Meaning Construction: Cognitive Processes of Conceptual Interaction

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Bing Ran

ABSTRACT

This thesis proposes a theoretical framework explaining cognitive processes of meaning construction through conceptual interactions. It was noted that while the nine models or theories (Fuzzy Sets, Selective Modification model, Amalgam theory, Concept Specialization model, Composite Prototype Model, Dual-Process model, Constraint model, CARIN model, and Coherence Theory) in literature on conceptual combination offered insights on the problem of how people understand conceptual combinations, most of them assumed a schematic representation of our knowledge of concepts. However, it is possible that our minds represent knowledge in less structured ways and that schematic structure may not necessarily play a role in making sense of conceptual combinations. In this thesis, I attempted to make fewer assumptions about how knowledge is represented to explain the cognitive processes of conceptual combinations. I assume that concepts are related to other concepts, and knowledge can be represented by associations among concepts. Based on this assumption, the meaning of a conceptual combination is constructed through interactions between these associated concepts. It is proposed that the cognitive processes involved in meaning construction start from a distinction between different roles each component concept plays (head or modifier), and then a system of associations are activated contingently, prototypically, and efficiently with the goal of forming a cognitive field (analytically represented as a closed cycle) to connect head and modifier in a balanced way. The balanced system of concepts is strengthened further by reconciling remaining tensions in the field. Experimental results confirmed that component concepts in a combination activate associations contingently, and prototypicality and balance are major factors influencing whether an association will be activated by the combination to construct the meaning. Head / Modifier and Novelty were also studied as moderating variables. The experimental results indicated that head is a stronger moderator for association activation than modifier, and novelty was not found to be a significant moderator in association activation. Implications of these findings are discussed and future research is identified.

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DEDICATION

To Jun

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Chapter 1 Introduction

We communicate.

What is communicated is a series of symbols or sound patterns between two humans. Fortunately, both parties involved in communication to some degree experience similar meanings attached to these symbols and sound patterns.

It is noticed that the patterns of these symbols and sounds are compositional. Simpler elements are organized into larger units, and complex meanings emerge from the combination of simpler elements. Using language as an example, complex meanings emerge from the combination of simpler linguistic elements such as words or phrases.

How is it possible that we can mentally construct complex meanings from the smaller elements? What is the process of this meaning construction? With the hope to shed some light on these very fundamental issues in human communication, this research tackles the question: "how do conceptual representations of single words interact in a two-word combination to construct meaning in human communication?"

It is widely accepted that meaning is built out of concepts. Humans experience the world through the conceptual structure of the mind. This experience *is* the meaning of the world in the mind. In communication, if symbols or sound patterns activate their conceptual structures reflecting what they represent in the world, then meaning construction becomes the interactions of these conceptual structures in order to form a larger one with a more complicated structure to reflect a more complicated world. The current research will explore the cognitive processes of this conceptual interaction for meaning construction.

This research is built on a rich literature on meaning and concepts. Meaning construction through conceptual interaction is treated as conceptual combination in current literature. The last 40 years have witnessed a growing interest in the area of conceptual combination. Roughly nine models and theories have been proposed to explain the phenomenon of conceptual combination (Chapter 2). Most of the models have a common characteristic of assuming a schematic representation of our knowledge of concepts. Concepts are represented as having dimensions or slots with features or properties as the values in the dimension or fillers of the slot. Based on this assumption, conceptual combination is understood as the combination of these two sets of properties along certain dimensions. However, it is possible that our minds represent knowledge in less structured ways and that schematic structure may not necessarily play a role in making sense of conceptual combinations.

In essence, our knowledge of concepts is represented in terms of associations. These associations might assume a schematic structure, or might not. The framework that I will propose to explain conceptual interactions (Chapter 3) assumes that concepts are related to other concepts and knowledge can be represented by associations among concepts. Based on this assumption, meanings of conceptual combinations are constructed through interactions between these associated concepts. It is proposed that the cognitive processes involved in meaning construction start from a distinction between different roles each component concept plays (head or modifier) and then a system of associations are activated contingently, prototypically, and efficiently with the goal of forming a cognitive field (analytically represented as a closed cycle) to connect head and modifier in a balanced way. The balanced system of concepts is strengthened further by reconciling remaining tensions in the field.

Based on the proposed cognitive processes on constructing meaning for conceptual combinations, a series of hypotheses were extracted (Chapter 3). Experiments were designed and conducted (Chapter 4) to test these hypotheses with satisfactory results (Chapter 5).

In the last chapter of this dissertation (Chapter 6), some difficulties, issues and contributions of the current research are explored and discussed.

Chapter 2 Literature Review

Conceptual combination is approached mainly by a discipline called the psychology of concepts. However, relevant work has also been conducted in linguistics, cognitive sciences, AI and philosophy. Roughly, nine models or theories have been proposed in recent years to explain the phenomenon of conceptual combination. These models or theories are: Fuzzy Sets (Zadeh 1965, 1976, 1982; Osherson and Smith 1981, 1982); Selective Modification model (Smith, Osherson 1984; Smith, Osherson, Rips and Keane, 1988); Amalgam theory (Thagard, 1984); Concept Specialization model (Cohen & Murphy, 1984; Murphy, 1988, 1990, 2002); Composite Prototype Model (Hampton 1987, 1988, 1989, 1990, 1991); Dual-Process model (Wisniewski, 1997a, 1997b, 1999; Wisniewski & Love, 1998), Constraint model (Costello & Keane, 2000, 2001), CARIN model (Gagné, 2000, 2001; Gagné & Shoben, 1997), and Coherence Theory (Thagard 1989; 1997). While each model offers some insight on the problem of how people understand combinations of words or concepts, they each have their own theoretical weaknesses. In the following section, I will review each of them critically. The sequence of this review is roughly based on the year that each model was first proposed in literature.

2.1 Conceptual Combination as the Intersection of (Fuzzy) Sets

The earliest attempt to describe the phenomenon of conceptual combination was conducted by mathematicians known as (fuzzy) set theorists.

2.1.1 The Model

The attempt to formulate a theory of conceptual combination based on set theory (Osherson and Smith 1981, 1982; Zadeh 1965, 1976, 1982) generated some formalized explanations on how humans combine smaller conceptual units into more complex ones. Referential semantics holds the idea that the concept represented by a word equates to the set of things it denotes (its extension). For example, the meaning of the concept *bird* refers to the set of all birds. When two concepts are combined, the resulting concept is the intersection of their extensional sets. Thus, if X and Y are the extensional sets of the concept *x* and *y* respectively, the conceptual combination *xy* is understood as the intersection of the set X and the set Y, that is, things that are both X and Y. For example, the meaning of *pet fish* is the intersection of *pets* and *fish*, i.e., the set of things that are both pet and fish. More formally, in classic set theory, the conceptual combination of XY is defined as follows: (Let X, Y be sets) the intersection of X and Y (denoted X∩Y) is the set $\{z : z \in X, z \in Y\}$. In fuzzy set theory, the intersection of two fuzzy sets A and B with respective membership functions f_A (x) and $f_B(x)$ is a fuzzy set C, written as C =A∩B, whose membership function is related to those of A and B by $f_C(x) = \text{Min}\ [f_A(x), f_B(x)]$, $x \in X$, or, in abbreviated form $f_C = f_A \wedge f_B$ (Zadeh 1965).

Both classic set theory and fuzzy set theory provide a formalized way to describe conceptual structure. Set theory quite accurately describes the classic view of categories (Lakoff 1987, Osherson and Smith, 1982) and fuzzy set theory (Zadeh 1965, 1982) has been used to model the prototype structure of categories with predictions that could be empirically tested. Conceptual combination as the intersection of sets is described clearly, logically, and parsimoniously by this theory.

However, as a description of conceptual structure, (fuzzy) set theory was strongly criticized by psychologists. Their major criticisms are summarized as follows.

2.1.2 Criticisms of the Model

The first criticism relates to whether set theory is an appropriate theory for concept representation. For example, the applicability of set theory in concept representation is limited. Osherson and Smith pointed out that the extensional view of concepts "is best suited to 'kind' notions (such as *dog*, *tree* and *animal*), to 'artifact' notions (like *tool* and *clothing*), and to simple descriptive notions (like *triangular* and *red*) where the extensional sets are easier to define. More difficult to describe are intentional or intricate concepts such as *belief*, *desire*, and *justice*" (Osherson and Smith, 1981 p.38). The diversity of different kinds of concepts imposes difficulties on how set theory formally describes their structure.

Non-kind or non-natural concepts are thus very difficult to be described using sets and whenever non-kind or non-natural concepts are combined, the intersection of those sets is very difficult to describe or formalize. Murphy also noticed that the nature of set theory is not psychological (Murphy, 1988, 2002). “It is very difficult to interpret it as a psychological theory at all. Even if all *pet fish* fall into the intersection of pets and fish, this does not tell us what people do with their concepts *pet* and *fish* in order to create a new concept” (Murphy 1988, p.531). Set theory does not provide an intensional explanation of why people combine concepts in order to be a psychological model.

The second criticism relates to what are known as conjunction effects: fuzzy set theory will lead to a contradiction in its calculation whenever an object is more prototypical of a conjunction set than of its constituent sets (Osherson and Smith, 1981). For example, it can be shown empirically that a guppie is more prototypical of the conjunctive concept *pet fish* than it is of either *pet* or *fish*. That is, $C_{\text{pet fish}}$ (guppie) > C_{pet} (guppy) or C_{fish} (guppy). However, the intersection of the fuzzy sets is defined as:

$$(\forall x \in F) \ (C_{\text{pet fish}}(\text{guppy})) = \min (C_{\text{pet}}(\text{guppy}), C_{\text{fish}}(\text{guppy}))$$

which implies: $C_{\text{pet fish}}$ (guppy) < C_{pet} (guppy) or C_{fish} (guppy).

In other words, “it is possible, contrary to fuzzy-set theory, for the characteristicness of an instantiation of a conjunctive concept to be greater than either of the characteristicnesses of its constituent simple concepts” (Jones, 1982 p.284). This apparent contradiction shows that intersection is not an appropriate tool to describe conceptual combination.

The third criticism is related to concepts that are not intersective. For example, Murphy (1988) noticed that intersection of sets does not account for non-intersective concepts such as *apartment dog* or *typewriter table*. They do not correspond to the intersection of the sets apartments and dogs or the intersection of typewriters and tables. Moreover, nonpredicating adjectives, when combined with nouns, do not produce meaningful intersections. “The intersection of atomic engineer as someone who runs equipment to make atomic energy is not the intersection of atomic things (whatever they are) and engineers. …. the intersection of the two sets does not define the combined concept" (Murphy, 2002 p.445).

The last criticism is related to the symmetric property of set intersection which contradicts our intuitive understanding of the meaning of a conceptual combination. Set theory predicts that noun-noun combinations are symmetric, because $X \cap Y$ is the same as $Y \cap X$. However, our intuitive understanding of the combination XY usually has very different meanings than their YX counterparts. For example, "a desk lamp is a kind of lamp, but a lamp desk is a kind of desk" (Murphy, 2002 p.445).

The criticisms by Osherson, Smith and Murphy are important and quite convincing intuitively. As a mathematician, Zadeh wrote his responses regarding the psychology of concepts and categories in 1982 to address those concerns raised by Osherson and Smith (1981, 1982). Unfortunately, Zadeh's 1982 paper was never seriously treated in the field of psychology of concepts. Thus, it is worth re-visiting Zadeh's anti-criticism to get a balanced view on the applicability of fuzzy set theory in describing conceptual structure and, in particular, on the appropriateness of intersection as the description of conceptual combination.

2.1.3 The Response of Zadeh (1982) and my comments

Zadeh responded to the first criticism in his 1982 paper in a very detailed way by reformulating the definition of the concept of prototype (Zadeh, 1982 pp.293 –297). I will not review all of Zadeh's responses here but rather comment briefly regarding this criticism. In general, it could be noted that what makes an explanation truly 'psychological' is still under debate and none of the current theories on conceptual combination are fully immune from the criticisms of applicability and intentionality. For example, the way schema theory describes the conceptual structure experiences the same problems. What is a schematic representation for *belief*, *desire*, or *justice*? How would schema theory "provide an intentional explanation of some kind in order to be a psychological model"?

To address the second criticism on the conjunction effect, Zadeh (1982, pp.291 – 292) pointed out that “when (a) the intersection of A and B is a subnormal fuzzy set (i.e., a fuzzy set whose maximal grade of membership is less than unity); and (b) we focus our attention on A ∩ B by giving it a label, say C, we are, in effect, tacitly normalizing C by relativizing the grades of membership in C with respect to the maximal grade of membership in A ∩ B. By so doing, we are generating a normalized fuzzy set Norm (A ∩ B) which is not a subset of A and B. Consequently, an object, u, may have a higher grade of membership in Norm (A ∩ B) than in A or B.” That is, the intersection of two fuzzy sets A and B is a fuzzy set C in itself. When we normalize this intersection set C, it is not a subset of A and B anymore. Thus, it is quite possible that an object is more prototypical of C than of A or B, leading to the conjunction effect.

To address the remaining criticisms, Zadeh pointed out that in natural language, “the denotation of a phrase of the form AN, where N is a noun (e.g., apple) and A is a descriptor of N, (e.g., striped), is not, in general, the intersection of the denotations of N and A, no matter how the intersection is defined. The reason for it is that in many cases A is not a descriptor of N but an operator which transforms the denotation of N into the denotation of AN” (1982, p.292). This is a very insightful observation that not all conceptual combinations of the form XY (where X and Y are two concepts) are truly conjunctives. In our research, we have encountered a large number of spurious conjunctions despite their syntactic similarity to genuinely conjunctive concepts and these conjunctions do not denote intersections. The intersection logic about genuinely conjunctive concepts (such as *pet fish* vs. *fish pet*) ought not to be faulted for its failure to account for such spurious conjunctions. Using Murphy’s example, in the combination *apartment dog*, *apartment* is an operator functioning on the concept of *dog*. The concept of *dog* is sub-classified along the dimension of *apartment*, forming a modification + noun structure, where the modifier specifies the relevant dimension that the noun concept is sub-categorized. It is erroneous to treat *apartment* as equally denoting something as *dog*. As well, it is clear that relative adjectives should not be treated as nouns denoting a set of things as in the case of *atomic* in the combination *atomic engineer*. Based on the same logic, quite often, phrases of the sort XY are not true conjunctives thus do not follow the symmetric property of set intersection. That is, XY and YX have different meanings because they have different central concepts and different operators functioning on these central concepts.

Although Zadeh addressed psychologists' concerns, there are still some further issues that I feel fuzzy-set theorists should address before this view can be accepted in the psychology of concepts.

First, the assumption of genuinely conjunctive concepts is questionable. Zadeh assumes the existence of genuinely conjunctive concepts that are distinguishable from spurious conjunctions and that fuzzy set intersection is applicable only to genuinely conjunctive concepts. However, are there any genuinely conjunctive concepts? Psychologically, there might be genuine conjunctives when we stay at the cognitive level of concepts to represent something that is both in category A and B. However, whenever we move to the linguistic level and use words to denote concepts and conceptual combinations, syntactic constraints function, by which one word sub-consciously functions as an operator (syntactically termed as modifier) while the other word functions as a denotation (syntactically termed as noun or head noun). Thus, it seems that whenever conceptual combinations are represented at the linguistic level, there are no genuine conjunctives. All the conceptual combinations XY become so-called spurious conjunctives characterized by the logical operator X that transforms the denotation of Y into the denotation of XY.

Second, the assumption of defining fuzzy intersection using the "min" operator for conjunctive concepts is questionable. Several researchers including Zadeh himself have pointed out that no single formula for conjunction can model the wide variety of ways in which conjunction enters into concept formation and meaning representation (Dubois and Prade, 1980; Zadeh, 1978, 1982). Thus, if intersection of fuzzy sets is used to explain the conceptual conjunctions, the specific operator for this intersection is worthy of more research.

Third, with respect to conceptual categories, the assumption that there is a single dimension along which two fuzzy sets are compared and intersected is questionable. "A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership characteristic function which assigns to each object a grade of membership ranging between zero and one" (Zadeh, 1965 p.338). This definition assumes the existence of one particular dimension on which the objects' membership is evaluated and described by its membership characteristic function. However, when two fuzzy sets are taken into consideration, the existence of one single dimension that differentiates members in both sets is questionable. Moreover, the existence of one single dimension along which the operation of sets (such as union, intersection, complement) is performed is also questionable. For example, while the conjunctive concept *young and middle aged* is calculated as the intersection of the fuzzy concepts *young* and *middle aged* along the dimension of age, what would be the dimension along which two concepts such as *apartment* and *dog* or *striped* and *apple* are compared and intersected?

Last, the assumption of the independence of sets is questionable. When dealing with concept combination, fuzzy set theory assumes the independence of the two fuzzy sets. So the understanding of the conjunctive concept is a calculation (here, intersection) of two independent sets. However, although a single concept denotes a set of its extensions that is more or less independent from other concepts, when we combine two such sets, are they still independent of each other? I believe the meaning of the conceptual combination is a function of its constituent concepts, and moreover, the meaning of each constituent concept is a function of the other constituent. For example, the meaning of the conceptual combination *bird furniture* depends on our understanding of *bird* and *furniture*, and more importantly, the meanings of the constituents influence one another, i.e., the meaning of *bird* in the combination *bird furniture* will largely depend on the meaning of *furniture* and vice versa. Thus, the meaning of a combination is not just an intersection or other set operands of two independent sets; on the contrary, it is a dynamic combination of constituent sets that are highly interactive and interdependent for its meaning in this combination.

In summary, as the first and last formal logic model of conceptual representation, (fuzzy) set theory provides a strong tool to describe and analyze conceptual phenomena such as conceptual combination. However, this theoretical approach has some weaknesses that need to be addressed before it can be fully accepted in the psychology of concepts.

2.2 Selective Modification Model

As an alternative to Fuzzy set theory in explaining the process of conceptual combination, Smith and Osherson proposed the selective modification model (Smith, Osherson 1984; Smith, Osherson, Rips and Keane, 1988).

2.2.1 The Model

The model has two parts: the first part provides a claim about how concepts are mentally represented and the second part explains how these mental representations are combined.

Smith and Osherson start their model by describing a schematic representation of the concept (Minsky, 1975; Rumelhart & Ortony, 1977). In this representation, concepts are represented by attribute-value pairs. For example, *apple* is represented by color-red, shape-round, taste-sweet etc. Each value is associated with a certain weight to indicate its salience. For example red is more salient than round in the apple concept (e.g., Glass & Holyoak, 1975; Halff, Ortony, & Anderson, 1976). Each attribute is associated with a certain weight as well, which Smith & Osherson termed as diagnosticity. It is “a measure of how useful the attribute is in discriminating instances of the concept from instances of contrasting concepts” (Smith et al. 1988 p.487). For example, when mentally representing the concept *apple*, humans are said to have a set of relevant attributes such as color, shape, and texture. The diagnosticity of each attribute for the concept is indicated by a certain numerical value decided empirically. For each attribute, there is a set of possible values that *apple* can assume (such as for the attribute color, the possible values include red, green, and brown). The salience of each value of an attribute is decided by "votes" for the value by subjects. This kind of representation is essentially a frame or a schema (e.g., Minsky, 1975; Rumelhart, 1980; Winston & Horn, 1981), with attributes being slot-names, features being values, and most-likely features being default values.

The second part in the selective modification model is called "adjective modification" in which, an adjective modifies the noun. More specifically, "Each attribute in the adjective concept selects the corresponding attribute in the noun concept; then, for each selected attribute in the noun, there is an increase in the salience (or votes) of the value given in the adjective, as well as an increase in the diagnosticity of the attribute. Consider shrivelled apple as an example. Presumably shrivelled contains attributes pertaining to shape and texture; accordingly, it would select these attributes in the apple prototype, boost their diagnosticities, and shift their votes away from round and smooth and toward irregular and bumpy" (Smith, et al. 1988 p.492).

2.2.2 Some Comments on this Model

Smith and Osherson's selective modification model is regarded as the first 'psychological' model of conceptual combination. The main contribution of this model is that it documented a number of phenomena in conceptual combination that their own and later models have tried to account for. These include typicality effects (the typicality of a combination is not a simple function of the typicality of the component concepts) and the conjunction effect (when an item is well described by a conceptual combination, it is usually more typical of that concept than of the two components).

However, the model suffers from several drawbacks. First, the scope of the model is quite limited. Smith et al. realized that the selective modification model only deals with one kind of conceptual combination, namely, adjective-noun phrases such as *red apple* or *long vegetable*. They did not consider many other types of conceptual combination such as noun-noun combinations (*bird dog*, *telephone television*) or nonpredicating adjective noun combination like Murphy's *atomic engineer* or *musical clock* examples.

Second, the way that concepts are represented in the model is problematic. More specifically, only nouns are represented schematically in the model while adjectives are not represented using the similar schematic representation, as if only nouns correspond to concepts and adjectives are just values of certain attributes of the concept. The implicit assumption that the parts of speech that are not nouns (i.e., adjectives, adverbials, verbs etc.) do not correspond to concepts is problematic. A suitable theory of concepts should include other linguistic forms than just nouns. Adjectives (such as red, musical or comfortable), verbs (such as go, run, sleep), prepositions (such as in, at, on) and adverbs (such as luckily, almost, quickly) etc. also correspond to certain concepts and deserve an equal status in terms of describing their conceptual representation.

Third, the assumption that in order to explain the process of conceptual combination, we need a level in our conceptual structure called dimension / slot[1] that summarizes or organizes values is problematic. In the model, concepts are represented by certain dimensions that have certain values forming dimension-value pair. For example, *apple* is represented by color-red, color-green, shape-round, texture-smooth pairs. In this representation, the color dimension is a summation or organization of all possible 'features' such as red, green, brown, etc. Organizing features into dimensions (color, taste) in this way allows a clearer picture of the relation between features. So red and green are in the dimension of color, while sweet and sour are in the dimension of taste. Features such as red and sweet are organized at a lower conceptual level relative to the superordinate dimensions of color and taste respectively. It is clear that when we logically think about the concept, we may summarize and organize their features (values) into dimensions. Analytically, there is nothing wrong with it. However, when we actually use concepts to communicate, the function of this additional layer of dimension or slot is not clear. That is, whether or not the meaning of *red apple* is understood as red-apple or as red-color-apple is unclear. From our viewpoint, the latter understanding is redundant, i.e., color is a redundant level that does not necessarily function in our understanding of conceptual combinations.

Fourth, the assumption of pre-existing dimensions (slots) is problematic. The model assumes that in our mind, we have a system of pre-stored dimensions / slots for each concept. This schematic representation uses a structured list of slots and fillers to represent

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[1] Smith et al. actually used of the term *attribute*, but their usage is consistent with what is called

a concept's properties and the potential values of each property. For example, the concept *apple* has a system of pre-stored dimensions such as color, shape and texture. However, it is not clear that these dimensions are pre-stored regardless of the communicative context, or are created in response to the communicative context. For example, how should one understand the meaning of the novel conceptual combination *tasty computer*? It is hard to imagine that a *computer* has a dimension / slot of taste or that *tasty* has a dimension of computer.

Fifth, the assumption about the exhaustiveness and the completeness of the set of dimensions / slots stored in our mind is problematic. In the concept representation part of the selective modification model, the dimensions are complete in terms of how many are necessary and sufficient to represent the concept. However, the number of dimensions as a pre-determined feature of concepts is very question begging. How could we know that a limited number of dimensions such as color, shape and texture etc. is capable of representing complete knowledge of the concept *apple*? How many slots are needed to describe all the possible knowledge that we have regarding a concept? And indeed, what are slots / dimensions anyway? Dimension such as shape or color organizes our knowledge of physical things. They describe the physical or chemical properties of physical objects. Then how about social entities such as *country*, *suicide* or conceptual entities such as *love* or *hate*? What will be the slots / dimensions representing these kinds of concepts?

Lastly, the process of conceptual combination described by this model is problematic. Murphy pointed out: "The main problem with this theory that latter writers have criticized is its assumptions about modification. Consider the way modification works for the concept *red apple*. The adjective *red* finds its match in the schema: There is a feature with the same name. That feature now gets all the votes, and its dimension gets a higher diagnosticity rating. However, there are more complex cases that aren't so easily accommodated. It has been argued that sometimes, the exact feature would not be present in the concept already,

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'dimension' or 'slot' in the rest of the literature.

and yet people can figure out how to modify it. Indeed, there may not be an obvious dimension for the modifier to affect. Furthermore, sometimes more than one dimension is altered. Thus, the modification process itself has been argued to be much more complex than Smith et al. let on" (Murphy, 2002 pp.449-450). Just as Murphy explained, conceptual combination process is much more complex than what the selective modification model proposed. Adjectives may not easily find a corresponding dimension to modify, and nouns may not have a single ready-made dimension waiting for the adjective.

In summary, although the selective modification model contributes to the conceptual combination literature by documenting some interesting phenomena such as typicality effects and the conjunction effect, it suffers from some serious theoretical shortcomings. The model oversimplifies the complex process of conceptual combination and the underlying assumptions on how concepts are represented are question begging.

2.3 Amalgam Theory

In the early 1980s, Thagard (1984) proposed a theory of conceptual combination within the context of philosophical investigations on the phenomenon of scientific concept development. Thagard proposed "a theory of how new concepts can arise, not by abstraction from experience or by definition, but by conceptual combination. Such combination produces a new concept as a non-linear, non-definitional amalgam of existing concepts" (Thagard, 1984 p.3). I will refer to this approach as amalgam theory.

2.3.1 The Theory

Amalgam theory starts from the basic observation that "conceptual combination requires mechanisms for reconciling the conflicting expectations contained in the candidate concepts" (Thagard, 1984 p.4). A description of procedural mechanisms is thus needed "by which aspects of existing concepts can be used to construct new ones, with greater flexibility than a definitional approach would produce" (Thagard, 1984 p.4).

The amalgam theory assumes a schematic representation of concepts (the paper adopted the term "frame" from Minsky 1975) with slots and values (i.e., each concept C_i has slots, $C_{i,1}$ ... $C_{i,n}$), and proposes that a new concept C_3 is formed from initial concepts C_1 and C_2 by selecting from $C_{1,j}$ and $C_{2,k}$, a subset of slots which will constitute the $C_{3,m}$. Six procedural rules are proposed to regulate the process of slots and value selection (Thagard, 1984 pp. 6-8). For example, "a concept concerning a kind of physical object which has a value for size is also likely to have a value for weight. Conceptual combination should preserve such linkages" (p.7). Other rules propose that if a slot is chosen by conceptual combination, the value of the slot will depend on the adjectival concept, the variability of the concept, specific examples of the combination, or representativeness of the given instances of the combination. Specifically, the theory proposed that when we try to reconcile conflicting slots, we usually favor those that contribute to desired problem solutions. For example, "suppose that in forming the combined concept of a Canadian violinist you notice that your friend the Canadian violinist prefers hamburgers to classical French cuisine. In order to explain this preference, you may add the default expectation about Canadians to your frame for Canadian violinist, overruling the expectation derived from the frame for violinists" (Thagard, 1984 p.9). To reconcile the conflicting preference of food by *Canadian violinist*, we favor the connotation that "Canadians usually prefer hamburgers" to resolve the conflict that was brought in by *Canadian* and *violinist* (who supposedly prefers classical French cuisine).

2.3.2 Some Comment on this Theory

The treatment of conceptual combination as a problem solving process of reconciling conflicting expectations contained in the candidate concepts is the contribution of this approach. This general line of thinking is consistent with Thagard's later theorizing of coherence on this problem (1997, to be discussed later in this chapter). Moreover, the basic theoretical claim that a description is needed of procedural mechanisms by which aspects of existing concepts can be used to construct new ones is a helpful observation. This model proposed several procedural mechanisms that could be tested empirically.

However, the proposed rules are still in need of more empirical examination. These rules are intended as guiding principles for the process of reconciling features from candidate concepts and instances into a non-conflicting set for the new, combined concept. However, how these rules might be implemented cognitively remains a question that needs to be addressed.

This theory assumes that the slots of the conceptual combination and its values come from the amalgam of component concepts and examples. However, later researchers have noted that many conceptual combinations have emergent features that are not derivable from their components. Thus, amalgam theory may need to address why there are emergent features and how these features emerge.

The theory also proposes that specific examples may be used to resolve the conflicting expectations contained in our component concept schema. However, some conceptual combinations do not have ready made examples, especially novel combinations such as *triangular basketball* or *tasty computer*. How conflicting expectations are reconciled for such novel combinations needs more theoretical exploration.

2.4 Concept Specialization Model

Murphy proposed the concept specialization model (Cohen & Murphy, 1984; Murphy, 1988, 1990, 2002) in the mid 80s to deal with “complex concepts” (e.g., noun-noun compounds) and to address the weaknesses in Smith & Osherson’s selective modification model.

2.4.1 The Model

Similar to the selective modification model and amalgam theory, the concept specialization model assumes a schematic representation of concepts where nouns are represented as schemata with slots (dimensions) and fillers (values for each dimension). For example, the concept *dog* has slots such as Habitat and Functions, which provide a general organization of knowledge about *dog*, with fillers being specific values that occupy these slots (e.g., “home” or “street” being fillers to the slot of Habitat).

Based on this representation, “conceptual combination is a process in which a head noun concept was specialized by one or more of its slots being filled by the modifying concept” (Murphy, 2002 p.453). In this process, “knowledge is involved in choosing the best-fitting slot” (Murphy, 2002 p.453). For example, to understand the combination *apartment dog*, the modifier *apartment* is used to fill some slot in the head concept *dog*. What dimension or slot of *dog* is picked by the modifier *apartment*? Our background knowledge will guide us to choose the slot of *dog* that makes the most sense with *apartment* as the filler. In this case, *apartment* is classified as a type of “Habitat” and so fills the Habitat slot in the head concept *dog*. This provides the interpretation of “a dog that lives in an apartment”.

After this slot-filling process, the model proposes that further interpretation and elaboration occurs in which we use world knowledge or background knowledge to expand our initial interpretation. This process seeks to make an interpretation more coherent and complete by retrieving information from our background knowledge that is relevant to the interpretation. For example, people might elaborate that an apartment dog is cleaner, smaller and quieter than other dogs. This elaboration generates a rich conceptual combination with features that were not part of the original concepts and these features are considered to be emergent.

2.4.2 Some Comments on this Model

Murphy’s conceptual specialization model is very similar to Smith & Osherson’s selective modification model. As Murphy explained: “one way to relate these two models is to think of the feature weighting model (selective modification model) as a simpler version or subset of the specialization model. That is, the specialization model is very similar in the way it deals with simple features, but it adds another layer of conceptual operations – the elaboration based on world knowledge” (Murphy 1988 p.535). Thus, most of the preceding comments about the selective modification model apply to this model as well. For example, the concept specialization model relies on slots / dimensions as the level of the explanation. As pointed out previously, it is not fully clear that slot, as an additional layer to organize values into a system, is the only level for us to explain the cognitive process of conceptual combination. Similarly, concept specialization model also assumes that slots are pre-existing and we have a system of pre-stored slots that is always ready to be used, and this set of slots is necessary, sufficient and exhaustive in that whenever a concept combines with any other concept, there is always a certain slot ready to be filled.

Both the selective modification model and the concept specialization model overemphasize one component of the combination: the head noun. The head noun concept is treated as the central concept with a complex schematic structure, while the other component – modifier is treated only as a value to modify or specialize the head noun. This might be due to an implicit assumption about the relation between parts-of-speech and concept. As I pointed out, concepts are not represented only by nouns. Adjectives, verbs, adverbs, prepositions etc have a conceptual structure as complex as nouns, rather than just serving as values to fill the slots of noun concepts. If modifiers in a conceptual combination do not just serve as values for slots of the head noun concept, what might be the schematic representation of the modifier concept? How do these two schemata of head and modifier concepts interact and influence each other in a conceptual combination? The two models do not address this issue.

Some researchers (Costello & Keane, 2000; Wisniewski & Gentner, 1993) pointed out that the biggest shortcoming of the concept specialization model lies in the limited types of interpretations it can account for. The model can only account for conceptual combinations where the head and modifier concepts are linked by some kind of thematic relation and ignore the possibility of property-based interpretation. For example, Wisniewski used *robin hawk* to explain the weakness. *Robin hawk* could be interpreted as "a hawk that preys on robins", by filling the Preys slot in the schema representation of *hawk* with the modifier name. The meaning generated this way explains the thematic relation between *hawk* and *robin*. However, it does not allow for properties of the modifier to be transferred into the head representation. This means that an interpretation such as "a hawk with a red breast" cannot be explained by this model.

Murphy argues that the biggest contribution of the concept specialization model was to bring in background knowledge to explain conceptual combination, especially why there are emergent features for a combination. However, it should be pointed out that in the selective modification model, Smith & Osherson implicitly assumed the existence of background knowledge as well. At least, we must 'know' that *red* is a color before we can modify the noun selectively. Regarding the role of the background knowledge in conceptual specialization model, I have a few concerns.

The first concern I have regards the nature of background knowledge in this model. The model analyzed two functions that knowledge serves: "first, outside knowledge must often be consulted in order to decide which slot is the appropriate one to specialize… the second reason for consulting outside knowledge is to elaborate or clean up the concept in order to make it more coherent and complete" (Murphy 1988 p.533). Although it is a central concept in the model, the nature of 'outside knowledge' is not clearly defined and is treated as a kind of black box in which the cognitive mechanisms that guide its function are unknown. For example, when we construct the meaning of *apartment dog*, our background knowledge allows us to choose the slot of *dog* that makes the most sense with *apartment*. But how knowledge helps us choose the best slot is not clear. Undoubtedly, knowledge plays an important role in the process of conceptual combination, but a model using this concept should explain or define in detail the denotation and the connotation of this concept.

A related question deals with the process of concept specialization. The model explains that people attempt to place the modifier into the best fitting slot in the head noun's schema. It explains which slot is chosen by its appeal to world knowledge. However, after choosing the best fitting slot, how to fill the slot, i.e., how to specialize a head concept is not specified. That is, what does it mean cognitively to "fill a slot"? For example, the model states that a combined concept is created by filling a slot of the head concept with the modifier concept. However, it is not the whole modifier concept that fills in the slot of the head concept. Intuitively, it should be some part of the modifier that fills in. For example, the meaning of *apartment dog* is not derived from the fact that the whole concept of *apartment* fills in the habitat slot of *dog*. It is some aspects of the concept *apartment* that fill in dog's habitat for the obvious reason: *apartment* is a concept with its own complex 'schematic' structure that might include, rent, size, storey, apartment number, landlord, etc. It is hard to imagine that such a rich concept could be filled into dog's habitat slot easily and it is hard to imagine how these rich aspects of the concept *apartment* are filtered so quickly in our cognition in order to be able to fill into *dog* concept. Besides a metaphorical description, what mechanisms are involved in filling a slot? I think this apparent gap in the explanation comes from the confidence that schema, as the representation of conceptual structure, is the level of the explanation for conceptual combinations. Certainly, slot as a static representation of human knowledge has its theoretical and explanatory power; however, there is little empirical evidence that cognitive processes of conceptual combination is carried on the level of slots as compared to other potential concept representational structures. Thus, an over-confidence in the slot explanation may hinder researchers from exploring the deeper cognitive processes that might lead to the phenomenon of slot.

The next concern I have is related to the over-restriction of the applicability of a model on the conceptual combination. For Murphy, a model of conceptual combination should only explain the "correct" meaning of the combination, in which, "correct" means that most people would generate such a meaning and would see such a meaning as appropriate. For him, a model that is capable of explaining all the possible meanings ("correct" or "incorrect") of a combination will "come up with interpretations that are too remote. For example, what is to stop such a model from claiming that a tiger squirrel is a statue of a squirrel that is made from a tiger, or a kind of toy squirrel that tigers like to play with? Once one allows the modifier and head noun to be construed as meaning different things, and if one allows many different relations to connect the two concepts, the model may generate more different interpretations for a phrase than people would accept"

(Murphy, 2002 p.469). However, I believe that a model should be descriptive and able to explain why people are capable of generating these many different meanings for a combination and how our cognition functions to generate these different meanings, rather than being prescriptive in terms of judging the "correct" meaning of a combination. A model of human cognition should describe the phenomenon whenever there is such a phenomenon. If people understand the meaning of *tiger squirrel* as "statue of a squirrel that is made from a tiger", the model should have the capability to explain why and how there is such an understanding. It seems quite apparent that people are capable of understanding very strange conceptual combinations without too much difficulty. For instance, the meaning of *furniture bird* appears to have been understood by most of the participants in my pilot experiments. And the very fact that Murphy is able to generate a few diverse meanings for *tiger squirrel* shows that people have the cognitive ability to easily construct various meanings for a conceptual combination. Then what is this ability and how this ability functions in conceptual combination should be taken into the scope of a psychological model of conceptual combination.

Lastly, Murphy and later researchers treat the grammatical distinction between head noun and modifier (typically nouns and adjectives) as equivalent to the psychological head and modifier concepts in a conceptual combination. For example, Murphy defines: "a final bit of terminology is that the first word *(in a two-word combination)* is called the *modifier*, and the final word, the *head* noun (because it is the head of the noun phrase in syntactic terms)" (Murphy, 2002 p.444). Grammatically, if a segment of language exhibits the endocentric structure (i.e., the meaning of the whole structure is functionally equivalent to that of one or more of its constituents), a distinction between head word and modifier is necessary. However, the psychological basis for this distinction is not clear. Will this grammatical distinction always equate to a psychological distinction? It is worth studying in more detail how closely grammatical head and modifier correspond to psychological head and modifier.

2.5 Composite Prototype Model

Hampton proposed the composite prototype model (Hampton 1987, 1988, 1989, 1990, 1991) at about the same time as Murphy proposed the concept specialization model.

2.5.1 The Model

Similar to other models, the composite prototype model has two parts: how concepts are represented and how concepts are combined (Hampton 1991 pp.105-108). The model assumes that concepts are represented as sets of attributes that are interconnected by higher-level theory-driven relations. For example, we all know that birds have wings and can fly (attributes) and that having wings is an enabling condition for flight. The attributes have a quantitative "degree of definingness" which Hampton termed as Importance[2]. “At the top end of the scale of attribute importance there may be some attributes which are so important as to be **necessary** for category membership. For example HAS GILLS may be treated as a necessary attribute of FISH” (Hampton 1991 p.106 emphasis in original). Hampton further assumes that “attributes are organized in such a way that at least some of them are represented as particular sets of values on particular dimensions. Obvious examples would be dimensions such as COLOR and SIZE... For example the fact that Pets are domesticated may be represented as a dimension (or frame-slot) labelled HABITAT taking a particular value [DOMESTIC]” (Hampton 1991 p.106).

Based on these assumptions about concept representation, Hampton proposed that “a conjunctive concept is then represented semantically by a composite prototype… which is formed as the union of the sets of attributes from both ‘parent’ (constituent) concepts. Thus initially the concept PET FISH will have all the attributes of both PET and FISH prototypes” (Hampton 1991 p.107). This new union of attributes is then modified based on

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[2] The notion of importance has been proposed as definingness (Smith, Shoben, and Rips, 1974), cue validity (Murphy, 1982), diagnosticity (Smith & Osherson 1984) or centrality (Barsalou & Billman, 1989). It reflects the relative likelihood of an item belonging to a category given that it does or does not have the particular attribute.

a necessity constraint. A necessary attribute of one constituent concept will also be a necessary attribute for the conjunctive. “For example if HAS GILLS is necessary for FISH, then it will also be necessary for PET FISH. This places a Necessity Constraint on attribute inheritance” (Hampton 1991 pp.107). For other attributes, the importance of them is determined as a monotonic positive function[3] of importance for each parent (constituent concept). For example, “LOVABLE is fairly important for PETS and irrelevant for FISH, it will be of intermediate importance for PET FISH” (Hampton 1991 pp.107). The attributes with low average importance will be dropped from the conjunctive set (or filtered out in the process of constructing meaning for conjunctive). “Thus, if LOVABLE is now of relatively low importance, a subject may simply exclude it from the prototype for PET FISH” (Hampton 1991 pp.107).

After forming the set of attributes for conjunctives, a consistency checking procedure is applied to this new set of attributes. “Where there are incompatible attributes, a choice has to be made to delete certain attributes” (Hampton 1991 pp.107). This consistency constraint follows the following rules. When a non-necessary attribute of a constituent concept has a conflict with the necessary attribute of the other constituent concept, it will not be used by the conjunctive. “For example, if PETS typically breathe air, but this is inconsistent with living underwater, which itself is necessary for the concept FISH, then breathing air will not be possible for PET FISH” (Hampton 1991 pp.108). When the conflict is between two necessary attributes of two constituents, then the conjunction is an empty set - a "logical impossibility." For example, “if asked to describe a FISH that is also a BIRD, subjects may say that such a creature is not possible since FISH must have GILLS, while BIRDS must have LUNGS. If the subject is pressed to continue into the realm of science fiction, or if the linguistic context is supportive of a nonliteral interpretation, then one or other of the necessary attributes will be deleted” (Hampton 1991 pp.108). “When the conflict involves two non-necessary attributes, then the choice of which to delete will

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3 A function which is either entirely nonincreasing or nondecreasing. A function is monotonic if its first derivative (which need not be continuous) does not change sign. Monotonic positive function is

depend on their relative importance, on the overall consistency that can be achieved with respect to the other inherited attributes, and on the context in which the phrase is being used" (Hampton 1991 pp.108).

2.5.2 Some Comments on the Model

The composite prototype model has a few advantages over previous models. In this model, concepts are represented by a set of attributes with a weighting factor associated with each attribute. This type of representation not only allows the model to deal with the question of sequence of attribute activation in the combination process, but also allows a more flexible representation of the meaning of a concept than a static schema. The necessity constraint and the consistency constraint are very important in the model for both concept representation and concept combination, which I believe are the contribution of this model. As Hampton explained, by applying these two constraints, "the proposed model could (also) be applied to the conjunction of well-defined concepts with a core of common element defining features, with the desired results. The necessity constraint would ensure that all defining features of each concept remain critical for the conjunctive concept, and the consistency constraint would ensure the correct identification of nonoverlapping sets. Well-defined concepts would therefore require no different treatment in the model" (Hampton 1991, p.108). Besides these advantages, this model, similar to the amalgam theory, also proposes underlying mechanisms that generate testable predictions. For example, the model predicts that necessary feature will show up in the combination when competing with non-necessary features, which is empirically testable.

The model also makes a few problematic claims. First of all, the claim of the necessary attributes is question begging. The necessary attribute is defined as an attribute that is so important as to be necessary for category membership. For example, if *has gills* was treated as a necessary attribute of *fish*, then any fish should have gills. If they don't have gills, they are not fish. This claim is potentially in conflict with the prototype theory

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always increasing; never remaining constant or decreasing.

(Rosch 1978). The problem is that the necessary attribute guaranties the category membership and a crisp boundary is drawn for the category membership (e.g. the animal is either a fish or not a fish), which contradicted with what Rosch demonstrated in terms of degree of category membership. Moreover, for many categories, it is almost impossible to identify such necessary features. To use Wittgenstein's (1953) well-known example, what would be the necessary feature for the category "game"?

In relation to the claim of necessary attributes, Hampton proposed the inheritance principle that a necessary attribute of one constituent concept will also be a necessary attribute for the conjunctive. There are some obvious mistakes in this claim. For example, *chocolate fish* might be understood as "a chocolate shaped like a fish", but it is not a real fish thus does not have the necessary attributes of a fish. Moreover, Hampton proposed that when a non-necessary attribute of a constituent concept has a conflict with the necessary attribute of the other constituent concept, it will not be used by the conjunctive. Hampton used example *pet fish* to show this point. "For example, if PETS typically breathe air, but this is inconsistent with living underwater, which itself is necessary for the concept FISH, then breathing air will not be possible for PET FISH" (Hampton 1991 pp.108). My questions are: why *breathe air* is a non-necessary attribute of *pet*? Who decide *breath air* is necessary or non-necessary? If both *breathe air* and *live underwater* are necessary attributes for *pet* and *fish* respectively, then based on Hampton, "when the conflict is between two necessary attributes of two constituents, then the conjunction is an empty set - a "logical impossibility". Clearly this is wrong because *bird fish* is not a logical impossibility. For the same reason, Hampton's model can not explain any conceptual combinations that are composed of two antonyms with opposite and non-reconcilable necessary attributes such as *lively mummy*, *true lies* etc. This analysis shows the weakness of treating some attributes as necessary and others as non-necessary and of trying to combine them in a consistent way.

