The Structuring of Ambiguous Stimuli in Human Communication

by

Geovania Pimenta

A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Doctor of Philosophy
in
Management Sciences

Waterloo, Ontario, Canada, 2016

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.

Geovania Pimenta

Abstract

Information theory (Shannon, 1948) and relative similarity (Rosch and Mervis, 1975) are used to investigate the problem of how people communicate about ambiguous, unstructured stimuli. Specifically, the following one-way communication setting is considered: given a set of ambiguous items available to both a sender and a receiver, the sender uses messages to describe one of the items from the set, such that the receiver is able to identify this target item correctly. It is argued that information reduces uncertainty in ambiguous communication settings through the development of structure, which is conceptualized in terms of a system of categories. During the communication process, distinguishing an item from a set of other items involves clustering items into subsets; that is, grouping items together that are similar to one another and leaving out items that are dissimilar. It is proposed that relative similarity is the cognitive mechanism involved in the development of those categories. It is further proposed that perceptions of relative similarity are made with respect to one attribute. People take advantage of the perceived structure of the ambiguous stimulus and form categories in a goal-directed manner, focusing on whatever attribute best enables them to distinguish the target item from the others (Barsalou, 1983). Each time one attribute is used in communication to refer to a cluster or subset of items, uncertainty is reduced. Furthermore, it is postulated that when people have the choice of one attribute from multiple possible attributes to communicate about unstructured stimuli, two categorization logics operate to reduce uncertainty. Hypothesis 1 predicts that people maximize distinctiveness by choosing the attribute that allows for a larger gap (i.e., greater dissimilarity) between the subset containing the target item and the subset of remaining items. Hypothesis 2 predicts that people maximize information gain by choosing the attribute that allows for the smaller subset containing the target item. The theoretical framework is built upon illustrative examples.

Three experiments were conducted to investigate the cognitive mechanisms that people use to identify and describe a specific ambiguous item from among a set of ambiguous items during communication. Participants took the role of either sender or receiver in a one-way communication situation. In the role of sender they ranked a set of descriptions/attributes based on the degree to which they thought the descriptions would enable an imagined receiver to identify a specific target item from a set of ambiguous items. As receiver, they were given specific descriptions/attributes from an imagined sender, and ranked a set of ambiguous items based on which of the items they thought the sender was referring to. Experiments 1 and 2 used two different kinds of unstructured stimuli; experiment 3 utilized a structured way of manipulating unstructured/ambiguous stimulus. The results of experiments 1 and 2 were consistent with hypotheses 1 and 2. There were strong consistency between the two different stimuli and, therefore, strong evidence for generalizability of the observed effects. The results of experiment 3 gave inconsistent support for the hypotheses. The theoretical framework, the design of the experiments, and the results are discussed.

Acknowledgements

I would like to express my deepest gratitude to Professor Rob Duimering. His insightful thoughts and words of encouragement were essential throughout those five years of hard work. Professor Duimering shared with me his critical view of research, a firm determination to careful understand and examine a problem. I owe him endless hours of learning and training.

I also would like to thank my parents, Nelisete and José Pimenta for all the wisdom and for the words of encouragement. I greatly miss you both. I am also thankful to my special friends Minerva and Hans Pintar for their emotional support.

Foremost, I am thankful to my husband, Newton, for all the loving support he provided throughout all these years. Without him, this dissertation would not be finished. Thanks for your patient, understanding, and care.

I would like to thank my Examination Committee Members, Dr. Parmit Chilana (member of the Comprehensive Examination Committee), Dr. Frank Safayeni, Dr. Kejia Zhu, Dr. Randy Harris, and Dr. Alberto Cañas for their creative suggestions and for all the time and effort they invested into understanding this work.

I would like to express my gratitude to the students that answered the surveys of this research. Their responses made the data collection for the three experimental studies possible.

Finally, I also would like to thank Lauren Duimering for carefully proofreading this dissertation, improving the readability and the understanding of it.

Dedication

To my mother,

Nelisete Pimenta.

No distance will ever separate us.

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Chapter 1

Introduction

Suppose an experimenter has hidden money in one of 8 boxes[1]. The experimenter wants to know the minimum number of guesses needed to find that money. The event – lifting one of the boxes – has 8 possible outcomes. In order to choose the right box, participants of the experiment need information, something that can reduce uncertainty in the outcome, i.e., anything that reduces the number of boxes from 8 to 1. A participant is told that s/he can ask any questions to which the experimenter can answer yes or no. The participant then lines up the boxes in a row, divides the 8 boxes into two sets of 4, and asks the experimenter whether the money is in the set on the left side. The experimenter confirms. By answering "Yes" or "No" to the question, the experimenter is giving information to the participant. The information given reduces the number of possible outcomes from the initial 8 to only 4. No money was found yet. The participant repeats exactly what was done before. S/he lines up the 4 boxes and divides them in two new subsets of 2 boxes each. Next, s/he inquires whether the money is hidden in the set on the left side or not, and the experimenter says "No". Two guesses were made up to this point, reducing the number of possible choices to two. The participant knows that with one more question s/he can get the money. With only 2 boxes remaining, if there is no money in the box on the left side, the money has to be in the box on the right side. As we can

[1] This example has been used by Professor Frank Safayeni to teach Organizational Theory and Behaviour, MSCI 605, at the University of Waterloo, during the Fall 2008. It was also used as introduction of my own Masters' thesis (Pimenta, 2011).

see, 3 guesses are necessary to find the money. By using this determined way of organizing things, 3 guesses are needed to get from 8 possible boxes to one. Holding constant all conditions of task performance, the number of guesses will not change regardless of which box the money is hidden in.

