Novel metaphor	A bribe is a trap
Novel metaphor	Peppers are fire
Novel metaphor	Genes are a lottery
Novel metaphor	Ideas are diamonds
Novel metaphor	Humour is a cure
Literally true	Canada is a country
Literally true	A dog is a pet
Literally true	Obama is a politician
Literally true	Robins are birds
Literally true	Water is a necessity
Literally true	Stealing is a crime
Literally true	Physics is a science
Literally true	Cocaine is a drug
Literally true	Fear is an emotion
Literally true	Coffee is a drink
Literally true	Cancer is a disease
Literally true	The kidney is an organ
Literally true	London is a city
Literally true	News is information
Literally true	Blood is a fluid
Literally true	Testosterone is a hormone
Literally true	Waving is a gesture
Literally true	Twins are siblings
Literally true	Pictures are images
Literally true	Dollars are money
Literally true	The Bible is a book
Literally true	A contract is an agreement
Literally true	The Earth is a planet
Literally true	A tower is a building
Literally true	A leg is a limb
Literally true	Christianity is a religion
Literally true	Sushi is food
Literally true	Wine is a beverage
Literally true	Walmart is a brand
Literally true	McDonald's is a restaurant
Literally true	Winter is a season
Literally true	A fight is a dispute
Literally true	Dinner is a meal
Literally true	Grandparents are adults
Literally true	Hairdressing is a profession
Literally true	A toddler is a child
Literally true	Reading is a skill
Literally true	Christmas is a holiday
Literally true	A lotion is a moisturizer
Literally true	Pines are trees
Literally true	Chess is a game

Literally true	A fridge is an appliance
Literally true	Milk is dairy
Literally true	Boxes are containers
Literally true	A square is a shape
Literally true	Roses are flowers
Literally false	A banana is a kangaroo
Literally false	Stilettos are cookies
Literally false	Potatoes are antlers
Literally false	An owl is a mammal
Literally false	A pantry is a buckle
Literally false	Shoulders are tissues
Literally false	Tunnels are cereals
Literally false	Knees are kettles
Literally false	A clarinet is a bucket
Literally false	A bow is a tremor
Literally false	Salt is gas
Literally false	A cabin is jewelry
Literally false	A ranch is a dress
Literally false	A snake is a cup
Literally false	A basket is a pencil
Literally false	A book is a vegetable
Literally false	A bridge is a fruit
Literally false	A curtain is a machine
Literally false	Diapers are noodles
Literally false	A document is a cucumber
Literally false	A drawer is a stone
Literally false	A leaf is a hammer
Literally false	A lemon is a utensil
Literally false	A piano is a mammal
Literally false	A ruler is a battery
Literally false	A vacuum is a drink
Literally false	A whistle is an animal
Literally false	Bats are plants
Literally false	Brooms are clothing
Literally false	Candles are shoes
Literally false	Meat is technology
Literally false	Squirrels are minerals
Literally false	A stallion is an atrium
Literally false	An attic is a trumpet
Literally false	A wheel is a cube
Literally false	A kidney is a powder
Literally false	Chickens are phones
Literally false	Sticks are crabs
Literally false	A towel is a cork
Literally false	An almond is a sandal
Literally false	Whiskers are cabbages

Literally false	An armour is liquor
Literally false	Zucchinis are predators
Literally false	Candles are collars
Literally false	A lobster is a gun
Literally false	A possum is a heater
Nonsense	Suburbs are eagles
Nonsense	Deception is an angel
Nonsense	A lawyer is a door
Nonsense	The baby is a map
Nonsense	The librarian is a cork
Nonsense	A desk is an oven
Nonsense	A forest is a mouse
Nonsense	A hippopotamus is a dessert
Nonsense	A sauna is a fish
Nonsense	A giraffe is a fountain
Nonsense	A ferry is a spider
Nonsense	A canary is truth
Nonsense	Horoscopes are bulldozers
Nonsense	Auditions are blimps
Nonsense	Mosquitoes are dinosaurs
Nonsense	A ballerina is a war
Nonsense	The camel is a ferret
Nonsense	The toaster is a sponge
Nonsense	A slum is a rocket
Nonsense	The coach is a dart
Nonsense	A seller is research
Nonsense	The genius is a top
Nonsense	Islands are boomerangs
Nonsense	A groupie is a cactus
Nonsense	A boat is a tumor
Nonsense	The casino is a cat
Nonsense	A stick is a boxer
Nonsense	The moat is a bridge
Nonsense	Detectives are fertilizers
Nonsense	A dragster is a fence
Nonsense	The submarine is a violin
Nonsense	Respect is a vampire
Nonsense	Beavers are umbrellas
Nonsense	Crime is an ambassador
Nonsense	A certificate is a virus
Nonsense	A cousin is thunder
Nonsense	Temper is a lamp
Nonsense	A leech is an egg
Nonsense	Hunters are shackles
Nonsense	A cigar is a beach
Nonsense	Diapers are teachers

Nonsense	An aristocrat is a jungle
Nonsense	A blizzard is a beard
Nonsense	Arrows are weeds
Nonsense	A plague is a hawk
Nonsense	An acid is a statue