Secondly, the way that attribute importance and necessity are evaluated is quite questionable. In this model, the importance of an attribute is evaluated within the concept itself. Thus, if certain attributes are most central for category membership, they will be assigned a higher importance score and those that are least relevant will be assigned a lower score. This score will be carried over to the conjunction. However, the importance of an attribute is not just related to individual concepts alone and should not be evaluated just within a single concept. Often, when a concept is combined with another concept, the importance of attributes of the concepts changes because of this pairing. For example, when the meaning of the combination *tasty computer* is understood as "a chocolate shaped like a computer", most of the important attributes of *computer* are dropped regardless of how important they might be for the concept of *computer*, and the importance of the feature *shape* increases from a low value for *computer* to the much higher value for the combination. It seems that a necessary attribute or a highly important attribute is decided by the combination, not by composite concept alone (e.g. even though *shape* is not important for the concept *dog*, it is a highly important attribute for *toy dog*). Because of the combination, certain attributes gain the importance where they may not be important at all for a component concept alone.

Thirdly, the model needs a more detailed description on how consistency is checked. What are the cognitive processes of assessing the features and what are the bases for evaluating consistency? The model relies on an intuitive understanding of the idea of consistency and this naïve understanding of consistency hinders it from proposing a more detailed description of the mechanisms functioning in consistency checking.

2.6 Dual-Process Model

Proposed by Wisniewski (1997a, 1997b, 1998, 1999), the dual-process model may be considered as a successor to the concept specialization model. In this model, Wisniewski provides certain extensions to Murphy's model so that the new model is capable of explaining more empirical data than the concept specialization model.

2.6.1 The Model

The dual-process model assumes that concepts are represented by a schematic structure, and proposes that conceptual combinations are associated with three general types of understanding: property-based, relation-based and hybrid understandings. "*Relation-linking* interpretations involve a relation between the referents of the modifier and head concepts. For example, people sometimes interpret *robin snake* as 'a snake that *eats* robins'. In *property* interpretations, people assert that one or more properties of the modifier concept apply in some way to the head concept, as in 'snake with a *red underbelly*', for *robin snake*. A third, less frequent type of interpretation is *hybridization*. These interpretations refer to a combination of the constituents (e.g., a *robin canary* is 'a bird that is a cross between the two – half robin and half canary') or to a conjunction of the constituents (e.g., a *musician painter* could refer to someone who is both a musician and a painter)" (Wisniewski 1997 pp.168-169). The dual process model proposes that these different understandings arise from different distinct cognitive processes: relational combinations result from integration, while property combinations result from comparison and construction (hybridization may be considered as both). Thus, conceptual combination may involve dual processes of integration and comparison-construction. Accordingly, the dual-process model proposes two primary mechanisms to describe the understanding of a conceptual combination: Scenario Creation and Comparison & Construction.

Scenario Creation generates a relation-based interpretation which amounts to "…creating a plausible scenario involving the constituents of the combination. … For example, a plausible interpretation of *truck soap* is 'soap for cleaning a truck', because *truck* can be bound to the *recipient* role of *cleaning* (i.e., the thing being cleaned), while *soap* to the *instrument* role (what is used to do the cleaning)" (Wisniewski, 1997 p.174). Comparison & Construction describe a process by which people can arrive at property-based interpretations. Property-based interpretations start from comparing the commonalities and differences between head and modifier concepts. On the basis of this comparison, a property is selected from modifier to apply to the head. Wisniewski used *zebra horse* to demonstrate this process: the schematic structures of the two concepts *zebra* and *horse* are aligned along commonalties (such as body parts) and differences (such as having vs. not having stripes, solid tail with tufts of hair vs. all-hair tail). When multiple differences are found, several factors such as the communicative context, the salience of the property, cue and category validity, and plausibility regulate the choice of the best property to be transferred to the head concept. For example in the interpretation of *zebra horse*, "having stripes" is selected to be transferred rather than "solid tail with tufts of hair", because while both are differences and both are plausible, "having stripes" is higher in category validity and more salient for the concept *zebra*.

After comparison, the selected property is not just copied over to the head concept. "Rather, a property in the modifier acts as a source of information for constructing a new version of that property in the head noun concept" (Wisniewski, 1997 p.176). This construction process is similar to the elaboration process of the concept specialization model with a slightly different focus: elaboration in the concept specialization model is applied to relation-based understanding, while construction is applied to property-based interpretation. Construction "is an interactive process, in which the new property is a function of constraints specified by both the modifier and head noun concepts" (Wisniewski, 1997 p.176). It is proposed that "the new property must bear enough resemblance to its source in the modifier so that people can determine how the modifier contributes to the meaning of the combination… at the same time, the construction of the new property must not alter the head noun concept in such a way that it destroys its integrity" (Wisniewski 1997, p.176). For example, "in interpreting *fork spoon*, people could begin by aligning the *handle* of *fork* with the *handle* of *spoon*, and the *end* of *fork* with the *end* of *spoon* and note an important difference: forks have prongs on their ends but spoons have 'little bowls' on their ends… the comparison process identifies where in the representation of *spoon* the property "has prong" can be incorporated (on the *end* of *spoon*). However, there is a conflict between mentally connecting this property to the *end* of *spoon* and staying within the referential scope of *spoon*… People can resolve this conflict by mentally attaching the prongs to the end of the little bowl and shortening them or by mentally attaching the prongs to the top of the spoon" (Wisniewski, 1997 pp.176 - 177).

2.6.2 Some Comments on this Model

The dual-process model extends the concept specialization model in some important ways: it provides an explanation of different types of interpretations (i.e., property-based, relation-based, and hybrid), provides an explanation of processes involved in property-based conceptual combinations (i.e., comparison and construction) and synthesizes schema based theories of conceptual combination into one model.

However, researchers suggest that the dual-process model lacks a detailed explanation of the underlying cognitive mechanisms to achieve these processes. For example, Costello and Keane noted that "the elaboration or construction process is to be singled out in this respect, as it is clearly a very complex process that is, as yet, unspecified" (Costello & Keane 2000, p.334). In line with this observation, some specific comments could be made. The first process in the model is scenario creation, which is intended to explain the cognitive process of generating a relation-based meaning for a conceptual combination. However, the mechanisms involved in creating a scenario and selecting from among various feasible scenarios so that a variety of acceptable meanings could be constructed are in need of more detailed specification. The second process of the model is about comparison / construction, which is intended to explain the cognitive process of generating property-based meaning for a combination. However, there are still a few issues remain unclear, such as how many properties should be generated for each component concept in order to finalize the comparison process.

Murphy pointed out that this weakness is not just for the dual-process model. Rather, most of the current theories on conceptual combination have this issue:

> "What is not yet known is the online process by which one of these interpretations is constructed / selected. It is clear that people do not always prefer to use a slot-filling interpretation whenever it is possible to do so, since they will choose feature-mapping interpretations for similar concepts that would have made sensible slot-filling concepts (see Wisniewski and Love 1998). But given that these ways of combining concepts are so different, it is

not clear how they could be carried out in parallel. The feature-mapping process involves comparing the two concepts, identifying a feature of the modifier that could be plausibly transferred over to the head noun, and carrying out that transfer. The slot-filling process involves seeing whether there is a relation available in the head noun that the entire modifier could fill, and then constructing that relation. Furthermore, both of these are complicated by the possibility of construal (e.g., interpreting skunk as referring to a bad smell), which allows many more ways of possibly relating the concepts. How all these alternatives are considered (or if they aren't, how they are ruled out) is at this point not clear" (Murphy, 2002 pp.458 - 459).

2.7 Constraint Model

The constraint model was proposed by AI scholars Costello and Keane (1997a, 1997b, 1998, 2000, 2001). This model focuses on the efficiency of the conceptual combination process with pragmatic principles that have been implemented as a computational model called C3. In the following paragraphs, I will focus on the theoretical part of the model and ignore the technical details for computational implementation of the model.

2.7.1 The Model

Similar to other models, the constraint model starts with an assumption that concepts are represented in a schematic structure and describes conceptual combination as a process of constructing interpretations that satisfy three constraints: diagnosticity, plausibility and informativeness which were abstracted from several sources, primarily from pragmatics (Grice 1975). For this reason Costello describes his model as a pragmatics of combination.

The general idea of the model is that when people understand a novel combination, they construct a combined concept to represent that combination. In the process of combining, people assume that everyone involved in the communication follows the cooperative principle as theorized by Grice (1975). "Three constraints of plausibility, diagnosticity, and informativeness follow from this assumption. By following these constraints the listener can construct the correct concept as intended by the speaker" (Costello 2004 PowerPoint presentation).

The first constraint is called plausibility. Because it is assumed that everyone in the communication is cooperating, the intended combined concept should be something the listener already somewhat knows. Thus the listener knows the new combined concept must describe something plausible (similar to things the listener has seen before).

The second constraint is called diagnosticity. Since the speaker is cooperating, the intended combined concept is one best identified by the two words in the phrase (otherwise the speaker would have selected other words). Thus the listener knows that the new combined concept must contain some properties which are best identified by (that is, are diagnostic of) each word in the phrase.

The third constraint is called informativeness. Since the speaker is cooperating, the intended combination is one for which both words in the phrase are necessary (otherwise the speaker would have used fewer words). Thus the new combined concept must be more informative than either of the constituent words.

For instance, Costello considers the example of *shovel bird* understood as "a bird that has a flat, wide beak like a shovel, for digging worms". In this understanding, the listener constructs an understanding with the diagnostic properties of *shovel* (flat, wide, and used for digging) that is something plausible (bird digging worms) and informative (flat, wide beak).

2.7.2 Some Comments on this Model

The constraint model explicitly addresses the possibility of multiple interpretations for novel combinations and how different interpretations are selected. By adopting Grice's Cooperative Principle, the model assumes that communication is a cooperative process between speaker and listener. The three constraints used to guide the process of selecting from among potential meanings are quite reasonable.

However, Costello & Keane did not justify the selection of these three constraints from among many other communicative and cognitive factors that might influence how conceptual combinations are understood. For example, Thagard (1997) proposed a coherence theory of conceptual combination that might well be added to the list of constraints. In 1986, two cognitive linguists Sperber & Wilson proposed a theory of Relevance trying to integrate Grice's four principles of communication into one – the principle of relevance (Sperber & Wilson, 1986, 1995). It is easy to argue that this principle should be added as constraints as well. The point here is that there are many constraints regulating human cognition, then why these particular three are chosen is not clear.

Diagnosticity in this model is basically identical to Smith & Osherson's diagnosticity and Hampton's Importance, i.e., degree of definingness. Similar to my comments on Hampton's Importance, diagnosticity of a feature is treated as an absolute value in all these models whereas it seems to vary relatively based on the context in which the concept is used. In other words, diagnostic features of a certain concept depend on the set of other concepts that are salient at the time of use, as my example *tasty computer* shows (that the diagnostic feature of *computer* changes when paired with *tasty*).

The other two constraints "plausibility" and "informativeness" are vague concepts which have face validity, but it is very difficult to describe the underlying cognitive mechanisms associated with these two constraints. That is to say, how plausibility and informativeness are implemented cognitively is not clear at all. (In computer simulations, Costello and Keane implemented these two constructs as a degree of overlap with stored instances and as the appearance of a new predicate that was not contained in the prototype of the head concept respectively. However, this kind of implementation in computer simulation has its own problems such as the quantity of the instances that need to be stored in computer memory and the calculation efficiency etc, which are not the focus of the current discussion). Moreover, these two constraints seem to function well when people interpret novel combinations, but might not predict the process of comprehending familiar or analogically related compounds such as *red apple* or *lion heart*. That is, it does not address the difference when people interpret common combinations or completely novel combinations.

2.8 CARIN Model

The Competition Among Relations In Nominals (CARIN) theory (Gagné, 2000, 2001; Gagné & Shoben, 1997, 2002) provides a model of conceptual combination that uses our prior experience of the kinds of relations that words have in compounds to predict what interpretations people will produce, and what compounds people will find easiest to understand.

2.8.1 The Model

The CARIN model draws on arguments from early linguistic work on the thematic relations of compound words (Kay & Zimmer, 1976; Gleitman & Gleitman, 1970; Downing 1977; Levi, 1978). In linguistics, the thematic relations between two component words in a compound have often been examined by developing taxonomies of relations required for interpreting combinations. For example, Levi (1978) identified 15 relations (thematic relations) that can be used to classify the meanings of many familiar combinations, such as a mountain brook is a brook *in* the mountain, but a mountain magazine is a magazine *about* mountains (Table 2-1). These 15 relations were used by Gagne in the CARIN model.

Table 2-1: List of thematic relations used by the CARIN model (Gagne & Shoben, 1997)

1. Noun *causes* Modifier	Flu virus
2. Modifier *causes* Noun	College headache
3. Noun *has* Modifier	Picture book
4. Modifier *has* Noun	Lemon peel
5. Noun *makes* Modifier	Milk cow

6. Noun *made of* Modifier	Chocolate bird
7. Noun *for* Modifier	Cooking toy
8. Modifier *is* Noun	Dessert food
9. Noun *uses* Modifier	Gas antiques
10. Noun *about* Modifier	Mountain magazine
11. Noun *located in* Modifier	Mountain cloud
12. Noun *used by* Modifier	Servant language
13. Modifier *located in* Noun	Murder town
14. Noun *derived from* Modifier	Oil money
15. Noun *during* Modifier	Morning prayers

Different from all the other models where a feature based schematic representation is used to represent a concept, the CARIN model assumes a schematic representation of the relations between concepts. That is to say, it assumes a slot-type structure where slots are not features of the concept but the kinds of relations it can have with other concepts. Based on this model, how concepts are represented internally is irrelevant to the goal of conceptual combination - to fit all compounds into existing relational templates (slots). The general argument is that people historically possess distributional knowledge about how often particular relations have been used (strength of a relation) with particular concepts, and these relations "compete for the interpretation of the combined concept and that the difficulty of interpretation is a function of the relative strength of the selected relation" (Gagné & Shoben, 1997 p.81). For example, "interpretations are easier if the required relation is of high strength than if the thematic relation is of low strength. Other things being equal, it is easier to arrive at the correct interpretation for *mountain stream* than it is for *mountain magazine* because the locative relation has a greater strength relation than does the *about* relation" (Gagné & Shoben, 1997 p.81).

Based on empirical studies, Gagné proposed that "the modifier exerts a greater influence on determining whether a phrase has a plausible meaning of a combined concept than does the head noun" (Gagné & Shoben, 1997 p.83). For example, "we examined the effects of the number of dominant relations for the modifier and head noun and the effects of ranked frequency of the relation for the modifier and head noun on response times for both Experiment 1 and Experiment 3. In no case did the correlations between variables based on the head noun and response time differ reliably from zero" (Shoben & Gagné, 1997 p.83). The model thus proposes that it is the modifying concept that guides the selection of the thematic relation. Moreover, the CARIN model claims that property-based interpretation is a secondary strategy for subjects. Only after they have failed to find an appropriate relation between the compound's constituents, they would go to property-based interpretation. Shoben and Gagné explained that "overall, there is little evidence to support the use of property mapping as a common strategy during the interpretation of noun-noun phrases. Instead, the interpretation of such phrases is heavily biased toward the use of relations" (Gagné, 2000 p.383). She also suggested one more thematic relation to interpret property-based understanding: "In some cases, participants provided interpretations that clearly show the use of the Resembles / LIKE relation. For example, *coat shirt* was interpreted as 'a shirt that looks like a coat.' *Magazine newspaper* was interpreted as 'a newspaper that is like a magazine'" (Gagné, 2000 p.385).

2.8.2 Some Comments on this Model

CARIN is proposed based on a linguistic taxonomy of the thematic relations between component words. By paying attention to the kinds of relations that words assume and adding weights to these relations, the model predicts the priority between different relations when constructing an interpretation for a compound, which was supported by their empirical analysis. The most interesting finding of their research is the observation that modifier actually plays more important role than head noun in terms of selecting a relation between head and modifier during the process of construction. This result provides evidence of different functions associated with the modifier and head in contributing relations or properties for the combination.

However, there are a few problems that need to be addressed.

First of all, are these 15 relations necessarily exhaustive? This is a natural question for any taxonomy-based explanation. For example, the recent addition of the "Resembles" relation (Gagné, 2000) hints that the proposed taxonomy is not necessarily comprehensive and complete.

If we carefully examine the 16 relations, it is easy to conclude that these relations are so high level and abstract that they cannot capture the real meaning between words, thus cannot provide meaningful interpretations. For example, the combinations *birthday cake* and *bravery medal* share the FOR relation between their constituents. However, the FOR relation cannot capture the crucial differences between the interpretations of these combinations: a birthday cake is a cake *used for the purpose of* celebrating birthday while a bravery medal is a medal rewarded *because of* bravery. That is to say, our intuitive understanding of the meaning of these relational words "cause, has, make, for, is, use, located" etc. cannot guarantee a meaningful interpretation, and the interpretations drawn from these high level relations cannot really represent the intended meaning. Moreover, the relations denoted by these simple words such as "make", "for" usually imply very complex meanings corresponding to a very complex conceptual structure. Using this complex conceptual structure to link two concepts will inevitably end up with a very vague interpretation.

Essentially, the models based on feature-schema and the models based on thematic relations are quite similar, in that the thematic relations of concepts function as connectors, where another concept could fit in this relation, similar to the slot filling idea in schema based models. Undoubtedly, our knowledge of concepts not only involves the dimensions where features are organized, but also the connecting relations that this concept usually has with other concepts. The questions that I have regarding the weaknesses of "dimension" or "slot" in explaining novel combinations could also be raised here. For example, it is not fully clear that the thematic relations, as one part of our conceptual structure to organize our knowledge, are the appropriate level for us to explain the cognitive process of conceptual combination. Similar to the assumptions of slot-filling, CARIN model also assumes that thematic relations are pre-existing and we have a system of pre-stored relations that is always ready to be used. This assumption is based on the confidence that proposed thematic relations are complete in terms of how many are necessary and sufficient and exhaustive in terms of whenever a concept combines with any other concept, there is always a pre-stored relation ready to be used. However, it is not clear that human mind pre-stores a complete set of thematic relations that are necessary, sufficient and exhaustive.

In the CARIN model, Gagné claimed property-based interpretations are a secondary strategy, used when subjects fail to find an appropriate relation between the compound's constituents. From their corpus analyses (Gagné, 2000; Gagné & Shoben, 1997), they concluded that property-based interpretations rarely occur and so relational interpretations are made by preference. They analyzed data from Warren (1978) and found that only 1.6% of interpretations were property-based compared to 86% relational interpretations. In her analysis of her own corpora, Gagné (2000) found only 0.6% of meanings involved property transfer. Interestingly, the proponents of property-based interpretation approaches found contradictory results. For example, Wisniewski & Love found that "the property mapping … characterized almost 30% of our sample. This finding does not agree with Downing's (1977) or Shoben and Gagne's (1997) claim that property meanings are not present in combinations that people produce" (Wisniewski & Love, 1998 p.197). How to decode these contradictory findings is another interesting topic that I will not get into in this thesis.

2.9 Coherence Theory

In 1997, Thagard proposed a coherence theory of conceptual combination (Thagard P. 1997) following the basic line of thinking in his 1984 paper that conceptual combination is to solve a problem of reconciling the conflicting expectations contained in the candidate concepts.

2.9.1 The Theory

The coherence theory of conceptual combination is based on Coherence theory proposed by Thagard (1989, 1997, 1998). The basic argument of Coherence theory is that elements in a system (concepts, propositions, parts of images, goals, actions etc.) can cohere (fit together) or incohere (resist fitting together). If two elements cohere, there is a positive constraint between them. Otherwise, there is a negative constraint between them. “A positive constraint between two elements can be satisfied either by accepting both of the elements or by rejecting both of the elements. A negative constraint between two elements can be satisfied only by accepting one element and rejecting the other. The coherence problem consists of dividing a set of elements into accepted and rejected sets in a way that satisfies the most constraints” (Thagard & Verbeurgt 1998 pp.2-3).

The coherence problem is solved by parallelly propagating the weights of the associations between elements to satisfy the constraints until all elements achieve unchanging activation values and then partitioning elements into accepted sets and rejected sets in such a way that maximizes coherence.

Based on this theory, the conceptual combination phenomenon is explained as a “instance of coherence conceived of as maximization of constraint satisfaction” which “requiries us to apply some concepts to a situation and withhold other concepts in such a way as to maximize the overall satisfaction of the constraints determined by the positive and negative associations between the concepts” (Thagard 1997 online version). More specifically, we need to construct a constraint network with elements of all possible inferences of the head concept and modifier concept, and with all constraints based on frequencies of association between the elements. Then, we need to use certain connectionist algorithms to do a parallel calculation that maximizes coherence by accepting some elements and rejecting others. The output of the network is “an interpretation of the relation between the head and modifier, as well as a collection of inferences about the object denoted by the head as characterized by the modifier. If the most coherent interpretation is nevertheless not very coherent, then move to other mechanisms such as analogy and explanation that produce the incoherence-driven conceptual combinations” (Thagard 1997 online version).

Thagard used the conceptual combination *well-dressed black* to demonstrate these mechanisms. When people understand this combination, they would activate a network of associated concepts. For example, *black* might activate *aggressive* or *poor ghetto inhabitant*. Contrastingly, *well-dressed* might activate *businessman*, *not poor* and *not aggressive*. The positive constraints in this network include the associations that ghetto blacks are aggressive, while negative constraints include the negative association that ghetto blacks tend not to be businessmen. Apparently, this is not a coherent network. To understand the meaning of this combination, we need to come up with the most coherent interpretation (the interpretation that best satisfies the constraints). A connectionist algorithm is used to maximize coherence by the rejection of aggressiveness. The final interpretation of the combination *well-dressed black* is "a black businessman who is not an aggressive ghetto black".

2.9.2 Some Comments on the Theory

Coherence theory is not proposed just to explain the conceptual combination problem. It has a much wider application area. The basic assumption of the coherence theory is that a conceptual system or network tends to evolve toward a more stable and harmonious state. By applying the coherence logic to the conceptual combination problem, the theory explains not only the specific mechanisms of conceptual combination, but also why there are such mechanisms. However, as explained by Thagard, the current coherence-driven constraint-satisfying model has difficulties explaining non-predicting combinations such as *apartment dog* and incoherence-driven combinations such as *web potato*. For such cases, networks of associations are involved and quite often, for novel combinations, the meaning is motivated not by coherence but by the failure to find coherence. Moreover, the connectionist algorithms used in coherence theory are not a direct reflection of mental activity, but rather, a simulated approximation of the mind.

Coherence theory stems from what is known as connectionism that started in 1980s and 1990s in the field of artificial intelligence. Connectionist theories try to understand cognition by viewing the brain as a network of interconnected neurons (Rumelhart et al. 1986). Connectionist models consist of interconnected processing units or nodes that perform simple computations transforming inputs into outputs to its neighboring nodes.

The system has two characteristics: one is that computations are carried out concurrently (parallel processing); the other is that knowledge is represented by patterns of network activations across multiple nodes (distributed) in the system; hence this computational approach is also called "parallel distributed processing (PDP)". Coherence theory adopts the computational mechanisms from this intellectual tradition.

As theorized by Thagard, coherence is understood as "the maximal satisfaction of multiple positive and negative constraints that is achieved by some parallel constraint satisfaction algorithms" (Thagard & Verbeurgt 1998 p.1). As such defined, coherence theory exhibits a strong connectionist orientation in terms of the basic assumptions of goodness-of-fit or harmony. The basic idea of harmony in connectionist approaches is very similar to what has been historically called cognitive balance or consistency in the psychological literature of consistency theories, and a few researchers have investigated relationships between these two groups of theories and used connectionist approaches to model certain consistency problems. For example, Simon and Holyoak (2002) used parallel constraint satisfaction to explain principles underlying consistency theories, and Shultz and Lepper (1996) used such approaches to simulate results from classic cognitive dissonance experiments. In this research, I draw on consistency theory, particular Heider's balance theory to analyze aspects of the conceptual combination process. Before I review balance theory at the end of this chapter, however, it is necessary to summarize the current theories of conceptual combination.

2.10 A Brief Summary

Most of the preceding models have a common characteristic of assuming a schematic representation of our knowledge of concepts, in which concepts are represented as having dimensions or slots, and each dimension or slot has features or properties as the values of the dimension or fillers of the slot. From this assumption, conceptual combinations are understood as the combination of these two sets of properties along certain dimensions. Some models emphasize thematic relations between the two constituent concepts, but if thematic relations are understood as a kind of dimension reflecting how concepts connect with one another, then, there is not too much difference between feature-based schema models and thematic relation models.

Schema theory describes "how knowledge is represented and about how that representation facilitates the use of the knowledge in particular ways" (Rumelhart 1980 p. 34). Schema theory assumes a logical structure to organize knowledge in the human mind, which seems to match our intuitive experience. When we think about a concept, we may feel that it is logically related to other concepts in a manner similar to the dimensions or slots proposed by schema theory. For example, we may know that apples are typically red or green, which are colors, so the concept *apple*, *red, green,* and *color* have a logic relationship that could be described by an apple schema consisting of a dimension / slot *color* with values *red* and *green*. However, the fact that we understand these concepts as being logically related to one another does not necessarily imply that our minds represent these concepts in such an organized manner. It is possible that our minds represent knowledge in less structured ways and logical structure is imposed after the fact, as an outcome of the process of thinking about these concepts and the logical relations between them. Moreover, even if our minds store information in such structured ways, is it necessarily the case that this structure plays a direct role in making sense of conceptual combination as proposed by theories of slot-filling? The fact that we can make sense of novel combinations quite easily would counter such a view. For example, the combination *smart apple* has the same structure as a *red apple*, but our knowledge of *apple* is unlikely to include a pre-existing dimension / slot for intelligence with different values in smartness.

An alternative view could be proposed on the cognitive processes of combining concepts. Rather than assuming that schematic structure has a causal role in the cognitive processes of making sense of conceptual combinations, in this thesis, I will try to make as few assumptions as possible about how knowledge is represented, and attempt to propose an explanation based on few assumptions. We know that concepts are related to other concepts. For example, the concept *apple* might be associated with the concept *red* if we know many apples are red. Thus, I will assume that knowledge can be represented by associations among concepts. When we try to make sense of a conceptual combination, our cognitive processing starts from the processing of the associations that were activated by component concepts. Thus, the meaning of a conceptual combination basically equates to a system of associated concepts drawn from component concepts that fit together consistently.

In psychology and cognitive sciences, there are two closely related groups of theories: consistency theories and connectionist theories that are focused on the harmonious state of a system of conceptual entities, hence could be used to describe the phenomenon of conceptual combination, as exemplified by Thagard's coherence theory on conceptual combination. My theory specifically will look at the harmony in a triad between two component concepts in a combination with a given association, a triad typically as a basic unit of what a combination means. Various consistency theories, Heider's balance theory in particular, use a triad as the unit of analysis, thus will be reviewed in the next section.

2.11 Balance Theory

Consistency theories began in 1940s and include a group of theories that were proposed in attempt to "uncover the structural-dynamic characteristics of human cognition" (Simon & Holyoak 2002, p.283) towards consistency. There are many theories proposed in this tradition, such as Heider's balance theory (1946, 1958); Festinger's cognitive dissonance theory (1957); Osgood & Tannenbaum's congruence theory (1955); Abelson & Rosenberg's symbolic psycho-logic theory (1958); Newcomb's strain towards symmetry theory (1953); Cartwright & Harary's structural balance theory (1956).

> "These conceptions, symmetry, consonance, balance, and simplicity, are, of course, implied in that idea with which Gestalt theory started and which always was central to it, namely, the idea of a 'good' figure… this model implies a number of different entities with certain properties and standing in certain relations, which make up a constellation of factors tending toward a standard (consistent) state" (Heider, 1960 p.168).

The basic assumption of these theories is that the cognitive elements tend to form stable structures, whereas inconsistent elements would operate towards a re-establishment of stability or harmony. “The reasoning behind (the consistency position) relates to the organism’s presumed need to apprehend and comprehend things and events about him. In monitoring, processing and interpreting information from the environment, some degree of consistency and equilibrium is seen as essential for reasons of parsimony and economy of effort, as well as to allow for the predictability of, and hence adaptability to, subsequent encounters… most assume a universal value for the organism in his having a stable predictable view of his environment” (Tannenbaum, 1968 p.346).

It is noted that “these theories have another feature in common. They all cite Heider’s principle of cognitive balance as an approach either similar or parallel to their approach and admit to its historical priority. (Heider explicitly discussed cognitive balance in a paper published in 1946 and it was adumbrated even earlier, in a paper published in 1944). Some, particularly Cartwright and Harary, and Abelson and Rosenberg, also admit their intellectual debt to Heider as having influenced them directly” (Jordan N. 1968 p.169). Thus, it is necessary to review the basic ideas in the balance theory proposed by Heider (1958).

With a Gestalt perspective, Heider (1944, 1946, 1958, 1960) had studied certain aspects of cognitive fields that tend to be organized in a harmonious and balanced manner and, if not, will generate a tendency to reach balanced cognitive states. Heider proposed the concept of cognitive balance based on the distinction between two types of relations: unit relations and sentiment relations. Unit relation between entities refers to the fact that “separate entities comprise a unit when they are perceived as belonging together. For example, members of a family are seen as a unit; a person and his deed belong together” (Heider, 1958 p. 176). “This unit formation includes such specific relations as similarity, possession, causality, proximity or belonging” (Cartwright et al. 1956 p.278). A sentiment relation between entities refers to the positive or negative feelings or valuation that one gives to an entity, such as a person, activity, or object. These relations may be for dyads, triads, or more complex cases, but all relations are from the perceiver’s subjective point of view. These relations are described by a concept called valence: there is a unit / sentimental relation (positive valence) or there isn't (negative valence). Based on this distinction, a balanced state is defined as: "by a balanced state (or situation) is meant a harmonious state, one in which the entities comprising the situation and the feelings about them fit together without stress" (Heider 1958 p. 180). More specifically, "A dyad is balanced if the relations between the two entities are all positive (L and U) or all negative (DL and notU). Disharmony results when relations of different sign character exist. A triad is balanced when all three of the relations are positive or when two of the relations are negative and one is positive. Imbalance occurs when two of the relations are positive and one is negative" (Heider 1958 pp.202 – 203). Briefly, in the case of three entities, balance means the positive product of signs of the relations.

The basic hypothesis of Balance Theory is that there is a tendency for cognitive units to achieve a balanced state, i.e., "if a balanced state does not exist, then forces toward this state will arise… If a change is not possible, the state of imbalance will produce tension" (Heider, 1958, p. 201). When tension caused by imbalance arises in the mind of the individual, the individual is likely to exercise some mental effort to eliminate the tension.

For example, in the case of two entities, it is balanced if Person 1 likes something he made (Figure 2-1). In the case of three entities, if Person 1 has a relation of affection for Person 2 and if Person 2 is seen as responsible for Object 3, then there will be a tendency for Person 1 to like or approve of Object 3 so that the system is balanced, i.e., the product of signs is positive (Figure 2-2).

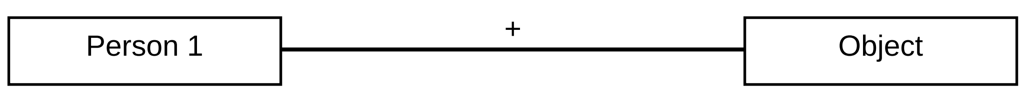

Figure 2-1: A balanced system of two entities

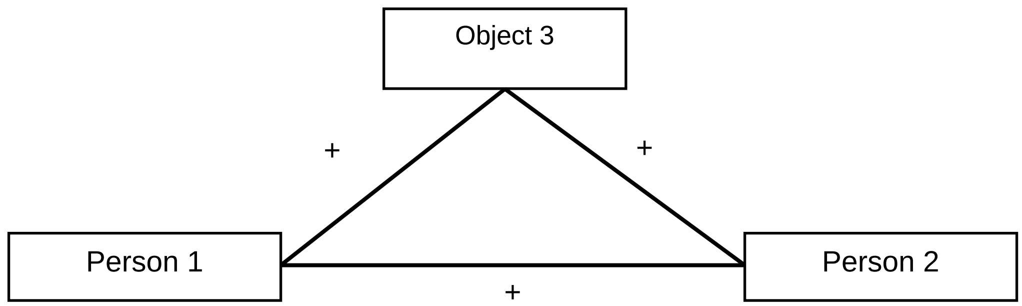

Figure 2-2: A balanced system of three entities

If balance does not exist in a system, the situation will tend to change in the direction of balance. For example, if Person 1 is a friend of Person 2 (positive valence), and Person 2 likes a movie (positive valence), but Person 1 dislikes the movie (negative valence). Then the system composed of Person 1, Person 2 and the Movie is not balanced. That is, the system contains two positive relations (Person 1 – Person 2; Person 2 – Movie) and one negative relation (Person 1 – Movie). This is an unpleasant situation for Person 1 from his perspective. Tension will arise and forces will appear to annul the tension. This situation is made harmonious by a valence change in one of the relations. For example, Person 1 could try to appreciate or even start to like the Movie, so that now the system contains 3 positive relations, thus balanced. Alternatively, Person 1 could start to dislike Person 2, so that now the system contains 2 negative relations and 1 positive relation and the product of signs is positive, thus balanced. Alternatively if Person 2 starts to dislike the Movie, so that the system contains 2 negative relations and 1 positive relation, it could also become a balanced system.

The attractiveness of balance theory is in its simplicity and explanatory power. Unfortunately, the impact of balance theory has mainly been in the field of social psychology, apparently due to a misunderstanding that this theory deals only with interpersonal or social situations. This misunderstanding is partially due to the fact that Heider himself used interpersonal examples to demonstrate his theory and following researchers mainly applied balance theory to interpersonal or social situations. However, it should be noted that balance theory treats interpersonal or social situations from the viewpoint of an individual, from how a particular individual make sense of his cognitions. That is, balance theory is proposed as a pure cognitive theory, but the object of the person's cognition happens to be a social situation in Heider's original book. Unfortunately, when later researchers applied and extended the theory, they basically ignored the fact that Heider's logic works from the cognition of a single person. Cartwright and Harary stated: "Although Heider's theory was originally intended to refer only to cognitive structures of an individual person, we propose that the definition of balance may be used generally in describing configurations of many different sorts, such as communication networks, power systems, sociometric structures, systems of orientations, or perhaps neural networks" (1956 p.292). Undoubtedly, balance theory could be extended logically to all these situations, but the perspective of looking at situations should be based on the individual's view of the situation rather than assuming an objective view that oversees the situation.

It is observed that connectionist theories and consistency theories are quite consistent in terms of the basic theoretical assumptions on the tendency towards a harmonious state. It could be predicted that if applying a connectionist model to any Heider's graph, it should give the same prediction of how that graph might change towards the direction of "harmony" as what Heider proposed. The reason is simple: a connectionist model defines a group of constraints that are implemented by the relations between nodes, which is what Heider did in the balance model. For example, "a likes b, b likes c" etc are set of constraints and the valence change is to maximize the consistency level of the system and simultaneously satisfy these constraints to a great extent. These two theories seem to predict very similar outcome, and although they use different underlying logics, they certainly bear some similarity in terms of how the system is defined in the first place, and how the system is likely to end up after either balancing in one model or the oscillation settling down in the other model.

There are also some important differences between these two theories. First of all, connectionist models are used mainly to deal with complex networks while balance model was applied mainly in simpler networks. However, it should be noted that both theories are applicable to either large scale networks or small scale simpler networks. Second, the underlying algorithm logic of most connectionist models is mainly weight propagation while balance model only deals with multiplication of signs and valence reversal. That is to say, connectionist theories accounts more for the fine difference of weights between associations while balance theory accounts more for the sudden Gestalt shifts in valence. Third, most connectionist theories use parallel processing algorithms where nodes and links are processed concurrently, while balance theory emphasizes the sequential processing where one closed cycle is processed after another one finished processing. Since balance theory is using a triad as the unit of analysis and computationally simpler, in the next chapter, I will mainly adapt balance theory to explain the phenomenon of conceptual combination in meaning construction.

Chapter 3 Theoretical Framework

Remarkably, we can communicate complex thoughts through simple combinations of words because of our ability to build very complex meanings from smaller linguistic units (such as words) or conceptual units (such as single concepts). How is it possible that we can mentally construct complex meanings from smaller conceptual units? What is the process of this meaning construction? With the hope to shed some light on these fundamental issues in human communication, this research tackles the question: "how do conceptual interactions influence meaning construction in human communication?"

In this research, a theoretical framework for understanding conceptual interaction in meaning construction is proposed. This framework is composed of two parts: the assumptions and the processes.

3.1 The assumptions of conceptual interaction in meaning construction

This research starts with a close observation of the function of language in human communication. Human language is a complex system composed lexicogrammatically of different elements: words, phrases, sentences, and discourses as a hierarchy. Single words and two-word combinations are fundamental to all the other elements, hence are the focus of the current research. Based on assumptions on how the meaning of a single word is conceptually represented, this research will focus on meaning construction of two-word combinations. More specifically, the research question of the current study can be reformulated as: how do conceptual representations of single words interact in a two-word combination to construct meaning? By addressing this question, this research will provide a foundation for understanding the meaning construction by other elements of language.

The research question proposed here deals with a three-way relationship among language, meaning and human mind. Meaning is a function of the human mind. When we talk about the meanings of "table", "democracy", "go", "beautiful", or "above", we psychologically experience them as mental images, or other forms of mental representations, i.e., meaning is mentally represented. Unfortunately, these mental representations can only be experienced by a particular individual (the meaning-holder). They are not directly accessible to others. Language partially removes this barrier by allowing us to verbally describe as closely as possible our mental representations. The verbal description expresses a set of associations that the meaning triggers in our mind. Obviously, the verbal description does not equate to the mental representation: not all aspects in the mental representation are expressible verbally, and what is expressed verbally may not necessarily correspond to the form of the mental representation. Nevertheless, this verbal description is the only means by which people have access to the thoughts of others.

It is important to note that the individual's verbal description is an idiosyncratic version of the meaning particular to that individual at that time in that location. Then, how could we understand each other if the expressed meaning is so idiosyncratic? Meaningful communication is possible because words are associated with a relatively stable consensus meaning across population that historically has been formed across population. For example, for each one of us, the word[4] "bird" might have slightly different meaning. Each one of us attributes to the word "bird" some idiosyncratic understanding that might be different from, contradictory, or complementary to another person's understanding. However, in our speaking community, "bird" is associated with a consensus meaning that is relatively stable as a flying animal with wings, feathers and a beak (Figure 3-1 &Figure 3-2). It should be noted that the two figures are not a representation of the individuals' understanding of "bird", but are at best empirical approximation to the consensus understanding of "bird".

Two basic questions need to be addressed when studying meaning: how meaning is represented and how meaning is constructed. The next two sections will discuss some basic assumptions about these two issues.

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[4] Words and concepts are closely related. Like much of the literature, this thesis will use these two terms interchangeably most of the time.

3.1.1 Assumptions about meaning representation

This research starts from some basic assumptions regarding how meaning is represented mentally and extends this representation to knowledge and context.

3.1.1.1 Meaning is mentally represented in the form of associations

Meaning is mentally represented in the form of associations. For example, when we attribute certain meaning to the word "bird", our mind triggers a lot of associations. Associations have many different forms such as images or concepts. Associative concepts are particularly relevant to human verbal communication, because these associative concepts are potentially expressible by some symbolic expressions such as words. In this thesis, I will call associative concepts as "associations".

The following figures are examples of associations we have when we interpret the meaning of "bird". A set of associations is abstracted, and each association has a certain probability of appearing in the set, suggesting the degree of consensus of this association and the strength of its activation. (The number on the linking line is the strength of the association calculated as the percentage of the number of a particular association mentioned over the total number of associations mentioned by participants[5]).

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[5] These data were acquired from our pilot studies, which will be discussed in the next chapter.

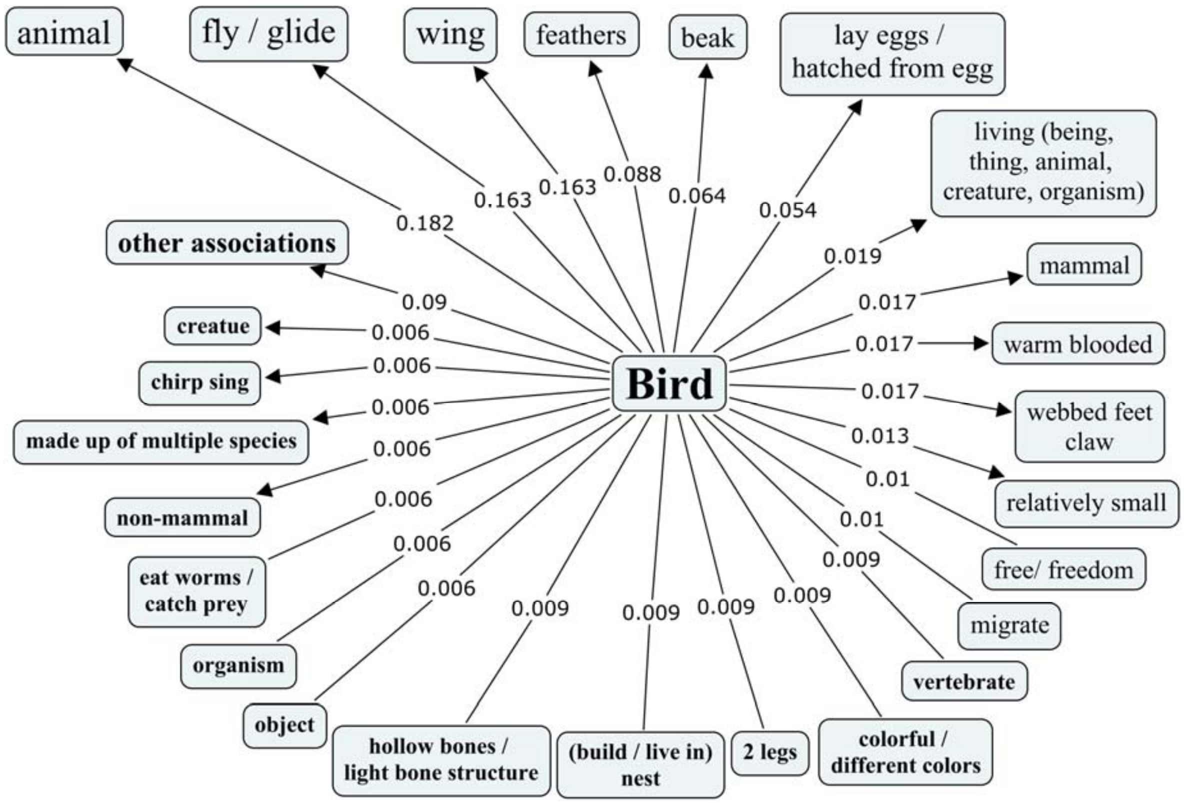

Figure 3-1: Associations of the concept *bird*: features.