The money in the box example can be used to illustrate Shannon's classic communication theory (Shannon, 1948). First, from the example, it is possible to learn Shannon's concept of entropy. There is initially a set of 8 boxes and money is hidden in one of them. With no information, there are 8 possible outcomes to the task. After dividing the set into two subsets of 4 boxes each, when the participant eliminates one of the subsets, according to Shannon, entropy (or uncertainty) is being reduced to half (from 8 outcomes to 4), corresponding to a gain of 1 bit of information for the experimental participant.

Second, in Information Theory messages are communicated as 1s and 0s. The money in the box example is based on the assumption that items can be lined up into one dimension or on a continuum and that the arrangement makes possible the use of codes to identify each item. The fact that the boxes were all lined up in a row, on a one dimensional axis, made it easy for the participant to consecutively divide them into two subsets and to code the subsets as left/right. In other words, dividing the set of 8 boxes into two sub-categories or sub-clusters, is the same as coding with 1s and 0s in Information Theory. In this case, 1 would be left and 0, right. The participant is allowed to ask whether the money is in the clustered boxes on the left side. By answering Yes/No to the question, the experimenter is reducing uncertainty because the participant can now discount one of the sub-clusters and focus on the other one. Since both of them can easily recognize the subcategories created, they can make clear reference to the two clusters of boxes.

Finally, it is the structure of the boxes (how they were organized) that allowed their division into two subsets which, in turn, permitted the experimenter to indicate in which subset the money was located. That information helped the participant to reduce the number of boxes by half each time s/he asked a question. Without the predefined subcategories no information could be conveyed and no uncertainty would be reduced. Therefore, structure refers to the internal system of categories of a set that allow for uncertainty to be reduced.

Sets such as the above example, where categories are known and well defined, do not always exist. Boundaries between categories are not always clear-cut; most are fuzzy and overlapping. Unlike the money in the box example, it is not always possible to line up items or to give binary answers to identify an item. When category boundaries are not clearly defined, the set of items has less structure or is unstructured. For instance, what if the money was hidden inside some undefined shape somewhere in the room. Some shapes could be said to be more like a circle because their sides are not very straight. Some have quasi-straight sides. Many of them are very similar to each other. Left/right in this case would not help. However, since it is still possible to perceive that some items are similar to each other and different from others with respect to some aspect or attribute, the initial set can still be divided into smaller subsets. For example, the participant could perceive that some shapes were more similar to each other with respect to being circular and try to make the experimenter perceive the same. By doing this, they would be dividing the shapes into two smaller subsets – for example, mostly circular shapes vs. non-circular shapes. Since the initial number of outcomes has been reduced, uncertainty also has decreased. A code has been created to facilitate communication. Finally, when smaller subsets or categories are created, the set becomes more structured.

Few studies examine what structure is and how it is cognitively developed during the communication process. In my master's thesis (Pimenta, 2011), I proposed that information and category structure are related and that they influence the communication process. As suggested by the money in the box example, the participant's selection of the message to be communicated to the experimenter depends on the category structure in which that message is embedded. On the other hand, the experimenter's interpretation of the message received also depends on his/her individual category structure. According to Shannon's Information Theory (Shannon, 1948), information conveyed in communication reduces uncertainty relative to a predefined set of possibilities. Thus in an unstructured situation, information can only be conveyed (and uncertainty reduced) after some structure has been created to define the available set of possibilities. In structured stimuli, such as the money in the box example, uncertainty comes from not knowing the outcome of an event. When the experimenter says "Yes" or "No" to one of the participant's questions, uncertainty is reduced because the number of boxes (outcomes) decreases by half. There is no uncertainty regarding which boxes the experimenter/participant are referring to because the boxes were lined up and coded – left side and right side – each time a division was made. In the case of unstructured stimuli, there are two sources of uncertainty to be dealt with. The sender experiences uncertainty with respect to which codes/categories can be used to best distinguish the target item from other items in the set (left/right in the money in the box example) and the receiver experiences uncertainty with respect to which item(s) from the set the sender is referring to by using a giving code (where the money is).

The aim of this current research is to investigate the cognitive mechanisms involved in developing a suitable structure for communication and human information processing. More specifically, I want to investigate how people communicate a target from a set of ambiguous items. I propose that when people have to communicate categories that are not well defined they use similarity judgments to cluster items into smaller subsets. Structure is thereby created by dividing a complex unstructured stimulus into a set of categories, as was done in the money in the box example by dividing the initial set into smaller subsets of lefts and rights. More specifically, I propose that items are categorized based on perceived relative similarity, whereby similarity is maximized within categories and minimized between categories with respect to one attribute or dimension. Further, I postulate that when multiple attributes are available, the sender perceives various ways of clustering the target item based on how similar/dissimilar it is to the other items with respect to the various attributes. In addition, I postulate that when dealing with multiple perceived attributes, sender and receiver of the message have to choose the attribute that best distinguishes the target item from the other items in the set. I hypothesize that the chosen attribute is the one that reduces uncertainty by: 1. maximizing the dissimilarity between the cluster containing the target and the cluster of the other items, and 2. minimizing the size of the subset containing the target item (i.e. by eliminating as many of the non-target items as possible).

The above hypotheses were tested experimentally. Participants performed three experiments in which they communicated about sets of items with different degrees of structure. The rest of this work is organized in the following manner. First, the literature pertaining to the fields of communication and categorization is reviewed. Second, the theoretical framework and hypotheses are developed. Third, the methodology is reported. Finally, the general implications of this study including limitations and future research are discussed.

Chapter 2

Research on communication and categorization

The main objective of this research is to investigate the cognitive mechanisms involved in developing a suitable knowledge structure for communication and human information processing. My work will touch upon some of the most basic notions of communication theory and categorization. Both phenomena, communication and categorization, have received substantial attention in literature. The following sections provide a brief summary of the research on communication and categorization followed by the description of current approaches.

2.1 Communication

Communication is a very broad concept. It has been the object of study in various academic fields for professionals including sociologists, linguists, psychologists, economists, communication engineers, rhetoricians, and others. Communication research can examine a wide variety of groups: organizational, international or intercultural groups, small group, interpersonal communication as well as public and mass communication. A few handbooks have been published about these subjects such as Jablin and Putnam (2004) on organizational communication and Knapp and John (2002) on interpersonal communication.

In general communication can be defined as the exchange of a message from one person to another. Most humans are born with the abilities of speaking and listening. By making use of those abilities we can communicate to each other. Because communication is so present in our lives, we take it for granted. We do not think about what is needed to communicate something, i.e. how we do it. Communication is an extremely complicated process in which many different elements are simultaneously involved. This explains why miscommunication or lack of understanding is so pervasive in society and academia and why there has been so much research on the subject. Recent research shows that doctors and patients do not understand one another (Hannawa, 2011; Morgan, 2013), team members in organizations miscommunicate (Metiu, 2006; Marceau, 2012; Parsons, M. & Urbanski, S., 2012), even legal practitioners, sentence appellants, and journalists are all victims of miscommunication (Siôn, 2013).

Research studying communication models has been plentiful, including Shannon and Weaver (1949), Berlo (1960), and Schramm (1954). The first major model of communication was conceived, by Shannon and Weaver in 1949, for Bell Laboratories. The Shannon and Weaver model of communication had 5 elements: an information source (which produces a message); a transmitter (which "encodes" the message into signals); a channel (to which signals are adapted for transmission); a receiver (which "decodes" the message); and a destination (where the message arrives). The research framework section of this paper references Shannon's Information Theory. Therefore the Information Theory is discussed in greater detail in a later section.

In 1960, David Berlo expanded Shannon and Weaver's model of communication and developed the Sender-Message-Channel-Receiver (SMCR) Model of Communication. Berlo's model has four elements to describe the communication process: sender, message, channel, and receiver. Each of the four elements is affected by several factors. For instance, sender and receiver are affected by their respective communication skills, attitudes, knowledge, social system, and culture.

Wilbur Schramm (1954) adapted a model from another theorist named Osgood and developed the Encode-Decode Model of Communication. Osgood had replaced Shannon and Weaver's linear model of communication with a circular one. The Osgood-Schramm model suggested a two-way communication process, and used feedback as an important feature.

As can be observed through this brief introduction, literature on communication is classified into different disciplines, theories, and models. Each one of these classifications is subject to sub-classifications. A huge amount of literature has been published under each of those sub-classifications. Although most of this literature is probably important to the respective disciplinary fields, it does not investigate how we organize the information processed from the environment and communicate it. The relationship between communication and structure has not been well explored. Since communication is a social process and effective communication is a function of individual category structure, my research focus is on developing a suitable framework to investigate this issue.

2.1.1 Communication Theory

In general, the term communication theory refers to both the study of the technical process of information and the human process of communication. Shannon's Information Theory (Shannon, 1948) is a mathematical model originally developed to describe and solve telecommunication problems such as improving message transfer from source to destination with minimal loss, and improving channel capacity. Shannon's model describes communication as a process where information is encoded and transmitted from a source A and decoded and received by a receptor B through some channel. It also explains important concepts such as uncertainty and information.

In Shannon's theory, uncertainty is a set of probable events and information is anything that reduces uncertainty. There is a finite set X of mutually exclusive alternatives in concern; only one of the alternatives is true; but we are not certain about which one it is. Anything helpful to eliminate alternatives is information. The money in the box example used in the introduction helps to elucidate these concepts. The initial set had 8 boxes. Only one of them had the money hidden inside. Therefore, without any information there were 8 possible outcomes. The boxes were divided in two subsets (left/right), and the information resulting from the binary answers (yes/no) reduced uncertainty because each time a division was made, the number of boxes decreased by half. Using Shannon's theory, one bit of information reduced the number of equally probable events by one half, thereby reducing entropy/uncertainty.

Mathematically, Shannon's entropy (or uncertainty) is defined by the expression

$$H = -\sum_{i} p_i \log_b p_i$$

where *H* is entropy, p_i is the probability of the ith message occurring and *b* is the base of the logarithm used. Since entropy is usually measured in bits, the value for *b* is 2.

After Shannon published his mathematical model, psychologists started to apply it in the context of psychological problems. Miller (1963) points out the main reason for that to happen. He says that Information Theory measures organization. A well-organized system is highly predictable – it is possible to know what is going to happen before it happens. Thus, there is no information or no learning acquired from this system when it does something. However, a disorganized system is unpredictable. When an unpredictable system does something, it gives information. If we consider communication between two individuals a system, it is a highly disorganized and unpredictable system; therefore, highly uncertain.

The way an individual organizes their knowledge of the world influences how a message is selected and communicated to another individual. According to Shannon a message is selected from a set of possibilities. In human communication the set of possibilities, i.e. the way an individual organizes the world, differs from one person to another.

Human communication is based on the fact that two individuals interacting with each other will not have the same structure, i.e., the way a sender and receiver of a message categorize that message may differ. The higher the commonalities between two people such as same culture, language, background, beliefs, and values, the higher the likelihood of overlap between their categories and subcategories. For instance, two civil engineers from the same country, educated in the same university have a higher probability of understanding each other while talking about a bridge, than does a Spanish doctor who speaks English as second language explaining to an English speaking store clerk what kind of screw he needs to finish his home project.