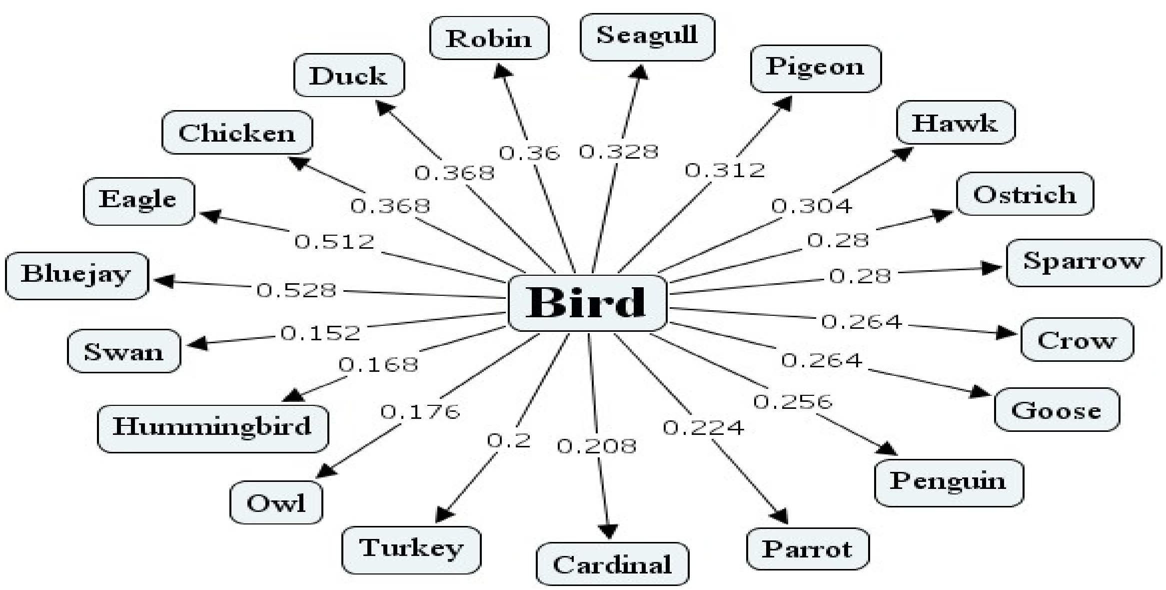

Figure 3-2: Associations of the concept *bird*: members of the bird category

Associations usually have three properties: strength, valence and direction.

Depending on context, associations might be activated or non-activated (possible mental connections between concepts). For example, the above figures have many associations for *bird*; however, not all of them will be activated when *bird* is used to mean something specific during our communication. Similarly, some 'new' associations will be activated when we use *bird* to mean something specific in a certain communicative context. When associations are activated, there are different degrees of the strength of the activation. Some associations are strongly activated and others are weakly activated. For example, in certain context, *fly / wings* might be strongly activated while *hollow bones / light bone structure* is activated relatively weaker. Therefore, strength of association is defined as the potential for one concept to activate another. For example, in our figures, each association of *bird* is accompanied with an indicator of the association strength that was derived empirically.

The valence[6] of an association reflects the grouping ability of our mental structure. It is assumed that grouping, as a very basic cognitive activity, is one of the fundamental ways for us to make sense of the world. We group things together and make judgments of whether things go together on a certain basis. Valence of association is defined as the positive or negative tendency that a concept is grouped with another concept on a certain basis. For example, in our *bird* figures, the valence of each association is positive since they are all associated with the concept *bird*. Certainly, there are negative associations as well. For example, *bird* is not a *mammal*; or *bat* is not a member of *bird* category. We could imagine a limitless set of negative associative concepts that is composed by a pure opposite plus anything that is not positively associated with the target concept. It is assumed that because there are potentially many negative associations, they are not normally salient. However, when we combine two concepts, some negative associations

[6] Different from some usage of the term valence, which mainly refers to sentimental relations, this research treats valence signifying the unit relationship.

might become salient when associations of two different concepts must interact with one another during the meaning construction.

The third property of the association is the direction. Although the current framework on conceptual interactions will not implement this property, however, it could still be postulated that there are two possible senses for the association direction. One is that the direction of association refers to the traverse route of the cognition from one associative concept to another. For example, when activating associations for *bird*, we might think about *fly* then think about *freedom*. The traverse route from *bird* to *fly* to *freedom* indicates the direction of these associations. The other sense for direction of association is the asymmetrical probability of one concept being associated with another concept. That is to say, if concept A is highly probable as an association of the concept B (e.g. p=0.5), but B is less probable as an association of A (p=0.2), then, the direction of the association between A and B should be treated respectively: the direction from B to A has probability of 0.5 and the direction from A to B has probability of 0.2. The direction in this sense indicates the specific probability related to which concept activates which.

The associations of a word / concept are not independent. There are logical relations between them. For example, in our pilot study, most of the participants mentioned that birds fly *because* they have wings *and* feathers. Unfortunately, our current graphic representation cannot represent these logical relations. Some kind of representation is yet to be developed that could capture both the associations and their logical relations.

3.1.1.2 Associations are prototypical

Concepts have prototypical structure (e.g. prototypes) in terms of its members and its associations. In this research, the term “prototypical” is used broader than the categorization literature in which the prototype often refers to a “best” example or a schematic representation of the category. Here, “prototypical” refers to the set of associations that are activated with highest degree of strength. For example, the prototypical associations of *bird* include a set of associations that are activated with highest degree of strength: {*animal, fly/glide, wing, feather, beak, lay eggs/hatched from egg* etc., and *bluejay, eagle, chicken, duck, robin, seagull, pigeon, hawk*, etc}[7]. Here, the numeric threshold of judging highest degree is not pre-determined. Rather, it is a comparative and subjective judgment. By this conceptualization, prototypes and typicality are not longer singled out as a special entity or phenomena in this framework; on the contrary, they are incorporated into the same representational framework undergoing the same cognitive processing as 'non-prototypes' or 'non-typicality', i.e., they are all reflected via strength of activation.

3.1.1.3 Context and knowledge are represented by mental associations

We assume that meaning is a subset of the individual's total knowledge activated by contextual situations. Two key terms need to be clarified in this definition: knowledge and context.

Knowledge is a set of historically collected associations with some historically derived activation[8] levels. For example, the meaning of *bird*, represented by a set of activated associations, is a subset of our total knowledge about *bird*. This knowledge is acquired historically through learning and experience. Historically, we learn about *bird* via various sources, and we experience *bird* directly and indirectly. What we have learned, or what we treat as knowledge, are the associations that the concept of *bird* could potentially activate. The strength of these associations is acquired historically as well. For example, for different people, *light bone structure / hollow bones* might have a quite different activation level than *relatively small*; and these different activation levels are derived historically from different learning and experience.

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[7] Due to the design of the pilot experiments, we have two sets of data: one on the properties of the thing that a concept denotes, the other on the examples of the things that a concept denotes. However, both properties and examples are associations of the concept. Based on our definition, the prototypical associations of the concept should include both.

[8] Here, activation means that the strength of the associations is adjusted above zero.

Meaning is context specific. Depending on context, associations might be activated or non-activated. For example, when I chat with a friend saying "I love birds", the associations activated by the word "bird" is quite different from when I teach my son "this is a bird". A context could be defined as a set of background information selectively attended to by the individual that is relevant to the communication. Its function is to add constraints on the meaning of the language. The more background information activated, the more constraints the context will exert. A context in this sense is not limited to information about the immediate physical environment or the immediately preceding utterances. Salient expectations about the future, scientific hypotheses or religious beliefs, anecdotal memories, general cultural assumptions, beliefs and perceptions about the mental state or intention of the individuals involved in the communication, may all play a role when constructing the meaning in communication. A subset of this background information is attended selectively by the individual for the purpose of processing information in communication. It is worth noting that the selection of the background information does not mean to choose information explicitly; rather, we may pay attention to certain background information based on particular goals. The organization of the individual's knowledge structure, and the mental activity in which the individual is engaged, would limit the class of potential contexts from which an actual context can be attended to at any given time. This subset of background information would be combined with the new information in our cognition for the sense-making.

Based on this analysis, context could be mentally represented as a set of activated associations selected by the individual. Clearly, in this framework the representation of context is identical to the representation of meaning: both are sets of activated associations organized into a cognitive field. This reflects the inseparable relationship between the meaning of a language element and the context in which this language element is used and understood. This also reflects the cognitive nature of both, in that, context is what we pay attention to as part of our cognitive representation of the meaning. When we construct the meaning of a language element, we activate a set of associations that could take the form of associative concepts or other mental representations such as images. The context that we activate and attend to is just a part of this activated association set.

3.1.2 Assumptions about meaning construction

Based on the preceding view of how meaning is represented, we can proceed to answer the question of how meaning is constructed.

3.1.2.1 Meaning is constructed through conceptual interactions

In this research, the meaning of a certain language element is represented as a set of the activated associations. Meaning, therefore, refers to a mental state resulting from the interactions of associative concepts (i.e., conceptual interaction) in the communicative context. This definition emphasizes that meaning is constructed through conceptual interaction, i.e., the influence of associative concepts on each other. For example, for a two-word combination such as “bird furniture”, the meaning is represented as the set of activated associations that come from the interactions between the two sets of associations that each word “bird” and “furniture” activates.

Specifically, in conceptual combination, the assumption that meaning is constructed through conceptual interactions has three senses. Firstly, the meaning of the combination is a function of its simpler constituent concepts. Using Costello’s example of *elephant fish*, the meaning of this combination is a function of its constituent concepts *elephant* and *fish*. Each constituent concept provides the combination with the ‘raw materials’, from which the meaning of the combination is constructed. Secondly, the meaning of each constituent concept is a function of the other constituent. For example, in the combination *bird furniture*, the meaning of *furniture* depends on the meaning of *bird* and vice versa. That is, the meaning of *furniture* is not just about *furniture* in a pure sense; it is somehow associated with the other concept *bird*, so that *furniture* becomes meaningful in the *bird* context. Thirdly, the meaning of the simpler constituent concepts is a function of the compound concept. Using Thagard’s example, the meaning of the constituent concepts *blind* and *lawyer* is a function of the meaning of the compound concept *blind lawyer*. Thus, *blind* would activate some associations that are somehow meaningful in the context of the combination *blind lawyer*.

3.1.2.2 Meaning construction is goal directed

It is assumed that meaning construction is a goal-directed cognitive act. For example, when we construct the meaning for a conceptual combination, the goal is to make sense of this combination. Usually in a meaning-holder's mind, associations are activated selectively to represent and construct meaning for a certain purpose in a certain context. For example, when we construct the meaning for the combination *zebra bird*, not all we know about *bird* will be activated. Only those associations that are relevant to the context, contribute to the goal of the communication, and have acquired historically a higher degree of strength will be activated. That is, context, goals, and the intrinsic property of the concept are the three factors that influence association activation. These activated associations will influence each other and will ultimately construct the meaning for the combination.

It should be noted here that the term "activation" has two senses in the framework. On the one hand, for a single concept, it refers to the strength of the associations of our general knowledge independent of the communicative context. For example, in figure 3-1 and figure 3-2, associations are activated based on our general knowledge of the concept *bird* independent of immediate communicative context. On the other hand, in conceptual combination, it refers to the strength of the associations activated for a specific communicative goal – to make sense of the combination in a certain context. In this sense, associations activated are a subset of our general knowledge, and the activation of this subset guarantees the satisfaction of the goal. For example, to construct the meaning for the combination *elephant fish* as "a big fish", one association "big" is activated by *elephant* from among many other general knowledge associations.

3.1.2.3 The roles of head and modifier are different

Since the focus of this research is on meaning construction of two-word combinations, it is necessary to discuss one unique feature of two word combinations. When constructing the meaning of a two-word combination, one word usually serves psychologically as the head concept which refers to the central concept that, if standing alone, could represent the whole category denoted by the combination. The other is the modifier concept which is used to change some aspects of the head concept. For example, when denoting a bird with stripes, we could say it is a *zebra bird*. *Bird* represents the basic category to which the thing we are referring belongs (the psychological head) while *zebra* modifies this central concept along some finer dimensions (the psychological modifier). It is worth noting that the grammatical head (Cohen & Murphy 1984; Murphy 1988) and the psychological head are not necessarily the same. Grammatically, the head of a two-word combination is always the second word while the first word in the sequence is the modifier (Murphy 2002 p.444). Using Murphy's example, the grammatical head of *stone squirrel* is *squirrel* while *stone* functions as the grammatical modifier. Psychologically, when people construct the meaning of the combination, the more central concept in the construction is usually treated as the head concept, and the concept that changes some aspects of the head is usually treated as the modifier concept. For example, as noticed by Costello that when *chair ladder* refers to a *chair* being used as a *ladder*, *chair* is the psychological head that is central to the meaning of this combination; and *ladder* used as the modifier, modifies some aspects of *chair*. Clearly, this is different from grammatical division where the word "ladder" is always the grammatical head because of its syntactic position. This mismatch sometimes confuses people when they construct a meaning for a combination. For example, in our pilot study of the phrase "furniture bird", about half of the participants treated *furniture* as the head (psychologically, but not grammatically) by referring to the object denoted as a kind of *furniture*, and the remaining half treated *bird* as the head (both psychologically and grammatically) by referring to the object denoted as a kind of *bird*.

As the central concept in the combination, the psychological head brings in most of its associations, while the modifier contributes much fewer associations for the combination. That is, the combination will inherit more of its associations from the head concept than from the modifier concept. For example, when *chair ladder* is understood as "a kind of chair that could be used to climb up and down", *chair* functions as the head concept and brings in most of its associations while *ladder* only brings in certain associations such as "climb up and down" for the combination. Thus, the combination denotes something that has more characteristics of *chair* than *ladder*. However, it should be noted that the number of associations contributing to the combination by head or modifier is different from the importance of associations contributing to the combination. Though the modifier concept contributes fewer associations to the combination, the ones it contributes may be quite important. In the *chair ladder* case, the gestalt image of the combination is much more like a *chair* than a *ladder*, but somehow, *ladder*'s one association "climb up and down" has an important effect on this gestalt image relative to the associations activated by *chair*. That is, the psychological head will bring in more associations for the combination, but the psychological modifier will bring in one or two very important associations for the combination. In this sense, the importance or diagnosticity of an association is not pre-determined by component concept alone, as assumed by Hampton. On the contrary, the importance of an association is a function of the combination. In the *chair ladder* example, many 'important' associations of *chair* become less important because of the combination.

3.2 The processes of conceptual interaction in meaning construction

Based on the views and assumptions in the previous section, we now focus on the cognitive processes of meaning construction.

There are two basic elements in our framework: concepts (component concepts and associative concepts) and the links between concepts. A geometric representation composed of nodes and links could be drawn for these basic elements (Figure 3-3). The nodes in this graph represent concepts and the lines represent the linking property, such as strength and valence.

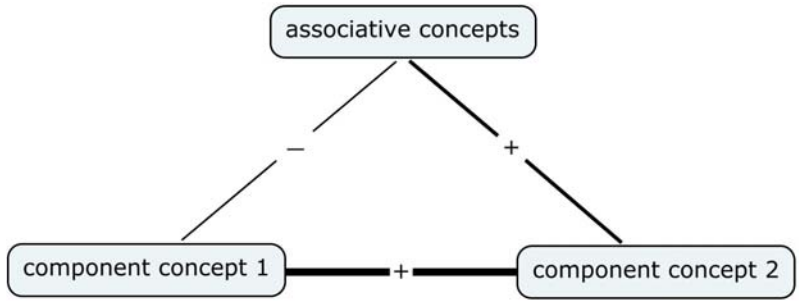

Figure 3-3: A geometric representation of concepts and associations

We propose that meaning is constructed through conceptual interactions, whereby each component concept in a conceptual combination influences the other. We further propose that the components in the triplet composed of two component concepts and their associations interact in organized patterns through which meaning and thoughts are structured dynamically[9]. This theoretical orientation demonstrates the characteristics of a Gestalt treatment of configurations and fields in human cognition. A gestalt is "a system whose parts are dynamically connected in such a way that a change in one part results in a change of all other parts" (Lewin, 1936, p. 218). This dynamic system is tension driven and strives toward equilibrium. When the system is perturbed (as in disequilibrium), a tension or a force is developed which leads to a psychological tendency towards the reduction of tension and the restoration of equilibrium. Based on this view, we assume that when we construct meaning in our communication, we experience concepts and associations as a cognitive field, within which conceptual interactions take place. In the following sections, I will first discuss the characteristics of the cognitive field and then discuss the processes of conceptual interactions.

3.2.1 Cognitive field for conceptual interactions

There are several important characteristics of the cognitive field: the field is a Gestalt; the basic unit of the field is a triangle, and the field should be balanced.

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[9] Different from schematic structure, here the structure is dynamic in that the meaning and thoughts are structured online dynamically, rather than pre-determined or pre-defined.

3.2.1.1 Cognitive field is a Gestalt

The cognitive field is a Gestalt with figure-ground properties. Figure is the spontaneous concentration of our cognition in contrast to those that we do not attend (the ground) at that moment. In conceptual interaction, component concepts and their activated associations form a figure, standing apart from background knowledge comprised of potential or latent associative concepts or weaker associations. This basic grouping of activated vs. latent concepts and strongly-associated vs. weaker-associated concepts forms the figure-ground segregation of the field. For example, when constructing the meaning of *furniture bird*, not all associative concepts of *furniture* or *bird* are activated, and not all associations are of equal strength. Therefore, during meaning construction, the activated associations form a figure against the background of all possible associations that could be activated.

The Gestalt organization of the cognitive field is dynamic. We are capable of restructuring the figure / ground relationship based on our focus of attention, which is influenced by our intentions, cognitive goals or needs, in a given situation. Thus, this figure-ground segregation is goal-directed. Based on the current goal, concepts and associations would change their linkage, change the strength of activation, and even change their valence. Understanding the meaning of a conceptual combination, therefore, corresponds with structuring the figure in the cognitive field so as to arrive at the goal state. It is proposed that arriving the goal state is a multi-step activity where each step might have its own figure/ground segregation.

3.2.1.2 Basic unit of cognitive field is a triangle

Graphically, the cognitive field is represented as a network of nodes and links in the form of cycles (drawing from Heider's representation system). The basic elements of the field are concepts and links between concepts, graphically represented as nodes and links. The smallest constitutive unit of the cognitive field is a pair of 2 concepts and a link between them, graphically represented as 2 nodes and a link. However, it is assumed that of particular importance in meaning construction is a closed cycle, representing a closed loop from component A to component B via certain associative concepts C, D, E, etc. The simplest closed cycle, sharing properties of all closed cycles, is a triangle. As the basic unit of the cognitive field, triangle is our focus of attention (3 concepts with 3 links, also called triplet). That is, a triangle is assumed to be the unit of analysis in the cognitive field for conceptual interactions, because it is the smallest closed cycle. At any given time, our cognition will mainly focus on one triangle configuration as the figure while pushing other triangles to the background.

It should be noted that forming a closed cycle indicates that our cognition establishes links between two component concepts via some associative concepts. Cycle formation is based on the pre-existing knowledge of the component concepts and sometimes, it may take a longer path (i.e., require more intermediate associative concepts) in order to establish a link between the two component concepts.

We perceive the cognitive field based on certain organizing bases, which could be analytically understood that our cognition partitions concepts and associations into groups of triangles using certain organizing bases and valence of these associations are perceived based on this grouping. For any particular triangle configuration, the organizing base will determine the valences assigned to the links connecting the 3 nodes. For example, if the organizing base for grouping the concepts of *apple*, *red* and *green* is "are they colors of apple?", then, the valences are assigned as in the following graph (Figure 3-4), which is understood as: *red* is a color of *apple*; *green* is a color of *apple*; in terms of both being colors of *apple*, *red* and *green* are similar.

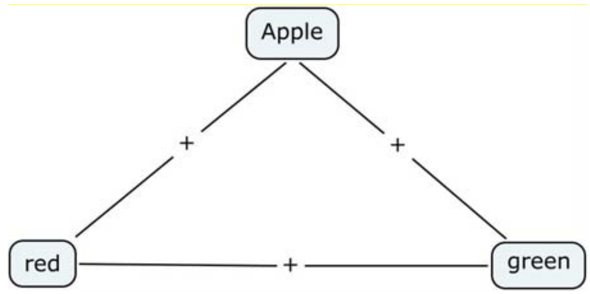

Figure 3-4: Grouping *red*, *green*, & *apple* based on the organizing base "are they colors of apple"

If the organizing base is "are they the same color for apple", the valence is assigned to the following graph (Figure 3-5) which is understood as: *red* is a color for *apple*; *green* is a color for *apple*; *red* is not the same color as *green*.

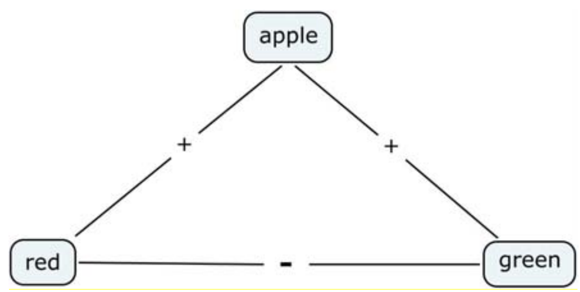

Figure 3-5: Grouping *red*, *green*, & *apple* based on the organizing base "are they the same color for apple"

When assigning valence to links in a conceptual combination, it is assumed that there is always a positive link between the two component concepts in the two-word combination, because these two words are now forced to combine as a new phrase. For example, when we graph the combination *elephant fish*, a positive valence exists for the link between *elephant* and *fish* (Figure 3-6).

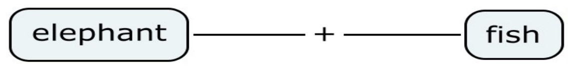

Figure 3-6: Positive valence between two component concepts: *elephant* & *fish*

The bases for organizing different triangles in a cognitive field could be different. However, it is assumed that our cognition uses as few organizing bases as possible for the cognitive field. For example, a certain cognitive field could be constructed for the combination *elephant fish* (Figure 3-7).

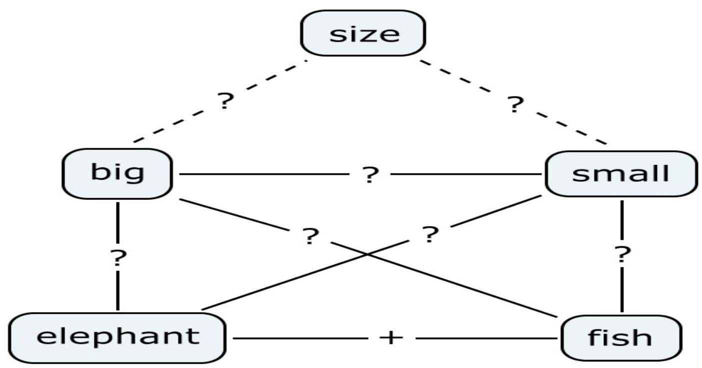

Figure 3-7: A certain cognitive field for *elephant fish*. Dotted lines represent the implicit knowledge we have that is not directly salient[10]

How should valence be assigned to the links in this graph? First of all, a positive valence is assigned to the link between *fish* and *elephant* because these two component concepts are now combined (Figure 3-7). There are a few triangles in the graph and based

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[10] Salient association is somewhat different from prototypical association. Prototypical association is a description of the conceptual structure drawn from the background knowledge, while salience is a degree of activation of associations in communication as an immediate experience. They are equivalent given a unit of a concept or a combination of a concept. For example, the prototypical associations of a given concept would be salient associations; and the prototypical associations of a given conceptual combination would be salient associations as well. However, the salient associations of a conceptual combination do not necessarily correspond to the prototypical associations of component concepts. For example, when *tasty computer* is understood as "chocolate shaped like a computer", *shape* is a very salient association of this combination. However, *shape* is

on our assumptions, we only attend to one at a time. For triangle Δsize-small-big, if the organizing base is the fact that both small and big are “sizes”, then the valence should be assigned as follows: (Figure 3-8)

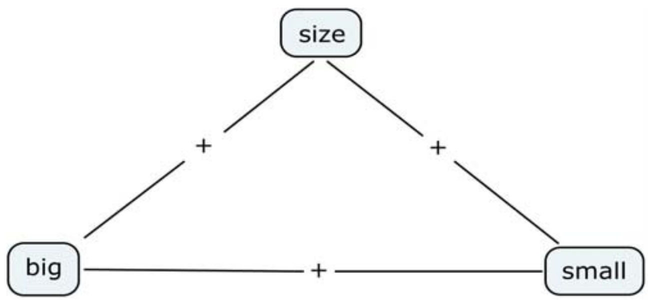

Figure 3-8: Valence assignment alternative 1 for triangle size-small-big

However, in this field, the triangle Δsize-small-big is embedded in a context of *fish* and *elephant*, thus, the organizing bases should be “are they same size for elephant and fish?” Then, the valence should be assigned as follows: (Figure 3-9. Dotted lines denote that they are not in current figure).

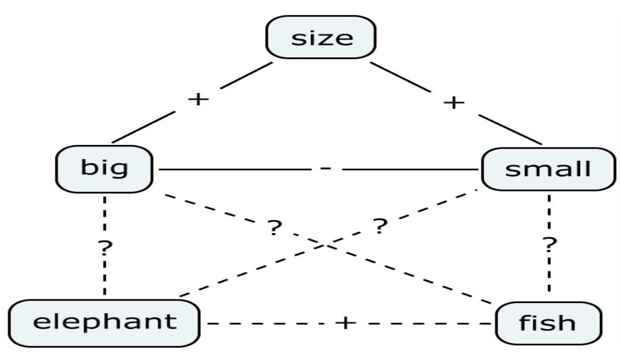

Figure 3-9: Valence assignment alternative 2 for triangle size-small-big

Of the remaining triangles, the simplest assignment is based on the “is” relationship: *fish* is *small*; *fish* is *big*; *elephant* is *small*; *elephant* is *big* (Figure 3-10).

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not a prototypical association of either component concept.

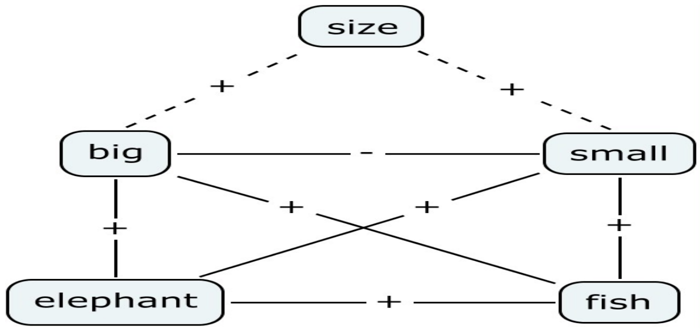

Figure 3-10: Valence assignment for the cognitive field of *elephant fish* (I)

However, the meaning of *small* in "fish is small" is different from in "elephant is small" since *small* is a relative concept. That is to say, *small fish* is quite different from *small elephant* in terms of sizes. Independent of *elephant*, *fish* could be small as well as big; and independent of *fish*, *elephant* could be small as well as big. However, in the context of the combination *elephant fish*, *big* / *small* acquires a very specific meaning, i.e., now *big* / *small* is meaningful in relation to the context of *elephant fish*. That is, in isolated cases, *big* / *small* is only relative to e*lephant* or only relative to f*ish*. But in combination, *big* / *small* is relative to a context of two concepts. In this context, *fish* is comparatively smaller than *elephant*; and *elephant* is comparatively bigger than *fish*. Thus, to be consistent with the meaning of *small* or *big* in this context, the link between *fish* and *big* should be negative, i.e., *fish* is *big* <u>*not*</u> in the same sense that *elephant* is *big*. Similarly, the link between *elephant* and *small* should be negative, i.e., *elephant* is *small* <u>*not*</u> in the same sense that *fish* is *small*. Thus, the valence should be assigned as in the following graph (Figure 3-11).

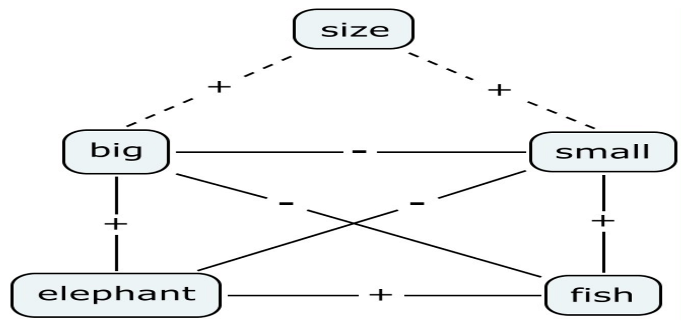

Figure 3-11: Valence assignment for the cognitive field of *elephant fish* (II)

3.2.1.3 Cognitive field should be balanced

Generally speaking, the cognitive field should be balanced. If not, forces or tension will be generated to change the field into a balanced state. As defined by Heider, "by a balanced state (or situation) is meant a harmonious state, one in which the entities comprising the situation and the feelings about them fit together without stress" (Heider 1958 p. 180). Mathematically, when there are three entities linked together in a triangle, a balanced state exists if the product of signs is positive, i.e., when all three links are positive or when two are negative and one positive (Heider, 1958). However, Heider treated balance as an absolute concept and restricted his analysis to binary cases in which a triangle was either balanced or imbalanced. In this research, balance will be defined as a variable with a scale of degree from less balanced to more balanced. Thus, if V_i represents the valence of the *i*th association and S_i represents the strength of the *i*th association, then, balance is defined as the product of V_i and S_i (where $V_i \in [+1, -1]$ and $0 \le S_i \le +1$). For example, in a triangle Δa-b-c, balance is defined as the product of every valence and strength of the three associations (Figure 3-12), i.e.,

$$\text{Balance} = (V_{ab}*S_{ab})*(V_{ac}*S_{ac})*(V_{bc}*S_{bc})$$

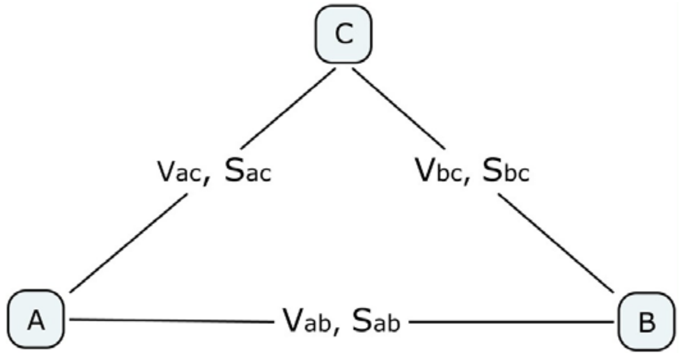

Figure 3-12: Balance Operationalization

Here, balance indicates how strongly an association could link the two component concepts in a closed cycle[11]. In the above equation, we assume point C is the association of the component concept B that could form a closed loop with the other component concept A in the combination AB. Thus, it is clear that balance indicates the degree of the strength that an association (in this example, C) activated by one component concept (in this example, B) could be linked to the other component concept (in this example, A).

We assume that the network reflecting links among all the associations (activated & potential) of a single concept is always in a balanced state. That is, the knowledge about a single concept is in a balanced state. For example, the cognitive field of *bird* and its associations (Figure 3-1) are assumed to be in a balanced state.

For a cognitive field larger than single concept, the basic hypothesis is that there is a tendency for the network of the cognitive units to achieve a balanced state. "If a balanced state does not exist, then forces toward this state will arise… If a change is not possible, the state of imbalance will produce tension" (Heider, 1958, p. 201). When tension caused by imbalance arises in the mind of the individual, the individual is likely to exercise some mental effort to reduce the tension as much as possible.

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[11] In Cartwright & Harary (1956) p.288, the degree of balance of an s-graph is defined as the amount of balance possessed by an unbalanced s-graph, i.e., degree of balance = the ratio of the

The cognitive field is balanced in a cognitively efficient manner. In theory, it is possible to form a balanced cycle between two component concepts through many different associative concepts; some are simple while others are quite complicated. Out of these possible cycles, we would always tend to choose the ones that are most convenient (easiest or quickest to form a closed cycle). It should be noted that we do not necessarily take the one that is maximally balanced; instead, it is more likely that we take the first one that is above a certain threshold, although we do not know empirically what that threshold is.

3.2.2 Cognitive steps in conceptual interactions

Having characterized the properties of the cognitive field, it is proposed that the following cognitive steps are involved in conceptual interactions to construct the meaning of a combination. Analytically, the conceptual interaction is achieved through four steps: 1. perceiving head and modifier; 2. activating associations to form a closed cycle; 3. balancing the cycle; 4. strengthening balance. However, it is important to note that these four steps are divided analytically for convenience of presentation only and should not be taken to imply a sharp and clear segregation between steps or that they happen in a linear sequential way. On the contrary, it is assumed that these four steps are always interwoven with one another and might happen concurrently.

3.2.2.1 Perceiving head and modifier

Perceiving head and modifier refers to the mental processing that each component concept in a conceptual combination is perceived as playing the role of (psychological) head or modifier. This perception is firstly based on the grammatical constraints of the language. In the English language, the first word in the sequence is normally the modifier and the second word is normally the head. If this interpretation is not working (judged by

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number of positive cycles to the total number of cycles. Clearly, what I defined as the degree of balance is different from what Cartwright & Harary defined "degree of balance".

the following steps), a reverse interpretation is given, i.e., the first word in the sequence is treated as head and the second word as the modifier.

As we explained, psychologically, the distinction between the head and modifier is that the head concept normally keeps most of its associations as default (activated or not), which are assumed to be in a balanced state. In contrast, the modifier may only contribute one or two of its associations to the meaning of the combination. The associations contributed by modifier is used and processed by later steps. As the example *chair ladder* shows, when *ladder* is interpreted to be the head and *chair* to be the modifier, most of the *ladder*'s associations are kept while only one or two associations of *chair* are used to construct the meaning, i.e., we are exploring the meaning of "a ladder (with some properties of a chair)". On the other hand, when *chair* is interpreted to be the head and *ladder* to be the modifier, most of the *chair*'s associations are kept while only one or two associations of *ladder* are used to construct the meaning, i.e., we are exploring the meaning of "a chair (with some properties of a ladder)".

3.2.2.2 Activating associations to form a closed cycle

Activating associations to form a closed cycle refers to the mental processing that each component concept activates its own set of associations selectively in order to form a cognitive field (graphically represented as a cycle). There are four general properties for association activation.

First, the activation is goal-directed. As we assumed, meaning construction is a goal-directed action. Here, the goal of association activation is to make sense of the combination, i.e., to understand how the meaning of the two component concepts can fit together harmoniously. Analytically, it equates to forming a balanced cycle from one component concept to the other. That is to say, only those associations that are necessary for constructing a (possibly) balanced cycle are activated consciously. If from the perspective of the individual, a highly prototypical association cannot satisfy the goal, it will be either not activated or dropped from the set of activated associations. For example, when the meaning of the combination *elephant fish* is understood as “a big fish”, some highly prototypical associations of *elephant* (e.g. *trunk*) are either not activated or dropped from the set of activated associations for the reason that for some people it is impossible to construct a potentially balanced cycle from *elephant* to *trunk*, and then from *trunk* to *fish* (the triangle elephant-trunk-fish does not fit together harmoniously). For these people, it is highly improbable for a fish to have a trunk even though trunk is very typical of elephant. The associations they attend to and activate are those that are already balanced for them, or can be balanced for them.

Second, the activation is contingent. There are two senses of contingency when activating associations to form a closed cycle: one, the meaning of each constituent concept is a function of the other constituent; and two, the meanings of the simpler constituent concepts are a function of the compound concept. For the first sense of contingency, the probability of one concept’s association being activated depends on the other concept’s activated associations. For example, when constructing the meaning of the combination *elephant fish*, *elephant* will activate a subset of its associations in relation to the other concept *fish*. A different subset of associations will be activated if, say, *elephant* is paired with the concept *cage* in the combination *elephant cage*. Similarly, because of the presence of the concept *elephant*, *fish* will activate certain associations that are different from, say, those that will be activated when *fish* is paired with *ocean* in the combination *ocean fish*. Empirically, we hope to demonstrate that the set of associations activated for the concept of *fish* or *elephant* is different in the context of different combinations such as *elephant fish*, *ocean fish* and *elephant cage*. For the second sense of contingency, the associations activated by each component concept are contingent upon the existence of the combination. That is, as a Gestalt, the combination influences how we understand the meaning of its components. As an example, the meaning of polysemous or homonymous words such as “bank” is influenced by the sentence in which the word is used: “I went to the bank of Yangtze River which was just merged with TD Canada” vs. “I went to the bank of Yangtze River over which a bridge was just constructed” . Here, the meaning of the constituent concept *bank* is clearly a function of the total meaning of each sentence.

Third, the activation is prototypical. The activation of an association is a function of the prototypicality of the associations. That is to say, the intrinsic property of the component concept itself influences association activation. The activation of associations is always from high-strength (more prototypical) associations to lower strength (less prototypical) associations. For example, when *elephant* is used in combinations such as *elephant fish*, high-strength associations of *elephant* such as "trunk, big, grey etc" will likely be activated before lower strength associations (such as sex, ears to cool itself, etc) are activated. It could be postulated that, other things being equal, an association activated with higher strength by at least one of the component concepts will be more likely to be activated high when constructing the meaning of combination. For example, the meaning of the combination *triangular computer* could be constructed as "a triangular-shaped computer". Because *shape* is a prototypical association of *triangular*, its relative strength is carried over to the combination too. Even though *shape* may be a very weak association of *computer*, it will still become a relatively high strength association for the combination *triangular computer*. However, if this highly prototypical association cannot form a balanced cycle, it will be dropped from the set of activated associations and a less prototypical association will be activated. As the example of *elephant fish* showed, if it can not be understood as a fish with *trunk*, then even though *trunk* is a highly prototypical association for *elephant*, it will be dropped from the set of activated associations.

Fourth, the activation is cognitively efficient. For example, many associations of *elephant* could be activated for further processing, and it is easy to list such associations: *trunk*, *large*, *grey*, *be eaten* etc. Then why should not the meaning of *elephant fish* be constructed as "a large grey fish with a trunk that eats elephants"? That is, this particular understanding of the combination *elephant fish* has many elephant associations while still being a fish. In theory, it is possible to use multiple associations of the modifier that could form balanced contingent cycles with *fish* to construct the meaning of *elephant fish*. However, it is assumed that the amount of cognitive effort required to balance a cognitive field increases with the complexity of the field. That is to say, the more *elephant* associations are brought into the cognitive field, the more cognitive work is required to make everything consistent. Thus, a simpler constructed meaning that requires less cognitive effort is likely to be perceived as a good enough meaning in most cases. However, in cases where multiple associations of the modifier are used, it could be postulated that they should make for a better example of the combination than when a single association of the modifier is used. For example, "a large grey fish with a trunk" should be judged as a better example of an *elephant fish* than just "a grey fish".

After associations are activated to form closed cycles, these cycles need to be balanced.

3.2.2.3 Balancing closed cycle

Balancing closed cycle refers to the mental processing that activated associations are formed into closed cycle and checked for its balance state; and if not balanced, some cognitive mechanisms (reverse valence, change strength, and / or activate n^{th}-order associations) are implemented to balance the cycle.

To check the balance state is to feel whether or not "the entities comprising the situation and the feelings about them fit together without stress" (Heider 1958 p. 180). Mathematically, it equates to deciding whether or not the product of signs of cycle links is positive. As we assumed, our focus of attention is always on the smallest closed cycle: a triangle. Thus, a balanced state for a triangle exists if all three links are positive or if two are negative and one positive. For example, when constructing the meanings of the combination *elephant fish*, the concept *elephant* will activate certain associations that are cognitively efficient, prototypical and possible to form a closed cycle. There might be numerous associations that might satisfy these conditions. I will use a couple of them as the examples to demonstrate the process of balancing.

Possibly, one of such associations is *big*. Contingently, *fish* will activate *small* corresponding to *big*, thus a closed cycle is formed (Figure 3-13).

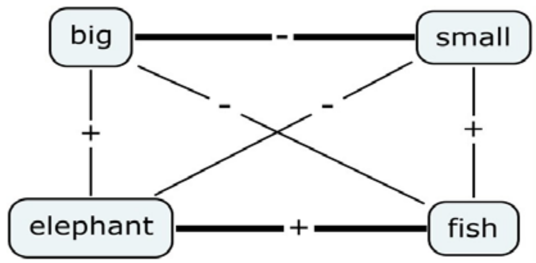

Figure 3-13: Balancing the cognitive field for *elephant fish*: via *big* (I)

In this graph, there are four nodes and six links (L). As we analyzed previously,

- $L_{elephant\text{-}fish}$ has positive valence and strong strength due to the fact that these two concepts are now combined.
- $L_{fish\text{-}small}$ has positive valence because generally *fish* is *small*.
- $L_{elephant\text{-}big}$ has positive valence because generally *elephant* is *big*.
- $L_{small\text{-}big}$ has negative valence and strong strength because *small* is definitely different from *big* in the context of comparing size of *elephant* and *fish*.
- $L_{fish\text{-}big}$ has negative valence because *fish* is not *big* in the same sense that *elephant* is *big* in the triangle $\Delta_{elephant\text{-}fish\text{-}big}$.
- $L_{elephant\text{-}small}$ has negative valence because *elephant* is not *small* in the same sense that *fish* is *small* in the triangle $\Delta_{elephant\text{-}fish\text{-}small}$.

Apparently, this is not a balanced cycle overall because it has 2 imbalanced triangles: Δelephant-fish-big and Δelephant-fish-small and 2 balanced triangles: Δfish-small-big (meaning "fish is small, not big) and Δelephant-big-small (meaning "elephant is big, not small). Based on our postulation, there should be a tendency to change the field into a balanced state by changing the valence of one or more associations.

We further postulate that change will first happen in the weaker link (lower strength), and the change should reduce the number of the unbalanced triangles rather than create more unbalanced triangles. Thus, one of such feasible changes in the two imbalanced triangles is to change the valence of the link $L_{fish\text{-}big}$ (dotted line) and the link $L_{fish\text{-}small}$

(dotted line) so that all 4 triangles are balanced and the whole structure is in balance as well (Figure 3-14). This kind of change is through reversing valence of certain associations so that the cycle becomes balanced. When a cycle is balanced, we will say the system reaches a stable state and the conceptual interaction is finished with a resultant meaning constructed. In this case, the resultant meaning is "elephant fish is a big fish".

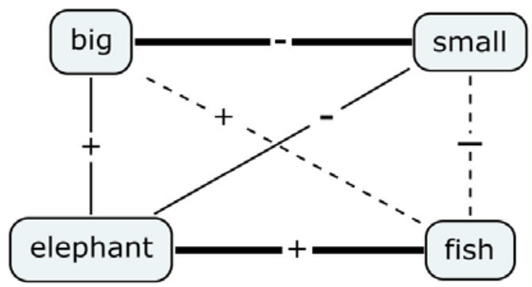

Figure 3-14: Balancing the cognitive field for *elephant fish* via *big* (II)

This graph could be understood as follows (based on the four triangles):

- Elephant fish is big (triangle Δelephant-fish-big)
- Elephant fish is not small (triangle Δelephant-fish-small)
- Fish is big, not small because small is not big (triangle Δfish-big-small)
- Elephant is big, not small because small is not big (triangle Δelephant-big-small)

Another possible association activated might be *trunk* when *elephant fish* is understood as "a fish with trunk" (Figure 3-15). Here, *elephant* and *fish* have a strong positive link $L_{\text{elephant-fish}}$ because these two words are now combined. *Trunk* as a prototypical association of *elephant* has a very strong positive link $L_{\text{elephant-trunk}}$ with *elephant*. The only (comparatively) weaker link is the negative link $L_{\text{fish-trunk}}$ between *fish* and *trunk* because fish normally does not have trunk.

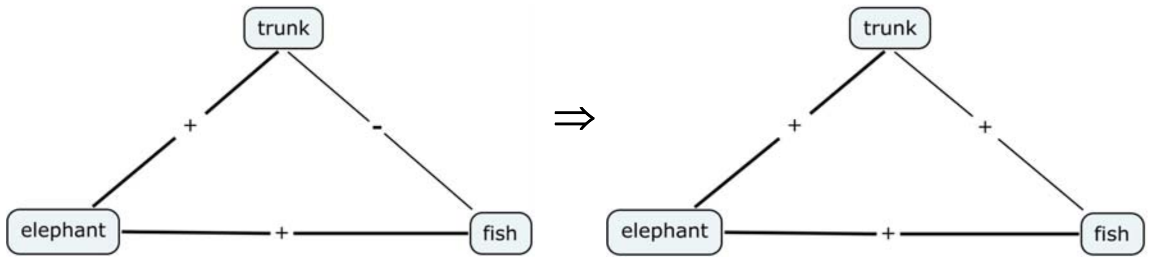

Figure 3-15: Balancing the cognitive field for *elephant fish* via *trunk*

Apparently, this is not a balanced structure, so the structure will generate a cognitive force driving changes from the imbalanced state to a balanced one. The most feasible change here is to change / reverse the valence of the weaker link $L_{fish\text{-}trunk}$ (Figure 3-15) so that *fish* could now be positively linked to *trunk* (hence the meaning "elephant fish is a fish with trunk" is constructed).

The third possible association activated to construct the meaning of *elephant fish* might be when it was understood as "a fish that eats elephant" (Figure 3-16). In this graph, *elephant* and *fish* has a strong positive link $L_{elephant\text{-}fish}$. *Eat* as the association of both *fish* and *elephant* (positive links: $L_{fish\text{-}eat}$ and $L_{elephant\text{-}eat}$) has the potential to form a closed cycle, thus might be activated saliently. Since the product of the links is positive, it is a balanced triangle and a meaning is constructed. Because the head of the combination *elephant fish* is *fish*, the meaning constructed is "elephant fish is a fish that eats elephant". Interestingly, this graphical representation also suggests another meaning. If for some reason, *elephant* were regarded as the head (e.g. the combination is *fish elephant*), then the meaning constructed is "fish elephant is an elephant that eats fish".

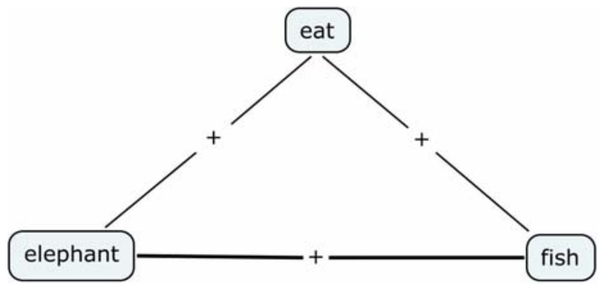

Figure 3-16: Balancing the cognitive field for *elephant fish* via *eat*

The above three examples demonstrate that balance could be achieve by valence reversal and how various meanings could be potentially constructed for the combination *elephant fish*. However, these meaning constructions are not equally probable in our mind. When we activate associations to form a cognitive field, the activation should be goal-directed, contingent, prototypical, and cognitively efficient. Clearly, all the associations activated in the above three examples are goal-directed contingent activations (i.e., to form a closed cycle with the other pairing concept). They can all form some closed cycle by activating corresponding associations. However, these associations are not all equally prototypical or equally cognitively efficient. For example, *eat* is probably less prototypical than *big* or *trunk* for the concept *elephant*. Thus, it could be predicted that the meaning "elephant fish is a fish that eats elephants" is less likely to be constructed than the meanings "elephant fish is a big fish" or "elephant fish is a fish with trunk". This phenomenon could be explained using our definition of balance.

As we defined, in a triangle $\Delta_{a\text{-}b\text{-}c}$, Balance (B) = $(V_{ab}*S_{ab})*(V_{ac}*S_{ac})*(V_{bc}*S_{bc})$. Thus, the balance value of the above examples[12] before the valence change (before the cycles are balanced) could be calculated as (Figure 3-17):

$$B_{trunk} = (V_{fish\text{-}elephant}*S_{fish\text{-}elephant})*(V_{elephant\text{-}trunk}*S_{elephant\text{-}trunk})*(V_{fish\text{-}trunk}*S_{fish\text{-}trunk}),$$

[12] When the meaning of "elephant fish" is constructed as "a fish that eats elephant", the direction of the link actually functions. However, the current framework did not incorporate direction when defining balance, thus this meaning is not including in the following discussion.

$B_{big} = (V_{fish-elephant} * S_{fish-elephant}) * (V_{elephant-big} * S_{elephant-big}) * (V_{fish-big} * S_{fish-big})$,

where[13], $V_{fish-elephant}=+1$, $S_{fish-elephant}=+1$, $V_{elephant-trunk}=+1$, $V_{fish-trunk}=-1$, $V_{elephant-big}=+1$, $V_{fish-big}=-1$. Thus, the above formulas could be shortened as:

$B_{trunk} = S_{elephant-trunk} * (-1) * S_{fish-trunk} = - S_{elephant-trunk} * S_{fish-trunk}$

$B_{big} = S_{elephant-big} * (-1) * S_{fish-big} = - S_{elephant-big} * S_{fish-big}$

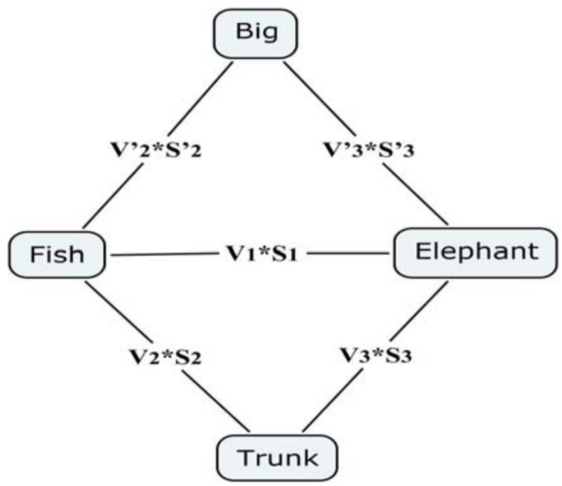

Figure 3-17: *Elephant fish* – meaning selection based on balance value

This formulation permits a few predictions on the process of conceptual interaction. For example, if *trunk* and *big* are equally prototypical associations of *elephant* ($S_{elephant-trunk} = S_{elephant-big}$), then, it could be postulated that the probability of using either association (*big* or *trunk*) as the final meaning of the combination is in direct relation to the degree of balance of this association, i.e., other things being equal, the more balanced an association is, the more probable this association will be selected as the meaning of the combination. Based on this prediction, under the above conditions, if $S_{fish-big}$ is higher than $S_{fish-trunk}$, *big* will be more likely to be selected as the meaning of the combination than *trunk*. Certainly,

[13] The details of getting the strength of an association will be discussed in the method section. Here, we will assume a weight of 1 and positive valence for the association between two component concepts.

there might be other predictions that are of interest to the research. It will be worthwhile to further explore the potential predictions using this way of theorizing.

Our next example demonstrates that balance could be achieved by changing strength of activated associations and by activating n^{th}-order associations. Based on our postulations, concepts will activate their associations contingently in order to form a balanced cycle. When constructing the meaning of *tasty computer*, let us assume that none of the prototypical associations of either concept easily form a closed cycle for balancing. That is, the first order activations (the associative concepts activated directly by the component concepts) can not form a path linking the two concepts. Then a second order activation (the associative concepts activated by the activated first order associations) will be activated in order to form a possible path from head to modifier. We postulate that when the first order activation cannot form a closed cycle, our cognition will activate second order (or third order, etc.) associations in order to form a closed cycle for balancing. In this example (among many other possible understandings), let us assume that *chocolate*, as a first order association of *tasty*, is activated with strong strength. Further, *moldable* or *shape* as associations of *chocolate* (i.e., second order associations of *tasty*) are activated in order to form a closed cycle with *computer*. *Shape* in this example represents a feasible, though very weak, first order association of *computer* that enables a closed cycle to be formed. Because of this potential for *shape* to satisfy the goal of this cognitive activity, the strength of *shape* increases significantly for *computer* and becomes very salient association for *tasty computer*. Thus, a closed cycle is constructed logically and feasibly from *tasty* to *computer*: *tasty-chocolate*-(*moldable*)-*shape-computer*, and the meaning "tasty computer is a chocolate shaped like a computer or a chocolate in the shape of a computer" is constructed (Figure 3-18).

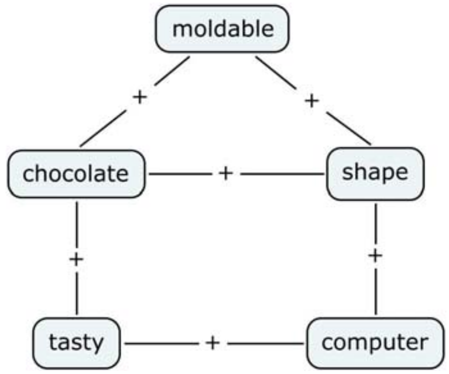

Figure 3-18: Balancing the cognitive field for *tasty computer* via second order associations

It is proposed that balancing includes two processes: checking the balance state of the cognitive field, and (if not balanced,) certain cognitive mechanisms such as valence reversal, strength change, and n^{th}-order association activation are implemented to balance the field. However, it should be noted that balancing, especially valence reversal, requires a lot of cognitive efforts afterwards as explained in the next section.

3.2.2.4 Strengthening balance

It is worth noting that, with the specific proposals on how to change the field from an imbalanced state to a balanced one, Heider concluded that "the situation can be made harmonious" by a change in valence (valence reversal). This is a correct observation based on his operationalization of balance. In Heider's examples, systems are balanced because balance was operationalized mathematically as the positive product of valence. However, at the same time, as a psychological concept, balance is defined by Heider as "a harmonious state, one in which the entities comprising the situation and the feelings about them fit together without stress" (Heider 1958 p. 180). It is easy to see the discrepancies in this definition of balance and the Heider's operationalization of the concept mathematically. Does the mathematical balance equate to psychological balance? Using Heider's example, "Let us suppose p likes o, and p perceives or hears that o has done something, which we call x… x may be something which is negative for p…..imbalance results: the triad contains two positive relations (o U x), (p L o) and one negative relation (p DL x). This is an unpleasant situation for p. Tension will arise and forces will appear to annul the tension.

The situation can be made harmonious either by a change in the sentiment relations or in the unit relations. (For example, to) change in sentiment relations, p can begin to feel that x is really not so bad, thereby producing a triad of three positive relations" (1958 pp.207 – 209). However, after *p* begins to feel that *x* is really not so bad, thereby producing a triad of three positive relations as suggested by Heider that is mathematically balanced, does *p* really feel harmonious psychologically? Psychologically, the shift from a feeling of disliking x to a feeling of liking x (a valence reversal) seems too easy and too quick. Using another Heider's example, if "*p* worships *o*; *o* told a lie; *p* disapproves of lying" (Heider 1958 p. 203), by feeling that lying "is really not so bad", can *p* feel harmonious now? Mathematically, a change from negative sign to a positive sign is quick and easy; however, psychologically, a change from "dislike lying" to "like lying" is not as easy and quick as flipping a sign (Figure 3-19).

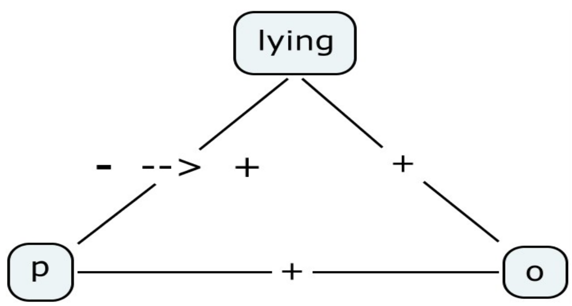

Figure 3-19: Valence reversal for balancing network of p-o-lying

It is quite clear that even after a cognitive field is balanced mathematically by valence reversal, there is still some psychological discomfort or imbalance remaining in the field. In the above example, after feeling that lying "is really not so bad", it might take *p* a while and require some additional cognitive effort to really feel that "the entities comprising the situation and the feelings about them fit together without stress" (Heider 1958 p. 180). Based on this analysis, even if *elephant fish* could be mathematically balanced as "a fish with trunk", there may still be some psychological imbalance left in the field and felt by people. That is to say, psychologically, we do not feel balanced or harmonious toward this constructed meaning. The remaining feeling of imbalance comes from a larger cognitive field that the specific constructed meaning is part of. That is, although the field of “a fish with trunk” could be balanced, a larger cognitive field that involves our knowledge (other associations) of *fish* might be inconsistent with the balanced field; thus, there are still a tension between the constructed meaning and a larger field (our knowledge). In this circumstance, it is likely that further cognitive effort will be exerted to strengthen the degree of balance and thereby reduce the remaining tension.

Strengthening balance refers to the mental processing that rationalizes, strengthens or weakens the associations in the activated cognitive field to increase the degree of balance. It is assumed that whenever a change happens in the cognitive field, there is always some remaining tension associated with this change, and there is always a need to provide further information to reduce the tension. The need to provide further information is to increase additional loops / cycles by activating additional associations. These newly activated additional associations will form new links between the activated associations of the two concepts. These additional loops will change the strength of the association that are still felt somewhat discomfort. Though I do not have a specific theory on the cognitive mechanism on strengthening, various methods such as PDP or weight propagation may explain this process.

Two kinds of strengthening could be postulated: a). strengthening some activated associations as more salient and weakening other non-reconcilable associations, b). providing additional associations that reconcile the possible tension that the newly modified associations might bring in. Essentially, these two kinds of strengthening imply one mechanism – to change the strength of the associations in the cognitive field.

For example, if the meaning of the combination *elephant fish* is somehow constructed as “a fish with trunk”, it may be in conflict with our general knowledge of what a fish is. This tension could be resolved by strengthening the modified associations in the cycle. More specifically, tension could be reduced by providing situational contexts (as additional associations) to add further details. For example, we could reduce the tension by constructing a context (providing additional associations) such as “in the deep and unknown sea" where any kind of strange animal might exist or "in a fairy land" where a fish might have a big long nose just like an elephant etc. As we assumed, context is another set of associations contributing to the meaning construction. If the additional association "strange fish" is activated, the process of this strengthening could be graphed as follows (Figure 3-20):

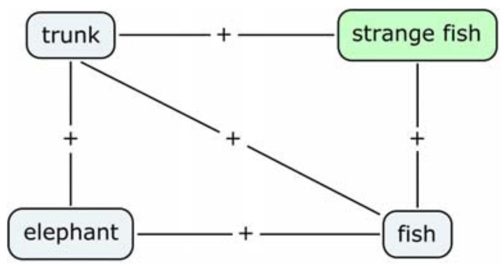

Figure 3-20: Strengthening *elephant fish* network after balancing

In this graph, "strange fish" as a newly activated association for the combination *elephant fish*, further strengthens the link between Fish and Trunk, i.e., the newly activated association seems to increase the number of positive associations that reinforce or add strength to the modified association $L_{fish\text{-}trunk}$. It is worth noting that at this stage, our focus of attention is on the combined concepts *elephant fish* as a whole rather than on the component concepts *fish* or *elephant* respectively. Thus, it is more accurate to graph this process as follows (Figure 3-21):

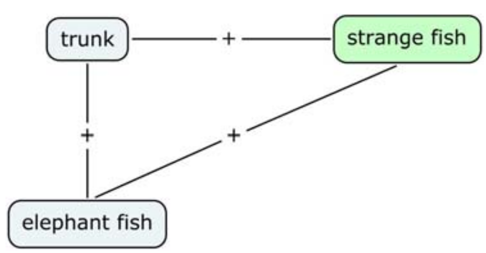

Figure 3-21: Strengthening *elephant fish* network after balancing – a more accurate graph

Strengthening balance not only refers to increasing the number of positive associations that reinforce or add strength to the constructed meaning, but also refers to rejecting or ignoring other non-reconcilable associations, i.e., negating imbalanced associations of the component concepts that are no longer valid for the combination. For example, when the meaning of *tasty computer* is constructed as "a chocolate shaped like a computer", people might still feel some tension that needs to be reconciled. This tension comes from the fact that *computer* normally has an implicit association of being "real" together with all other associations (CPU, keyboard, calculation, internet etc) that computer has in a balanced state. The newly constructed meaning brings the incompatible concept *chocolate* into the field of *computer* associations, creating tension that now needs to be adjusted. To do this, a new association "real computer" could be activated to help adjust the relation between *tasty computer* and *real computer* (Figure 3-22). This newly activated association negates the link between *tasty computer* and *real computer* and thereby eliminates imbalance elsewhere in the network.

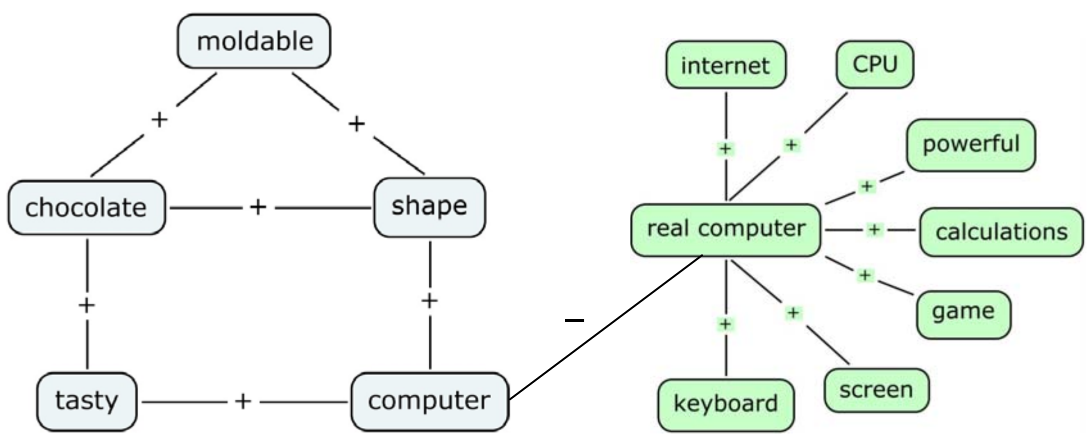

Figure 3-22: Strengthening *tasty computer* network after balancing

Both negative and positive strengthening seem mainly to add additional information to reduce residual tension associated with the balanced meaning. In this sense, negative strengthening and positive strengthening function in a similar way and lead to similar effects. For example, *elephant fish* could be strengthened by activating a new association "strange fish" to positively strengthen the constructed meaning as described above, or by activating the negative association "normal fish" as follows (Figure 2-23):

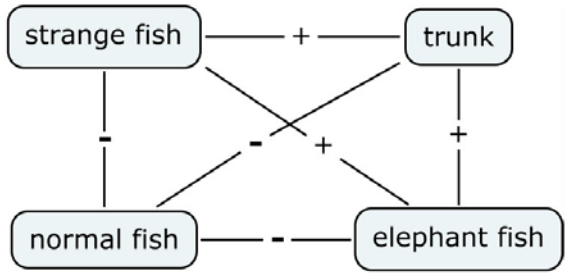

Figure 3-23: Strengthening *elephant fish* by both positive and negative strengthening

Strengthening the degree of balance is not absolutely necessary but is assumed as an extra optional step in the meaning construction process. It is postulated that strengthening is necessary when there is some remaining tension felt in the cognitive field, such as when constructing the meaning of novel combinations like *tasty computer*. It is noted that constructing the meaning of a novel combination involves combining two sets of originally balanced associations of the two component concepts, some of which might now be in conflict with one another. To construct a balanced and harmonious meaning in such cases, major cognitive work such as valence reversal might be involved, leaving residual tension to be reduced.

3.3 Mundane and novel combinations

It is worth noting that when constructing the meaning of everyday / mundane conceptual combinations, we do not experience the same degree of cognitive complexity as such novel combinations. Here, it is necessary to define what I mean by mundane or novel combinations. Based on my framework, a novel combination is defined as one in which the probability of one component concept being present in the cognitive field of the other component concept is very low, i.e., the two component concepts are not part of the prototypical knowledge for each other. For example, *tall stapler* is considered as the novel combination because the probability of *tall* being present in the cognitive field of *stapler* is quite low. Correspondingly, an everyday / mundane combination is defined as one in which the probability of one component concept being present in the cognitive field of the other component concept is quite high, i.e., either one or both component concepts are part of the prototypical knowledge for the other. For example, *red apple* is understood as "apple that are red (colored)", in which *red*-colored itself is a prototypical knowledge of *apple*. Since they are part of the prototypical knowledge of each other, we are so accustomed to co-activate these two set of associations for the meaning of such mundane combinations in our everyday life that they do not seem to require any complex cognitive processes to balance the cognitive field. They are used so frequently that the cognitive field *already* seems to be balanced for most of us. In a way, we seem to use some sort of 'short-cut' to construct the meaning of these mundane combinations. However, we would argue that this 'short-cut' comes originally from the complex cognitive processing that require the activation of contingent associations and balancing the activated cycles. It is just because these combinations are so frequently used that the two component concepts become part of the prototypical knowledge for each other, thus requires no need for further balancing.

Compound words such as daybreak, blackboard, playboy, haircut, windmill, brainwash, lipread, babysit, dutyfree etc., represent extreme cases of the everyday / mundane combinations Taking "blackboard" as an example, it is a single word with its own distinct meaning that is separated from its original conceptual components "black" or "board". Although it is still possible to trace the meaning of this word back to its conceptual components, the process of the original conceptual combination is so "short-cut" that the original combination now is reduced to a single word of its own. There is almost no cognitive effort involved to combine "black" with "board" any more. However, this seeming lack of cognitive processing is due to the cognitive efficiency from the repeated use, and due to the fact that later generation learned the compound words as one word rather than a conceptual combination. That is, this type of everyday / mundane combination should originally have the same cognitive processes as more novel ones, though now they are processed quicker due to cognitive efficiency that we gained through learning or experience.

3.4 A brief summary

The framework proposed here tries to address one of the fundamental questions in human communication: how is complex meaning constructed from smaller linguistic units such as words? By conceptualizing meaning as a mental state resulting from the interactions of associative concepts in the communicative context, we studied the process of meaning construction through a detailed discussion on the conceptual interactions of the associations activated by these units. More specifically, these linguistic units are first perceived playing the role of either head or modifier, and then associative concepts are activated contingently and prototypically to form a cognitive field exhibiting Gestalt figure-ground characteristics. If the field is not balanced, certain cognitive mechanisms are implemented to balance it. After balancing, a rationalization or strengthening of the modified associations could be conducted to increase the salience of the activated associations and decrease the salience of other non-reconcilable associations.

Essentially, meaning construction could be theorized as a process of cycle formation and cognitive balancing. Constructing complex meaning from simpler concepts equates to two processes: one is to form a feasible and logical cycle between these concepts with least cognitive effort; the other is to change from an imbalanced state of the field to a balanced one. These two cognitive activities are the driving forces for conceptual interaction in meaning construction. The concepts interact in the field by changing the properties of the linkages between them, that is, by changing the valence and / or the strength of links.

3.5 Hypotheses

Meaning construction through conceptual interactions is a complex phenomenon. The tentative framework proposed suggests many possibilities for theoretical predictions that are worth exploring. However, in this section, I will not present a full list of all possible predictions that the framework could entertain; instead, I will provide some suggestions on the kind of hypotheses that could be formulated based on this framework.

For example, the central claim of the framework is conceptual interactions, where two component concepts are first interpreted as either head or modifier (H4), and then associative concepts are activated contingently (H1) and prototypically (H2) to form a cognitive field for balancing (H3). Moreover, novel combinations have their own characteristics that are different from everyday / mundane combinations, thus worth some further exploration (H5).

Some of these hypotheses are quite interactive. For example, the theory predicts that the process of association activation is a process demonstrating multiple properties such as goal-directed, contingent, prototypical and cognitive efficiency that jointly contribute to the activation. Based on this observation, even though I treat each of these properties as an independent factor when proposing hypotheses, I will examine their interactive effects at the end of hypotheses testing.

It is proposed in the framework that conceptual interaction starts from association activation of the two component concepts. Association activation refers to the mental processing that each component concept brings in its own set of associations selectively in order to form a closed cycle between the head and modifier. In this process, we assumed that "slots" of a concept (associations) are not necessarily inherent with the concept but are mutually selected by the two component concepts. As I explained in the contingent property of association activation, the probability of one concept's association being activated depends on the other concept's activated associations. For example, when constructing the meaning of the combination *chocolate church*, *chocolate* and *church* each brings in its own set of associations in relation to the other concept present. The concept *chocolate* will activate only a small subset of all possible associations that it might entertain because of the existence of the pairing concept *church*. A different subset of associations would be activated if *chocolate* were paired with the concept *cake* in the combination *chocolate cake*. Similarly, because of the presence of the concept *chocolate*, *church* will activate certain associations that are different from, say, those that would be activated when *church* is paired with *Baptist* in the combination *Baptist church*. Based on this theorizing, it could be hypothesized:

- H1: Other things being equal, associations of one component concept are activated contingently upon the existence of the other component concept.
    - Corollary 1-1: Other things being equal, a concept will activate different associations when paired with different concepts.

The theory proposed that the potential associations of a concept are not activated with equal probability, and it predicts that the prototypical associations – associations with stronger strength generally - are more easily to be activated than less prototypical associations, i.e., the activation of associations is usually from high-strength associations to lower strength associations. This certainly does not mean that the one with stronger strength will be the one that could be used to construct the meaning, however, our sense making process for a feasible association that might connect the two component concepts will begin with the strongest associations. Thus, it is predicted that the stronger an association is for each component concept, the more likely it would be activated and used to construct the meaning of the combination (assuming equal degree of balance). Based on this observation, it could be hypothesized:

- H2: Other things being equal, the relative probability of an association activated in combination increases with the relative probability of the association activated in component concepts.

As discussed in the framework, balance indicates how strongly an association could link the two component concepts in a closed cycle. Mathematically, in a triangle Δa-b-c, Balance (B) = $(V_{ab}*S_{ab})*(V_{ac}*S_{ac})*(V_{bc}*S_{bc})$ where we assume point B is the association of one component of the combination AC. Thus, it is clear that balance indicates the degree of the strength that an association (in this example, B) activated by one component concept (in this example, C) could be linked to the other component concept (in this example, A). If an association is comparatively easier to form a linkage between the two component concepts (i.e., S_{ab} and S_{bc} are comparatively larger), the balance score calculated by the above equation will be larger. Based on this analysis, it is hypothesized:

- H3: Other things being equal, the likelihood of an association of one of the component concepts being activated in the combination increases with the degree of balance of the triplet consisting of the 2 component concepts and the association.

In a two-word combination, the role each word plays is different. Murphy defines: "a final bit of terminology is that the first word (in a two-word combination) is called the modifier, and the final word, the head noun (because it is the head of the noun phrase in syntactic terms)" (Murphy, 2002 p.444). This syntactic distinction leads to what I called grammatical head and grammatical modifier. As assumed in the framework, there is a difference between grammatical head / modifier and psychological head / modifier. Psychologically, when people construct the meaning of the phrase, the more central concept in the construction is usually treated as the head concept, and the concept that changes some aspects of the head is usually treated as the modifier concept. Here "more central concept" is not defined in terms of syntactic relations, but refers to the fact that more of psychological head's associations will contribute to the meaning of the combination, while one or two of psychological modifiers' associations will be incorporated in the combination. Based on this distinction on the syntactic or psychological role, it is interesting to explore how closely grammatical head and modifier correspond to psychological head and modifier.

- H4: Other things being equal, more associations originated from the second concept (grammatical head) will contribute to the meaning of the combination than associations originated from the first concept (grammatical modifier) in the combination.

It could be expected, that in cases where H4 holds true, it will provide a useful link between psychological head / modifier and grammatical head / modifier and may provide a useful operational definition for head and modifier in conceptual combination literature. Further, it could be predicted that if a concept is put into different syntactic positions in different combinations, this concept will contribute more when it functions as head than when it is functions as a modifier, as hypothesized:

- Corollary 4-1: Other things being equal, a concept will contribute more to the meaning of a combination when it functions as a grammatical head than when it functions as a grammatical modifier.

It is observed that everyday / mundane conceptual combinations are quite different from the novel combinations in terms of the probability of one component concept being present in the cognitive field of the other component concept (i.e., whether or not the two component concepts are part of the prototypical knowledge for each other). If novel combination implies that the prototypical associations of the component concepts are not in the cognitive field for each other and thus could not be easily used to construct the closed cycle for meaning construction, then, to construct the meaning for novel combinations will require the activation of less prototypical associations. It will require more effort to search for potentially useful associations to construct the meaning for novel combinations.

- H5: The meaning of a novel combination is more likely to incorporate low strength associations from its components than everyday / mundane combinations.

The current hypotheses focus on the major factors that will influence the conceptual interactions in meaning construction, such as contingency property, prototypicality property, balance property, head/modifier effects, and novelty effects. Clearly, this is only a small subset of the possible hypotheses that this framework could entertain. Because of the scope of this research, I will only focus on testing of these proposed hypotheses in the next chapter, although there are lots of other factors whose effects could be predicted and tested.

Chapter 4 Method

When designing experiments to test hypotheses, it is important to note that an individual's mental representation of meaning is only accessible to others via some kind of symbolic system, such as verbal descriptions using language; and what is expressed verbally is an idiosyncratic version of the meaning particular to that individual at that time in that location. Two issues arise when we verbally express what we mean: one is that not all aspects of the mental representation of meaning are expressible verbally, and what is expressed may not necessarily correspond to the form of the mental representation; the other is how to represent the consensus meaning across population through an aggregation of the individual's verbal descriptions.

I do not have any method to address the first issue except for a tentative trial in which participants were asked to draw a picture of what a concept means to them while verbally describing these things. This tentative trial was based on the assumption that some mental representations take the form of mental image on top of verbal descriptions. However, this trial was not successful because different people have different abilities to draw mental images and the analysis of drawing is too subjective. As for the second issue, I propose to use an aggregated verbal description across a population of participants to identify the relatively stable consensus meaning of concepts. This proposal is based on the observation that although in communications, idiosyncratic characteristics of the individual and contextual information influence the specific understanding of the meaning of concepts, the meaning of concepts largely depends on the consensus of a social group. The dictionary definitions of concepts are examples of such a consensus meaning. Thus, it is possible for me to empirically abstract the consensus meaning of a language element or a concept from a population.

4.1 Pilot experiment

A pilot experiment was conducted in the course of developing the experimental methods. The participants were 125 undergraduate students at University of Waterloo, who received a bonus mark added to their final exam mark for participating.

The pilot experiments were designed to examine the following issues: 1. could we induce associations from individuals' verbalizations of their understanding of concepts and combinations? 2. Could we induce an aggregated verbal description across participants to identify the relatively stable consensus meaning of concepts? 3. Could we find a way of measuring the strength of associations? 4. Is it feasible to analyze this type of data objectively?

The choice of stimulus concepts was based on our intuitive feeling of mundane conceptual combinations and more novel combinations. We chose 2 very common nouns "furniture" and "bird" that have been used extensively in the concepts and categorization literature. We then chose 4 adjectives to modify these two concepts. Two of these adjectives were common modifiers for one of the nouns: "fast" for "bird" and "comfortable" for "furniture". The third adjective was a common modifier for both nouns: "small" for "small bird" or "small furniture". The last adjective was more novel modifier for both nouns: "difficult" for "difficult bird" or "difficult furniture". In experimental conditions, these 2 nouns and 4 adjectives were mix-matched to generate 10 conceptual combinations: *fast bird*, *fast furniture*, *comfortable bird*, *comfortable furniture*, *small bird*, *small furniture*, *difficult bird*, *difficult furniture*, *furniture bird*, and *bird furniture*. Thus, in total, there were 6 concepts and 10 conceptual combinations. In the pilot experiment, 125 participants were randomly assigned to 5 groups. Group #1 – #4 each was assigned the 2 noun concepts (*furniture*, *bird*), 1 adjective concept, and 2 of the 10 combinations. Group #5 was assigned the 2 noun concepts and 2 of the 10 combinations.

Each group of students was asked to do two kinds of tasks: 1. to give as many examples of the listed concepts as they can think of (up to 15 examples) and to write these examples in the order that they think of them; 2. to define / explain / describe the meaning of the concept or combination in their own words. For example, one of the groups was given the following tasks (Table 4-1):

Table 4-1: Tasks in the pilot experiments

Task 1 Please give as many examples of the following concept as you can think of. Write these examples in the order that you think of them. ***"Furniture"*** Please define / explain / describe what "Furniture" means in your own words:
Task 2 Please give as many examples of the following concept as you can think of. Write these examples in the order that you think of them. ***"Bird"*** Please define / explain / describe what "Bird" means in your own words:
Task 3 Please give as many examples of the following concept as you can think of. Write these examples in the order that you think of them. ***"Small Bird"*** Please define / explain / describe what "Small Bird" means in your own words:
Task 4 Please give as many examples of the following concept as you can think of. Write these examples in the order that you think of them. ***"Fast Furniture"*** Please define / explain / describe what "Fast Furniture" means in your own words**:**

A tentative analysis was conducted using data collected about *bird*. Definitions / descriptions of *bird* by 125 participants were analyzed by breaking the verbal descriptions into simplest ideas. For example, the description "animal with wings and feathers that nests and lay eggs" was broken into *animal*, *wings*, *feathers*, *nests*, and *lay eggs*. Each of these ideas was treated as one association of the concept *bird*. By counting how many of these ideas were listed by participants, I got a rough description of the general understanding on the meaning of *bird*. Examples of birds listed by the 125 participants were aggregated as well. Partial results were given in Figure 3-1 and Figure 3-2. The strength of these simplest ideas (association / example) was calculated as the percentage of the number of a particular association / example mentioned over the total number of associations / examples mentioned by participants.

Other data were closely observed, although there was no formal analysis on these data. However, by looking through these results, a few conclusions were drawn:

1. People are able to define, describe or explain their mental representation of meaning using language.

2. Associations that were activated by concepts could be abstracted from participants' verbal descriptions.

3. By analyzing all of the descriptions for the same concept, it was possible to identify associations that were common across participants, reflecting consensus across the population.

4. The relative frequency of associations could be calculated to indicate the strength of the association.

Based on these conclusions, the following experiments were designed to test hypotheses derived from the proposed conceptual framework.

4.2 Experiments

Two experiments were designed and conducted at University of Waterloo from September, 2005 to December, 2006. Experiment One was designed to identify associations for conceptual entities (i.e., single word concepts and two-word conceptual combinations) and to obtain familiarity / novelty scores for the conceptual combinations. Experiment Two was designed to evaluate the associations identified in Experiment One under various manipulations and experimental conditions.

4.2.1 Experiment One: Identify Associations

The design of the experiment 1 started from selecting the experiment stimulus set.

4.2.1.1 Stimulus

The North American Industry Classification System, NAICS, 2002 US, a newly designed industry classification system that replaced the U.S. Standard Industrial Classification (SIC) system, was used to select the stimulus for experiment one. NAICS was developed jointly by U.S., Canada, and Mexico to provide new comparability in statistics about business activity across North America. The 2002 manual includes definitions for each industry, tables showing correspondence between the 2002 NAICS and 1997 versions of NAICS for codes that changed, and a comprehensive index. We focus on the NAICS codes and titles (http://www.census.gov/epcd/naics02/naicod02.htm) as the raw materials from which our experiment stimulus set was drawn.

The coding system of NAICS is designed as a six-digit categorization system where each subsequent digit further specifies a subcategory of a higher level digit. Specifically, the first two digits designate the economic sector, the third digit designates the sub sector, the fourth digit designates the industry category, the fifth digit designates the NAICS industry, and the sixth digit designates the national industry. For example, the following hierarchical categorization is used to describe the information industry and one of its sub-industries.

51	Information
512	Motion Picture and Sound Recording Industries
5121	Motion Picture and Video Industries
51213	Motion Picture and Video Exhibition
512132	Drive-In Motion Picture Theatres

NAICS classifies business activities into 20 economic sectors. In order to accommodate the scale of my experiments, I focused on the manufacturing sector. The manufacturing sector has 765 industrial categories and subcategories, among which there are 591 noun concepts. Our selection of the experiment stimulus started from these 591 noun concepts. Because of the large number of possible concepts, we used a series of criteria to filter through these noun concepts. For example, the criteria included selecting concepts that refer to a product (e.g. chocolate) rather than a raw material (e.g. cacao beans); selecting concepts that are not polysemous (e.g. dressing could refer to either "seasoning" or "clothing", thus not selected); selecting single concepts that are meaningful as the industry category (e.g. cigarette is selected but sugar cane is not) etc. After this round of filtering, 280 concepts were selected (Appendix 1) representing specific manufactured products.

A second round of selection was done by ranking these 280 concepts based on familiarity. Five graduate students and one faculty member of the department were asked to rank the familiarity of these concepts as industry products. The survey was worded as follows:

"We are interested in how familiar you are with the following types of products. For example, most of us are very familiar with "books" and "computers", but very unfamiliar with "die-cast" or "forged metal products". Please rate the following products from 1 to 5 based on your familiarity with these products. (1 means extremely unfamiliar and 5 means extremely familiar)".

The survey was conducted to collect both rankings and verbal comments from participants on these concepts. The average rankings were calculated. Out of 280 concepts, 55 concepts were selected (Appendix 2) based on their familiarity ranking (higher than 3.5) and participants' verbal comments such as connotations (underwear was not selected) and ambiguous meanings (can, oven, sign, etc were not selected). These 55 concepts were mapped back into the NAICS categorization scheme for the final selection.

The final selection was based on the consideration of the size of the subject pool, the experimental task, the workload per participant, and the characteristics of the individual concepts and their combinations. Especially, concepts were randomly chosen to be organized into different concept sets that were composed of concepts from different industry categories (the 4th digit in NAICS) to create within-industry or between-industry combinations. Based on this consideration, 5 sets of the experimental concepts were selected. Among these 5 sets, 4 concept sets were composed of 2 concepts from the same industry category and 1 concept from a different industry category; and 1 concept set was composed of 3 concepts from the same industry category.

In the process of selection, two groups of concepts in 2 industry categories drew our attention. The concepts are *Air-Conditioner, Fan, Heater* (in 3334 Ventilation, Heating, Air-Conditioning, and Commercial Refrigeration Equipment Manufacturing) and *Refrigerator, Freezer, Furnace* (in 3352 Household Appliance Manufacturing). These concepts denote conflicting yet strongly correlated characteristics. We chose 4 concepts from these two industry categories: {*Air-Conditioner, Heater, Refrigerator, Furnace*} as one group of the experimental stimuli. Thus, the full set of experimental stimuli was composed of 6 groups (Table 4-2).

Table 4-2: The full set of experimental stimuli

Concept sets	Conceptual Units (NAICS Industry Codes)		Conceptual Combinations	*Number of conceptual entities*
#1	Hat, Mitten (3159)	Butter (3115)	Hat Mitten, Hat Butter, Mitten Butter,Mitten Hat, Butter Hat, Butter Mitten	*9*
#2	Telephone, Television (3342)	Soap (3256)	Telephone Television, Telephone Soap, Television Soap, Television Telephone, Soap Telephone, Soap Television	*9*
#3	Cereal, Chocolate (3112)	Watch (3345)	Cereal Chocolate, Cereal Watch, Chocolate Watch, Chocolate Cereal, Watch Cereal, Watch Chocolate	*9*
#4	Bread, Cookie, Pasta (3118)		Bread Cookie, Bread Pasta, Cookie Pasta, Cookie Bread, Pasta Bread, Pasta Cookie	*9*
#5	Box, Envelope (3222)	Carpet (3141)	Carpet Box, Carpet Envelope, Box Envelope, Box Carpet, Envelope Carpet, Envelope Box	*9*
#6	Air-	Refrigerator,	Furnace Air-conditioner, Furnace	*16*

	conditioner, Heater (3334)	Furnace (3352)	Heater, Furnace Refrigerator, Air-conditioner Heater, Air-conditioner Refrigerator, Heater Refrigerator, Air-conditioner Furnace, Heater Furnace, Refrigerator Furnace, Heater Air-conditioner, Refrigerator Air-conditioner, Refrigerator Heater	

4.2.1.2 Procedure

Experiment One was designed to identify associations of conceptual entities (single concepts and conceptual combinations) and to obtain familiarity / novelty rankings for combinations. In this experiment, participants were asked to do two tasks. In the first task, participants were presented with one of the conceptual entities from the experiment stimuli and asked 3 questions:

1. What are the first things that come to your mind when you think of this product?

2. Please define / describe / explain this product in your own words:

3. What are some of the characteristics or attributes of this product and how might this product be used?

By asking participants to describe their initial impressions about the real or hypothetical products denoted by the given conceptual entity, to define this product, and to explain its characteristics & functionality, these questions were designed to identify as many associations as possible relevant to participants. In the second task, participants were asked to rate how familiar the product denoted by the conceptual combination was to them or how easy it was to imagine such a product (presumably novel concepts are harder to imagine that everyday concepts), using a scale from 1 (least familiar or most difficult to imagine) to 5 (most familiar or easiest to imagine).

140 undergraduate students registered in one Management Sciences course in the Fall 2005 were recruited to participate in this experiment for a bonus mark. Students who

declined to participate in this experiment were given an opportunity to complete an alternative assignment with comparable workload to earn the same bonus mark.

Participants were divided into 7 groups. Each group was assigned a different experimental stimulus. The 7 stimuli were designed such that there would be minimum repetitions of the same concepts (as a single concept or as a part of a conceptual combination) within a given stimulus. The division of the stimuli into student groups (S.G.) for the first task is presented in Appendix 3. The division of the stimuli into student groups for task 2: familiarity / novelty ranking is presented in Appendix 4.

Since 140 participants were divided into 7 groups, there were 20 participants per student group. To avoid potential bias associated with the sequence effects within a given stimulus, 4 versions of the experimental stimulus assigned to each student group were created, which varied the order of conceptual entities presented to the participants. Thus, a total of 28 different stimuli were used in this experiment.

The experiment was conducted through UW-ACE, a tailored version of the ANGEL web-based course management and collaboration portal used at University of Waterloo. ANGEL's build-in survey function was used to design and conduct the experiment.

The experiment started from a web page describing the experiment tasks, followed by a consent form where students could choose "Continue" or exit for an alternative assignment of equal bonus mark. If students chose "Continue", they were presented a series of tasks in 30 to 33 web pages designed to be finished in about 30 to 40 minutes. A sample of the experiment webpages for one version is presented in Appendix 5.

4.2.1.3 Results

Out of 140 students, 120 chose to participate in the experiment (Table 4-3). The quality of responses was quite good and participants provided detailed descriptions for each of the three questions related to each conceptual entity.

Table 4-3: The distribution of the number of participants participating in each group

Student Group #	Number of students participated
1	17
2	18
3	13
4	18
5	18
6	18
7	18
Total	120

The results acquired from experiment one were analyzed. Two analyses were conducted: one identified associations of conceptual entities; the other calculated the familiarity / novelty rankings of the conceptual combinations.

The first analysis started by aggregating all the responses in relation to each conceptual entity. For example, 17 participants provided 51 descriptions regarding *butter* (Appendix 6). Each of these 51 verbal descriptions was treated as one unique description of a particular understanding of *butter*. A detailed text (content) analysis was conducted to identify the most prominent associations mentioned among these verbal descriptions. Prominent associations refer to the associations that were mentioned most commonly by participants. In this analysis, each description was broken into simplest ideas which were treated as the associations of the conceptual entity. For example, one of the descriptions of *butter* was "its soft and usually yellow. it tastes better with butter. its oily and makes u fat!" (given by the participant coded as g1v1-1). This description was broken into the following 5 simplest ideas: *soft*, *usually yellow*, *tastes better with butter*, *oily*, and *makes u (you) fat*. After all 51 descriptions were analyzed this way, the 10 most prominent associations for *butter* were identified. The analysis was conducted for all 61 conceptual entities and 10 most prominent associations for each conceptual entity were identified. These associations are stated in predicate forms, using typical wording used by participants, but "cleaned up" to be grammatically correct for use in Experiment Two. A sample of the most prominent associations is given in Table 4-4, and a full list is in Appendix 7.