2.1.2 Studies in Communication Theory

One of the studies that builds on Shannon's Information Theory is Uncertainty Reduction Theory (URT). Developed by Berger and Calabrese (1975) URT was created to study how uncertainty is reduced during the first interactions between strangers. The theory contains 7 axioms which describe relationships between uncertainty and communication factors. As Berger (2005) points out, URT motivated research concerning the different strategies individuals use – active, passive or interactive – to obtain information from others (Berger & Bradac, 1982; Berger & Douglas, 1981; Berger & Kellermann, 1983, 1989, 1994; Kellermann & Berger, 1984). More recently, Kramer et al. used URT to investigate the communication experience of pilots involved in an acquisition by another airline (Kramer, Dougherty, & Pierce, 2004). Their results indicated that pilots experienced high uncertainty with respect to job security over time. In addition, although URT proposes that uncertainty causes information seeking, not all pilots responded in this way. Some of the pilots preferred to avoid information while others delayed seeking for it and interacted with other pilots not to reduce their uncertainties but to seek comfort.

Recent research dealing with uncertainty and information management is based on Uncertainty Management Theory (UMT). Developed originally by Brashers (2001) UMT states that uncertainty is not necessarily negative and therefore should not always be avoided. Some people prefer to maintain their current level of uncertainty, rather than risk encountering a negative future uncertainty, by avoiding upsetting situations (Brashers et al, 2000). Others might seek a higher level of uncertainty if that uncertainty offers them hope (Brashers et al, 2000).

2.1.3 Communication Theory and Categories

Purdy (1989), a PhD student of the University of Waterloo, studied the communication process as a function of the set structure in which it is embedded. She suggested that specifying an item, i.e. how much information has to be given to distinguish an item, is a function of the structure of the set. According to Purdy, a set has an internal structure based on groupings of its items that have subjective probabilities of choice associated with them. She theorized that as the similarity within a set increases, that is, as the items within a set become more alike, there are changes in the way messages are encoded.

To investigate the issue, Purdy used a numbered 5x5 grid (Safayeni, 1975) to represent the psychological experience of how a person perceives items in the grid. She then defined similarity of the different positions in the grid as the number of steps that it takes to turn one square into another ("amount of transformation", p. 12). The similarity measure was developed and validated for this particular stimulus. According to her, the more steps it takes to turn one object into another, the less similar are the two objects. Next she created sets of three locations, each embedded with a different degree of similarity. One location was targeted. Participants were then asked to write down all the different ways they could describe the target location to another person. She found that as similarity between the items in the set increases, the average number of different codes, or descriptions that can be used to distinguish one item from the set decreases. According to Purdy, as the similarity increases, the number of similar properties in the set increases. Since the similar properties do not reduce any uncertainty they are of no use in distinguishing an item, hence, there are fewer properties that can be encoded.

Purdy's research findings suggest that there are fewer ways to distinguish an item within a set of similar items than if the same item were in a set of dissimilar items. For example, if the set consists of three different things such as an apple, a key and a mug and a person is asked to write down all possible ways of distinguishing an apple, the result will be a very long list of different codes or descriptors. However, if the set contains three apples, the list decreases, because many of the descriptors used before will be of no use anymore.

Tabatabai (2009) did a related study also at the University of Waterloo. She linked communication to categorical knowledge. She studied how technical and non-technical people communicate to each other. According to Tabatabai, categorical sets between technical and non-technical people will have to match if they are to effectively communicate with each other.

To study the phenomena, she designed a three-person task where participants communicated to each other through the use of categories. There were only two sets of numerical categories to be used – a broader set (big, small), and a narrower one (odd, even, prime, square root, cube root). The objective of the task was to communicate a randomly selected number from 1 to 10 from one person (A) to another person (C) using predefined cards representing the predefined categories. In the middle there was a translator (B), a middle-level knower who facilitated the communication process between those with technical (narrow) and non-technical (broad) knowledge. Nobody was allowed to talk or use body expression. Person (A) communicated the selected number to the translator (B) using one of their cards (big/small). (B) translated the card to (C) using their own cards, also available to (C). (C), then, based on the cards s/he received from (B) guessed the number (from 1 to 10) and showed the answer to (A). Person (A) gave feedback to the translator (B) to indicate whether or not C had guessed correctly. This example illustrates how communication flows from the nontechnical (general categories) to the technical (narrowed categories) knowledge. In her experiment, the author investigated both directions.

Tabatabai concluded that when people do not share the same categorical knowledge miscommunication happens. In order to understand each other, both communicators have to adjust their categorical sets. One of her findings was that group performance improved after the translator (B) created a third categorical set in addition to the two initial ones and used that to translate the number communicated from (A) to (C).

Finally, during my Masters' Degree (Pimenta, 2011), I investigated how people communicate to each other in the context of structured and unstructured stimuli. I suggested that communication effectiveness is highly dependent on the degree of structure of the stimuli.

To study the problem, I designed three experimental conditions[2] where two people had to communicate to each other. Tasks 1 and 2 were designed with different stimuli but the same type of category structure – two different categorical attributes clearly identifiable by both participants. Shapes and sizes were used for task 1 and clothing items

[2] There were 4 conditions and conditions 1 and 2 each had two different designs. Therefore, in total each pair of participants performed 5 rounds of tasks. Since condition 4 and the variants of conditions 1 and 2 are not relevant for this study, I have not reported these in detail in the literature review.

and shades of blue for task 2. The objective of the tasks was to observe the effect of those known attributes on the communication process.

Task 3 required a different sort of stimulus to study information in the context of a category structure with categories that were not well-defined, i.e. a set of cards in which no attributes would be intentionally obvious, therefore, I drew random lines on 6 white cards (See Figure 1).