Table 4-4: The most prominent associations for conceptual entities *hat*, *butter*, *hat butter*, and *butter hat*

Concept	**Most Prominent Associations**	**Association #**
Hat	It is worn on the head	1
	It protects the head	2
	It is used in different environmental conditions (sun, rain, cold)	3
	It adds fashion or style	4
	It is used in baseball	5
	It is made from different materials	6
	It is an article of clothing	7
	It has various shapes	8
	It has different types such as toques	9
	It is mass-manufactured	10
Butter	It is used in cooking, baking and frying	21
	It is spread on toast	22
	It is yellowish beige	23
	It adds flavour to food	24
	It is extracted from milk	25
	It is a type of food	26
	It is fattening	27
	It is greasy and oily	28
	It is soft when warm	29
	It is solid when cold	30
Hat Butter	It is a type of hat	51
	It is a type of butter	52
	It is a lubricant	53
	It is a sculpture	54
	It is worn in cold weather	55
	It is yellow	56
	It is soft	57
	It is used to soften hair	58
	It is not easy to melt	59
	It smells pretty bad	60

Butter Hat	It is a type of hat	61
	It is a type of butter	62
	It cannot be worn	63
	It is made of yellow leather	64
	It prevents insect damage	65
	It is soft	66
	It is used for dispensing	67
	It is warm	68
	It makes dishes more tasty	69
	It is used for decoration	70

The second analysis was to calculate familiarity / novelty rankings of the conceptual combinations. Each combination received 13 – 18 rankings and the average rankings were calculated (Table 4-5). Higher rankings indicate more familiar / less novel combinations.

Table 4-5: Familiarity Ranking acquired after step 1 experiment

Conceptual Combinations	Familiarity Ranking	n
Chocolate Cereal	4.78	18
Telephone Television	4.23	13
Cereal Chocolate	3.94	18
Television Telephone	3.78	18
Air-conditioner Heater	3.78	18
Furnace Heater	3.56	18
Bread Cookie	3.54	13
Heater Furnace	3.50	18
Envelope Box	3.38	13
Pasta Bread	3.28	18
Heater Air-conditioner	3.28	18
Cookie Bread	3.12	17
Furnace Air-conditioner	3.00	18
Bread Pasta	2.83	18
Box Envelope	2.83	18
Mitten Hat	2.78	18
Air-conditioner Furnace	2.67	18
Air-conditioner Refrigerator	2.54	13

Refrigerator Air-conditioner	2.50	18
Soap Television	2.50	18
Cookie Pasta	2.50	18
Carpet Box	2.39	18
Heater Refrigerator	2.39	18
Refrigerator Furnace	2.33	18
Watch Chocolate	2.28	18
Chocolate Watch	2.24	17
Hat Mitten	2.23	13
Box Carpet	2.18	17
Carpet Envelope	2.17	18
Television Soap	2.12	17
Furnace Refrigerator	2.00	18
Refrigerator Heater	1.88	17
Pasta Cookie	1.85	13
Cereal Watch	1.83	18
Envelope Carpet	1.67	18
Butter Mitten	1.67	18
Butter Hat	1.61	18
Watch Cereal	1.56	18
Soap Telephone	1.50	18
Hat Butter	1.28	18
Telephone Soap	1.24	17
Mitten Butter	1.22	18

The results of Experiment One were used as input into the design of Experiment Two.

4.2.2 Experiment Two: Evaluate Associations

In this experiment, associations of conceptual entities identified in Experiment One were used to construct a close-ended questionnaire, which was administrated to another group of UW student participants. The objective of the experiment was to acquire the strength of associations using a standardized quantitative measure.

4.2.2.1 Design

The stimuli used in Experiment Two were developed from the results of Experiment One: 10 associations from each of the 61 conceptual entities for a total of 610 associations. Table 4-6 provides a generic summary of the data obtained in Experiment One, which was used in the design of the questionnaire in Experiment Two. In the table, for a 2-concept pair (C1-C2), each concept (C1 or C2) or conceptual combination (C1C2 or C2C1) are represented by capitalized letters. Ten associations obtained for each of these conceptual entities in Experiment One are represented by capitalized letter A with a subscript of each conceptual unit plus a number from 1 to 10. In total, for a pair of concepts C1 and C2, there are 40 associations, with 10 originating from each conceptual entity C1, C2, C1C2, and C2C1 in Experiment One.

Table 4-6: The basic format of the raw data for Experiment Two

C1	C2	C1C2	C2C1
A_{C1}-1	A_{C2}-1	A_{C1C2}-1	A_{C2C1}-1
A_{C1}-2	A_{C2}-2	A_{C1C2}-2	A_{C2C1}-2
A_{C1}-3	A_{C2}-3	A_{C1C2}-3	A_{C2C1}-3
A_{C1}-4	A_{C2}-4	A_{C1C2}-4	A_{C2C1}-4
A_{C1}-5	A_{C2}-5	A_{C1C2}-5	A_{C2C1}-5
A_{C1}-6	A_{C2}-6	A_{C1C2}-6	A_{C2C1}-6
A_{C1}-7	A_{C2}-7	A_{C1C2}-7	A_{C2C1}-7
A_{C1}-8	A_{C2}-8	A_{C1C2}-8	A_{C2C1}-8
A_{C1}-9	A_{C2}-9	A_{C1C2}-9	A_{C2C1}-9
A_{C1}-10	A_{C2}-10	A_{C1C2}-10	A_{C2C1}-10

Three steps were used to generate the experimental stimuli for Experiment Two. Firstly, these 40 associations were randomly regrouped into 4 new groups containing different associations from each conceptual entity as Table 4-7 exemplifies.

Table 4-7: Randomize the 40 associations and randomly regroup them into 4 new groups

Randomized Association	Randomized Association	Randomized Association	Randomized Association

group #1	group #2	group #3	group #4
A_{C2}-10	A_{C2C1}-1	A_{C2}-9	A_{C1C2}-2
A_{C1}-9	A_{C2C1}-8	A_{C1C2}-5	A_{C2C1}-3
A_{C2}-8	A_{C2C1}-5	A_{C1C2}-7	A_{C1C2}-1
A_{C2}-2	A_{C2C1}-10	A_{C1C2}-9	A_{C2}-4
A_{C2}-5	A_{C1}-8	A_{C1}-2	A_{C1}-4
A_{C1C2}-4	A_{C2}-6	A_{C1C2}-10	A_{C2C1}-9
A_{C1C2}-8	A_{C1}-1	A_{C2C1}-4	A_{C1}-3
A_{C2C1}-2	A_{C1}-7	A_{C1}-5	A_{C2C1}-7
A_{C1}-10	A_{C2C1}-6	A_{C2}-1	A_{C1}-6
A_{C1C2}-6	A_{C2}-3	A_{C1C2}-3	A_{C2}-7

Secondly, each of these 4 randomized association groups were to be evaluated against the original 4 conceptual entities, generating 16 tasks to be assigned to particular experimental participants. (Table 4-8)

Table 4-8: Randomized associations to be evaluated against original conceptual entities

	C1	C2	C1C2	C2C1
Randomized Association group #1	Task 1	Task 2	Task 3	Task 4
Randomized Association group #2	Task 5	Task 6	Task 7	Task 8
Randomized Association group #3	Task 9	Task 10	Task 11	Task 12
Randomized Association group #4	Task 13	Task 14	Task 15	Task 16

Thirdly, these 16 tasks were randomly assigned to one of the 16 participant groups (participants in Experiment Two were divided into 16 groups). This is the generic design for a 2-concept pair.

In the full stimuli set there were 5 concept sets composed of 3 concepts (C1, C2, C3) and 1 set composed of 4 concepts (C1, C2, C3, C4) (Table 4-2). For each 3-concept set, there are 3 two-concept pairs (C1-C2, C1-C3, C2-C3). For the 4 concept set, there are 6 two-concept pairs (C1-C2, C1-C3, C1-C4, C2-C3, C2-C4, C3-C4). Thus in total, there were 5*3+6=21 two-concept pairs in the stimuli. For each two-concept pair, the 3 design steps demonstrated above were applied. After this design stage, each of the 16 participant groups had 19 tasks. Each of these tasks consisted of 8 – 12 rating decisions (a particular association evaluated against a conceptual entity) as discussed below.

It should be noted that in the process of generating Randomized Association Groups, there were quite a few identical associations within each 2-concept pair (Appendix 8). For example, in the 2-concept pair *Hat-Mitten*, associations #12, #34 and #44 all refer to "used in cold winter weather" which are regarded as identical. These identical associations were used in the experiment only once to avoid repetition. For example, in the experiment, participants evaluated "used in cold winter weather" once. Because of these identical associations within each 2-concept pair, the total number of Randomized Association groups generated for each 2-concept pair varied. For example, the concept pair *Hat- Mitten* generated 3 Randomized Association groups, while the concept pair *Hat-Butter* generated 4 Randomized Association groups. For the same reason, the number of associations within each Randomized Association group varied from 8 to 12, thus there were 8 – 12 particular associations evaluated against a conceptual entity within each task. After processing identical associations, there were 2585 unique association-conceptual entity pairs for participants to evaluate.

4.2.2.2 Procedure

Experiment Two was conducted in 2006. The experiment was designed for 320 participants, consisting of 16 groups of 20 students each. Therefore, each evaluation of a specific association-conceptual entity pair would be judged by 20 participants. 284 undergraduate students were recruited from Management Sciences courses in the Winter 2006 term. These students earned one percent bonus grade for participation. From September 2006 to December 2006, 35 graduate students registered in a Management Sciences graduate course were recruited to participate in this experiment, and also received one percent bonus grade in this course. Among these 35 graduate students, 14 indicated that they had language difficulties understanding the content of the questionnaire, so their responses were dropped from the results. Finally, 15 additional graduate students who were native English speakers were recruited to participate in this experiment as volunteers. Thus, by December 2006, the total number of participants reached 320 (284 + 35 – 14 + 15 = 320).

320 participants were randomly assigned to 16 student groups of 20 participants each. Each student group was randomly divided into 2 subgroups of 10 students each. Each subgroup performed a different version of the questionnaire for a given experimental condition. The different versions varied the randomized sequence of evaluation tasks performed by participants. The questionnaires were printed on paper and distributed to participants as 20 stapled pages. The questionnaire began with a description of the task and a consent form (Appendix 9).

Figure 4-1 A sample questionnaire page from the Experiment Two

Page 1 of 19

Imagine you were asked to define / explain / describe the following product:

Carpet

On the scale from "definitely no" to "definitely yes", please indicate how likely is it that you would mention the following ideas?

	Definitely no			Not sure			Definitely yes
It is made of paper							
It has a sealable flap							
It is used to mail things							
It is large in shape							
It is cheap							
It is a plastic wrap to protect something							
It is made of thick fabrics							
It is small in size							
It is folded on the floor							

Do you have any comments regarding this task?

Following this page was the 19-page questionnaire with each page dedicated to one experimental task. For each page, participants were asked to think about how to define / explain / describe a certain product, such as *carpet*. Then they were asked to indicate on a 7-point scale from "definitely no" to "definitely yes", how likely they were to mention the following associations as part of their definition / explanation / description. After these judgments, they were given an opportunity to provide any comments regarding this task. A sample of such a page is provided in Figure 4-1.

For the 35 Management Sciences graduate students, we were warned by the course instructor that some students had language difficulties for various reasons. Thus, for that group of participants, an additional page was added to the end of the questionnaire which asked the following question: “If this is your first time living in an English speaking country, did you have any difficulties completing this questionnaire?” Students could circle “Yes”, “No” or “Not Applicable”. 14 students indicated that they had difficulties understanding the contents of the questionnaire, thus their responses were discarded.

4.2.2.3 Results

The participants’ evaluations were firstly assigned to numeric ratings from 1 to 7, where “definitely no” was assigned as 1, “not sure” was assigned as 4, and “definitely yes” was assigned as 7. And then the ratings were inputted to Microsoft Excel spreadsheets and later imported to SPSS for hypothesis testing.

From the Experiment Two, I obtained 58,418 unique ratings from participants. On average, each participant made 182.56 ratings[14]. Each individual rating was coded in terms of 9 variables in SPSS as described in Table 4-9.

Table 4-9: The meaning of the 9 variables in SPSS

Variable Name	Variable Meaning	Values
IndustryType	Denotes the different types of organizing principles of the concept sets.	Type 1: A 3-concept set where 2 concepts come from the same industry category and the 3rd concept comes from a different industry category. Type 2: A 3-concept set where all 3 concepts come from the same industry category. Type 3: A 4-concept set where 2 concepts come from one industry category, and the other 2 concepts come from a different industry category.
Set	Concept set	Set 1: Hat, Mitten, Butter Set 2: Telephone, Television, Soap Set 3: Cereal, Chocolate, Watch Set 4: Bread, Cookie, Pasta Set 5: Carpet, Box, Envelope Set 6: Air-conditioner, Heater, Refrigerator,

[14] Some associations were left unrated by some participants.

		Furnace
OriginalSource	Denotes the source concept from which associations were originally obtained in Experiment One	For example, association # 1 to #10 were originally obtained from *hat* in Experiment One.
FamiliarityIndex	The familiarity score obtained in Experiment One	Examples see Table 4-5.
Association	The verbal description of the each association	For example: "It is worn on the head"
Association#	A unique number assigned to each association	From #1 to #610
EvaluatedAgainst	The concept against which the association was evaluated	For example: association #1 "It is worn on the head" was evaluated against *Hat*, *Mitten*, *Butter*, *Hat Mitten, Mitten Hat*, *Hat Butter*, or *Butter Hat* respectively
StudentID	A unique number assigned to each participant	A unique identifier was assigned to each participant.
Rating	The specific rating given by a participant for a particular association – conceptual entity pair	1 – 7

The distribution of the ratings could be summarized in many different ways. For example, a new variable was calculated: "value_mean" representing the mean value of the participants' ratings for each association evaluated against a conceptual entity. A histogram of the distribution of value_mean is provided in Figure 4-2. Here, n means the number of the unique association – conceptual entity pairs that participants evaluated. In order to understand the codes that were assigned to the data which will be used in the hypothesis testing, Table 4-11 provides a reference.

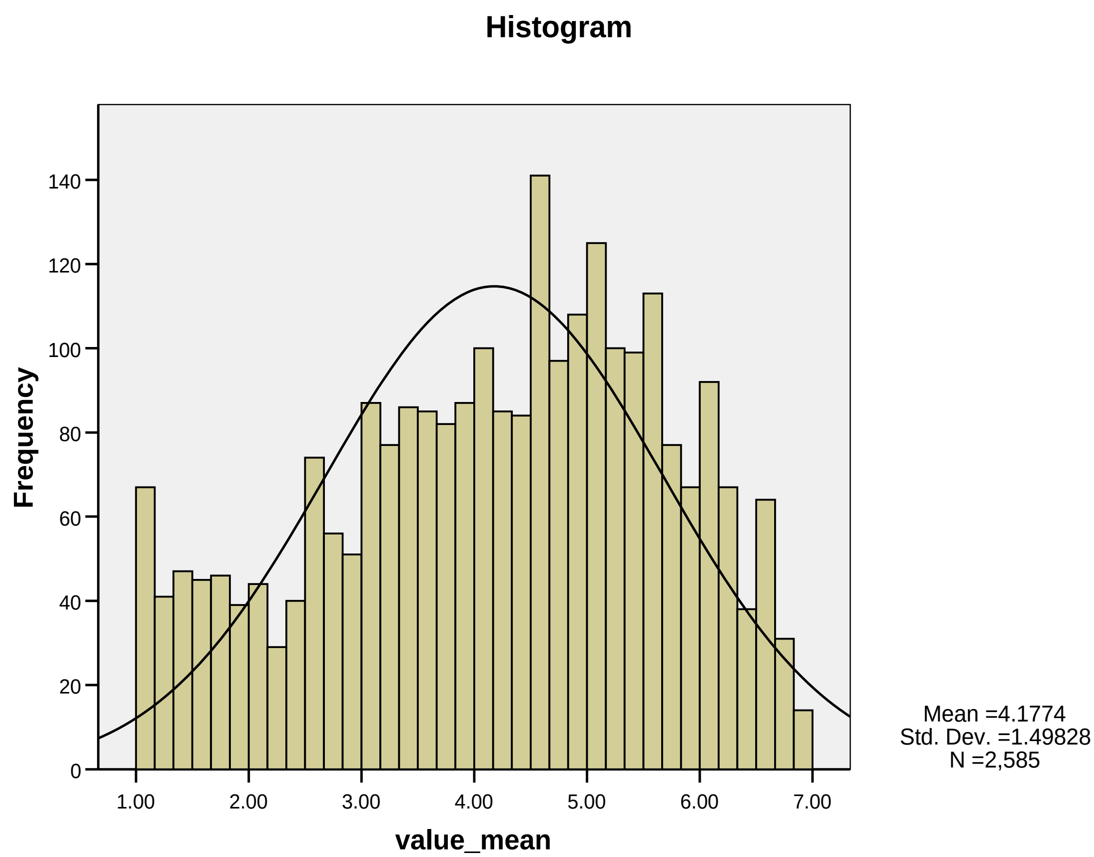

Figure 4-2: Histogram of the distribution of value_mean

Table 4-10: Summary statistics for value_mean

	value_mean
N	2585
Minimum	1.00
Maximum	7.00
Mean	4.1774
Std. Deviation	1.49826

Table 4-11: The codes assigned to the data for hypothesis testing

Concept sets	Conceptual Entities (Codes used in thesis)	
	Component Concept	Conceptual Combinations
Set 1	Hat (C1) Mitten (C2) Butter (C3)	Hat Mitten (C1C2) Hat Butter (C1C3) Mitten Butter (C2C3) Mitten Hat (C2C1) Butter Hat (C3C1) Butter Mitten (C3C2)
Set 2	Telephone (C1) Television (C2) Soap (C3)	Telephone Television (C1C2) Telephone Soap (C1C3 Television Soap (C2C3) Television Telephone (C2C1) Soap Telephone (C3C1) Soap Television (C3C2)
Set 3	Cereal (C1) Chocolate (C2) Watch (C3)	Cereal Chocolate (C1C2) Cereal Watch (C1C3) Chocolate Watch (C2C3) Chocolate Cereal (C2C1) Watch Cereal (C3C1) Watch Chocolate (C3C2)
Set 4	Bread (C1) Cookie (C2) Pasta (C3)	Bread Cookie (C1C2) Bread Pasta (C1C3) Cookie Pasta (C2C3) Cookie Bread (C2C1) Pasta Bread (C3C1) Pasta Cookie (C3C2)
Set 5	Carpet (C1) Box (C2) Envelope (C3)	Carpet Box (C1C2) Carpet Envelope (C1C3) Box Envelope (C2C3) Box Carpet (C2C1) Envelope Carpet (C3C1) Envelope Box (C3C2)
Set 6	Air-conditioner (C1) Heater (C2) Refrigerator (C3) Furnace (C4)	Air-conditioner Heater (C1C2) Air-conditioner Refrigerator (C1C3) Air-conditioner Furnace (C1C4) Heater Refrigerator (C2C3) Heater Furnace (C2C4) Refrigerator Furnace (C3C4) Heater Air-conditioner (C2C1) Refrigerator Air-conditioner (C3C1) Refrigerator Heater (C3C2) Furnace Air-conditioner (C4C1) Furnace Heater (C4C2) Furnace Refrigerator (C4C3)

Chapter 5 Hypothesis Testing

This chapter focuses on the hypothesis testing and discussion of test results.

5.1 Testing Hypothesis 1

Hypothesis 1 predicts that associations of one component concept are activated contingently upon the existence of the other component concept. The corollary derived from this hypothesis predicts that a concept will activate different associations when paired with different concepts. For example, hypothesis 1 predicts that the concept C1 will activate different associations when C1 is used in the following combinations:

C1C2 vs. C1C3 (C1 functions as a modifier, paired with different head concepts)

C2C1 vs. C3C1 (C1 functions as a head, paired with different modifier concepts)

In the study, activating different associations corresponds to the idea that associations originating from C1 will have different activation strengths when C1 is paired with different concepts. For example, “It is worn on the head” is an association originating from Hat in Experiment One. When Hat is paired with Mitten or Butter, hypothesis 1 predicts different activation strengths for this association in Hat Mitten vs. Hat Butter (also different in Mitten Hat vs. Butter Hat). Here, the null hypothesis is that associations activated by a concept are no different in strength when the concept is paired with different concepts.

5.1.1 Test Statistic

A series of independent samples T tests were used to test this hypothesis. For example, there are 10 associations originated from a given concept C1 identified in Experiment One. For each of these 10 associations, the mean rating of the association against C1C2 was compared to its mean rating against C1C3. Similarly, its mean rating against C2C1 was compared to its mean rating against C3C1. Concept sets #1 - #5 consisted of 3 individual concepts each, so there were 60 t tests per concept set, and a total of 300 t tests for all 5 concept sets. Concept set #6 consisted of 4 individual concepts, so considering all possible combinations, there were 240 t tests for concept set #6. In total, for the whole data set, 300+240=540 t tests were performed and the results are provided in Appendix 10. Of the 540 t values, there were 262 cases where $p \leq 0.05$ which support H1 (rejecting H0). In a random condition, it is expected there will be 5% of cases that t test will be significant (95% confidence level) by chance. The percentage of t value that support H1 is 262/540=48.5%, which is significantly higher than chance.

To generalize from the individual t-test results to the full data set, a chi-square test was performed to test whether the acquired distribution of t-values was significantly different from chance. If we assume conservatively that $p<0.05$ would result 50% of the time, the chi-square test does not provide support for the hypothesis ($\chi^2=0.474$; $p=0.491$; df=1; n=540). If we assume 40% as the sufficient support threshold, the chi-square test supports the hypothesis ($\chi^2=16.327$; $p<0.001$; df=1; n=540). This analysis suggests that H1 is accepted based on the judgment on what is the appropriate level of criteria of the support by chance.

5.1.2 Analysis of the test result

In a sense, the degree of the support of this hypothesis is a matter of judgment. A few reasons could be postulated. First, the 7-point scale has a constraint on the variance of the ratings the experiment could get. From the summary statistics of the Experiment Two data, the mean of all ratings is 4.1774 which implies that participants' ratings can only vary from the mean by about +/- 3. For data that is roughly normally distributed, we expect that about 68.3% of the data will be within 1 standard deviation of the mean (i.e., in the range Xavg ± s.d.) and about 95% of the data will be within 1.96 standard deviation of the mean (95% confidence interval for the sample). Thus, there is a limit on how far 95% of the ratings can different from each other, which would lead to the fact that a lot of t tests would not be significant because of this upper / lower boundary of the scale.

Secondly, there might be some interactive effects between hypotheses. For example, there are conceptual influences between the contingency property that H1 predicts and the prototypicality property that H2 predicts. The contingency property predicts that the strengths of associations of C1 will be different when evaluated against C1C2 or C1C3. The prototypicality property predicates that the relative probability of an association activated in combination increases with the relative probability of the association activated in component concepts. Thus, if an association is a strong association for C1, then in any combination involving C1 as one component concept, this association will be relatively stronger. Thus, on the one hand, H1 predicts that C1 will activate different associations when paired with C2 or C3; on the other hand, H2 predicts that C1 will activate similar associations in any combination. This potential contradiction reflects the essential property of the cognitive system in meaning construction. Meaning construction is to create an integrated system that is based on the knowledge of two concepts, thus, stronger associations of component concepts will have more impact on the combination relative to weaker ones (H2). On the other hand, the pairing concept will have some impact on the combination as well, leading to some differences on the association activation of both component concepts (H1). Thus, it is understandable that there is an interaction effect between H1 and H2, leading to the weak support for both H1and H2.

Another possible interactive effect is between contingency property (H1) and the different types of combinations. When designing the experiment stimulus, concept sets are composed of individual concepts from different industry categories (the 4th digit in NAICS), thus creating within-industry or between-industry combinations. For example, concept set #4 was composed of 3 concepts (Bread, Cookie, Pasta) that were drawn from the same industry category, thus generating 6 within-industry combinations; while concept set #1 (Hat, Mitten, Butter) was composed of 2 concepts from the same industry category and 1 from a different industry category, thus generating 2 within-industry combinations and 4 between-industry combinations. When evaluating associations against within-industry combinations, it might be more difficult to differentiate their relative strength. For example, association #294 "It is made from flour and water" is originated from Pasta.

When participants evaluated this association against Bread Pasta or Cookie Pasta, they gave almost identical ratings. Thus, most of the t-test results for within-industry combinations were quite insignificant.

The preceeding analysis indicates the importance of interaction effects between different variables in the conceptual interaction process, which will be tested later.

5.2 Testing Hypothesis 2

Hypothesis 2 predicts that the relative probability of an association activated in combination increases with the relative probability of the association activated in component concepts. This hypothesis is a correlational prediction about the relation between the strength of the associations in components and in combination. For example, based on the prediction, if "it is worn on the head" is a stronger association than other associations originated from Hat, then, it will be a relatively stronger association in Hat Mitten, Hat Butter, Mitten Hat, and Butter Hat. The null hypothesis is that the strength of the component associations do not covary with the strength of the associations evaluated against combination.

5.2.1 Test Statistic

Pearson's Correlation Coefficient (r) was used to test this hypothesis. The generic design of this test is structured as follows: for any two-concept pairing such as C1-C2, up to 40 associations were evaluated. Each association was evaluated by 20 participants against C1, C2, C1C2 and C2C1 respectively. A mean rating was calculated across 20 participants for every association, based on which Pearson correlation coefficients were calculated between the mean ratings of C1 and C1C2, as well as between C1 and C2C1, between C2 and C1C2, between C2 and C2C1. For concept sets with 3 component concepts (sets #1 to #5), 12 Pearson correlation coefficients were required for each set, thus a total of 60 Pearson's r were computed. For concept set #6 with 4 component concepts, 24 Pearson correlation coefficients were required. Thus in total, 84 correlation were computed. The results are given in Appendix 11.

Out of 84 Pearson correlation coefficients, there were 48 results with $p \leq 0.05$ and 52 results with $p \leq 0.10$. Using the same thinking as hypothesis One, in a random condition, it is expected there will be 5% of cases that Pearson's coefficient r will be significantly supporting H2 by chance based on 95% confidence level. The percentages of Pearson's coefficients (r values) that support H2 in the results are 57% at 95% confidence level and 62% at 90% confidence level, which are significantly higher than chance. Chi-square tests were conducted on these correlation results. Assuming 40% chance of obtaining a significant correlation (for correlations significant at the 0.05 level) between the strength of an association in the component and the strength of the same association in a combination, $\chi 2=10.286$ (p=0.001; df=1; n=84). Even assuming 50% chance of obtaining a significant correlation, for correlations significant at the 0.10 level, $\chi^2=4.762$ (p=0.029; df=1; n=84). The chi-square results further confirmed that the distribution of Pearson's correlation coefficients is significantly different from chance at the 0.05 level (assuming 40% chance) and at the 0.1 level of significance (assuming 50% of chance). Thus, we are at least 95% confident that the strength of the component associations covaries with the strength of the associations evaluated against combination for correlations significant at the 90% confidence level.

5.2.2 Analysis of the test result

Observation of the distribution of Pearson's correlation coefficients in Appendix 11 suggests that when a concept functions as the grammatical head (i.e. the second word) in a combination, the relation predicted by H2 is more likely to be supported than when a concept functions as the grammatical modifier (i.e. the first word) in a combination. That is, for the concept pair C1 and C2, it appears that the association strengths of C1 are more likely to be significantly correlated with those of C2C1 (when C1 is the head) than with those of C1C2 (when C1 is the modifier).

As a preliminary test of the moderating effect of a concept's Head / Modifier role in combination on the relation between the strength of the component associations and the strength of the associations evaluated against combination, 2 chi-square tests were conducted. When the correlation was between Head and combination, 32 out of 42 Pearson correlations were significant at the 0.05 level (χ^2=11.542; p=0.001; df=1; n=42). When the correlation was between Modifier and combination, 16 out of 42 Pearson correlations were significant at the 0.05 level (χ^2=2.381; p=0.123; df=1; n=42). These results suggest that whether a concept functions as the Head or Modifier in a conceptual combination will influence the relation between the strength of its associations and the strength of these associations evaluated against the combination. Further investigation of the moderating effect of Head-Modifier role will be reported in Section 5.7

5.3 Testing Hypothesis 3

Hypothesis #3 predicts that the likelihood of an association of one of the component concepts being activated in the combination increases with the degree of balance of the triplet (i.e., the cognitive network consisting of the 2 component concepts and the association). Since there is a unique balance value for every association, for the easiness of the expression, I will refer to the balance value of the cognitive network as the balance of the association. Essentially, this is a correlational hypothesis, comparing two associations in terms of their relative balance values and the relative likelihood of their activations in the combination. For example, assume that both association #1 and #2 could potentially link concept C1 and concept C2 into a closed cycle. If the balance-score of the association #1 is larger than the balance-score of the association #2, then the hypothesis predicts that association #1 is more likely to be activated by the combination C1C2 (or C2C1) than association #2 (i.e., association #1 will obtain higher ratings when evaluated against C1C2 or C2C1 than association #2). The null hypothesis is that there is no relation between the likelihood of an association of one of the components concepts being activated in the combination and the degree of balance of this association.

As explained in Chapter 3, balance is defined as the product of V_i and S_i for the three link (where $V_i \in [+1, -1]$ and $0 \leq S_i \leq +1$) between 2 component concepts (C1, C2) and an association A.

$$\text{Balance} = (V_{C1C2}*S_{C1C2})*(V_{C1A}*S_{C1A})*(V_{C2A}*S_{C2A})$$

In this equation, the product of the valence and the strength of the link between the two component concepts in a conceptual combination ($V_{C1C2}*S_{C1C2}$) is always assumed to be 1. The other two factors (V*S) between an association and each component concept were obtained from Experiment Two based on participants' mean ratings of each association-conceptual entity pair.

Thus, balance is operationalized as the product of the mean ratings of an association against the 2 component concepts in a conceptual combination. The current ratings of the associations against concepts or combinations are of Likert scale type from 1 to 7. In this scale, 1 means that participants would *definitely not* mention the association when asked to define / explain / describe the concept; 7 means they would *definitely* mention the association; and 4 means they were *not sure* whether they would mention the association. Since each association would have a mean rating from 1 to 7 against each component concept, balance-scores varied from 1 to 49. In essence, this operationalization of balance is a kind of joint-prototypicality based on the product of an association's typicality ratings for the 2 component concepts.

Linear regression models were used to test the effects of an association's balance score on its mean rating against a conceptual combination. In the analysis, the balance score for an association of a given concept pair C1-C2 was the independent variable and the mean rating of the association against the combination such as C1C2 was the dependent variable.

It should be noted that in a two-concept pair C1 – C2, there are two conceptual combinations C1C2 and C2C1. The associations for this two-concept pair (e.g. association A) were evaluated against both combinations, corresponding to 2 mean ratings. That is to say, as independent variable, each balance-score predicts 2 different dependent variable values: the mean rating of an association against C1C2 and the meaning rating of the association against C2C1. Therefore, to test this hypothesis, 2 regression models were designed: one is the regression of the balance-score on the mean ratings against one combination (such as C1C2); the other is the regression of the balance-score on the mean ratings against the reverse combination (such as C2C1). By implementing 2 regression models, each balance-score appears only once in a given data set for regression analysis. Because it is arbitrary which concept is considered to be C1 and C2 in a given conceptual combination, I expected the two models to exhibit very similar properties, as each model incorporated half of the data in the data set.

The result of these two regression models is as follows:

Table 5-1: Model I Summary and Parameter Estimates

R Square	Adjusted R Square	F	df1	Sig.
.320	.319	325.718	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.449		53.388	.000
Balance score	0.061	.566	18.048	.000

Table 5-2: Model II Summary and Parameter Estimates

R Square	Adjusted R Square	F	df1	Sig.
.375	.374	415.030	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.382		54.506	.000
Balance score	0.066	.613	20.372	.000

The results indicate that both models are significant (F test sig<0.001) and both models predict a positive coefficient (Beta = 0.566 and 0.613 respectively), indicating that the mean rating of an association for a given combination increases slightly with balance score for the association-combination triplet. Moreover, balance-score explains about one third of the variance of the mean ratings of associations against combinations, indicating that balance is a strong explanatory variable in the model.

The preceding analysis used data aggregated across all conceptual combinations in the data set. A set of more detailed regression analyses was conducted at the level of specific conceptual combinations. For instance, for a concept pair C1 – C2, the specific balance scores of the 40 associations were used to predict the mean ratings of those associations for combination C1C2 (or C2C1). Thus, for each concept set containing 3 component concepts (sets #1 - #5), there were 6 regression models, and for concept set #6 with 4 component concepts, there were 12 regression models, for a total of 42 regression models.

The test design for the linear regression models is given in Appendix 12. The results of the linear regression models are summarized in Appendix 13. Among these 42 regression models, 10 (model #3, #5, #9, #11, #12, #17, #18, #25, #28, #32) did not accept H3, either due to insignificant F statistics or negative coefficients, and 32 models supported H3 with significant positive coefficients. Chi-square test result (χ^2=11.524; p=0.001; df=1; n=42) indicated that this distribution of the regression models was significantly different from chance (assuming 50% vs. 50%). Chi-square test for the distribution of the regression coefficients supports the idea (with 99.9% confidence level) that the likelihood of an association being activated in the combination increases with the degree of balance of the association.

5.4 Testing Hypothesis 4

Hypothesis #4 predicts that more associations originating from the second concept (grammatical head) than from the first concept (grammatical modifier) will contribute to the meaning of the combination. This hypothesis suggests a useful operational definition for psychological head (the one contributing more associations to the meaning of the combination) and modifier in the conceptual combination literature. The null hypothesis is that fewer associations originating from second concept in a combination will be used to construct the meaning of the combination than the first concept.

In this hypothesis, the term “contribute to the meaning of the combination” refers to the idea that the meaning of the combination would tend to activate these associations. The mean ratings of associations by participants give an index to association activation for a concept or conceptual combination. If more associations originating from the second concept contribute to the meaning of the combination than the associations originating from the first concept, then the mean ratings of association of the second concept will be relatively higher than those of the first concept. To test this hypothesis, three statistical methods were used: chi-square test and paired t test on the relation between Pearson’s correlations were used to test the hypothesis at the level of each concept pair, and regression was used to test the hypothesis across the whole data set. First, Pearson’s correlations between the mean ratings of associations for a single concept and those for combinations in which the concept is either grammatical head or modifier were used to measure the difference between the relative contributions of the mean ratings evaluated against first or second concept to the combination. Based on this logic, two statistical techniques were used to test this hypothesis: chi-square test on the distribution of Pearson’s correlation coefficients and a paired sample t test comparing Pearson’s correlation coefficients where components function as either grammatical head or modifier. Second, linear regression models were used to examine the relative contributions of the first or second concept to the meaning of the combination.

5.4.1 Chi-square test on the distribution patterns of the Pearson’s r

Based on the above analysis, we expect that in a combination, the associations of a concept will be more highly correlated with those of the combination when the concept functions as the grammatical head than when it functions as the modifier. For example, in a 2-concept pair (C1 – C2), the meaning of the combination C1C2 will be more correlated with the meaning of the C2 (as the grammatical head) than with the meaning of C1 (as the grammatical modifier) as exemplified in Table 5-3:

Table 5-3: Expectations based on hypothesis 4 on the 2-concept pair *Hat – Mitten* (C1 – C2)

Concept Pair	Association number	Evaluated Against		Pearson's r
C1 – C2	#1 … #10	C1 (Modifier)	C1C2	r 1
	#11 … #20	C2 (Head)	C1C2	r 2
	#31 … #40	expectation: r2 > r1		
	#41 … #50	C2 (Modifier)	C2C1	r 3
		C1 (Head)	C2C1	r 4
		expectation: r4 > r3		

The distribution of the Pearson's correlation coefficients is summarized in Appendix 14. Considering all combinations of single concepts and conceptual combinations in the data set, 84 Pearson's correlation coefficients were computed, resulting in 42 comparisons between a given concept functioning as either grammatical head or modifier in a combination. Of these 42 comparisons, there were 31 cases in which the correlation was higher when the single concept functioned as grammatical head in the combination, and 11 cases in which the correlation was higher when the single concept functioned as modifier in the combination. Chi-square test results (χ^2=9.524; p=0.002; df=1; n=42) indicate that this distribution of correlation results is significantly different from chance.

5.4.2 Paired t-test on Pearson's r

The proceeding chi-square analysis indicated that associations' strengths are more highly correlated between single concept and combinations when the single concept functions as the grammatical head than when it functions as modifier. To determine whether these differences in degree of correlation were significant, a paired t-test was conducted, between the two matched sets of the Pearson's correlation coefficients (r). The results are presented in Table 5-4.

Table 5-4: Paired t test results for hypothesis 4

	Paired Samples Statistics			Paired Differences head_r - modifier_r	
	Mean	N	Std. Deviation	Mean	Std. Deviation

Pair 1	head_r	.49757	42	.267171	.317024	.565049
	modifier_r	.18055	42	.396464		
				t	df	Sig. (2-tailed)
Pair 1 head_r - modifier_r				3.636	41	.001

The correlation coefficient between grammatical head and combination is 0.317 higher on average than the correlation coefficient between modifier and combination. The t test result (t=3.636, p=0.001) indicates this difference is highly significant.

Collectively, the chi-square and t test results indicate that the grammatical head (i.e. the second concept) contributes significantly more to the meaning of a combination than modifier (i.e. the first concept). This result suggests that the logic behind these two methods gives us a means of assessing how people actually interpret psychological head. By comparing the relative contribution of the component concepts to the meaning of the combination, we could differentiate psychological head from modifier.

5.4.3 Linear Regression models

Regression analysis was conducted to examine the relative contribution of the first or second concept to the meaning of the combination. The data set was evenly split into 2 sub-sets of 1386 data points each, composed of the mean rating of the each association evaluated against either head or modifier. The regression models are as follows:

Model #1: Mean_rating_combination = a0 + Beta*mean_rating_first_concept

Model #2: Mean_rating_combination = a0 + Beta*mean_rating_second_concept

The results of the two regression analyses are provided in Table 5-5:

Table 5-5: The regression models to examine the relative contribution of 1st or 2nd concept

Model #1 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.052	.051	75.347	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.875		54.299	.000
Mean_rating_first_concept	0.138	.016	8.680	.000
Model #2 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.264	.263	496.398	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.161		50.273	.000
Mean_rating_second_concept	0.311	.514	22.280	.000

Both mean_rating_first_concept and mean_rating_second_concept have positive coefficients (beta = 0.016 and 0.514 respectively), indicating the probability of an association activated in combination increases with the probability of the association activated in both component concepts (consistent with the prototypicality hypothesis H2). However, mean_rating_second_concept explains much more variance of mean_rating against combination than mean_rating_first_concept (R^2 = 0.264 vs. 0.052 respectively), and there is a greater degree of change (beta = 0.514 and 0.016 respectively) in Mean_rating_combination for each unit change in Mean_rating_second_concept than for each unit change in Mean_rating_ first_concept. Thus the probability of an association activated in combination increases much more with the probability of the associations activated in the second concept than in the first concept. That is, the second concept (grammatical head) contributes more to the meaning of the combination than the first concept (grammatical modifier).

5.5 Testing Hypothesis 5

Hypothesis 5 predicts that the meanings of novel combinations are more likely to incorporate lower strength associations from their component concepts than the meanings of everyday / mundane combinations. If a combination's novelty implies that its component concepts share no prototypical associations, it is difficult to construct a closed loop / cycle during the meaning construction process. Thus, constructing the meaning of a novel combination should require the activation of less prototypical associations and require more search effort to identify potentially useful associations to construct a meaningful connection between the two component concepts. That is to say, the more novel a combination is regarded, the more low-strength associations from its components are required to construct its meaning.

Essentially this hypothesis is about the moderating effect of Novelty on the relation between prototypicality and the meaning of the combination. It predicts that the more novel a conceptual combination is, the less prototypical associations from its component concepts will be used to construct its meaning. In this section, I will test this effect using a fairly strict measure of the novelty effect, and in next section, I will use moderated multiple regression to test this effect more explicitly.

Novelty was operationalized in two ways in this study. First, novelty was directly judged by participants in Experiment One, who were asked to judge the familiarity of conceptual combinations on a scale of 1 ("least familiar") to 5 ("most familiar"). Familiarity scores were obtained by calculating the average participant ratings for each conceptual combination (Table 4-5).

Novelty was also operationalized through the selection of particular concepts from the NAICS industry classification scheme used to design the experiment stimuli. Based on my conceptual framework, novelty is inversely related to the probability of one component concept and its associations being present in the cognitive field of the other component concept. Thus, novel combinations share few if any associations, such that neither component concept is part of the prototypical knowledge related to the other concept.

Everyday / mundane combinations, by contrast, share overlapping associations, such that one component concepts and their associations are likely to be part of the prototypical knowledge related to the other.

In the design of the 6 concept sets for the experimental stimuli, sets 1 - 5 were composed of 3 individual concepts and 6 conceptual combinations, and set 6 was composed of 4 concepts and 12 combinations. For sets 1, 2, 3, and 5, 2 concepts were selected from the same industry category (4 digit code in NAICS) and 1 was selected from a different industry category; for set 4, all 3 individual concepts were selected from the same industry category; and for set 6, 2 concepts were selected from one industry category and the other 2 concepts were selected from another industry category. Thus, the combinations generated from each concept set included some combinations within the same industry category, and some combinations between different industry categories. If we assume that products within the same industry category are likely to be more similar to one another than products from different industry categories, then combinations of 2 concepts from the same industry category should be less novel (more mundane) than combinations of 2 concepts from different industry categories. Table 5-6 summarizes the conceptual combinations within and between industry categories.

Table 5-6: The conceptual combinations within and between industry categories

Concept Set	Conceptual Combination	
	Within the same industry category	Between industry categories
#1	Hat Mitten, Mitten Hat	Hat Butter, Butter Hat, Mitten Butter, Butter Mitten
#2	Telephone Television, Television Telephone	Telephone Soap, Soap Telephone, Television Soap, Soap Television
#3	Cereal Chocolate, Chocolate Cereal	Cereal Watch, Watch Cereal, Chocolate Watch, Watch Chocolate
#4	Bread Cookie, Bread Pasta, Cookie Pasta, Cookie Bread, Pasta Bread, Pasta Cookie	
#5	Envelope Box, Box Envelope	Envelope Carpet, Carpet Envelope, Box Carpet, Carpet Box
#6	Air-conditioner Heater, Heater	Air-conditioner Refrigerator,

	Air-conditioner, Refrigerator Furnace, Furnace Refrigerator	Refrigerator Air-conditioner, Air-conditioner Furnace, Furnace Air-conditioner, Heater Refrigerator, Refrigerator Heater, Heater Furnace, Furnace Heater
Total	18	24

Based on these two ways of judging combination novelty, two methods were used to test hypothesis 5: Pearson's correlation coefficient and independent samples t test. Because the previous hypothesis (H4) predicts a difference between head and modifier in contributing to the meaning of the combination, 2 separate tests were conducted by only examining head or modifier respectively for each method.

To test the hypothesis, the description "more likely to incorporate lower strength associations from its components" was quantified as the percentage of low strength associations from either head or modifier which were high strength associations for the combination. Specifically, for each 2-concept pair (C1 – C2), participants rated up to 40 associations against the single concepts and combinations (C1, C2, C1C2, C2C1). The top 10 associations evaluated against each combination were treated as most representative of the meaning of the combination (high strength associations), and the lowest 10 associations for each component concept were treated as least representative (lower strength associations) for the component concepts. The percentage of lower strength (bottom 10) associations for either head or modifier included among the higher strength (top 10) associations for the combination provided a quantitative measure used to test H5.

5.5.1 Pearson's correlation coefficient

Pearson's correlation coefficients were used to examine the relationship between the preceding percentage measure for head (or modifier) and familiarity scores. Hypothesis 5 predicts that lower percentages should correspond with higher familiarity scores, thus a negative Pearson's correlation was expected. Two Pearson's correlations were obtained: for the correlation between the preceding percentage measure for head associations and familiarity score, and for the correlation between the percentage measure for modifier associations and familiarity score. For the first correlation, the results (r=0.267, p=0.087, n=42) did not indicate support for the predicted relationship between the percentage of head associations and familiarity score. On the contrary, this result indicates a weak support for the opposite relationship between the percentage of head and familiarity score (i.e., more novel combinations activate more prototypical associations of the head concept). For the second correlation, the results (r=-0.257, p=0.101, n=42) indicated weak support for the predicted relationship between the percentage of modifier associations and familiarity score, but below the traditional 95% confidence level.

5.5.2 Independent sample t test

Independent samples t test was also used to test hypothesis 5, using the percentage of lower strength associations of either the head or modifier that are high strength associations of the combination as previously defined. The t tests compared the percentage measure for combinations composed of 2 concepts from the same industry category with the percentage measure for combinations composed of 2 concepts from different industry categories. The hypothesis predicts that percentages should be higher for combinations from different industry categories than combinations within the same industry category. Two results of the t test were obtained: one used the percentage of head associations and the other used the percentage of modifier associations. The results of the t tests are given in Table 5-7 and 5-8.

Table 5-7: The result of independent sample t test using percentage of the head

		Samples Statistics		
		Mean	N	Std. Deviation
Percentage_Head	within_industry	0.1457	18	0.1155
	between_industry	0.0954	24	0.1267
		t	df	sig. (1-tailed)
		1.338	38.416	.378

For the percentage of the head's low strength associations included in the combination's top associations, the descriptive statistics indicate that the mean percentage was lower for combinations from different industries than for combinations from the same industry. The t value 1.338 (p=0.378 one tailed, df=38.416) indicates that the hypothesis is not supported.

Table 5-8: The result of independent sample t test using percentage of the modifier

		Samples Statistics		
		Mean	N	Std. Deviation
Percentage_Modifier	within_industry	0.2378	18	0.1209
	between_industry	0.3121	24	0.1722
		t	df	sig. (1-tailed)
		-1.641	39.867	.218

For the percentage of the modifier's low strength associations included in the combination's top associations, the descriptive statistics indicate that the mean percentage for combinations from different industries was marginally higher than for combinations from the same industry. The t value -1.641(p=0.218 one tailed, df=39.867) indicates that the hypothesis is not supported.

Collectively, the Pearson's correlation and the independent sample t test did not support hypothesis 5. That is, the above statistical methods did not capture the influence of novelty on the meaning of combinations. There are a few potential reasons for this result. Firstly, the tests are overly strict. The percentage of top 10 vs. bottom 10 associations is quite extreme operationalization regarding novelty effects. This operationalization assumes that meaning of the novel combinations is more likely to incorporate associations with lowest strength (bottom 10) from its components, which might be an overly strict assumption. It is quite possible that before reaching to the bottom associations, a meaning has already been constructed using associations with medial strength. Moreover, another reason could be proposed. Theoretically, to construct the meaning of novel combinations, more search effort is required to identify potentially useful associations. Based on hypothesis 2, when we construct the meaning of a novel combination, prototypical associations will be activated firstly as the first order activation. And then, it could be postulated that for novel combinations, second order associations might be necessary to construct a closed loop / cycle between the two components that do not share first order associations. However, the current data did not capture second order activations during the meaning construction process. To test how second order activation influences the meaning construction for novel combinations, it is necessary to collect more data to confirm this postulation.

5.6 Testing Interaction Effects

In the process of testing various factors influencing the meaning construction of conceptual combinations, each hypothesis was basically treated independently without considering interaction effects between variables. However, as the framework theorized, these factors mutually influence one another and this section will examine some of these interaction effects. The 5 factors influencing the meaning of conceptual combinations that were tested in this thesis are: contingency effects (H1), prototypicality effects (H2), balance effects (H3), head/modifier effects (H4) and novelty effects (H5). These 5 factors are likely to influence one another in complicated ways, but all such interactions are beyond the scope of this thesis. The current thesis will examine the following interaction effects. Test 1 will examine the moderating effects of head/modifier role on the relationship between prototypical associations of component concepts and association strength of combinations. Test 2 and 3 will examine the moderating effects of combination novelty on prototypicality and balance respectively.

Moderated multiple regression procedures were used to test for the existence of moderator effects using models of the form $Y_i = \beta_0 + \beta_x X_i + \beta_z Z_i + \beta_{xz} X_i Z_i + \varepsilon_i$, where the $X_i Z_i$ moderating term represents the product of the two independent variables (Aiken and West 1991). Thus, the null hypothesis is formulated as H0: $\beta xz = 0$.

It is suggested by Aiken and West (1991) that before conducting moderated regression analysis, the covariances C (X, XZ) and C (Z, XZ) between the independent variables and their product should be reduced by "centering" the independent variables and using the centered variables, together with their product, in the regression model. Centering a variable is achieved by subtracting its mean from all observations. In all of the following regressions, centering was performed.

In the following regression analyses, the dependent variable was the meaning of the conceptual combination, operationalized as the ratings of associations in a two-concept pairing as in the previous chapter. Independent and moderating variables were also operationalized as they were in the previous chapter.

5.6.1 Test 1 – Head / Modifier and Prototypicality

In testing hypothesis #2, a preliminary analysis indicated that when a component concept functioned as a grammatical head, prototypicality effects were much stronger than when the concept functioned as a modifier. Test 1 examined the moderating effects of Head / Modifier role on prototypicality more explicitly. In the following regression, Head / Modifier were treated as a dummy variable, where 1 represents Head and 0 represents Modifier. Descriptive statistics for the independent variables and the results of the regression analysis are given in Table 5-9:

Table 5-9: Regression analysis on the moderating effects of head/modifier

	N	Minimum	Maximum	Mean	Std. Deviation
Mean_rating against component	2772	1.00	7.00	4.1128	1.82048
H_M	2772	0	1	.50	.500

Model Summary				
R Square	Adjusted R Square	F	df1	Sig.
.158	.157	172.887	3	.000

Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		

Constant	4.442		230.787	.000
Mean_rating against component	0.225	.371	21.241	.000
H_M	2.43E-006	.000	.000	1.000
Mean_rating_H_M	.174	.143	8.214	.000

The regression model is significant and the overall R^2 is 0.158. From Table 5-9, we see variable H_M sig.=1.000 > 0.05, so removing H_M from this model will not significantly reduce the model's predictive capability.

It can be concluded that the coefficient of the independent variable "mean_rating against component" is positive, indicating that the relative probability of an association activated in combination increases with the relative probability of the association activated in component concepts (supporting H2). However, the coefficient of the other independent variable H_M is insignificant (p=1.000), indicating that Head / Modifier by themselves do not predict the activation of an association in combination. The coefficient of the product of the two independent variables "Mean_rating_H_M" is positive (0.174, t = 8.214 and p < 0.001), indicating a significant moderating effect between Head/Modifier and prototypicality. Consistent with the preliminary results reported earlier, the effect of an association's prototypicality for a component concept on its activation strength for the combination is higher when the component concept functions as the head of the combination than when it functions as the modifier of the combination.

Logically, the effects of Head/Modifier role on the relationship between an association's balance score and its strength in combinations should also be examined. However, since balance was calculated as the product of the mean_rating of the head and the mean_rating of the modifier, and multiplication has the commutative property, it is not expected that Head or Modifier will moderate the effect of balance.

5.6.2 Test 2 – Novelty and Prototypicality

Test 2 focuses on the moderating effect of Novelty on prototypicality (H5). It was postulated that when constructing the meaning for a novel conceptual combination, lower strength (less prototypical) associations from component concepts will be more likely to be used. The more novel a conceptual combination is, the less prototypical associations from its component concepts will be used to construct its meaning.

Similar to hypothesis #5 testing, there are two ways to operationalize combination novelty: familiarity score, and within/ between industry categories. Thus, 2 multiple regression models were examined. Model I used the familiarity score and Model II used the categorical variable within / between industry categories.

Descriptive statistics for the independent variables in Model 1 and regression results are given in Table 5-10:

Table 5-10: Regression Model I for the moderating effects of Novelty on prototypicality

	N	Minimum	Maximum	Mean	Std. Deviation
Mean_rating against component	2772	1.00	7.00	4.1128	1.82048
Familiarity score	2772	1.2222	4.8333	3.42352	1.09102

Model Summary

R Square	Adjusted R Square	F	df1	Sig.
.142	.141	152.486	3	.000

Parameter Estimates

	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	4.455		223.067	.000
Mean_rating against component	.221	.364	20.035	.000
Familiarity score	.034	.033	1.803	.071
Mean_rating_Familiarity	-0.029	-0.052	-2.902	.004

The regression model is significant with $R^2 = 0.142$. The coefficient of the independent variable "mean_rating against component" is positive, indicating that the probability of an association activated in combination increases with the probability of the association activated in component concepts (supporting H2). However, the coefficient of Familiarity score is weakly significant (t=1.803, p=0.071), indicating that Novelty by itself weakly predicts the activation of an association in combination. The coefficient of the product of the two independent variables “Mean_rating_Familiarity” is negative (B=-0.029, t = 8.214 and p < 0.001), indicating that there are moderating effects between these two independent variables.

Two conclusions can be drawn. First, as familiarity score increases (a combination becomes less novel), the slope for the independent variable “mean_rating against component” decreases, indicating for a unit change in familiarity score, the unit change in “mean_rating against combination” decreases. That is, the strength of association against component will predict smaller relative changes in the strength of the association against combination. The more familiar a combination is, the less important the strength of association against component is in terms of predicting the strength of association against combination. Second, as familiarity score decreases, the strength of associations evaluated against components also decreases. This suggests that when constructing a novel conceptual combination, lower strength (less prototypical) associations from component concepts are more likely to be used, thus supporting H5.

In regression model II, Novelty was treated as a dummy variable, where 1 represents Between Industry categories (implying more novel combinations) and 0 represents Within Industry category (implying less novel combinations). The descriptive statistics of the independent variables and the regression results are given in Table 5-11:

Table 5-11: Regression Model II for the moderating effects of Novelty on prototypicality

	N	Minimum	Maximum	Mean	Std. Deviation
Mean_rating against component	2772	1.00	7.00	4.1128	1.82048
Within_between	2772	0	1	.58	.493

Model Summary				
R Square	Adjusted R Square	F	df1	Sig.
.164	.163	180.976	3	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	4.437		227.400	.000
Mean_rating against component	0.209	.345	19.339	.000

Within_between	-0.361	-0.162	-9.109	.000
Mean_rating_within_between	-0.035	-0.027	-1.540	.124

The regression model is significant with overall $R^2 = 0.164$. The coefficient of the independent variable "mean_rating against component" is positive, indicating that the probability of an association activated in combination increases with the probability of the association activated in component concepts (supporting H2). The coefficient of "Within_between" is negative (B=-0.361), indicating that other things being equal, Novelty negatively predicts the activation of an association in combination (supporting H5). The coefficient of the moderating term "Mean_rating_within_between" is insignificant (t=-1.54, p = 0.124), indicating a weak moderating effect between the two independent variables.

Comparing the two regression models, three observations could be made. First, both models indicate that probability of an association activated in combination increases with the probability of the association activated in component concepts (supporting H2). Second, the direct effect of novelty on the dependent variable "mean_rating against combination" is strong in Model II and relatively weaker in Model I. The magnitude of the direct effect in Model I is much smaller than in Model II. Third, the moderating effects are significant in model I but insignificant in model II. However, considering the relative crudeness of within/between industry category as an indicator of combination novelty (Model II), compared to the more direct participants' rating of novelty using familiarity scores (Model I), it is reasonable to conclude that model I provides a more accurate assessment of the moderating effects of combination novelty on prototypicality (supporting H5). In general, the results provide relatively weak support for hypothesis 5, suggesting novel combinations do not necessarily incorporate more lower-strength associations from their components than everyday / mundane combination.

5.6.3 Test 3 – Novelty and Balance

Test 3 focused on the moderating effects of Novelty on the effects of balance. Since balance is defined as joint prototypicality and previous tests found some moderating effect of novelty on prototypicality, it is reasonable to examine the moderating effect of novelty on balance as well.

Similar to the hypothesis 3 testing, Balance effects were tested using two identical regression models, each considering half of the data set, because a single balance score for an association-combination triplet predicts two association ratings against combination in reverse sequence (C1C2 and C2C1). Similar to the preceding analysis, novelty is operationalized in two ways: familiarity score, and within/ between industry category. Thus, a total of four regression models were analyzed (Table 5-12).

Table 5-12: The four models used to analyze the moderating effect of novelty on balance

Novelty	Balance (C1C2) (using one half of the data set)	Balance (C2C1) (using the other half of the data set)
familiarity score	Regression Model #1	Regression Model #2
within / between industry category	Regression Model #3	Regression Model #4

The descriptive statistics and regression results for Model #1 and #2 are given in Table 5-13.

Table 5-13: Regression Models #1 & #2 for the moderating effect of novelty on balance

	N	Minimum	Maximum	Mean	Std. Deviation
Balance_score	1386	1.49	45.00	16.1459	10.23245
Familiarity_score	1386	1.2222	4.8333	3.42352	1.091217

Model #1 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.321	.320	217.888	3	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	4.436		173.511	.000
Balance_score	0.062	.574	24.749	.000
Familiarity_score	-0.030	-0.030	-1.217	.224
Balance_score_familiarity	-0.001	-0.006	-0.261	.794

Model #2 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.376	.375	277.474	3	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	4.453		181.330	.000
Balance_score	0.067	.620	27.895	.000
Familiarity_score	-0.029	-0.029	-1.214	.225
Balance_score_familiarity	-0.001	-0.009	-0.381	.703

Both regression models were significant with $R^2 > 0.3$. The coefficients of the independent variable Balance_score were positive (0.574 and 0.620 respectively), indicating that the probability of an association activated in combination increased with the balance score of the association (supporting H3). However, the coefficients of the other independent variable Familiarity_score were insignificant (p=0.224 and 0.225 respectively), indicating that Novelty by itself does not predict the activation of an association in combination. The coefficients of the moderating terms Balance_score_familiarity were also insignificant (p=0.794 and 0.703 respectively), indicating that there are no moderating effects between these two independent variables.

In regression models #3 and #4, Novelty was treated as a dummy variable, where 1 represents Between Industry categories (implying more novel combinations) and 0 represents Within Industry category (implying less novel combinations). The descriptive statistics and regression results for Model #3 and #4 are given in Table 5-14.

Table 5-14: Regression Models #1 & #2 for the moderating effect of novelty on balance

	N	Minimum	Maximum	Mean	Std. Deviation
Balance_score	1386	1.49	45.00	16.1459	10.23245
Within_between	1386	0	1	.58	.493

Model #3 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.328	.326	224.345	3	.000
Parameter Estimates				

	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	4.460		174.673	.000
Balance_score	0.060	.561	24.049	.000
Within_between	-0.110	-0.049	-2.111	.035
Balance_score_within_bw	0.017	0.074	3.329	.001
Model #4 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.384	.382	286.696	3	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	4.478		182.832	.000
Balance_score	0.065	.606	27.113	.000
Within_between	-0.128	-0.057	-2.573	.010
Balance_score_within_bw	0.017	0.078	3.646	.000

Both regression models were significant with $R^2 > 0.3$. The coefficients of the independent variable Balance_score were positive (0.561 and 0.606 respectively), indicating that the probability of an association activated in combination increased with the balance score of the association (supporting H3). The coefficients of the other independent variable Within_between were significantly negative (p=0.035 and 0.010 respectively), indicating a slight negative effect of Novelty on the activation of an association in combination. The coefficients of the moderating term Balance_score_within_bw had a small beta (0.074 and 0.078 respectively) but were significant (p=0.001 and p<0.001 respectively), indicating a moderating effect on the effects of balance on the likelihood of an association being activated in a combination.

Comparing the results of these 4 regression models, it is very difficult to make a general conclusion about whether or not there is a moderating effect between novelty and balance. However, even if there is a moderating effect as suggested by model #3 and #4, it is relatively small.

5.7 Testing relative contributions of prototypicality and balance

One of the interesting issues derived from the framework is how prototypicality and balance contribute to the meaning construction of a combination. Prototypicality refers to the strength of the activation of an association by a concept. Previous results have shown that other things being equal, associations activated with higher strength by at least one of the component concepts are more likely to be activated when constructing the meaning of combination. However, the balance hypothesis (H3) predicts that if a highly salient association cannot form a balanced cycle, it will be dropped from the set of activated associations and less salient associations will be activated. In the framework, balance is defined as the product of valence and strength of the associations linking two components in a conceptual combination and is therefore a kind of joint prototypicality. Previous results have also shown that other things being equal, the likelihood of an association of one of the component concepts being activated in the combination increases with the degree of balance of this association. The results therefore supports both the prototypicality and balance hypotheses, but the relative contributions of prototypicality and balance are not yet clear. To explore this question, multiple linear regression models were constructed for comparison.

To explore the relative contributions of prototypicality and balance to the meaning of the combination, the data set was split into 2 sub-sets, each contains mean ratings of associations evaluated against combinations in one sequence (C1C2) or evaluated against combinations in reverse sequence (C2C1) based on the same logic as the hypothesis #3 testing (i.e., each balance score predicts 2 ratings for a given associations against combination C1C2 or C2C1, so these predictions are analyzed separately). Within each subset, data were further divided into 2 more subsets composed of the mean rating of the each association evaluated against either head or modifier. This leads to 4 subsets of the data; each containing 693 data points as demonstrated in Table 5-15. 3 regression analyses were conducted in each data sestet. These 3 regression models examined incremental effects of meaning ratings evaluated against components (either as head or modifier), balance score and both of mean ratings against components and balance as exemplified in the Table 5-16.

Table 5-15: The division of the data set to test the relative contribution of prototypicality and balance.

	Balance (C1C2)	Balance (C2C1)
Mean_rating_head	Regression Model #1, #2, #3	Regression Model #7, #8, #9
Mean_rating_modifier	Regression Model #4, #5, #6	Regression Model #10, #11, #12

The results of 6 regression analyses, corresponding to the first column (C1C2) of Table 5-15 are reported here. The corresponding results for the 6 regressions in the second (C2C1) column in Table 5-15 are highly consistent with those presented below and are reported in Appendix 15.

Table 5-16: Regression analyses conducted for each data subset

RM #1. Mean_rating_combination = a0 + Beta1*mean_rating_head
RM #2. Mean_rating_combination = a0 + Beta1*balance_score
RM #3. Mean_rating_combination = a0 + Beta1* mean_rating_head + Beta2*balance_score
RM #4. Mean_rating_combination = a0 + Beta1*mean_rating_modifier
RM #5. Mean_rating_combination = a0 + Beta1*balance_score
RM #6. Mean_rating_combination = a0 + Beta1* mean_rating_modifier + Beta2*balance_score

The regression results for Models #1 to #3 are reported in Table 5-17:

Table 5-17: The regression results for Models #1 to #3 to examine relative contributions of prototypicality and balance

Model #1 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.320	.319	325.774	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.

	B	Beta		
Constant	3.029		35.223	.000
Mean_rating_head	0.345	.566	18.049	.000
Model #2 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.375	.374	415.030	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.382		54.506	.000
Balance_score	0.066	.613	20.372	.000
Model #3 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.443	.441	273.845	3	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	2.905		36.954	.000
Mean_rating_head	0.194	.318	27.113	.000
Balance_score	0.046	0.429	12.294	.000

Comparing the results of these regression models, 2 basic observations could be made: the adjusted R square increases from Model #1 to #3; and for Model #3, the relative effect of balance on the dependent variable is more than that of the prototypicality of head (mean_rating_head). The results indicate that the effects of balance generally explain more of the variance in the dependent variable (mean_rating against combination) than prototypicality of the head concept (mean_rating_head). When the effects of both balance and prototypicality are considered (Model #3), the explained variance of the dependent variable is the greatest. The larger beta value for Balance compared to the beta value for mean_rating_head indicates that the strength of the association against combination increases more sharply for a unit of change in Balance than for a unit of change in mean_rating_head. That is, generally balance is a better indicator of the strength of the association against combination than prototypicality.

The regression results for Model #4 to #6 are presented in Table 5-18.

Table 5-18: The regression results for Models #4 to #6 to examine relative contributions of prototypicality and balance

Model #4 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.042	.041	30.317	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.942		38.978	.000
Mean_rating_modifier	0.124	.205	5.506	.000
Model #5 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.375	.374	415.030	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.382		54.506	.000
Balance_score	0.066	.613	20.372	.000
Model #6 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.413	.412	242.945	2	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.733		46.759	.000
Mean_rating_modifier	-0.146	-0.242	-6.682	.000
Balance_score	0.082	0.755	20.892	.000

Comparing the results of these regression models, the same 2 basic observations could be made: the adjusted R square increases from Model #4 to #6; and for Model #6, the relative effect of balance on the dependent variable is more than that of the prototypicality of modifier (mean_rating_modifier). The results indicate that the effects of balance generally explain more of the variance in the dependent variable (mean_rating against combination) than prototypicality of the modifier concept (mean_rating_modifier). When the effects of both balance and prototypicality are considered in Model #6, the explained variance of the dependent variable is the greatest. The larger beta value for Balance compared to the negative beta value for mean_rating_modifier indicates that the strength of the association against combination increases for a unit of change in Balance, but decreases for a unit of change in mean_rating_modifier. That is, generally balance is a better indicator of the strength of the association against combination than prototypicality, and the prototypicality of the associations of the modifier concepts is negatively related to the strength of these associations evaluated against combination.

In summary, the relative contribution of the balance variable is larger than that of the prototypicality variable in constructing the meaning of the combination. Moreover, the relative contribution of the head concept is much larger than that of the modifier concept to the meaning of the combination.

Chapter 6 Discussion

This thesis has proposed a framework explaining the cognitive processes of meaning construction through conceptual interactions. It is proposed that when we construct complex meanings from smaller conceptual units, the associations of these units combine to form a cognitive field exhibiting Gestalt figure-ground characteristics. Meaning construction, therefore, is theorized as a goal-directed cognitive process. The goal is to make sense of the combination of concepts, which analytically equates to a search for a system of associative concepts that connect two (or more) conceptual units in a balanced way. Experiments were conducted to test the hypotheses derived from the framework. In this chapter, I will summarize the major findings from the experiments, identify some of the limitations as well as future work, and propose some potential contributions of this research.

6.1 Summary of findings, limitations and future work

Four general findings could be summarized regarding the processes of conceptual interactions in meaning construction: contingency, prototypicality, balance, and the effects of head/modifier and novelty. In this section, I will discuss these findings, and then present a general discussion on the limitations of the research.

The first property of conceptual interactions examined in the experiments is related to the assumption of the mutual influence of component concepts in meaning construction. Meaning, in this thesis, is defined as a mental state resulting from the interactions of associative concepts (i.e., conceptual interaction) in the communicative context. This definition emphasizes that meaning is constructed through the influence of associative concepts on each other. The results of the Hypothesis 1 and 2 testing provided two kinds of evidence for this assumption. The first evidence is that the meaning of the combination is a function of its simpler component concepts. The chi-square results for Hypothesis 2 indicated that for correlations significant at 0.1 level, χ^2=4.762 (p=0.029; df=1; n=540), which means that we are at least 95% confident that strength of the associations of the component concepts covaries with the strength of the associations evaluated against combination for correlations significant at 90% confidence level. That is, each component concept provides the combination with the 'raw materials', from which the meaning of the combination is constructed. The second evidence is that the meaning of each component concept is a function of the other concept. The chi-square results for Hypothesis 1 indicated that if we consider 40% as the sufficient support threshold, (χ^2=16.327; p<0.001; df=1; n=540), associations of a component concept will be activated contingently in combination, depending on the other component concept.

The second property of conceptual interactions examined in the experiments is regarding to the relationship between the strength of associations in component concepts and the strength of associations in combinations. Experimental results indicated that the prototypicality of associations of the component concepts significantly affects the meaning of the combination (H2); and among the 2 component concepts, the head concept has significantly more explanatory power than the modifier (H4). Regression analyses indicated that prototypicality on average explains about 15% of the variance in mean rating against combination and this explanatory power is moderated by the role of head/modifier. This finding is consistent with Hampton's findings (Hampton, 1987, 1999). Hampton found that the average prototypicality of 2 component concepts accounted for a very large part of the variance in conjunctive prototypicality (about 80 – 90% of variance in the meaning of the combination). In my experiment, I found a much lower predicative power for prototypicality of associations of component concepts. My data indicated that the head concept explains about 25% of variance and the modifier explains about 5% of variance in the meaning of the combination.

There are also some important differences between Hampton's findings and mine. For example, in Hampton's model, the joint effect of the two component concepts was measured as the average of the two typicalities of the attributes of the components. In my model, the joint effect of the two was measured as a product of the prototypicalities of the associations of the head and the modifier, which has a very good predicative power (though lower than Hampton's findings), explaining about 37% of variance. In Hampton's experiments, he did not differentiate the head concept from the modifier concepts and only dealt with so called true conjunctives of the form "X that is also Y" (such as "pets that are also birds"), whereas I did not use combinations phrased as relative clauses in my experiment. Instead, I used the direct combinations such as C1C2 or C2C1 (*hat butter* or *butter hat*). Thus, Hampton's experiment results did not differentiate the relative contributions of the two component concepts; instead, he gave equivalent weight to the 2 components by taking the average of the typicalities of attributes from the components. In my experiment, I differentiated the different roles that each component concept plays in the combination and found that the head concept has a much larger effect than the modifier on the meaning of the combinations. This finding is also inconsistent with Gagne's finding (1997) that modifiers exerted a greater influence than head on determining the relation between 2 components in meaning construction. However, this difference is not difficult to explain. Gagne studied thematic relations between two components when constructing the meaning of the combination while I focus on the semantic meaning of the combination. Because conceptual combination is a relational phenomenon, the way we make sense of a combination is by making sense of some kind of relation between the two components. In this process, modifiers may have a major effect on how concepts relate to one another, but that does not imply that a combination's overall meaning is dominated by the meaning of the modifier. I found that the resultant meaning of the combination is largely dependent on the head concept, suggesting that the grammatical head is usually the more central concept in combination.

The third property of conceptual interactions examined in the experiments regards the relationship between balance and the strength of association in combination. In the thesis, balance was operationalized as a joint prototypicality of head and modifier, reflecting the systemic characteristics of triplets composed of two component concepts and an association. Through the study on the relative contributions of prototypicality and balance, it was found that balance has more explanatory power than prototypicality to the meaning of a combination. However, it should be noted that the current operationalization of balance is somewhat different from Heider's conceptualization. In Heider's theory, balance indicates the total system of the entities (i.e. all three entities in a triplet), while in my current method, balance mainly reflects the two links between an association and the two component concepts. The strength of the link between the two component concepts is conveniently assumed as 1. As a result, I have really tested the joint prototypicality of an association in relation to the head and the modifier (3 entities with 2 links), rather than the triplet composed of 3 entities and 3 links. This assumption is based on the fact that participants were forced to make sense of a combination that was presented to them in the experiment. Thus, combinations were treated as perfectly linked concept pairs without any uncertainty about the link, although, it is clear that participants should still experience a degree of uncertainty about the link between 2 components. In future research, I will explore ways of operationalizing balance more consistent with Heider's conceptualization by considering perceived uncertainty in the link between the two components of a combination. For example, instead of assuming the strength of the link between head and modifier as 1, I could potentially use the familiarity score as an indicator of the degree of the uncertainty between the 2 components. Moreover, this operationalization might resolve another difficulty in the current methods, the fact that one balance score was used to predict the mean ratings of an association against two different combinations (C1C2 and C2C1). If C1C2 has a different familiarity score from C2C1, an association's balance score for C1C2 should be different from its score for C2C1, thus, leading to 2 different predictions of its mean rating against the two combinations.

In coding participants' association ratings, I used a numeric scale from 1 to 7, where a rating of "definitely no" was coded as 1, "not sure" as 4, and "definitely yes" as 7. All of the subsequent data analyses were based on this transformation. However, the appropriateness of this transformation is worth considering. Specifically, this transformation has difficulty dealing with negative associations. In a preliminary analysis, I tried coding participants' ratings from -3 to +3, where "definitely no" was coded as -3, "not sure" as 0, and "definitely yes" as +3, a scheme that resulted in numerous associations with negative activation strength. However, there were several problems with this coding scheme. For example, the mapping between the wording of the questionnaire and a -3 to +3 scale is not clear in this transformation. Based on the wording of the question ("on the scale from 'definitely no' to 'definitely yes', please indicate how likely is it that you would mention the following ideas"), responses reflect an estimate of the probability of mentioning a certain idea, thus "definitely no" should correspond to a probability of 0 rather than -3; 'not sure' should correspond to a probability of 0.5 rather than 0; and 'definitely yes' should correspond to a probability of 1 rather than +3. Thus, coding participant ratings from -3 to +3 did not seem to capture the intended meaning of the questions. A coding scheme from 0 to 1 may be used; however, such a coding scheme would not capture negative associations as well.

Another problem with using a -3 to +3 scale or a 0 to 1 scale was related to apparent inconsistencies in the computation of balance scores, especially when calculating balance between a weak negative link and a strong positive link. For example, in a system composed of my wife, me and a movie, if I like the movie very much (a strong positive, say +3), but my wife slightly dislikes the movie (a weak negative, say -1), then the balance score for the system (calculated as the product of the three links between me, my wife, and the movie) would be a strong negative (+3*-1=-3,assuming the link between my wife and me is 1). That is, there is a strong negativity in the system of my wife, me and the movie, which is in conflict with our intuitive understanding on this situation. If we use a 0 to 1 scale, the balance score for the system would be smaller than either link between the movie and my wife or me (i.e., the degree of the liking relation between the movie and us as a couple is even lower), which is in conflict with our intuitive understanding on the situation as well. Using data from my experiment, the mean rating of association #21 "used in baking, cooking & frying" was 3.05 against *hat*, 6.58 against *butter*, 3.83 against *hat butter*, and 3.2 against *butter hat* on the current scale from 1 to 7. If the scale was transformed into a new scale from -3 to +3, the mean ratings would become -0.95, 2.58, -0.17 and -0.8 respectively. Then the balance score calculated in the system of *hat*, *butter*, and "used for cooking etc." becomes a quite strong negative value (-0.95X2.58=-2.451), indicating that the association is strongly negatively linked to the combination *hat butter* or *butter hat*, which is in conflict with the observed slightly negative values (-0.17 and -0.8 respectively). It is clear that in the attempt to code participants' judgments in a way that captures negative associations (e.g. using a scale from -3 to +3), there are some difficulties yet to be solved.

The last property of conceptual interactions examined in the experiments regards the moderating effect of novelty on the relationship between prototypicality / balance and the combinations' association activation. The experimental results indicated that any direct effects of combination novelty on the first order association activation are marginal at best. Moreover, it seems that novelty does not have obvious interaction effects on either prototypicality or balance. As previously noted, there may be several reasons for these results. Methodologically, the current experiment captured only first order association activations by asking participants to evaluate associations directly against a conceptual entity. It did not capture potential second order association activations by, for example, asking participants first to generate second order associations related to the first order associations and then later to evaluate these against the first order associations. However, as I conceptualized in the framework, constructing the meaning of novel combinations should require more search effort to identify potentially useful associations to construct a closed loop / cycle between two component concepts that do not share first order associations. Thus, novelty should have an effect on meaning construction, but the current statistical techniques were not able to capture such effects. To test how second order activations may influence the meaning construction of novel combinations, further data collection would be required.

A related issue is that novelty was operationalized using NAICS categories (within-between) and participants' familiarity scores, and the results suggest these two measurements were measuring different things. The familiarity score was the most direct measure of novelty but the data indicate a very small moderating effect on prototypicality and balance. The within/between category measure presumes that the structure of NAICS reflects the overlapping nature of the cognitive fields associated with concepts drawn from these categories. As an indirect measure, it exhibited a relatively larger moderating effect on balance, but a relatively smaller moderating effect on prototypicality. However, it should be noted that the products in the same NAICS industry category may be quite heterogeneous, while products from different categories might share several similarities, suggesting that NAICS classification does not necessarily correspond with human similarity perceptions.

The third reason for the weak effects of novelty might be due to the fine grained effect was not captured by the current test logic. Maybe when we understand the novel combinations and search for the possible associations that could link the two components, we do not need to go to the bottom 10 associations of either head or modifier. Thus the current percentage measure of top 10 vs. bottom 10 is too strict to capture the movement of associations' weights in the middle, thus leading to the incapability of finding effects of novelty.

Besides issues related to the findings regarding these properties of conceptual interactions, certain conceptual difficulties have been encountered that requires further research. I will not list all of the difficulties, but will focus on a few issues that are interesting to discuss.

The current framework focuses attention on the triplet involving 2 concepts and a single association. The role of the larger cognitive network reflecting other associative concepts in the meaning construction processes are not clearly understood. For example, in my current framework, the meaning of *elephant fish* is represented as a triangle Δ fish-trunk-elephant when it is interpreted as "a fish with a trunk". However, there is no empirical evidence at this stage that the cognitive field of *elephant fish* for this interpretation is composed only of these 3 nodes. Experimentally, it is possible to obtain information on the resultant meaning of the combination; however, it is not clear whether this meaning comes from the interaction of just these 3 nodes or from interactions involving multiple associated concepts. It has also been proposed that the larger network of concepts may play a role in reducing the remaining tensions in the cognitive network after it is balanced (strengthening balance), however, the precise mechanisms by which this is happening remain a subject of future research.

Following the previous point, in the framework I proposed that the activation of associations is goal-directed, where the goal is to understand how the meaning of the two component concepts can fit together harmoniously. Graphically, this equates to constructing a linking path between nodes representing the two component concepts via other nodes representing associated concepts to form a balanced cycle. Based on this conceptualization, it is proposed that only those associations that are necessary for constructing a (potentially) balanced cycle are activated. As people encounter difficulties forming a closed cycle using first order associations, they are increasingly likely to use second order associations, as the *tasty computer* example used previously (section 3.2.2.3 Balancing closed cycle) demonstrated. However, the specific mechanisms have not been specified. Further work is required to specify the processes involved in constructing a cognitive field including such higher order associations.

The direction of an association is another important variable in the cognitive network, which has not yet been incorporated in the current framework. Directionality can be understood in two ways. First, direction could be defined as the asymmetric probability of one concept being associated with another concept; that is two concepts may have different probabilities of being associated with one another depending on which concept is the focus of attention. Second, direction can be understood in terms of the path through the network of associated concepts reflecting our knowledge of some domain, which our cognition follows to link one concept to another concept, as we construct the meaning of a conceptual combination. The importance of the second type of direction can be demonstrated by the following example. When elephant fish is understood as “a fish that eats elephant”, eat as the association of both fish and elephant has the potential to form a contingent cycle with two directions (second type direction). Our cognition could traverse from fish through eat to elephant to construct a meaning “fish that eats elephant”; or it could traverse from elephant through eat to fish to construct a meaning “elephant that eats fish”. It is not clear why cognition prefers the direction from fish through eat to elephant, though it could be postulated that in this situation, the head of the combination (fish) has the priority. Future work is needed to examine how direction functions in constructing a balanced cycle and why certain directionality takes preference over others.

Lastly, there are some methodological issues in the current data analysis. The current analysis used the mean rating across population as the indication of the prototypicality of the association relative to other associations when evaluated against a conceptual entity, which is consistent with the view that meaning is based on social consensus. However, this operationalization results in a loss of information about the variance in individual participant rankings. If two associations have different mean ratings but nonetheless significantly overlap in their general distributions, the regression results obtained in data analyses might be over-estimated due to ignoring the variances between participants' individual ratings. However, the alternative is to obtain information on prototypicality via a within-subject experimental design, which has its own problems, such as possible memory effects between different rounds of data collection, or difficulties associated with asking participants to make comparisons on which association is most salient for them. Another way that might improve the current data collection is to design the question to be more generic in point of view. For example, instead of asking "how likely you would mention the following associations", participants could be asked "how likely *most people* would mention the following associations" to obtain participants' understanding of consensus meaning directly.

6.2 Conclusion

This research proposed a theoretical framework describing cognitive processes involved in constructing the meaning of conceptual combinations through conceptual interactions. My exploration of the phenomenon started from first principles by thinking about the question: what minimal assumptions are needed to understand the meaning of a conceptual combination? It seems that the minimum assumption is to have an association between 2 concepts, i.e., two concepts are associated with each other. Based on this assumption, meaning, knowledge, and contexts are all represented in the same way as a set of associated concepts, and the meaning of a conceptual combination is conceptualized as the result of interactions between these associated concepts. This interaction is a goal-directed cognitive process. The goal is to make sense of a conceptual combination by searching for a system of associated concepts that connects two (or more) conceptual units in a balanced way. It is proposed that the cognitive processes involved in meaning construction start from a distinction between the different roles each component concept plays (head or modifier) and then a system of associations are activated contingently, prototypically, and efficiently with the goal of forming a cognitive field (analytically represented as a closed cycle) to connect head and modifier in a balanced way. The balanced system of concepts is strengthened further by changing the strength of the activated associations to reconcile the remaining tension in the cognitive field.

More importantly, this research opens up a question: what is the relationship between schema-based models on conceptual combination and the association framework proposed in this thesis? Could we derive the schema based models from the association framework? I agree with Gagne that we know that certain words do related to one another in certain ways, and I agree with schema theorists that we know *apple* does have *color* and *color* could be *red*. In a sense, we do have various ways to structure our knowledge in certain ways. The difference that I am suggesting is that the causal mechanism is not built in that structure; rather, the simple associations may be guiding the combination process. For example, when we combine *red apple*, do we treat *color* as logically prior to *red* so that *apple* is associated to *red* via *color*? Or do we treat *red* as the direct association of *apple*, and *color* is just another association of both *apple* and *red*? In a sense, does *color* enjoy a special characteristic of being an organizer, a slot, or a dimension that is different from so-called value *red*? Or may be *color* is not different from *red* in terms of being associations of *apple* and they are only different when we generate a logical structure (a schema of *apple*) later? That is, what is logically prior in combining concepts?

Clearly, the syntactic relations and schema structure must play a role in combining concepts, such as putting constraints of certain types. How these kinds of knowledge structures, which could be grammatical in nature, or more cognitive in nature, related to the association framework that I proposed? For instance, could we derive from the association framework a kind of mechanism similar to slot filling?

In the framework, the meaning of a combination amounts to a coherent Gestalt understanding. The parts that make up the meaning are the knowledge of the conceptual units. Thus, the meaning construction process is to construct a Gestalt representation that draws on, as its inputs, the knowledge we have related to these conceptual units. However, not all we know about a conceptual unit will show up in the meaning of a combination. Only relevant associations are activated based on contingency, prototypicality, balance and cognitive efficiency constraints. Thus, activation is biased in terms of fulfilling the goal: only associations that are most probable in terms of linking the component concepts will be activated, and activation will stop when a meaning that suits our current goal has been constructed. Here, the salience of an association (activated strongly) is based on the context, rather than as a property inherent to a concept. Thus, whether or not an association is salient depends on the current goal of activation and the context in which activation happens. This theorizing explains the emergent nature of association activation during meaning construction.

The framework emphasizes the goal-directed nature of meaning construction and that balance is a perspective-based variable, i.e., different people have different perspectives / goals when they construct a balanced cycle; and the same individual may take different perspectives at different stages of the meaning construction process. Indeed, the construction of a balanced cycle involves shifting figure-ground relationship as different parts of our knowledge are organized into different Gestalts based on different perspectives and goals.

In conclusion, a framework on meaning construction through conceptual interactions is proposed and tested in this thesis. Future research is needed to examine a few remaining issues.

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Appendix 1

280 concepts selected after the first round of examination of the raw data

Actuator, Air-Conditioner, Aircraft, Alcohol, Alkalies, Alumina, Aluminum, Apparel, Automobile, Bag, Battery, Bearing, Belting, Beverage, Binders, Blade, Blankbook, Block, Blouse, Blower, Boiler, Bolt, Books, Bottle, Box, Brake, Bread, Brick, Broom, Brush, Bulb, Butter, Button, Cabinet, Cable, Cakes, Camper, Can, Canvas, Cap, Capacitor, Carburetor, Carpet, Casket, Cement, Ceramics, Cereal, Cheese, Chemical, Chlorine, Chocolate, Cigarette, Circuit, Clay, Clock, Clothes, Coat, Coffee, Coil, Compressor, Computer, Concrete, Connector, Container, Conveyor, Cookie, Copper, Cord, Cordage, Corn, Costume, Countertop, Cracker, Crane, Curtain, Cutlery, Cylinder, Detergent, Die, Doll, Door, Dough, Drapery, Dress, Drum, Dye, Earthenware, Electronic, Elevator, Embroidery, Engine, Envelope, Explosives, Fabric, Fan, Fastener, Fertilizer, Fibers, Filaments, Fixture, Flatware, Flooring, Flour, Foam, Footwear, Forms, Freezer, Fruit, Furnace, Furniture, Game, Garden, Gas, Gasket, Gear, Generator, Glass, Glassware, Glove, Graphite, Grease, Gum, Handbag, Handsaw, Handtool, Hat, Heater, Hoist, Hollowware, Hoses, Hosiery, Housewares, Ice, Inductor, Ink, Jacket, Jean, Jig, Juice, Lace, Lamp, Laundry, Lawn, Lens, Lighting, Linen, Lingerie, Locker, Loungewear, Luggage, Lumber, Malt, Mayonnaise, Meat, Medicine, Metals, Milk, Millwork, Missile, Mitten, Mold, Monorail, Mop, Motor, Neckwear, Needle, Newsprint, Nightwear, Nuts, Ordnance, Outerwear, Oven, Overcoat, Packaging, Pallet, Pan, Paper, Paperboard, Partition, Pasta, Pastries, Pen, Pencil, Pesticide, Petrochemical, Pharmaceutical, Pies, Pigment, Pin, Pipe, Piston, Plastics, Plumb, Plywood, Polystyrene, Porcelain, Pot, Pottery, Printer, Pulp, Pump, Purse, Radio, Refrigerator, Relay, Resin, Resistor, Ribbon, Rice, Rivet, Roof, Rope, Rubber, Rug, Sauce, Saw, Sawmill, Screw, Seasoning, Seat, Semiconductor, Shelve, Shingle, Shirt, Shirt, Showcase, Sign, Skirt, Slack, Slipper, Snack, Soap, Sock, Spice, Stacker, Starch, Stationery, Steer, Sugar, Suspension, Switchboard, Switchgear, Syrup, Tablet, Tank, Tea, Telephone, Television, Textile, Thread, Tile, Tire, Tobacco, Tool, Tortilla, Toy, Tractor, Trailer, Transformer, Transmission, Trouser, Truck, Truss, Tube, Turbine, Twine, Underwear, Urethane, Utensil, Vacuum, Valve, Vegetable, Vehicle, Veneer, Ventilation, Washer, Watch, Window, Woodwork, Yarn

Appendix 2

The second round of data filtered with 55 concepts (bold face) left

311 Food Manufacturing	
3112	Grain and Oilseed Milling: **Flour, Cereal, Sugar, Chocolate**
3115	Dairy Product Manufacturing: **Milk, Butter, Cheese**
3118	Bakeries and Tortilla Manufacturing: **Bread, Cakes, Pies, Cookie, Cracker, Pasta**
312	Beverage and Tobacco Product Manufacturing
3121	Beverage Manufacturing: **Beverage, Ice**
314 Textile Product Mills	
3141	Textile Furnishings Mills: **Carpet, Curtain**
315 Apparel Manufacturing	
3152	Cut and Sew Apparel Manufacturing: **Coat, Jean, Clothing, Jacket**
3159	Apparel Accessories and Other Apparel Manufacturing: **Hat, Cap**, **Glove Mitten**
322 Paper Manufacturing	
3222	Converted Paper Product Manufacturing: **Paper, Box, Stationery, Envelope**
325 Chemical Manufacturing	
3251	Basic Chemical Manufacturing: **Gas, Gum, Alcohol**
3256	Soap, Cleaning Compound, and Toilet Preparation Manufacturing: **Soap, Detergent**
332 Fabricated Metal Product Manufacturing	
3322	Cutlery and Handtool Manufacturing: **Pot, Pan**
333 Machinery Manufacturing	
3334	Ventilation, Heating, Air-Conditioning, and Commercial Refrigeration Equipment Manufacturing: **Air-Conditioner, Fan, Heater**
334 Computer and Electronic Product Manufacturing	
3342	Communications Equipment Manufacturing: **Telephone, Radio, Television**
3345	Navigational, Measuring, Electromedical, and Control Instruments Manufacturing: **Watch, Clock**
335 Electrical Equipment, Appliance, and Component Manufacturing	
3351	Electric Lighting Equipment Manufacturing: **Lamp, Bulb**
3352	Household Appliance Manufacturing: **Refrigerator, Freezer, Furnace**
336 Transportation Equipment Manufacturing	
3361	Motor Vehicle Manufacturing: **Vehicle, Automobile**
337 Furniture and Related Product Manufacturing	
3371	Household and Institutional Furniture and Kitchen Cabinet Manufacturing: **Furniture, Cabinet**
3372	Office Furniture (including Fixtures) Manufacturing: **Shelving, Locker**

Appendix 3

The stimuli distribution for experiment one - task 1

Concept set	Conceptual Entity	S. G. 1*	S. G. 2	S. G. 3	S. G. 4	S. G. 5	S. G. 6	S. G. 7
1	Hat	x						
	Mitten	x						
	Butter	x						
	Hat Mitten		x					
	Hat Butter			x				
	Mitten Butter				x			
	Mitten Hat					x		
	Butter Hat						x	
	Butter Mitten							x
2	Telephone		x					
	Television		x					
	Soap		x					
	Telephone Television	x						
	Telephone Soap			x				
	Television Soap				x			
	Television Telephone					x		
	Soap Telephone						x	
	Soap Television							x
3	Cereal			x				
	Chocolate			x				
	Watch			x				
	Cereal Chocolate	x						
	Cereal Watch		x					
	Chocolate Watch				x			
	Chocolate Cereal					x		
	Watch Cereal						x	
	Watch Chocolate							x
4	Bread				x			
	Cookie				x			
	Pasta				x			
	Bread Cookie	x						
	Bread Pasta		x					

	Cookie Pasta			x				
	Cookie Bread					x		
	Pasta Bread						x	
	Pasta Cookie							x
5	Carpet					x		
	Box					x		
	Envelop					x		
	Carpet Box	x						
	Carpet Envelop		x					
	Box Envelop			x				
	Box Carpet				x			
	Envelop Carpet						x	
	Envelop Box							x
6	Heater						x	
	Air-conditioner						x	
	Furnace							x
	Refrigerator							x
	Heater Air-conditioner					x		
	Air-conditioner Heater							x
	Heater Furnace		x					
	Furnace Heater	x						
	Heater Refrigerator				x			
	Refrigerator Heater			x				
	Air-conditioner Furnace				x			
	Furnace Air-conditioner			x				
	Air-conditioner Refrigerator		x					
	Refrigerator Air-conditioner	x						
	Furnace Refrigerator						x	
	Refrigerator Furnace					x		

* S. G. refers to student group

Appendix 4

The Stimuli distribution for experiment one - task 2

S. G. 1*	S. G. 2	S. G. 3	S. G. 4	S. G. 5	S. G. 6	S. G. 7
Telephone Soap	Hat Butter	Hat Mitten	Mitten Hat	Mitten Butter	Butter Mitten	Butter Hat
Television Soap	Cereal Chocolate	Telephone Television	Television Telephone	Soap Telephone	Soap Television	Cereal Watch
Chocolate Watch	Chocolate Cereal	Bread Cookie	Watch Cereal	Watch Chocolate	Bread Pasta	Cookie Pasta
Cookie Bread	Pasta Bread	Pasta Cookie	Carpet Box	Air-conditioner Heater	Carpet Envelope	Box Envelope
Box Carpet	Envelope Carpet	Envelope Box	Heater Air-conditioner	Heater Furnace	Furnace Heater	Heater Refrigerator
Refrigerator Heater	Air-conditioner Furnace	Air-conditioner Refrigerator	Furnace Air-conditioner	Refrigerator Air-conditioner	Refrigerator Furnace	Furnace Refrigerator

*S. G. refers to student group

Appendix 5

A sample of the experiment web pages for experiment one:

Information Letter

You are being invited to participate in a Bonus Activity. If you choose to participate in this voluntary activity, you will receive 1 bonus mark on top of your total grade for this course. If you agree to participate, please complete this web-based survey that will take about 40 minutes. The survey has multiple pages divided into 3 sections. This is not a test, and there are no correct answers. We are really interested in your initial reactions in terms of how you understand certain **well-known** products or **new & creative** products. Please read and follow instructions and provide your answers carefully. Please do not use dictionaries and do not go back to change any of your answers after completing. We want you to take this activity seriously. In order to receive the bonus mark, we will be looking at your response to determine if you have complied**.**

In the first section, you will be presented with either a well-known or creatively new product. We are interested in your initial thinking about this product, and your task will be to define this product and explain its characteristics & functions using your own words. In the second section, you will be presented 6 products that you are either familiar with or unfamiliar with, and your task will be to rank how familiar you are with these products.