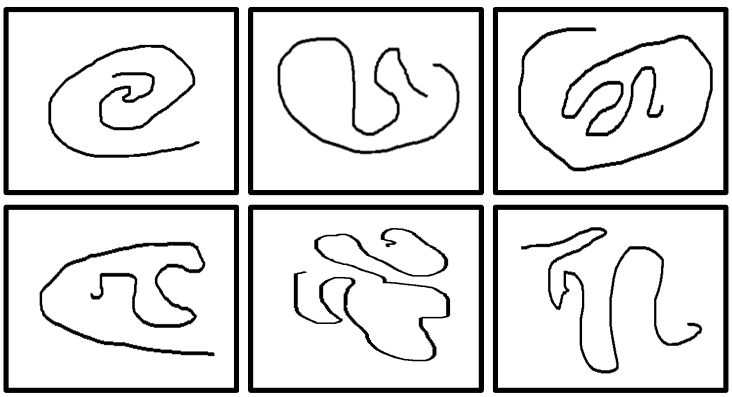


Figure 1 – Random drawings

The tasks were performed by groups of two participants. Each participant received a set of identical cards. One participant was instructed to make a sequence of their set of cards and then communicate that sequence to the other participant. Person 2 followed verbal instructions from Person 1 to end up with the same sequence at task completion. They were allowed to talk about everything, but not show one another their cards.

Analysis of the structured tasks showed that participants relied on the given attributes to communicate. Their presence helped participants to cluster the cards into sub-categories and to eliminate uncertainty as to which items in the set participants were referring to. In the unstructured task, participants also relied on attributes to reduce uncertainty in communicating, but in the absence of known attributes, they needed to develop some of their own. When dealing with the unstructured stimulus, participants identified various attributes on the cards that enabled them to create sub-categories and distinguish certain cards from others. For example, some participants perceived the whole drawing or parts of the drawings as being similar to certain objects in the real world such as animals, tools, shapes, etc. Other participants distinguished items based on perceived properties of the drawings, such as the endpoints of the lines, the number of curves, etc. By drawing such distinctions, they were able to group the cards into smaller subsets and reduce the number of potential outcomes. In other words, they used similarity judgments to create the missing categories. Creating these categories reduced uncertainty in the communication task.

2.2 Summary of the literature review on communication

Studies such as the ones on Uncertainty Reduction Theory (URT) and Uncertainty Management Theory (UMT) bring contributions to both psychological and behavioral fields. But in those studies uncertainty is not connected with communication of an item. Uncertainty is not related to the cognitive processes involved in communication either. On the other hand, Purdy (1989), Tabatabai (2009) and Pimenta (2011) are examples of research that investigated the role of either a well-defined set of possibilities or an individual system of categories within the communication context. Purdy (1989) studied the communication process as a function of its set structure. Tabatabai (2009) linked communication to categorical knowledge by studying how technical and non-technical people communicate to each other. Pimenta (2011) investigated how people communicate to each other in the context of unstructured stimuli. Although these studies bring important contributions to both communication and categorization fields there are still questions to be answered.

According to Shannon a message is selected from a set of probable messages (Shannon, 1948). When the set of possibilities is not well-defined, uncertainty increases. In human communication what defines a set of possibilities are categories. If categories overlap, people experience a high level of uncertainty and communication becomes complicated. Therefore, during the communication process, both the sender and receiver of a message have to identify an attribute that allows them to make similarity judgments and to cluster items. In other words, the sender perceives a certain structure and highlights it to the receiver by clustering items. The investigation of this process is the focus of this work.

2.3 Theoretical approaches to categorization

Many studies have shown that we have a limited capacity for processing information (Macrae, C. N. and Bodenhausen, 2001), therefore we try to categorize received information based on attributes or characteristics. For instance, we categorize by clustering similar things together. We not only think in terms of categories but we also talk in categorical terms (Searle, 1998). Hence, communication and categorization are interconnected.

To categorize "means to recognize that certain things belong 'together'"

(Rapoport, 1950), that they have common properties or characteristics and can be referred to as a group. As human beings, we all have the ability to categorize. Without that ability, we would be overwhelmed with all the information we get from the environment surrounding us. If we had to name each different thing we ever had contact with, language and communication would not be possible.

Items are put together in the same category if they share at least one similar attribute. Different items such as a shirt, a star, and a triangle can be classified in the same category if they share at least one attribute in common, if they are all black, for instance. If they have no attributes in common they cannot belong to the same category.

Categories also provide means of distinguishing between items. If items are not in the same category, the reason for putting them in different categories implies a lack of similarity or a distinction between them with respect to some attribute. For instance, items such as white and black circles of the same size can be classified in two distinct subcategories: the subcategory of white circles and the subcategory of black circles. On one hand all items in the set are similar with respect to the attribute ‘shape’ (all items are circles) on the other hand some items are distinct from others with respect to the attribute ‘colour’ (some items are white while others are black). In this example, ‘colour’ groups certain items within a subcategory (for instance, white items) and distinguishes those items from others outside the subcategory (non-white items).

There are different views as to how these categories are formed. Next sections discuss the three most famous categorization views. I start with the Classic view. In general, studies in categorization are related to cognition and are not connected to communication; therefore, I will not refer to the communication process except at the very end of the section.

2.3.1 Classical View

Until the 1970s, the prevailing theory on categorization was the classical view. According to the classic view, all instances of a concept share certain common properties, and these common properties are necessary and sufficient to define that concept. That is, possession of these properties distinguishes the members of a given category from non-members (necessary), and if something has these particular properties it must be a member (sufficient) (Smith and Medin, 1981). In other words, for the classical view, to categorize means to construct definitions (Murphy, 2002).