Informed Consent Form

I state that I wish to participate in a program of research being conducted by Dr. R. Duimering and Bing Ran, Fall 2005, Department of Management Sciences, Faculty of Engineering, University of Waterloo.

This survey meets with ethical guidelines and complies with the University of Waterloo's standards for ethical research. There are no known risks to participating in this research. Participation in this survey is voluntary. All information will be kept confidential and on a secure server. You may decline to answer any question that you do not wish to answer and you can withdraw your participation at any time. Your participation or non-participation will have no impact on your relationship with the University of Waterloo. If you decline to participate, you could do an alternative assignment with comparable workload to earn the same bonus mark within the deadline. Please contact Bing Ran for this alternative.

This research is being conducted under the supervision of Dr. R. Duimering. Questions or comments may be directed to the Department of Management Sciences at 888-4567, ext. 2974 or e-mail bran@engmail.uwaterloo.ca

This survey will be available for your input from Wednesday, November 39th, 2005 to Wednesday December 14th, 2005 (2 weeks).

If you agree to participate, please click the button "Continue".

Continue

Section 1 (9 products)

The following products are either well-known or creatively new. We are interested in your initial thinking about this product, and your task will be to define this product and explain its characteristics & functions using your own words.

Butter

1. What are the first things that come to your mind when you think of this product?

Next Question >>

Section 1 (9 products)

The following products are either well-known or creatively new. We are interested in your initial thinking about this product, and your task will be to define this product and explain its characteristics & functions using your own words.

Butter

2. Please define / describe / explain this product in your own words:

Next Question >>

Section 1 (9 products)

The following products are either well-known or creatively new. We are interested in your initial thinking about this product, and your task will be to define this product and explain its characteristics & functions using your own words.

Butter

3. What are some of the characteristics or attributes of this product and how this product might be used?

Next Question >>

Section 2 (6 products)

The following products may be familiar or unfamiliar to you because they are either real products or hypothetic products. Using your general knowledge or imagination, please rate these products based on how familiar they are to you or how easy it is for you to imagine such a product. Please rate on a scale from 1 to 5 where 1 means least familiar or most difficult to imagine and 5 means most familiar or easiest to imagine. Select your rating from the drop-down list.

1	2	3	4	5
Least Familiar				Most Familiar

28. Telephone Soap

Next Question >>

Appendix 6

Experiment One Raw data: the Butter example

Subject code	Butter Question #1	Butter Question #2	Butter Question #3
g1v1-1	its soft and usually yellow. 'it tastes better with butter'. its oily and makes u fat!	This product is categorized as food. You use it as an additive to food to make it taste better. it is yellow and soft and can be spread on bread with a knife. It is considered to be fattening..	It is soft and yellow. It can be spread on bread using a knife. It can be rubbed on meat or put in rice to make it taste better. People have it with a whole array of different foods.
g1v1-2	Toast. Cooking; we can use it instead of oil. Easy to spread when it is warm. Salted or unsalted, Margarine is an alternative to butter.	Butter is a type of fat (animal fat) that can be used to improve the taste of various food elements, such as toast, potatoes, vegetables, turkey, etc. It can also be used to cook/fry, instead of cooling oil.	Characteristics are: -Colour: Yellow _Taste: Salted or unsalted -Texture: Greasy This product can be used as cooking oil or as a spread on toasts.
g1v1-3	this is a food item that is also used in baking.	Butter is obtained from fats and used in different baking and also as a spread.	its solid when cold. Melts to oils when heat is applied. It is used in baking and as a spread for bread and other pastries.
g1v1-4	Margarine. You see a lot more margarine ads on TV than you do for butter. Besides this, butter invokes thoughts about food, particularly other dairy products like say, havarti cheese. The point I want to make is that it never invokes thoughts of itself, ie - butter never makes me think of butter itself, perhaps because its always available, eihter at home or in the store.	Butter is in my words, a dairy product, that is readily available and commonly used, especially in breakfast.	Characteristics: - needs to be refrigerated - looks yellow - soft when not in the fridge, otherwise hard - tastes creamy Usage: - primarily in food as added flavour - in breakfast with toast - when cooking, say, eggs or any other usage with food - not used beyond the scope of food.

g1v1-5	The first things that come to mind when I think of butter are: greasy, shiny, slippery, beige, baking, toast	Butter, is churned from milk, which is made naturally by cows. It is a greasy product (grease consisting of fats and other natural ingredients) that can be used for a wide array of things from 'buttering' toast to preparing baked goods.	It is slippery, greasy, shiny, yellowish in colour, it can be salted or unsalted, it can come in different percentages of fat content, it is sometimes substituted with margarine, a similar substance. Butter can be used for baking, cooking, it can be used as a topping and it is even used by some as a natural remedy for sore muscles.
g1v2-1	Butter is a spread that is often used on toast or used in pans to prevent the food from sticking while cooking. Butter is generally yellow and creamy.	Butter is an oily creamy paste. Butter is made from churned milk and can be used as a spread on toast and to prevent food from sticking in the pan.	Butter is creamy and is a churned milk product. The product is used to enhance the flavour of toast and bagels.
g1v2-2	The first thing that comes to my mind is a Yellow bar of butter that is eaten with slices of bread for breakfast.	Butter is a food product that is derived from milk. Butter is thought of being extremely delicious and because of this quality it is used in the preparation of many different kinds of food products. Butter is used in cakes, pastries as well as curries and rice.	Derived from Milk - Extremely tasty - Used for frying products. frying food products in butter gives it a great taste - Has very high cholestrol, therefore, it is not good for health, if too much of it is consumed. - Used all over the world in different culinary items.
g1v2-3	cooking, toast, cooking material	A dariy product that can be made from a variety of different animals milk, usually cows. It is made from the fat in the milk. It is soild and easy to spread when needed.	It is mainly used for cooking purposes. It can be used for food, butter with toaste to to ensure that the food will not stick to the pan.
g1v2-4	It goes on bread or muffins	It is made from cow's/goat's milk by turning it	It is usually found refridgerated. It is usually yellow or white. It is usually hard cold and soft warm It can be used as a spread or for baking, instaed of oil

g1v2-5	Milk, margerine, toast, pancakes, fat	Butter is a milk product made from the agitation of milk. It is a yellow, thick substance that is in solid state when cold.	Butter has oil-like properties and assists in cooking, baking and frying. Butter can be used to grease up a frying pan or it can be used on bread, pancakes to improve flavor.
g1v3-1	A yellow substance extracted from milk that is used in food to cook or add flavour.	Extracted from milk, it is used to enhance the cooking of food. furthermore, it is yellow in colour and smooth in texture. When used in food it adds flavour but is high in chlosterol.	Yellow in colour, smooth in texture. When heated it becomes a liquid. This product is used to cook food. It adds flavour to common food like bread.
g1v3-2	Dairy products, and butter on toast comes to mind. I also think about melted butter.	Butter is used for a number of food related uses, since you eat it. It is generally a yellow white colour and tastes good on bread. Can be used to make cookies or added in different cooking recipies	Butter is used to be added to food. Usually you do not eat it alone, but instead spread it on bread or add it to recipies
g1v4-1	Bread	A grease that will add some taste to the food when u put it on	oily, made by milk, fat it can be used to cook, to eat, to bake, to make cake
g1v4-2	cow	dairy oil	characteristics: fatty, natural, yellow used: cooking, eat with bread
g1v4-3	it's a high calory food, and it contains a lot of fat.	It's an aside food, not a main dish, and it's yellow in colour.	it's really fatteny. We use it to add more taste to food, such as bread or soup.
g1v4-4	bread, toaste,	it is used to put on the bread and make a breakfast	milky, tasty, used to cook , used to make sandwitch
g1v4-5	Butter is a type of food. It tastes great with bread, toast and bagel. Its characteristics are that it easily melts and it is fattening.	Butter is a type of food. It easily melts and it tastes great with bread, toast and bagel.	Butter easily melts and it is fattening. It is usually eaten with bread, toast and bagel. Also, melted butter is to be dipped in with lobster meat or crab meat.

Appendix 7

Experiment One result: the most prominent associations for each conceptual entity

Conceptual Entity	Most Prominent Associations	Association #
Hat	It is worn on the head	1
	It protects the head	2
	It is used in different environmental conditions (sun, rain, cold)	3
	It adds fashion or style	4
	It is used in baseball	5
	It is made from different materials	6
	It is an article of clothing	7
	It has various shapes	8
	It has different types such as toques	9
	It is mass-manufactured	10
Mitten	It protects the hands	11
	It is used in cold weather	12
	It is made of wool or cotton	13
	It separates thumb from other fingers	14
	It is worn on the hands	15
	It is a type of glove	16
	It is made up of polyester materials	17
	It is an article of clothing	18
	It is used in some sports	19
	It is used primarily by children	20
Butter	It is used in cooking, baking and frying	21
	It is spread on toast	22
	It is yellowish beige	23
	It adds flavour to food	24
	It is extracted from milk	25
	It is a type of food	26
	It is fattening	27
	It is greasy and oily	28
	It is soft when warm	29
	It is solid when cold	30
Hat Mitten	It is a type of mitten	31
	It is a type of hat	32

	It keeps you warm	33
	It is used in cold winter weather	34
	It is made out of warm materials	35
	It has different colours	36
	It is used for both head and hand	37
	It is for kids or babies	38
	It is thick	39
	It is comfortable and cozy	40
Mitten Hat	It is a type of hat	41
	It is a type of mitten	42
	It keeps you warm	43
	It is used in cold weather	44
	It is made out of wool	45
	It is worn on both head and hands	46
	It is colourful	47
	It adds fashion and style	48
	It is a type of winter clothing	49
	It has a universal shape to fit most people	50
Hat Butter	It is a type of hat	51
	It is a type of butter	52
	It is a lubricant	53
	It is a sculpture	54
	It is worn in cold weather	55
	It is yellow	56
	It is soft	57
	It is used to soften hair	58
	It is not easy to melt	59
	It smells pretty bad	60
Butter Hat	It is a type of hat	61
	It is a type of butter	62
	It cannot be worn	63
	It is made of yellow leather	64
	It prevents insect damage	65
	It is soft	66
	It is used for dispensing	67
	It is warm	68
	It makes dishes more tasty	69
	It is used for decoration	70

Mitten Butter	It is a type of butter	71
	It is a type of mitten	72
	It is shaped like a glove	73
	It is a hand lotion for moisturizing	74
	It is a lubricant	75
	It is used to serve something warm	76
	It is a source of warmth	77
	It is yellow coloured	78
	It is a stain	79
	It is slippery	80
Butter Mitten	It is a type of mitten	81
	It is a type of butter	82
	It is sticky	83
	It is used to handle slippery objects	84
	It is grease-proof	85
	It is used when cooking something hot	86
	It is a lid for a container	87
	It is made of latex or silicone	88
	It protects hands from the cold	89
	It is easy to clean	90
Telephone	It is a communication device	91
	It is used to talk to people	92
	It has a dial pad	93
	It requires phone numbers	94
	It connects to a cable	95
	It could be mobile	96
	It is a small, handheld device	97
	It rings	98
	It comes in different models	99
	It comes in different shapes	100
Television	It is an entertainment device	101
	It is a source of information	102
	It shows various shows, events, etc	103
	It has a flat screen	104
	It has a large screen	105
	It has buttons to change the volume and channel	106
	It is connected to cable	107
	It is an electrical device	108

	It has remote control	109
	It is a diversion from reality	110
Soap	It is used for cleaning	111
	It removes dirt	112
	It is in the shape of a bar	113
	It has an aroma	114
	It is liquid or solid	115
	It dissolves in water	116
	It forms bubbles	117
	It is slippery when wet	118
	It is used in the shower or bath	119
	It is antibacterial	120
Telephone Television	It is a type of television	121
	It is a type of telephone	122
	It identifies callers	123
	It is used for videoconferencing	124
	It has a screen	125
	It is used to play videos	126
	It is very practical	127
	It is small	128
	It is ideal for people who can not speak	129
	It is used to participate in polls or surveys	130
Television Telephone	It is a type of television	131
	It is a type of telephone	132
	It uses advanced technology	133
	It can view TV shows	134
	It has a coloured screen	135
	It is used to share and transfer information	136
	It is used for entertainment	137
	It is easy to use	138
	It is plasma or LCD	139
	It is similar to a web cam	140
Telephone Soap	It is a type of soap	141
	It is a type of telephone	142
	It cleans electrical appliances	143
	It sanitizes and gets rid of germs	144
	It is easy to hold	145
	It is marketed towards younger children	146

	It comes in a liquid gel or spray can	147
	It is for decorative purpose	148
	It refers to clean talking	149
	It is portable	150
Soap Telephone	It is a type of telephone	151
	It is a type of soap	152
	It is used in the bathtub or shower	153
	It is waterproof	154
	It is self cleaning	155
	It generate bubbles instead of ringing	156
	It is a decorative piece	157
	It is has a slippery exterior	158
	It is used by kids	159
	It looks like a bubble	160
Television Soap	It is a type of soap	161
	It is a type of television	162
	It is a daytime show	163
	It is a spray or liquid	164
	It is a product advertisement	165
	It refers to censorship for filtering programmes	166
	It has different colours	167
	It has a fragrance like new factory plastic	168
	It involve a never-ending drama	169
	It is loaded with sex appeal	170
Soap Television	It is a type of soap	171
	It is a type of television	172
	It refers to soap opera	173
	It is a channel for shows	174
	It is used in bath rooms	175
	It is waterproof	176
	It is a way to waste time	177
	It is especially big	178
	It is very loud	179
	It is melodramatic	180
Cereal	It is a breakfast food	181
	It is eaten with milk	182
	It is healthy	183
	It has sweet taste	184

	It is fast and easy to make	185
	It is a light snack	186
	It comes in boxes	187
	It is an energy booster	188
	It is made with wheat, oats, corn, grains, seed or fruits.	189
	It is eaten using bowl and spoon	190
Chocolate	It is sweet	191
	It is dark brown	192
	It is delicious	193
	It is an additive to other foods	194
	It is loved by everyone especially kids	195
	It is milky and creamy	196
	It is high in fat and calories	197
	It is a gift for all occasions	198
	It is romantic	199
	It gets soft when it is warmed	200
Watch	It tells and tracks time	201
	It is worn on the wrist	202
	It is digital or analog	203
	It is small and portable	204
	It has a circular shape	205
	It shows people's stature	206
	It is an organizational tool	207
	It is a fashionable accessory	208
	It has numbers or tick marks	209
	It has a display for dates	210
Cereal Chocolate	It is a type of cereal	211
	It is a type of chocolate	212
	It is a breakfast item	213
	It is sweet	214
	It is unhealthy	215
	It is eaten with milk	216
	It is a snack	217
	It is tasty	218
	It is nutritious	219
	It is brown	220
Chocolate Cereal	It is a type of cereal	221
	It is a type of chocolate	222

	It is a breakfast food	223
	It is sweet	224
	It is eaten with milk	225
	It is tasty	226
	It has cocoa flavour	227
	It is crunchy	228
	It is made from cocoa powder	229
	It is for kids	230
Cereal Watch	It is a type of watch	231
	It is a type of cereal	232
	It is cheap	233
	It is a free gift	234
	It is for breakfast	235
	It is a toy	236
	It has low quality	237
	It is designed for children	238
	It is made of plastic	239
	It is made out of corn flakes	240
Watch Cereal	It is a type of cereal	241
	It is a type of watch	242
	It is a toy	243
	It is small	244
	It is shaped like numbers	245
	It helps children to learn to tell time	246
	It is colourful	247
	It is a marketing tool	248
	It has very bad quality	249
	It is low in calories	250
Chocolate Watch	It is a type of watch	251
	It is a type of chocolate	252
	It is brown in colour	253
	It is edible	254
	It is sweet	255
	It is a toy for kids	256
	It is a candy necklace	257
	It might melt	258
	It is sticky and messy	259
	It is a novelty snack	260

Watch Chocolate	It is a type of chocolate	261
	It is a type of watch	262
	It is made out of cocoa	263
	It is a snack	264
	It is brown coloured	265
	It is sweet	266
	It is a piece of decoration	267
	It is a novelty gift	268
	It is tasty	269
	It is a kind of candy	270
Bread	It is made from wheat or grain	271
	It is used to make sandwiches	272
	It is a source of carbohydrates	273
	It is eaten with jam	274
	It is for breakfast	275
	It is soft	276
	It is oven baked	277
	It is made from dough	278
	It is made from flour and yeast	279
	It is white or brown	280
Cookie	It is sweet	281
	It is a type of dessert	282
	It is round in shape	283
	It is a snack	284
	It is made of oatmeal	285
	It is crispy and crunchy	286
	It is baked	287
	It is tasty and chewy	288
	It is sold in large quantities	289
	It is used as a reward for children	290
Pasta	It is an Italian food	291
	It has lots of carbohydrates	292
	It is easy to cook	293
	It is made from flour and water	294
	It is eaten with tomato sauce	295
	It is used to make spaghetti	296
	It is tasty	297
	It is cheap to buy	298

	It is soft	299
	It is yellow in colour	300
Bread Cookie	It is a type of bread	301
	It is a type of cookie	302
	It is sweet	303
	It has slices	304
	It is round shaped	305
	It is crispy	306
	It is soft	307
	It is a snack or a small meal	308
	It has white crumbs	309
	It is surrounded by a thick crust	310
Cookie Bread	It is a type of bread	311
	It is a type of cookie	312
	It is sweet	313
	It is tasty	314
	It is round in shape	315
	It is crispy and crunchy	316
	It is a food product	317
	It has chocolate chips	318
	It is soft	319
	It is chewy	320
Bread Pasta	It is a type of bread	321
	It is a type of pasta	322
	It is made from flour	323
	It is made from whole wheat	324
	It is a food product	325
	It provides carbohydrates	326
	It is starchy	327
	It is like pita	328
	It has different colours	329
	It has different shapes	330
Pasta Bread	It is a type of bread	331
	It is a type of pasta	332
	It is shaped like thin strips	333
	It is eaten with sauce	334
	It contains very little sugar	335
	It is an appetizer	336

	It is something sold at a sub restaurant (e.g., Subway)	337
	It has a light brown crust	338
	It cooks very easily	339
	It is healthy	340
Cookie Pasta	It is a type of pasta	341
	It is a type of cookie	342
	It is sweet	343
	It is a type of dessert	344
	It is a snack	345
	It is a main dish	346
	It is a children's food	347
	It is eaten with chocolate sauce	348
	It is eaten with tomato or cheese sauce	349
	It is red in colour	350
Pasta Cookie	It is a type of cookie	351
	It is a type of pasta	352
	It is tasty and delicious	353
	It has sugar	354
	It is Italian	355
	It is a snack	356
	It is filling	357
	It looks disgusting	358
	It is served as an appetizer	359
	It is long in length	360
Carpet	It covers an area of floor	361
	It is soft	362
	It is colourful	363
	It is used to decorate	364
	It is smooth	365
	It is dirty	366
	It provides warmth	367
	It is cleaned by vacuuming	368
	It is made of thick fabrics	369
	It has floral patterns	370
Box	It stores things	371
	It is cubic / rectangular in shape	372
	It is made of cardboard	373
	It is brown	374

	It is used to transport / ship items	375
	It is heavy	376
	It has a rigid exterior	377
	It is used for packaging	378
	It is wooden	379
	It is large	380
Envelope	It is used to mail things	381
	It is white	382
	It is made of paper	383
	It has a sealable flap	384
	It is for safe keeping	385
	It has security features	386
	It is rectangular	387
	It is thin	388
	It is light	389
	It is cheap	390
Carpet Box	It is a type of box	391
	It is a type of carpet	392
	It is used for storage	393
	It is covered by a thick layer	394
	It protects something against scratch and damage	395
	It is used for shipping	396
	It is long	397
	It has a rectangular shape	398
	It is impact resistant	399
	It has wheels on the bottom	400
Box Carpet	It is a type of box	401
	It is a type of carpet	402
	It is foldable	403
	It is covered with thick material	404
	It is small	405
	It is aesthetically pleasing	406
	It is cheap	407
	It is used when christmas approaches	408
	It is shaggy	409
	It is modular	410
Carpet Envelope	It is a type of envelope	411
	It is a type of carpet	412

	It is used to hold something	413
	It is made of paper	414
	It is a plastic wrap to protect something	415
	It has colourful designs	416
	It is heavy	417
	It is thick	418
	It is big	419
	It adds extra protection to the packaging	420
Envelope Carpet	It is a type of carpet	421
	It is a type of envelope	422
	It is small in size	423
	It has a triangular flap	424
	It is folded on the floor	425
	It is uncomfortable to walk on	426
	It holds things	427
	It is large in size	428
	It is rectangular in shape	429
	It is used on the walls and the ceiling	430
Box Envelope	It is a type of box	431
	It is a type of envelope	432
	It is used for mailing	433
	It is thin	434
	It is easy to seal and open	435
	It is light weight	436
	It is made out of paper	437
	It has shipping labels	438
	It holds something	439
	It has a large carrying capacity	440
Envelope Box	It is a type of box	441
	It is a type of envelope	442
	It stores mail accessories	443
	It is found in an office desk	444
	It is used in the post office	445
	It holds mail or letters	446
	It is small and compact	447
	It is red	448
	It is rectangular in shape	449
	It seals up quickly	450

Air-conditioner	It cools down a space	451
	It circulates cool air	452
	It is used in the summer	453
	It is expensive to run	454
	It uses a lot of electricity	455
	It is a relatively large device	456
	It has large fans	457
	It is used in windows	458
	It creates a lot of heat	459
	It provides a comfortable temperature	460
Heater	It is used to heat up or warm	461
	It is used in cold winters	462
	It is small	463
	It is a plug-in device	464
	It requires gas	465
	It uses electricity	466
	It has fans or vents behind a grill	467
	It is in the basement	468
	It is expensive to run	469
	It hums a little	470
Refrigerator	It keeps things cold	471
	It keeps things fresh	472
	It stores food or drinks	473
	It has two sections: fridge and freezer	474
	It is white	475
	It can be used efficiently as a heat pump	476
	It is rectangular shaped	477
	It is usually big (not portable)	478
	It is an electric appliance	479
	It has a distinct humming sound	480
Furnace	It heats or warms a house or building	481
	It is in the basement	482
	It is used in cold climates, in winter	483
	It uses gas	484
	It is a bulky appliance	485
	It is a metallic device	486
	It burns wood	487
	It uses electricity	488

	It has a thermostat to control its operations	489
	It is white	490
Air-conditioner Heater	It is a type of heater	491
	It is a type of air-conditioner	492
	It is an all-in-one appliance	493
	It has a ventilation system	494
	It heats or warms air	495
	It is used in apartments or small offices	496
	It is small and portable	497
	It provides cool air	498
	It is useless	499
	It is placed in a window	500
Heater Air-conditioner	It is a type of air-conditioner	501
	It is a type of heater	502
	It provides hot or cool air	503
	It is used in all seasons	504
	It is ideal for apartments, houses, buildings	505
	It can be used in a car	506
	It is economically cheap	507
	It is small and portable	508
	It is used in tight / packed spaces	509
	It pollutes	510
Air-conditioner Refrigerator	It is a type of refrigerator	511
	It is a type of air-conditioner	512
	It keeps things cold	513
	It emits cool air	514
	It is used in summer	515
	It is big	516
	It cools a lot of food at once	517
	It uses electricity	518
	It produce ice	519
	It has improved efficiency	520
Refrigerator Air-conditioner	It is a type of air-conditioner	521
	It is a type of refrigerator	522
	It has a large cool-air producing capacity	523
	It is ideal in large households, offices, and buildings	524
	It is an all-in-one device	525
	It has vents to circulate cold air	526

	It is expensive	527
	It is not used in houses	528
	It expels cold air by fans	529
	It is used in the summer	530
Air-conditioner Furnace	It is a type of furnace	531
	It is a type of air-conditioner	532
	It has heating and cooling capabilities	533
	It cleanses air	534
	It is a two-way unit	535
	It uses heat exchange principles	536
	It saves energy	537
	It is used in all seasons	538
	It is difficult to maintain	539
	It requires little maintenance	540
Furnace Air-conditioner	It is a type of air-conditioner	541
	It is a type of furnace	542
	It is dual function machine	543
	Its usage depends on the season	544
	It saves space	545
	It saves cost	546
	It saves energy	547
	It is rectangular shaped	548
	It can adjust the temperature	549
	It has a control panel	550
Heater Refrigerator	It is a type of refrigerator	551
	It is a type of heater	552
	It is big and bulky	553
	It has three compartments: fridge, freezer, and microwave	554
	It produces heat to warm up a space	555
	It keeps food warm or cold as desired.	556
	It produces heat at the back	557
	It is a heavy piece of equipment	558
	It heats or cools the air	559
	It raises the electricity bills	560
Refrigerator Heater	It is a type of heater	561
	It is a type of refrigerator	562
	It is an all-in-one device	563
	It is used for travel purposes	564

	It speeds up the rate of defrosting in a fridge	565
	It is box shaped	566
	It reduces heating costs	567
	It is small	568
	It cools food and heats food	569
	It is hot in the back	570
Heater Furnace	It is a type of furnace	571
	It is a type of heater	572
	It warms up a home	573
	It has a chamber to produce heat	574
	It is used in winter when it is cold outside	575
	It consumes lots of energy	576
	It is large	577
	It is expensive to run	578
	It has fire retardant material	579
	It provides hot water	580
Furnace Heater	It is a type of heater	581
	It is a type of furnace	582
	It is a centralized system	583
	It distributes warm air	584
	It is portable	585
	It is connected to the ventilation system	586
	It is big	587
	It is used in cold weather	588
	It is powered by natural gas or wood	589
	It is energy efficient	590
Refrigerator Furnace	It is a type of furnace	591
	It is a type of refrigerator	592
	It has dual function	593
	It is a great energy saver	594
	It utilizes the heat it produces to warm up something	595
	It is aimed at protecting the environment	596
	It is located in a kitchen	597
	It maintains food quality	598
	It maintains low temperature	599
	It is a single box-like unit	600
Furnace Refrigerator	It is a type of refrigerator	601
	It is a type of furnace	602

	It is a big machine	603
	It cools down something	604
	It is an all in one appliance	605
	It keeps food hot	606
	It prevents excessive heat	607
	It is economical to produce and use	608
	It is expensive to buy	609
	It is expensive to run	610

Appendix 8

Identical Associations dropped from Experiment Two

Association Numbers for Identical Associations in Brackets	Two-Concept Pair
(48, 4); (41, 32); (42, 31); (18, 7); (34, 12, 44); (43, 33)	Hat – Mitten
(62, 52); (61, 51); (66, 57); (23, 56)	Hat – Butter
(82, 71); (81, 72); (78, 23)	Mitten – Butter
(132, 122); (131, 121); (107, 95); (137, 101)	Telephone - Television
(152, 141); (151, 142); (119, 153);	Telephone – Soap
(171, 161); (172, 162)	Television – Soap
(223, 181, 213); (221, 211); (222, 212); (225, 182, 216); (224, 214, 191); (226, 218)	Cereal – Chocolate
(236, 243); (241, 232); (242, 231); (204, 244)	Cereal – Watch
(261, 252); (262, 251); (253, 265); (266, 191, 255)	Chocolate – Watch
(311, 301); (312, 302); (316, 286); (315, 283, 305); (319, 276, 307); (313, 281, 303)	Bread – Cookie
(273, 326); (331, 321); (332, 322); (293, 339); (299, 276)	Bread – Pasta
(356, 284, 345); (351, 342); (344, 282); (352, 341); (343, 281); (297, 353)	Cookie – Pasta
(401, 391); (402, 392); (372, 398); (393, 371)	Carpet – Box
(421, 412); (422, 411); (414, 383); (429, 387)	Carpet – Envelope
(441, 431); (442, 432); (436, 389); (383, 437); (449, 387); (434, 388); (433, 381)	Box – Envelope
(501, 492); (502, 491); (454, 469); (500, 458); (508, 497)	Air-conditioner - Heater
(521, 512); (522, 511); (530, 515, 453); (478, 516); (471, 513)	Air-conditioner – Refrigerator
(541, 532); (542, 531); (547, 537)	Air-conditioner - Furnace
(480, 470); (561, 552); (562, 551); (568, 463)	Heater - Refrigerator
(481, 573); (582, 571); (572, 581); (587, 577); (578, 469); (468, 482); (588, 483, 462); (488, 466); (484, 465)	Heater – Furnace
(602, 591); (601, 592); (478, 603); (490, 475)	Refrigerator - Furnace

Appendix 9

Information Letter and Consent Form for the Experiment Two

Title of the study: Meaning Construction in Novel Conceptual Combinations

Student Investigator: Bing Ran

University of Waterloo, Department of Management Sciences

(519) 884-4567 Ext. 2974

Faculty Supervisor: Professor Rob Duimering

University of Waterloo, Department of Management Sciences

(519) 888-4567 Ext.2831

You are being invited to participate in a survey that investigates the meaning of the conceptual combinations. In the survey, you will be asked to write down your description of certain products, either the familiar products, such as “table” or “coat”, or creatively new products, such as “table coat” or “coat table”.

Participation in this survey is voluntary, and will take approximately one hour of your time. By volunteering for participating the survey, you will learn about research in Organizational Behaviour sciences in general and the topic of creativity, innovation, and communication in particular. In addition, you will receive a detailed feedback sheet about the study when the study is complete, and 1% bonus mark towards your final grade. Or alternatively, you could earn the same bonus mark by doing an assignment. You may decline to answer any questions presented in the survey if you so wish. You may decide to withdraw from this survey at any time, and may do so without any penalty or loss of the bonus marks. All information you provide is considered completely confidential; indeed, your name will not be included or in any other way associated, with the data collected in the survey. Furthermore, because the interest of this study is in the average responses of the entire group of participants, you will not be identified individually in any way in any written reports of this research. All the date obtained in this survey will be retained indefinitely, in a locked office to which only researchers associated with the study have access. There are no known or anticipated risks associated with participation in this survey.

I would like to assure you that this study has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo. However, the final decision about participation is yours. If you have any comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes at this office at (519) 888-4567 Ext. 6005.

If you have any questions about participation in this survey, please feel free to ask me. If you have additional questions at a later date, please contact Bing Ran at (519) 888-4567 ext. 2974 or by email at bran@engmail.uwaterloo.ca

Thank you for your assistance in this survey.

Informed Consent Form

I agree to participate in a survey being conducted by Dr. R. Duimering and Bing Ran, Department of Management Sciences, Faculty of Engineering, University of Waterloo. I have made this decision based on the information I have read in the Information-Consent Letter and have had the opportunity to receive any additional details I wanted about the study. I understand that I may withdraw this consent at any time without penalty or lose of the bonus marks. My participation or non-participation will have no impact on my relationship with the University of Waterloo. If I decline to participate in this survey, I could do an alternative assignment to earn the same bonus mark.

I also understand that this survey has been reviewed by, and received ethics clearance through, the Office of Research Ethics at the University of Waterloo. I was informed that if I have any comments or concerns resulting from my participation in this study, I may contact the Director, Office of Research Ethics, at (519) 888-4567 ext. 6005.

With full knowledge of foregoing, I agree, of my own free will, to participate in this survey.

Yes No

Name:

Signature:

Student ID number:

Please proceed and thank you for your participation.

Appendix 10

The t test results for hypothesis 1 testing[15]

Concept Set	Original Source	Association Number	Evaluated Against Concept #1	Evaluated Against Concept #2	t value	p value
s1	c1	1	c1c2	c1c3	4.17	0.00
s1	c1	1	c3c1	c2c1	3.20	0.00
s1	c1	2	c1c2	c1c3	2.32	0.03
s1	c1	2	c3c1	c2c1	3.09	0.00
s1	c1	3	c1c2	c1c3	2.59	0.02
s1	c1	3	c3c1	c2c1	3.52	0.00
s1	c1	4	c1c2	c1c3	3.09	0.01
s1	c1	4	c3c1	c2c1	2.27	0.03
s1	c1	5	c1c2	c1c3	4.78	0.00
s1	c1	5	c3c1	c2c1	4.12	0.00
s1	c1	6	c1c2	c1c3	1.68	0.10
s1	c1	6	c3c1	c2c1	2.72	0.01
s1	c1	7	c1c2	c1c3	4.72	0.00
s1	c1	7	c3c1	c2c1	3.46	0.00
s1	c1	8	c1c2	c1c3	3.40	0.00
s1	c1	8	c3c1	c2c1	1.60	0.11
s1	c1	9	c1c2	c1c3	2.09	0.05
s1	c1	9	c3c1	c2c1	2.41	0.02
s1	c1	10	c1c2	c1c3	4.64	0.00
s1	c1	10	c3c1	c2c1	3.29	0.00
s1	c2	11	c1c2	c3c2	1.55	0.12
s1	c2	11	c2c1	c2c3	3.01	0.01
s1	c2	12	c1c2	c3c2	4.63	0.00
s1	c2	12	c2c1	c2c3	5.56	0.00
s1	c2	13	c1c2	c3c2	5.34	0.00
s1	c2	13	c2c1	c2c3	7.40	0.00
s1	c2	14	c1c2	c3c2	1.24	0.18
s1	c2	14	c2c1	c2c3	0.10	0.39
s1	c2	15	c1c2	c3c2	1.10	0.22
s1	c2	15	c2c1	c2c3	2.96	0.01
s1	c2	16	c1c2	c3c2	0.07	0.40
s1	c2	16	c2c1	c2c3	1.88	0.07
s1	c2	17	c1c2	c3c2	0.25	0.38
s1	c2	17	c2c1	c2c3	5.33	0.00
s1	c2	18	c1c2	c3c2	3.16	0.00

[15] The coding scheme used in this appendix is listed in Table 4-11.