The classic theory received several criticisms. For instance, using the category of games as an example, Wittgenstein (1953) questioned the possibility to define all concepts/categories in terms of a set of necessary and sufficient properties. A definition for game should include all games. But considering that activities such as those that are played by groups, those that are sports (like hunting), workouts, and throwing the ball against the wall are all called games what really defines a game? What is necessary and sufficient? Defining a concept implies determining membership discretely. In the real world, it is not that easy to identify whether or not things are in or out of a category. Many people find it difficult to determine whether an avocado is a fruit or a vegetable, for instance. Not only may different people disagree about whether or not certain items belong to a category, but an individual might change his mind if asked the same question after an interval of time (McCloskey and Glucksberg, 1978).

A second problem is that the Classical View assumes that all members of a category are equal. But, Rosch (1975) showed that categories may have graded structures, where people perceive some items as being more typical of a given category than others, meaning there may be better or worse examples of the category. Murphy (2002) describes typical members as the good examples of a category, or the ones we normally think of when we think of the category, whereas atypical members may be weaker examples of the category. Thus in North America, robin would be a typical example of the category bird and penguin an atypical one.

Finally, Hampton (1982) points out some failures of transitivity, which can cause problems for those using the classical view. One advantage of the classical view is that it can explain how categories are hierarchically ordered. The classical view points out that if all X are Y, then the definition of Y must be included in the definition of X. For example, if all kitchen chairs are chairs, kitchen chairs must have four legs, have a back and arms, and be used for people to sit on, because that is the definition of a chair. This is the rule of transitivity. Hampton, however, found a number of cases in which people identify an item as a member of the subset category but not of the superordinate category. For example, subjects judged chairs as furniture and a car seat as a chair, but they did not consider a car seat to be furniture. By the rule of transitivity, if the car seat has the defining features of chair, and the chair has the defining features of furniture, both car seat and chair should be nested under furniture, since furniture should have the defining features of both.

In summary, the classic view fails to explain human categorization for at least three main reasons. First, it is not possible to find definitions that are necessary and sufficient to all concepts. Second, it does not explain the phenomena of typicality and unbounded membership. Third, it does not predict the existence of intransitive categories.

Since Rosch's empirical findings were fundamental to challenging the predominance of the classical view, the next section is dedicated to some of her studies as well as to some of the critics of her work.

2.3.2 Prototype view

Rosch was one of the main critics of the classical view and also provided much of the empirical findings that revealed its pitfalls. She pointed out that categories are ill-defined or "fuzzy", not discrete entities as proposed by the traditional view. Rosch suggested that categories are organized around a set of clusters of correlated attributes that are only characteristic of category membership (Rosch, 1975). Therefore category membership is defined in terms of a gradient of membership, whereby some exemplars are more representative of a category than others.

Rosch and Mervis (1975) developed a series of studies to investigate the internal structure of the categories organized around clusters of correlated attributes. In those studies, first they asked participants to list attributes for categories such as car, chair, and airplane. They then asked other people to perform typicality ratings. The researchers found that there were some listed attributes which were common to all members of the categories but that there were also many listed attributes which were not common to all members.

They also showed that the more typical members were those that had the most attributes in common with other members of the category. Rosch and Mervis gave the name 'family resemblance' to the empirically based, derived measurement of prototypicality in their studies. For a member of a category, family resemblance increases with the number of attributes it shares with members of its own category and decreases with the number of attributes it shares with other members of the contrasting categories.

Using the family resemblance measurement and the empirical data, Rosch and her associates also introduced the concept of prototype (Rosch and Mervis, 1975; Rosch, Mervis, Gray, Johnson, and Boyes-Braem, 1976). Prototype is "the clearest cases of category membership defined operationally by people's judgment of goodness of membership in the category" (Rosch, 1978, p.36). For instance, in most cases "orange" is a better example than "olive" for the "fruit" category. Rosch and her associates proposed that category members were considered as the most prototypical ones when they bore the most family resemblance to their category, and the least family resemblance to other categories. In other words, the most prototypical members have more attributes which overlap with those of other members of their category, and fewer attributes which overlap with members of other categories. Family resemblance refers to relationships in which each item has at least one, and probably several, elements in common with one or more other items, but no, or few, elements are common to all items (Rosch and Mervis, 1975). Therefore, Rosch and Mervis postulated natural semantic categories as networks of overlapping attributes, where prototypical members would share more family resemblance within the category and least family resemblance across category.

Rosch and Mervis' (1975) work should be read in the context of cognitive psychology. As Rosch clarifies in a later work (Rosch, 1978), her argument about family resemblance as a basis for categorization is related to cognitive economy. According to her, two principles regulate category formation: 1. the resultant system of categories has to provide the maximum information with the least cognitive effort; and 2. the perceived world has to come as structured information (not random attributes) (Rosch, 1978). Thus from the first principle it is possible to say that categorizing means maximizing information while saving resources, and from the second that categorizing involves organizing the world according to our perception of it.

She also says that because categories do not always have clear-cut boundaries (i.e. members are not discretely separated) cognitive economy is achieved through prototypes or best representatives. Because a prototype has higher family resemblance with other members of a category, it affects dependent variables used as measures in psychological research. For instance, the speed with which subjects can judge statements about category membership (reaction time) is much faster for the items rated as prototypical than for atypical members. As mentioned before, family resemblance refers to the idea that members of a category may be related to one another not by one essential common feature but by a series of overlapping similarities, where no one feature is common to all members of the category (Rosch and Mervis, 1975).