s1	c2	18	c2c1	c2c3	7.97	0.00
s1	c2	19	c1c2	c3c2	0.86	0.27
s1	c2	19	c2c1	c2c3	0.36	0.37
s1	c2	20	c1c2	c3c2	2.71	0.01
s1	c2	20	c2c1	c2c3	1.22	0.19
s1	c3	21	c2c3	c1c3	2.55	0.02
s1	c3	21	c3c1	c3c2	2.90	0.01
s1	c3	22	c2c3	c1c3	0.89	0.26
s1	c3	22	c3c1	c3c2	4.45	0.00
s1	c3	23	c2c3	c1c3	0.96	0.25
s1	c3	23	c3c1	c3c2	2.51	0.02
s1	c3	24	c2c3	c1c3	1.47	0.13
s1	c3	24	c3c1	c3c2	1.26	0.18
s1	c3	25	c2c3	c1c3	0.09	0.39
s1	c3	25	c3c1	c3c2	1.30	0.17
s1	c3	26	c2c3	c1c3	1.34	0.16
s1	c3	26	c3c1	c3c2	0.42	0.36
s1	c3	27	c2c3	c1c3	0.32	0.38
s1	c3	27	c3c1	c3c2	3.30	0.00
s1	c3	28	c2c3	c1c3	0.29	0.38
s1	c3	28	c3c1	c3c2	3.86	0.00
s1	c3	29	c2c3	c1c3	0.63	0.32
s1	c3	29	c3c1	c3c2	0.50	0.35
s1	c3	30	c2c3	c1c3	1.11	0.21
s1	c3	30	c3c1	c3c2	2.15	0.04
s2	c1	91	c1c2	c1c3	9.42	0.00
s2	c1	91	c3c1	c2c1	4.95	0.00
s2	c1	92	c1c2	c1c3	6.68	0.00
s2	c1	92	c3c1	c2c1	4.12	0.00
s2	c1	93	c1c2	c1c3	4.38	0.00
s2	c1	93	c3c1	c2c1	2.86	0.01
s2	c1	94	c1c2	c1c3	3.97	0.00
s2	c1	94	c3c1	c2c1	3.99	0.00
s2	c1	95	c1c2	c1c3	4.41	0.00
s2	c1	95	c3c1	c2c1	2.85	0.01
s2	c1	96	c1c2	c1c3	2.87	0.01
s2	c1	96	c3c1	c2c1	2.69	0.01
s2	c1	97	c1c2	c1c3	3.09	0.01
s2	c1	97	c3c1	c2c1	3.02	0.01
s2	c1	98	c1c2	c1c3	6.23	0.00
s2	c1	98	c3c1	c2c1	4.13	0.00
s2	c1	99	c1c2	c1c3	3.90	0.00
s2	c1	99	c3c1	c2c1	2.55	0.02
s2	c1	100	c1c2	c1c3	2.37	0.03
s2	c1	100	c3c1	c2c1	2.88	0.01
s2	c2	101	c1c2	c3c2	1.05	0.23

s2	c2	101	c2c1	c2c3	2.26	0.03
s2	c2	102	c1c2	c3c2	1.56	0.12
s2	c2	102	c2c1	c2c3	3.02	0.01
s2	c2	103	c1c2	c3c2	0.38	0.37
s2	c2	103	c2c1	c2c3	1.14	0.21
s2	c2	104	c1c2	c3c2	1.78	0.08
s2	c2	104	c2c1	c2c3	4.00	0.00
s2	c2	105	c1c2	c3c2	0.80	0.29
s2	c2	105	c2c1	c2c3	3.72	0.00
s2	c2	106	c1c2	c3c2	3.88	0.00
s2	c2	106	c2c1	c2c3	3.87	0.00
s2	c2	107	c1c2	c3c2	0.36	0.37
s2	c2	107	c2c1	c2c3	4.47	0.00
s2	c2	108	c1c2	c3c2	4.38	0.00
s2	c2	108	c2c1	c2c3	4.79	0.00
s2	c2	109	c1c2	c3c2	0.65	0.32
s2	c2	109	c2c1	c2c3	1.48	0.13
s2	c2	110	c1c2	c3c2	1.40	0.15
s2	c2	110	c2c1	c2c3	3.43	0.00
s2	c3	111	c2c3	c1c3	2.88	0.01
s2	c3	111	c3c1	c3c2	2.11	0.05
s2	c3	112	c2c3	c1c3	3.97	0.00
s2	c3	112	c3c1	c3c2	1.21	0.19
s2	c3	113	c2c3	c1c3	2.37	0.03
s2	c3	113	c3c1	c3c2	2.28	0.03
s2	c3	114	c2c3	c1c3	3.41	0.00
s2	c3	114	c3c1	c3c2	3.96	0.00
s2	c3	115	c2c3	c1c3	1.12	0.21
s2	c3	115	c3c1	c3c2	3.07	0.01
s2	c3	116	c2c3	c1c3	3.44	0.00
s2	c3	116	c3c1	c3c2	2.09	0.05
s2	c3	117	c2c3	c1c3	3.70	0.00
s2	c3	117	c3c1	c3c2	1.34	0.16
s2	c3	118	c2c3	c1c3	3.49	0.00
s2	c3	118	c3c1	c3c2	3.19	0.00
s2	c3	119	c2c3	c1c3	2.69	0.01
s2	c3	119	c3c1	c3c2	3.26	0.00
s2	c3	120	c2c3	c1c3	4.08	0.00
s2	c3	120	c3c1	c3c2	1.28	0.17
s3	c1	181	c1c2	c1c3	3.53	0.00
s3	c1	181	c3c1	c2c1	2.05	0.05
s3	c1	182	c1c2	c1c3	4.26	0.00
s3	c1	182	c3c1	c2c1	3.99	0.00
s3	c1	183	c1c2	c1c3	5.16	0.00
s3	c1	183	c3c1	c2c1	2.31	0.03
s3	c1	184	c1c2	c1c3	5.24	0.00

s3	c1	184	c3c1	c2c1	2.54	0.02
s3	c1	185	c1c2	c1c3	2.17	0.04
s3	c1	185	c3c1	c2c1	1.90	0.07
s3	c1	186	c1c2	c1c3	3.51	0.00
s3	c1	186	c3c1	c2c1	3.86	0.00
s3	c1	187	c1c2	c1c3	1.34	0.16
s3	c1	187	c3c1	c2c1	1.05	0.23
s3	c1	188	c1c2	c1c3	3.02	0.01
s3	c1	188	c3c1	c2c1	2.81	0.01
s3	c1	189	c1c2	c1c3	3.30	0.00
s3	c1	189	c3c1	c2c1	3.32	0.00
s3	c1	190	c1c2	c1c3	2.04	0.05
s3	c1	190	c3c1	c2c1	2.41	0.02
s3	c2	191	c1c2	c3c2	2.26	0.03
s3	c2	191	c2c1	c2c3	2.25	0.03
s3	c2	192	c1c2	c3c2	0.63	0.32
s3	c2	192	c2c1	c2c3	1.48	0.13
s3	c2	193	c1c2	c3c2	0.70	0.31
s3	c2	193	c2c1	c2c3	2.78	0.01
s3	c2	194	c1c2	c3c2	1.70	0.10
s3	c2	194	c2c1	c2c3	2.37	0.03
s3	c2	195	c1c2	c3c2	0.69	0.31
s3	c2	195	c2c1	c2c3	0.31	0.38
s3	c2	196	c1c2	c3c2	0.21	0.39
s3	c2	196	c2c1	c2c3	1.89	0.07
s3	c2	197	c1c2	c3c2	0.36	0.37
s3	c2	197	c2c1	c2c3	1.05	0.23
s3	c2	198	c1c2	c3c2	2.03	0.05
s3	c2	198	c2c1	c2c3	7.74	0.00
s3	c2	199	c1c2	c3c2	1.42	0.15
s3	c2	199	c2c1	c2c3	3.36	0.00
s3	c2	200	c1c2	c3c2	1.34	0.16
s3	c2	200	c2c1	c2c3	2.46	0.02
s3	c3	201	c2c3	c1c3	0.76	0.30
s3	c3	201	c3c1	c3c2	2.89	0.01
s3	c3	202	c2c3	c1c3	0.71	0.31
s3	c3	202	c3c1	c3c2	2.18	0.04
s3	c3	203	c2c3	c1c3	2.28	0.03
s3	c3	203	c3c1	c3c2	4.12	0.00
s3	c3	204	c2c3	c1c3	0.63	0.32
s3	c3	204	c3c1	c3c2	0.56	0.34
s3	c3	205	c2c3	c1c3	2.06	0.05
s3	c3	205	c3c1	c3c2	1.13	0.21
s3	c3	206	c2c3	c1c3	0.09	0.39
s3	c3	206	c3c1	c3c2	0.27	0.38
s3	c3	207	c2c3	c1c3	0.96	0.25

s3	c3	207	c3c1	c3c2	3.02	0.01
s3	c3	208	c2c3	c1c3	1.75	0.09
s3	c3	208	c3c1	c3c2	1.15	0.20
s3	c3	209	c2c3	c1c3	1.15	0.20
s3	c3	209	c3c1	c3c2	0.35	0.37
s3	c3	210	c2c3	c1c3	0.61	0.33
s3	c3	210	c3c1	c3c2	0.29	0.38
s4	c1	271	c1c2	c1c3	3.35	0.00
s4	c1	271	c3c1	c2c1	1.10	0.22
s4	c1	272	c1c2	c1c3	4.61	0.00
s4	c1	272	c3c1	c2c1	3.24	0.00
s4	c1	273	c1c2	c1c3	0.20	0.39
s4	c1	273	c3c1	c2c1	0.14	0.39
s4	c1	274	c1c2	c1c3	5.56	0.00
s4	c1	274	c3c1	c2c1	3.52	0.00
s4	c1	275	c1c2	c1c3	2.68	0.01
s4	c1	275	c3c1	c2c1	4.56	0.00
s4	c1	276	c1c2	c1c3	0.80	0.29
s4	c1	276	c3c1	c2c1	0.48	0.35
s4	c1	277	c1c2	c1c3	3.01	0.01
s4	c1	277	c3c1	c2c1	2.93	0.01
s4	c1	278	c1c2	c1c3	0.44	0.36
s4	c1	278	c3c1	c2c1	2.20	0.04
s4	c1	279	c1c2	c1c3	0.59	0.33
s4	c1	279	c3c1	c2c1	3.07	0.01
s4	c1	280	c1c2	c1c3	2.28	0.03
s4	c1	280	c3c1	c2c1	4.05	0.00
s4	c2	281	c1c2	c3c2	2.10	0.05
s4	c2	281	c2c1	c2c3	1.20	0.19
s4	c2	282	c1c2	c3c2	0.50	0.35
s4	c2	282	c2c1	c2c3	3.75	0.00
s4	c2	283	c1c2	c3c2	1.53	0.12
s4	c2	283	c2c1	c2c3	0.18	0.39
s4	c2	284	c1c2	c3c2	1.62	0.11
s4	c2	284	c2c1	c2c3	4.45	0.00
s4	c2	285	c1c2	c3c2	0.09	0.39
s4	c2	285	c2c1	c2c3	0.00	0.40
s4	c2	286	c1c2	c3c2	1.18	0.20
s4	c2	286	c2c1	c2c3	1.49	0.13
s4	c2	287	c1c2	c3c2	3.54	0.00
s4	c2	287	c2c1	c2c3	3.60	0.00
s4	c2	288	c1c2	c3c2	0.63	0.32
s4	c2	288	c2c1	c2c3	1.90	0.07
s4	c2	289	c1c2	c3c2	1.45	0.14
s4	c2	289	c2c1	c2c3	1.39	0.15
s4	c2	290	c1c2	c3c2	0.34	0.37

s4	c2	290	c2c1	c2c3	0.74	0.30
s4	c3	291	c2c3	c1c3	2.99	0.01
s4	c3	291	c3c1	c3c2	2.57	0.02
s4	c3	292	c2c3	c1c3	2.97	0.01
s4	c3	292	c3c1	c3c2	0.30	0.38
s4	c3	293	c2c3	c1c3	2.30	0.03
s4	c3	293	c3c1	c3c2	1.51	0.13
s4	c3	294	c2c3	c1c3	0.80	0.29
s4	c3	294	c3c1	c3c2	0.75	0.30
s4	c3	295	c2c3	c1c3	1.74	0.09
s4	c3	295	c3c1	c3c2	5.17	0.00
s4	c3	296	c2c3	c1c3	2.07	0.05
s4	c3	296	c3c1	c3c2	0.24	0.38
s4	c3	297	c2c3	c1c3	1.23	0.18
s4	c3	297	c3c1	c3c2	3.96	0.00
s4	c3	298	c2c3	c1c3	0.27	0.38
s4	c3	298	c3c1	c3c2	0.39	0.37
s4	c3	299	c2c3	c1c3	0.85	0.27
s4	c3	299	c3c1	c3c2	4.56	0.00
s4	c3	300	c2c3	c1c3	1.95	0.06
s4	c3	300	c3c1	c3c2	1.53	0.12
s5	c1	361	c1c2	c1c3	4.04	0.00
s5	c1	361	c3c1	c2c1	3.32	0.00
s5	c1	362	c1c2	c1c3	2.21	0.04
s5	c1	362	c3c1	c2c1	3.73	0.00
s5	c1	363	c1c2	c1c3	3.79	0.00
s5	c1	363	c3c1	c2c1	2.15	0.04
s5	c1	364	c1c2	c1c3	1.22	0.19
s5	c1	364	c3c1	c2c1	1.76	0.09
s5	c1	365	c1c2	c1c3	3.86	0.00
s5	c1	365	c3c1	c2c1	1.60	0.11
s5	c1	366	c1c2	c1c3	1.42	0.14
s5	c1	366	c3c1	c2c1	4.58	0.00
s5	c1	367	c1c2	c1c3	3.23	0.00
s5	c1	367	c3c1	c2c1	0.67	0.31
s5	c1	368	c1c2	c1c3	3.85	0.00
s5	c1	368	c3c1	c2c1	3.48	0.00
s5	c1	369	c1c2	c1c3	3.48	0.00
s5	c1	369	c3c1	c2c1	3.44	0.00
s5	c1	370	c1c2	c1c3	3.32	0.00
s5	c1	370	c3c1	c2c1	2.75	0.01
s5	c2	371	c1c2	c3c2	1.03	0.23
s5	c2	371	c2c1	c2c3	3.12	0.00
s5	c2	372	c1c2	c3c2	0.73	0.30
s5	c2	372	c2c1	c2c3	0.32	0.38
s5	c2	373	c1c2	c3c2	0.51	0.35

s5	c2	373	c2c1	c2c3	3.32	0.00
s5	c2	374	c1c2	c3c2	0.24	0.39
s5	c2	374	c2c1	c2c3	0.09	0.39
s5	c2	375	c1c2	c3c2	2.01	0.06
s5	c2	375	c2c1	c2c3	3.94	0.00
s5	c2	376	c1c2	c3c2	2.08	0.05
s5	c2	376	c2c1	c2c3	1.69	0.10
s5	c2	377	c1c2	c3c2	0.87	0.27
s5	c2	377	c2c1	c2c3	2.92	0.01
s5	c2	378	c1c2	c3c2	1.67	0.10
s5	c2	378	c2c1	c2c3	3.10	0.00
s5	c2	379	c1c2	c3c2	1.40	0.15
s5	c2	379	c2c1	c2c3	2.13	0.04
s5	c2	380	c1c2	c3c2	1.12	0.21
s5	c2	380	c2c1	c2c3	4.25	0.00
s5	c3	381	c2c3	c1c3	4.06	0.00
s5	c3	381	c3c1	c3c2	3.06	0.01
s5	c3	382	c2c3	c1c3	1.67	0.10
s5	c3	382	c3c1	c3c2	5.05	0.00
s5	c3	383	c2c3	c1c3	4.71	0.00
s5	c3	383	c3c1	c3c2	5.64	0.00
s5	c3	384	c2c3	c1c3	0.44	0.36
s5	c3	384	c3c1	c3c2	1.58	0.12
s5	c3	385	c2c3	c1c3	1.16	0.20
s5	c3	385	c3c1	c3c2	5.49	0.00
s5	c3	386	c2c3	c1c3	0.17	0.39
s5	c3	386	c3c1	c3c2	0.66	0.32
s5	c3	387	c2c3	c1c3	2.32	0.03
s5	c3	387	c3c1	c3c2	2.81	0.01
s5	c3	388	c2c3	c1c3	0.08	0.39
s5	c3	388	c3c1	c3c2	0.52	0.35
s5	c3	389	c2c3	c1c3	3.97	0.00
s5	c3	389	c3c1	c3c2	0.61	0.33
s5	c3	390	c2c3	c1c3	0.44	0.36
s5	c3	390	c3c1	c3c2	1.54	0.12
s6	c1	451	c1c2	c1c3	3.59	0.00
s6	c1	451	c1c2	c1c4	3.92	0.00
s6	c1	451	c1c3	c1c4	0.54	0.34
s6	c1	451	c2c1	c3c1	2.65	0.01
s6	c1	451	c2c1	c4c1	2.35	0.03
s6	c1	451	c3c1	c4c1	0.11	0.39
s6	c1	452	c1c2	c1c3	0.00	0.40
s6	c1	452	c1c2	c1c4	0.11	0.39
s6	c1	452	c1c3	c1c4	0.13	0.39
s6	c1	452	c2c1	c3c1	2.35	0.03
s6	c1	452	c2c1	c4c1	0.26	0.38

s6	c1	452	c3c1	c4c1	2.00	0.06
s6	c1	453	c1c2	c1c3	2.28	0.03
s6	c1	453	c1c2	c1c4	1.81	0.08
s6	c1	453	c1c3	c1c4	0.61	0.33
s6	c1	453	c2c1	c3c1	0.28	0.38
s6	c1	453	c2c1	c4c1	0.83	0.28
s6	c1	453	c3c1	c4c1	0.49	0.35
s6	c1	454	c1c2	c1c3	2.62	0.02
s6	c1	454	c1c2	c1c4	0.29	0.38
s6	c1	454	c1c3	c1c4	3.48	0.00
s6	c1	454	c2c1	c3c1	0.17	0.39
s6	c1	454	c2c1	c4c1	1.35	0.16
s6	c1	454	c3c1	c4c1	1.45	0.14
s6	c1	455	c1c2	c1c3	0.80	0.29
s6	c1	455	c1c2	c1c4	2.11	0.05
s6	c1	455	c1c3	c1c4	2.95	0.01
s6	c1	455	c2c1	c3c1	2.08	0.05
s6	c1	455	c2c1	c4c1	1.14	0.21
s6	c1	455	c3c1	c4c1	0.95	0.25
s6	c1	456	c1c2	c1c3	3.54	0.00
s6	c1	456	c1c2	c1c4	2.25	0.03
s6	c1	456	c1c3	c1c4	1.80	0.08
s6	c1	456	c2c1	c3c1	2.36	0.03
s6	c1	456	c2c1	c4c1	1.95	0.06
s6	c1	456	c3c1	c4c1	0.50	0.35
s6	c1	457	c1c2	c1c3	2.04	0.05
s6	c1	457	c1c2	c1c4	1.51	0.13
s6	c1	457	c1c3	c1c4	3.14	0.00
s6	c1	457	c2c1	c3c1	3.52	0.00
s6	c1	457	c2c1	c4c1	2.74	0.01
s6	c1	457	c3c1	c4c1	0.45	0.36
s6	c1	458	c1c2	c1c3	3.42	0.00
s6	c1	458	c1c2	c1c4	2.10	0.05
s6	c1	458	c1c3	c1c4	1.39	0.15
s6	c1	458	c2c1	c3c1	3.11	0.00
s6	c1	458	c2c1	c4c1	1.75	0.09
s6	c1	458	c3c1	c4c1	1.16	0.20
s6	c1	459	c1c2	c1c3	2.36	0.03
s6	c1	459	c1c2	c1c4	0.29	0.38
s6	c1	459	c1c3	c1c4	1.99	0.06
s6	c1	459	c2c1	c3c1	2.28	0.03
s6	c1	459	c2c1	c4c1	0.62	0.33
s6	c1	459	c3c1	c4c1	2.96	0.01
s6	c1	460	c1c2	c1c3	4.13	0.00
s6	c1	460	c1c2	c1c4	1.37	0.15
s6	c1	460	c1c3	c1c4	2.99	0.01

s6	c1	460	c2c1	c3c1	0.20	0.39
s6	c1	460	c2c1	c4c1	2.06	0.05
s6	c1	460	c3c1	c4c1	2.19	0.04
s6	c2	461	c2c1	c2c3	3.35	0.00
s6	c2	461	c2c1	c2c4	1.24	0.18
s6	c2	461	c2c3	c2c4	4.01	0.00
s6	c2	461	c1c2	c3c2	2.07	0.05
s6	c2	461	c1c2	c4c2	1.75	0.09
s6	c2	461	c3c2	c4c2	4.15	0.00
s6	c2	462	c2c1	c2c3	3.83	0.00
s6	c2	462	c2c1	c2c4	0.69	0.31
s6	c2	462	c2c3	c2c4	3.95	0.00
s6	c2	462	c1c2	c3c2	3.97	0.00
s6	c2	462	c1c2	c4c2	2.40	0.03
s6	c2	462	c3c2	c4c2	9.78	0.00
s6	c2	463	c2c1	c2c3	0.38	0.37
s6	c2	463	c2c1	c2c4	1.45	0.14
s6	c2	463	c2c3	c2c4	0.94	0.25
s6	c2	463	c1c2	c3c2	0.57	0.34
s6	c2	463	c1c2	c4c2	0.37	0.37
s6	c2	463	c3c2	c4c2	0.15	0.39
s6	c2	464	c2c1	c2c3	2.99	0.01
s6	c2	464	c2c1	c2c4	0.18	0.39
s6	c2	464	c2c3	c2c4	2.56	0.02
s6	c2	464	c1c2	c3c2	0.49	0.35
s6	c2	464	c1c2	c4c2	1.74	0.09
s6	c2	464	c3c2	c4c2	2.00	0.06
s6	c2	465	c2c1	c2c3	0.09	0.39
s6	c2	465	c2c1	c2c4	2.81	0.01
s6	c2	465	c2c3	c2c4	2.64	0.01
s6	c2	465	c1c2	c3c2	1.31	0.17
s6	c2	465	c1c2	c4c2	3.18	0.00
s6	c2	465	c3c2	c4c2	2.28	0.03
s6	c2	466	c2c1	c2c3	1.68	0.10
s6	c2	466	c2c1	c2c4	1.29	0.17
s6	c2	466	c2c3	c2c4	3.54	0.00
s6	c2	466	c1c2	c3c2	0.92	0.26
s6	c2	466	c1c2	c4c2	2.18	0.04
s6	c2	466	c3c2	c4c2	1.44	0.14
s6	c2	467	c2c1	c2c3	3.98	0.00
s6	c2	467	c2c1	c2c4	1.26	0.18
s6	c2	467	c2c3	c2c4	2.08	0.05
s6	c2	467	c1c2	c3c2	0.09	0.39
s6	c2	467	c1c2	c4c2	1.31	0.17
s6	c2	467	c3c2	c4c2	1.61	0.11
s6	c2	468	c2c1	c2c3	0.76	0.30

s6	c2	468	c2c1	c2c4	3.22	0.00
s6	c2	468	c2c3	c2c4	4.12	0.00
s6	c2	468	c1c2	c3c2	0.59	0.33
s6	c2	468	c1c2	c4c2	5.64	0.00
s6	c2	468	c3c2	c4c2	6.04	0.00
s6	c2	469	c2c1	c2c3	0.30	0.38
s6	c2	469	c2c1	c2c4	0.42	0.36
s6	c2	469	c2c3	c2c4	0.81	0.28
s6	c2	469	c1c2	c3c2	0.74	0.30
s6	c2	469	c1c2	c4c2	0.81	0.28
s6	c2	469	c3c2	c4c2	1.96	0.06
s6	c2	470	c2c1	c2c3	1.48	0.13
s6	c2	470	c2c1	c2c4	2.16	0.04
s6	c2	470	c2c3	c2c4	0.94	0.25
s6	c2	470	c1c2	c3c2	1.30	0.17
s6	c2	470	c1c2	c4c2	2.46	0.02
s6	c2	470	c3c2	c4c2	1.24	0.18
s6	c3	471	c3c1	c3c2	2.11	0.05
s6	c3	471	c3c1	c3c4	1.53	0.12
s6	c3	471	c3c2	c3c4	0.58	0.33
s6	c3	471	c1c3	c2c3	2.69	0.01
s6	c3	471	c1c3	c4c3	3.11	0.00
s6	c3	471	c2c3	c4c3	0.58	0.33
s6	c3	472	c3c1	c3c2	3.58	0.00
s6	c3	472	c3c1	c3c4	0.32	0.38
s6	c3	472	c3c2	c3c4	2.89	0.01
s6	c3	472	c1c3	c2c3	0.44	0.36
s6	c3	472	c1c3	c4c3	1.03	0.23
s6	c3	472	c2c3	c4c3	0.56	0.34
s6	c3	473	c3c1	c3c2	0.80	0.29
s6	c3	473	c3c1	c3c4	0.14	0.39
s6	c3	473	c3c2	c3c4	0.62	0.32
s6	c3	473	c1c3	c2c3	1.42	0.14
s6	c3	473	c1c3	c4c3	0.29	0.38
s6	c3	473	c2c3	c4c3	1.66	0.10
s6	c3	474	c3c1	c3c2	2.61	0.02
s6	c3	474	c3c1	c3c4	0.27	0.38
s6	c3	474	c3c2	c3c4	2.09	0.05
s6	c3	474	c1c3	c2c3	4.18	0.00
s6	c3	474	c1c3	c4c3	2.27	0.03
s6	c3	474	c2c3	c4c3	1.41	0.15
s6	c3	475	c3c1	c3c2	4.74	0.00
s6	c3	475	c3c1	c3c4	2.64	0.01
s6	c3	475	c3c2	c3c4	2.44	0.02
s6	c3	475	c1c3	c2c3	0.00	0.40
s6	c3	475	c1c3	c4c3	1.31	0.17

s6	c3	475	c2c3	c4c3	1.19	0.19
s6	c3	476	c3c1	c3c2	3.87	0.00
s6	c3	476	c3c1	c3c4	1.80	0.08
s6	c3	476	c3c2	c3c4	1.88	0.07
s6	c3	476	c1c3	c2c3	3.08	0.01
s6	c3	476	c1c3	c4c3	4.04	0.00
s6	c3	476	c2c3	c4c3	0.88	0.27
s6	c3	477	c3c1	c3c2	0.52	0.35
s6	c3	477	c3c1	c3c4	1.26	0.18
s6	c3	477	c3c2	c3c4	1.93	0.06
s6	c3	477	c1c3	c2c3	0.39	0.37
s6	c3	477	c1c3	c4c3	0.32	0.38
s6	c3	477	c2c3	c4c3	0.09	0.39
s6	c3	478	c3c1	c3c2	3.19	0.00
s6	c3	478	c3c1	c3c4	0.48	0.35
s6	c3	478	c3c2	c3c4	2.28	0.03
s6	c3	478	c1c3	c2c3	0.61	0.33
s6	c3	478	c1c3	c4c3	1.95	0.06
s6	c3	478	c2c3	c4c3	1.37	0.15
s6	c3	479	c3c1	c3c2	0.67	0.31
s6	c3	479	c3c1	c3c4	0.15	0.39
s6	c3	479	c3c2	c3c4	0.62	0.33
s6	c3	479	c1c3	c2c3	2.65	0.01
s6	c3	479	c1c3	c4c3	2.66	0.01
s6	c3	479	c2c3	c4c3	0.35	0.37
s6	c3	480	c3c1	c3c2	0.00	0.40
s6	c3	480	c3c1	c3c4	0.16	0.39
s6	c3	480	c3c2	c3c4	0.19	0.39
s6	c3	480	c1c3	c2c3	1.43	0.14
s6	c3	480	c1c3	c4c3	1.27	0.18
s6	c3	480	c2c3	c4c3	0.00	0.40
s6	c4	481	c4c1	c4c2	2.32	0.03
s6	c4	481	c4c1	c4c3	1.15	0.20
s6	c4	481	c4c2	c4c3	4.02	0.00
s6	c4	481	c1c4	c2c4	3.31	0.00
s6	c4	481	c1c4	c3c4	2.08	0.05
s6	c4	481	c2c4	c3c4	5.00	0.00
s6	c4	482	c4c1	c4c2	3.22	0.00
s6	c4	482	c4c1	c4c3	1.02	0.23
s6	c4	482	c4c2	c4c3	4.60	0.00
s6	c4	482	c1c4	c2c4	1.52	0.13
s6	c4	482	c1c4	c3c4	2.01	0.05
s6	c4	482	c2c4	c3c4	3.38	0.00
s6	c4	483	c4c1	c4c2	3.09	0.01
s6	c4	483	c4c1	c4c3	4.19	0.00
s6	c4	483	c4c2	c4c3	6.67	0.00

s6	c4	483	c1c4	c2c4	2.13	0.04
s6	c4	483	c1c4	c3c4	1.64	0.10
s6	c4	483	c2c4	c3c4	4.37	0.00
s6	c4	484	c4c1	c4c2	0.09	0.39
s6	c4	484	c4c1	c4c3	2.83	0.01
s6	c4	484	c4c2	c4c3	2.85	0.01
s6	c4	484	c1c4	c2c4	1.53	0.12
s6	c4	484	c1c4	c3c4	0.55	0.34
s6	c4	484	c2c4	c3c4	2.09	0.05
s6	c4	485	c4c1	c4c2	3.52	0.00
s6	c4	485	c4c1	c4c3	0.09	0.39
s6	c4	485	c4c2	c4c3	2.90	0.01
s6	c4	485	c1c4	c2c4	0.48	0.35
s6	c4	485	c1c4	c3c4	0.74	0.30
s6	c4	485	c2c4	c3c4	1.05	0.23
s6	c4	486	c4c1	c4c2	0.79	0.29
s6	c4	486	c4c1	c4c3	0.98	0.24
s6	c4	486	c4c2	c4c3	1.72	0.09
s6	c4	486	c1c4	c2c4	0.44	0.36
s6	c4	486	c1c4	c3c4	0.31	0.38
s6	c4	486	c2c4	c3c4	0.74	0.30
s6	c4	487	c4c1	c4c2	2.78	0.01
s6	c4	487	c4c1	c4c3	0.44	0.36
s6	c4	487	c4c2	c4c3	2.50	0.02
s6	c4	487	c1c4	c2c4	3.13	0.00
s6	c4	487	c1c4	c3c4	2.01	0.06
s6	c4	487	c2c4	c3c4	0.85	0.27
s6	c4	488	c4c1	c4c2	1.69	0.10
s6	c4	488	c4c1	c4c3	1.16	0.20
s6	c4	488	c4c2	c4c3	0.44	0.36
s6	c4	488	c1c4	c2c4	2.89	0.01
s6	c4	488	c1c4	c3c4	0.36	0.37
s6	c4	488	c2c4	c3c4	2.32	0.03
s6	c4	489	c4c1	c4c2	2.24	0.04
s6	c4	489	c4c1	c4c3	1.19	0.19
s6	c4	489	c4c2	c4c3	0.61	0.33
s6	c4	489	c1c4	c2c4	0.18	0.39
s6	c4	489	c1c4	c3c4	0.29	0.38
s6	c4	489	c2c4	c3c4	0.13	0.39
s6	c4	490	c4c1	c4c2	0.11	0.39
s6	c4	490	c4c1	c4c3	0.37	0.37
s6	c4	490	c4c2	c4c3	0.28	0.38
s6	c4	490	c1c4	c2c4	0.11	0.39
s6	c4	490	c1c4	c3c4	2.85	0.01
s6	c4	490	c2c4	c3c4	2.38	0.03

Appendix 11

Pearson Correlation Coefficients for Hypothesis 2 testing[16]

Concept Pairing	Evaluated Against		Concept Set	Pearson r	*p*
C1 – C2	C1	C1C2	1	0.107	0.552
			2	0.242	0.156
			3	0.408	0.023
			4	0.263	0.167
			5	-0.282	0.095
			6	0.413	0.026
	C1	C2C1	1	0.566	0.001
			2	0.582	0.000
			3	0.544	0.002
			4	0.342	0.069
			5	0.679	0.000
			6	0.409	0.028
	C2	C1C2	1	0.464	0.007
			2	0.242	0.154
			3	0.245	0.183
			4	0.756	0.000
			5	0.652	0.000
			6	0.381	0.041
	C2	C2C1	1	0.149	0.407
			2	-0.027	0.877
			3	0.010	0.959
			4	0.596	0.001
			5	-0.228	0.182
			6	0.337	0.074
C1 – C3	C1	C1C3	1	-0.449	0.009
			2	-0.535	0.001
			3	-0.254	0.148
			4	0.062	0.725
			5	0.029	0.873
			6	0.453	0.009
	C1	C3C1	1	0.478	0.005
			2	0.273	0.107
			3	0.837	0.000
			4	0.444	0.008

[16] The coding scheme used in this appendix is listed in Table 4-11.

			5	0.232	0.193
			6	0.669	0.000
	C3	C1C3	1	0.820	0.000
			2	0.867	0.000
			3	0.561	0.001
			4	0.803	0.000
			5	0.371	0.033
			6	0.636	0.000
	C3	C3C1	1	0.058	0.748
			2	0.247	0.147
			3	-0.520	0.002
			4	0.468	0.005
			5	0.178	0.321
			6	0.376	0.034
C2 – C3	C2	C2C3	1	-0.557	0.000
			2	-0.058	0.732
			3	0.633	0.000
			4	0.646	0.000
			5	0.594	0.000
			6	0.210	0.257
	C2	C3C2	1	0.347	0.038
			2	0.534	0.001
			3	0.730	0.000
			4	0.636	0.000
			5	0.697	0.000
			6	0.303	0.098
	C3	C2C3	1	0.822	0.000
			2	0.021	0.900
			3	-0.374	0.027
			4	-0.115	0.537
			5	0.509	0.003
			6	0.495	0.005
	C3	C3C2	1	0.155	0.368
			2	-0.555	0.000
			3	-0.444	0.008
			4	0.010	0.957
			5	0.416	0.020
			6	0.640	0.000
C1 – C4	C1	C1C4	6	0.716	0.000
	C1	C4C1	6	0.683	0.000
	C4	C1C4	6	0.436	0.011
	C4	C4C1	6	0.492	0.004
C2 – C4	C2	C2C4	6	0.718	0.000
	C2	C4C2	6	0.641	0.000
	C4	C2C4	6	0.912	0.000
	C4	C4C2	6	0.872	0.000
C3 – C4	C3	C3C4	6	0.670	0.000

	C3	C4C3	6	0.575	0.000
	C4	C3C4	6	0.193	0.274
	C4	C4C3	6	0.324	0.062

Appendix 12

The linear regression test design for hypothesis 3[17]

Concept Set	Concept Pair	Evaluated Against		Regression Model (RM)
Set 1	C1 – C2	B (C1*C2)	C1C2	RM1
		B (C1*C2)	C2C1	RM2
	C1 – C3	B (C1*C3)	C1C3	RM3
		B (C1*C3)	C3C1	RM4
	C2 – C3	B (C2*C3)	C2C3	RM5
		B (C2*C3)	C3C2	RM6
Set 2	C1 – C2	B (C1*C2)	C1C2	RM7
		B (C1*C2)	C2C1	RM8
	C1 – C3	B (C1*C3)	C1C3	RM9
		B (C1*C3)	C3C1	RM10
	C2 – C3	B (C2*C3)	C2C3	RM11
		B (C2*C3)	C3C2	RM12
Set 3	C1 – C2	B (C1*C2)	C1C2	RM13
		B (C1*C2)	C2C1	RM14
	C1 – C3	B (C1*C3)	C1C3	RM15
		B (C1*C3)	C3C1	RM16
	C2 – C3	B (C2*C3)	C2C3	RM17
		B (C2*C3)	C3C2	RM18
Set 4	C1 – C2	B (C1*C2)	C1C2	RM19
		B (C1*C2)	C2C1	RM20
	C1 – C3	B (C1*C3)	C1C3	RM21
		B (C1*C3)	C3C1	RM22
	C2 – C3	B (C2*C3)	C2C3	RM23
		B (C2*C3)	C3C2	RM24
Set 5	C1 – C2	B (C1*C2)	C1C2	RM25
		B (C1*C2)	C2C1	RM26
	C1 – C3	B (C1*C3)	C1C3	RM27
		B (C1*C3)	C3C1	RM28
	C2 – C3	B (C2*C3)	C2C3	RM29
		B (C2*C3)	C3C2	RM30
Set 6	C1 – C2	B (C1*C2)	C1C2	RM31
		B (C1*C2)	C2C1	RM32
	C1 – C3	B (C1*C3)	C1C3	RM33
		B (C1*C3)	C3C1	RM34

[17] The coding scheme used in this appendix is listed in Table 4-11.

	C1 – C4	B (C1*C4)	C1C4	RM35
		B (C1*C4)	C4C1	RM36
	C2 – C3	B (C2*C3)	C2C3	RM37
		B (C2*C3)	C3C2	RM38
	C2 – C4	B (C2*C4)	C2C4	RM39
		B (C2*C4)	C4C2	RM40
	C3 – C4	B (C3*C4)	C3C4	RM41
		B (C3*C4)	C4C3	RM42

Appendix 13

The results of the linear regression models for H3[18]

Linear Regression Model 1 Summary

R Square	Adjusted R Square	F	df1	Sig.
.197	.171	7.599	1	.010
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.903		12.574	.000
Balance score	0.039	.444	2.757	.010

Linear Regression Model 2 Summary

R Square	Adjusted R Square	F	df1	Sig.
.302	.279	13.394	1	.001
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.458		9.475	.000
Balance score	0.061	.549	3.660	.001

Linear Regression Model 3 Summary

R Square	Adjusted R Square	F	df1	Sig.
.096	.067	3.300	1	.079
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.337		14.451	.000
Balance score	0.033	.310	1.817	.079

Linear Regression Model 4 Summary

R Square	Adjusted R Square	F	df1	Sig.
.302	.279	13.408	1	.001
Parameter Estimates				

[18] See Appendix 12 for the test design details.

	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	2.986		17.479	.000
Balance score	0.049	.549	3.662	.001

Linear Regression Model 5 Summary

R Square	Adjusted R Square	F	df1	Sig.
.072	.044	2.629	1	.114
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.220		9.674	.000
Balance score	0.051	.268	1.621	.114

Linear Regression Model 6 Summary

R Square	Adjusted R Square	F	df1	Sig.
.198	.175	8.406	1	.007
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.122		12.030	.000
Balance score	0.071	.445	2.899	.007

Linear Regression Model 7 Summary

R Square	Adjusted R Square	F	df1	Sig.
.123	.097	4.770	1	.036
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	4.570		17.205	.000
Balance score	0.027	.351	2.184	.036

Linear Regression Model 8 Summary

R Square	Adjusted R Square	F	df1	Sig.
.146	.121	5.806	1	.022
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	4.399		14.077	.000

Balance score	0.035	.382	2.410	.022

Linear Regression Model 9 Summary

R Square	Adjusted R Square	F	df1	Sig.
.018	-.011	.629	1	.433
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.889		11.131	.000
Balance score	0.022	.135	.793	.433

Linear Regression Model 10 Summary

R Square	Adjusted R Square	F	df1	Sig.
.237	.215	10.585	1	.003
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.472		16.403	.000
Balance score	0.055	.487	3.254	.003

Linear Regression Model 11 Summary

R Square	Adjusted R Square	F	df1	Sig.
.005	-.024	.160	1	.691
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.138		8.829	.000
Balance score	0.015	.068	.400	.691

Linear Regression Model 12 Summary

R Square	Adjusted R Square	F	df1	Sig.
.003	-.026	.104	1	.749
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.719		8.475	.000
Balance score	-0.015	-.054	-.322	.749

Linear Regression Model 13 Summary

R Square	Adjusted R Square	F	df1	Sig.
.395	.374	18.961	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.475		9.687	.000
Balance score	0.070	.629	4.354	.000

Linear Regression Model 14 Summary

R Square	Adjusted R Square	F	df1	Sig.
.232	.205	8.742	1	.006
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.384		5.498	.000
Balance score	0.081	.481	2.957	.006

Linear Regression Model 15 Summary

R Square	Adjusted R Square	F	df1	Sig.
.128	.101	4.698	1	.038
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.516		14.912	.000
Balance score	0.046	.358	2.168	.038

Linear Regression Model 16 Summary

R Square	Adjusted R Square	F	df1	Sig.
.166	.140	6.367	1	.017
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.235		9.993	.000
Balance score	0.073	.407	2.523	.017

Linear Regression Model 17 Summary

R Square	Adjusted R Square	F	df1	Sig.
.032	.003	1.088	1	.305

Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	4.424		11.300	.000
Balance score	0.033	.179	1.043	.305

Linear Regression Model 18 Summary

R Square	Adjusted R Square	F	df1	Sig.
.063	.034	2.202	1	.147
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.983		11.936	.000
Balance score	0.040	.250	1.484	.147

Linear Regression Model 19 Summary

R Square	Adjusted R Square	F	df1	Sig.
.546	.529	32.415	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	2.982		9.131	.000
Balance score	0.071	.739	5.693	.000

Linear Regression Model 20 Summary

R Square	Adjusted R Square	F	df1	Sig.
.510	.491	28.056	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.059		8.160	.000
Balance score	0.076	.714	5.297	.000

Linear Regression Model 21 Summary

R Square	Adjusted R Square	F	df1	Sig.
.436	.419	25.498	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		

Constant	2.970		8.054	.000
Balance score	0.074	.660	5.050	.000

Linear Regression Model 22 Summary

R Square	Adjusted R Square	F	df1	Sig.
.449	.432	26.911	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.375		11.595	.000
Balance score	0.060	.670	5.188	.000

Linear Regression Model 23 Summary

R Square	Adjusted R Square	F	df1	Sig.
.198	.170	7.163	1	.012
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.636		13.763	.000
Balance score	0.038	.445	2.676	.012

Linear Regression Model 24 Summary

R Square	Adjusted R Square	F	df1	Sig.
.343	.320	15.130	1	.001
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.687		16.298	.000
Balance score	0.047	.586	3.890	.001

Linear Regression Model 25 Summary

R Square	Adjusted R Square	F	df1	Sig.
.099	.073	3.747	1	.061
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.388		9.817	.000
Balance score	0.047	.315	1.936	.061

Linear Regression Model 26 Summary

R Square	Adjusted R Square	F	df1	Sig.
.159	.134	6.425	1	.016
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.545		14.391	.000
Balance score	0.044	.399	2.535	.016

Linear Regression Model 27 Summary

R Square	Adjusted R Square	F	df1	Sig.
.205	.179	7.976	1	.008
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.129		9.826	.000
Balance score	0.070	.452	2.824	.008

Linear Regression Model 28 Summary

R Square	Adjusted R Square	F	df1	Sig.
.106	.078	3.690	1	.064
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.449		14.021	.000
Balance score	0.037	.326	1.921	.064

Linear Regression Model 29 Summary

R Square	Adjusted R Square	F	df1	Sig.
.453	.434	23.976	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.238		10.010	.000
Balance score	0.067	.673	4.897	.000

Linear Regression Model 30 Summary

R Square	Adjusted R Square	F	df1	Sig.

.446	.426	23.302	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	2.967		8/035	.000
Balance score	0.075	.667	4.827	.000

Linear Regression Model 31 Summary

R Square	Adjusted R Square	F	df1	Sig.
.215	.186	7.394	1	.011
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.849		10.310	.000
Balance score	0.046	.464	2.719	.011

Linear Regression Model 32 Summary

R Square	Adjusted R Square	F	df1	Sig.
.129	.097	4.004	1	.056
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	4.218		11.920	.000
Balance score	0.032	.359	2.001	.056

Linear Regression Model 33 Summary

R Square	Adjusted R Square	F	df1	Sig.
.516	.500	32.035	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.368		11.137	.000
Balance score	0.074	.719	5.660	.000

Linear Regression Model 34 Summary

R Square	Adjusted R Square	F	df1	Sig.
.480	.463	27.713	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.

	B	Beta		
Constant	3.697		12.476	.000
Balance score	0.067	.693	5.264	.000

Linear Regression Model 35 Summary

R Square	Adjusted R Square	F	df1	Sig.
.475	.458	28.050	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.657		12.779	.000
Balance score	0.068	.689	5.296	.000

Linear Regression Model 36 Summary

R Square	Adjusted R Square	F	df1	Sig.
.457	.440	26.093	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.558		11.457	.000
Balance score	0.071	.676	5.108	.000

Linear Regression Model 37 Summary

R Square	Adjusted R Square	F	df1	Sig.
.250	.224	9.672	1	.004
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.976		14.528	.000
Balance score	0.047	.500	3.110	.004

Linear Regression Model 38 Summary

R Square	Adjusted R Square	F	df1	Sig.
.395	.374	18.956	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.743		17.160	.000
Balance	0.053	.629	4.354	.000

score				

Linear Regression Model 39 Summary

R Square	Adjusted R Square	F	df1	Sig.
.773	.764	88.412	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	2.617		9.005	.000
Balance score	0.095	.879	9.403	.000

Linear Regression Model 40 Summary

R Square	Adjusted R Square	F	df1	Sig.
.673	.661	53.535	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	2.734		7.296	.000
Balance score	0.096	.820	7.317	.000

Linear Regression Model 41 Summary

R Square	Adjusted R Square	F	df1	Sig.
.358	.338	17.869	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	t	Sig.
	B	Beta		
Constant	3.754		14.441	.000
Balance score	0.057	.599	4.227	.000

Linear Regression Model 42 Summary

R Square	Adjusted R Square	F	df1	Sig.
.421	.403	23.274	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.583		15.249	.000
Balance score	0.059	.649	4.824	.000

Appendix 14

The distribution of Pearson's coefficients for hypothesis 4 testing

Concept Pair	Concept Set	C1&C1C2 Pearson r	C2&C1C2 Pearson r
C1 – C2	1	0.107	0.464
	2	0.242	0.242
	3	0.408	0.245
	4	0.263	0.756
	5	-0.282	0.652
	6	0.413	0.381
	Concept Set	C2&C2C1 Pearson r	C1&C2C1 Pearson r
	1	0.149	0.566
	2	-0.027	0.582
	3	0.010	0.544
	4	0.596	0.342
	5	-0.228	0.679
	6	0.337	0.409
	Concept Set	C1&C1C3 Pearson r	C3&C1C3 Pearson r
C1 – C3	1	-0.449	0.820
	2	-0.535	0.867
	3	-0.254	0.561
	4	0.062	0.803
	5	0.029	0.371
	6	0.453	0.636
	Concept Set	C3&C3C1 Pearson r	C1&C3C1 Pearson r
	1	0.058	0.478
	2	0.247	0.273
	3	-0.520	0.837
	4	0.468	0.444
	5	0.178	0.232
	6	0.376	0.669
	Concept Set	C2&C2C3 Pearson r	C3&C2C3 Pearson r
C2 – C3	1	-0.557	0.822
	2	-0.058	0.021
	3	0.633	-0.374
	4	0.646	-0.115
	5	0.594	0.509
	6	0.210	0.495
	Concept Set	C3&C3C2 Pearson r	C2&C3C2 Pearson r
	1	0.155	0.347
	2	-0.555	0.534
	3	-0.444	0.730
	4	0.010	0.636
	5	0.416	0.697
	6	0.640	0.303

	Concept Set	C1&C1C4 Pearson r	C4&C1C4 Pearson r
C1 – C4	6	0.716	0.436
	Concept Set	C4&C4C1 Pearson r	C1&C4C1 Pearson r
	6	0.492	0.683
	Concept Set	C2&C2C4 Pearson r	C4&C2C4 Pearson r
C2 – C4	6	0.718	0.912
	Concept Set	C4&C4C2 Pearson r	C2&C4C2 Pearson r
	6	0.872	0.641
	Concept Set	C3&C3C4 Pearson r	C4&C3C4 Pearson r
C3 – C4	6	0.670	0.193
	Concept Set	C4&C4C3 Pearson r	C3&C4C3 Pearson r
	6	0.324	0.575

Appendix 15

Regression analyses on the relative contribution of prototypicality and balance conducted for the other half of the data subset

1. Mean_rating_combination = a0 + Beta1*mean_rating_head
2. Mean_rating_combination = a0 + Beta1*balance_score
3. Mean_rating_combination = a0 + Beta1* mean_rating_head + Beta2*balance_score
4. Mean_rating_combination = a0 + Beta1*mean_rating_modifier
5. Mean_rating_combination = a0 + Beta1*balance_score
6. Mean_rating_combination = a0 + Beta1* mean_rating_modifier + Beta2*balance_score

Model #7 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.214	.212	187.616	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.289		35.968	.000
Mean_rating_head	0.278	.462	13.697	.000
Model #8 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.320	.319	325.718	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.449		53.388	.000
Balance_score	0.061	.566	18.048	.000
Model #9 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.345	.343	181.993	2	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.165		37.609	.000

Mean_rating_head	0.118	.196	5.131	.000
Balance_score	0.049	0.450	11.786	.000
Model #10 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.062	.061	45.970	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.808		37.767	.000
Mean_rating_modifier	0.152	.250	6.780	.000
Model #11 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.320	.319	325.718	1	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.449		53.388	.000
Balance_score	0.061	.566	18.048	.000
Model #12 Summary				
R Square	Adjusted R Square	F	df1	Sig.
.329	.328	169.519	2	.000
Parameter Estimates				
	Unstandardized coefficients	Standardized Beta	T	Sig.
	B	Beta		
Constant	3.624		42.120	.000
Mean_rating_modifier	-0.071	-0.117	-3.061	.002
Balance_score	0.068	0.634	16.579	.000