In this research, I will refer to the phenomenon of family resemblance later on and I will call it relative similarity. Two members of a category can be more or less similar to each other depending on the attributes they have in common. The problem is that, most frequently, there are many attributes along which such members can be compared. Our minds have finite capacity to process information from the environment; hence creating categories is a way of handling information based on the classification of some attributes of received information (Macrae and Bodenhausen, 2001). According to Rosch, cognitive economy can be achieved if common attributes are selected and things are grouped based on these attributes. One or more items are considered to belong to a category based on similar attributes so that the amount of information needed to distinguish them within their own category is maximized but the amount of information needed to distinguish them across categories is minimized (Rosch, 1978).

Murphy (2002) states that according to the prototype view family resemblance categories should be noticed, because they create clusters of similar items in the environment. In addition, according to Murphy, proponents of the prototype theory would argue that the single dimension sorting is biased because it is task-dependent. The design of the tasks would override "the true category-construction processes that are found in the wild" (Murphy, 2002, p. 133). Interestingly, although the human mind has means to differentiate things with almost infinite details, it generally does not differentiate beyond what is necessary and reasonable in a given situation. For instance, unless necessary, we do not need to break a chair into its attributes: beam of wood with four legs, bunch of nails, backrest, arms on both sides, and so on, to come to identify it as a chair and not as something else. Except for a good reason, nobody would give this as description of a chair. Most probably if we see a new object that looks like a chair, we will make an overall comparison, a holistic similarity judgment relative to some chair-attribute and quickly come to the conclusion that it is a chair.

The context of this study is cognition and communication. More specifically, participants want to communicate an item from a set of items. If in cognitive studies categorization aids in the development of more permanent and stable structures, which can be retrieved from memory and used to make comparisons, in communication of new stimuli that is not possible. When two people are given a messy set of stimulus items and they have to communicate one item from that set, they make use of categorization processes to distinguish. They perceive an attribute which allows them to judge how similar items are with respect to each other and, based on that attribute, they form two subcategories. That clustering or categorization is temporary. It is goal directed only, i.e. it is used to create the necessary categories in order to select the message to be communicated. As soon as the item is communicated, the categories might be forgotten.

2.3.3 Exemplar view

The exemplar view of categories was first formulated by Medin and Schaffer in 1978. They argued against Rosch's idea of a prototype as a unified representation of the category. For the followers of the exemplar view, the entire category is represented by multiple stored representations or a set of exemplars, rather than a separate representation for each member, or a prototype (Murphy, 2002). Membership judgments are made comparing new stimulus to those stored instances of the category. One's concept of a chair is not a list of attributes that are found to a certain degree in chairs (as Rosch would argue) but a set of actual chairs that the person remembers. In other words, there is no prototype because there is no summary representation that stands for all chairs.

The exemplar model proposes that every time a person encounters a particular entity it leaves a trace in the person's memory. Those traces accumulate over time and are used as mental references for comparison when the person categorizes new members. For example, an individual sees a new object in a room, s/he has to decide what that is. S/he sees it as quite similar to two or three objects that s/he knows about, fairly similar to a few more, and not too similar to many others. What s/he does is quickly consult her memory for which things it is most similar to and then makes a conclusion. Typicality effects are also accounted for in the exemplar approach. In its more extreme form, exemplar theory postulates that on each trial people perform some sort of global match between the representation of the stimulus they perceive and the memory representation they have of every exemplar of each category and to choose a response on the basis of these similarity computations (Brooks, 1978; Medin and Schaffer, 1978; Nosofsky, 1986). Compared to prototypes, exemplars can account faster for atypical category members, because an exemplar does not average out the characteristics of a category as the prototype does. They also can better explain variable categories such as "games" (categories with less distinguished characteristics) (Smith and Medin, 1981).

2.4 Summary of the categorization approaches

The theories reviewed in the field of categorization are all concerned with how categories are formed. The classical approach states that category membership can be discretely defined because categories contain singly necessary and jointly sufficient attributes. Both the prototype and exemplar views explain category membership based on perceived similarity. Prototype theory explains category membership by similarity to the category prototype (i.e. the member that shares the most attributes with other members of the category and fewest attributes with members of contrasting categories). Exemplar theory, in turn, proposes that category judgments are made by comparing attributes of a new member with attributes of other exemplars encountered and stored in memory. Thus, both prototype theory and exemplar view emphasize the importance of relative similarity for categorization. Researchers from both approaches agree that categories maximize perceived similarity within categories and minimize perceived similarity between categories.

2.5 Research on relative similarity

Rosch and Mervis' family resemblance categories have received many criticisms. Despite the plausibility of the family resemblance category-construction process and prototypicality theory, many empirical studies have demonstrated that categorization decisions are made based on a single attribute or dimension. For instance, Medin et al. (1987) reported a series of studies where people were given a set of stimulus items and asked to categorize them. According to Medin et al., the Rosch and Mervis (1975) measure of family resemblance accounts only for the frequency of the attribute, giving the same weight to all attributes or properties. Moreover, they state that "family resemblance traditionally has been defined in terms of matching and mismatching properties or attributes where the individual properties are treated as independent of and unrelated to each other" (p. 243). Therefore, to test categorization on the basis of family resemblance, Medin et al. (1987) varied the number of dimensions, the stimuli used and the instructions given to the participants in their initial experimental studies. For example, in one experiment, they varied every dimension with three different values. They used dimensions such as bugs with tails that were long, medium and short, in equal numbers. Each bug was printed on a card. Then they asked participants to categorize the cards into two groups of equal size, so that single dimension categorization would be avoided. However, the authors reported that participants put the bugs with short tails into one category and the ones with long tails into another category. They then categorized the remaining cards into one of the previous categories by looking at the medium tailed bugs until noticing tiny differences in tail length. They concluded that, people have a strong preference to categorize things by a single dimension rather than by family resemblance as defined by Rosch.

Regehr and Brooks (1995) also tried to prevent sorting by a single dimension. They used complex multidimensional shapes which could not be easily divided into single dimensions as stimuli. However they found that participants sorted items based on features that they arbitrarily identified in the stimuli. Those results are consistent with other studies (Martin and Caramazza, 1980; Milton and Wills, 2004).

Based on those results, Anh and Medin (1992) pointed out that Rosch's family resemblance measurement treats the attributes of members as independent of each other (or unrelated to one another). According to them, the measurement also assigns equal weight to the different attributes, and therefore,, fails to be the natural way that people would categorize things as Rosch suggested it would be. Ahn and Medin (1992) designed a series of experiments to test the similarity-based model. They used a two-stage model. In stage 1, participants chose a salient feature on which to sort the stimuli into two categories. In stage 2, the remaining items were classified into one of the previous categories based on relative similarity. For example, suppose participants created small vs. large categories and the rest of the items had a different dimension such as color. Participants would then have to create another basis for comparison regarding the initial categories so they could place the items in the more similar category. The authors concluded that, when there is no salient dimension in the stimulus, i.e. category structure is so complex that participants do not pay attention to any particular dimension, family resemblance categories can be formed. Similar results had been found and reported by Nosofsky et al, 1994.

As can be seen, although family resemblance category formation seems to be a reasonable process, results from experimental studies point in a different direction. Family resemblance construction has been successful only under specific conditions such as very complex stimuli. In general, rather than utilising family resemblance, people prefer to sort items based on single dimensions. If this is true regarding psychological studies, the same should happen in communication studies.

2.5.1 Relative Similarity in Cluster Analyses

The concept of relative similarity has also been used in machine learning, specifically in cluster analysis, which is a procedure used to create a classification by creating clusters or groups of highly similar entities (Aldenderfer and Blashfield, 1984). Entities in the same cluster are more similar to each other than they are to entities in other clusters. Researchers have developed various algorithms and similarity measures for use in cluster analysis. Each of those algorithms has its own notion of what a cluster means and how it is formed. For example, in centroid-based clusters, such as K-means, clusters are represented by a central vector, which may not be a member of the data set. The algorithm itself is quite simple. First it is necessary to select K initial centroids, where K is the number of clusters desired and has to be specified by the user. Each point is then assigned to the closest centroid, and each collection of points assigned to a centroid forms a cluster. The centroid of each cluster is then updated and the steps are repeated until the centroids remain the same (Kaufman & Rousseeuw, 1990). Agglomerative hierarchical clustering, on the other hand, connect points to form clusters based on their distances. The agglomerative hierarchical clustering starts with the points as individual clusters and, at each step, merges the closest pair of clusters. The key step for hierarchical clustering is to define the computation of the proximity between clusters (Aldenderfer and Blashfield, 1984).

Clustering has been used in different disciplines and with a variety of data. Documents are hierarchically clustered for efficient information access (Sahami, 1998) or retrieval (Bhatia and Deogun, 1998). Clustering is also used in marketing to group customers into different segments (Reuterrer et al, 2006; Cooil et al, 2007). In computer science, clustering can be used to divide a digital image into distinct regions for object recognition (Dorai and Jain, 1995), and to design recommender systems, i.e. systems that can predict a user's preference based on the preferences of other users in the user's cluster (Lee and Kwon, 2014).

No doubt these studies on cluster analyses contribute to their respective fields of knowledge. Clustering analysis is very useful when there is a need to classify abundant information into meaningful clusters. Moreover clustering algorithms classify various groups and variables at the same time. For example, different people can be classified into different clusters according to their incomes, level of education, gender, and so on. However, clustering analyses have limitations. Because of the different criterion of merging clusters, different methods of clustering give different results. More importantly, cluster analysis studies do not help to understand what structure is and how it is cognitively developed during the communication process.

2.5.2 Relative Similarity in a Communication Study

Tabatabai (2014) designed a series of experiments to study how categorical knowledge affects the learning of categories and communication. She examined how differences in the structure of categories affect the processing of information in category learning and in the communication of the learned categories. In her experiments, participants learned about categories of flowers from two different geographic regions. Category structure was defined in terms of the variability of items within the categories, a concept closely related to relative similarity. The flowers were either from a "simple" categorical structure (low within and high between variability) or from a "complex" categorical structure (high within and low between variability).

Three different experiments were designed to test hypotheses. To test the learning and communication process of the categories with different structure, participants learned about the flowers of the two regions in a supervised learning situation. Then they were separated into two groups. One group was presented with a simple set of flowers and the other group with a complex set. Next, they were asked to guess the origin of the flowers and to explain to which features they had paid attention. Finally, they were instructed to write instructions on how to distinguish between the flowers of the two regions. To measure the degree of effectiveness of the communication process of the learned categories, Tabatabai designed a second experiment in which participants learned about the flowers from the two different regions from the written instructions provided by experiment 1. Finally, to investigate the communication process between a person who learned a set of simple categories and a person who learned a set with complex categories, the author used an experiment similar to the first one. The third experiment differed from the first one only with respect to the written instructions. While in the first experiment each participant wrote their own instructions, in the third experiment one participant from the simple condition and one participant from the complex condition wrote the instructions on how to distinguish the flowers from the two regions in collaboration.

Tabatabai found that the structure of the categories influenced the number of features that the participants paid attention to. Participants who learned the complex categorical structure had to pay attention to more features than those who learned the simple structure. Second, participants who learned the more complex structure were less effective during the communication process. Finally, during interaction, participants who learned the simple categorical structure were more convincing about their knowledge than participants who learned the more complex one.

Most of the cognitive and/or psychological studies have focused on the process of category learning (Murphy (2002). Tabatabai (2014) is perhaps an exception. Although her studies are centered on category learning, they included communication. This allowed the author to draw some conclusions about the structure of learned categories and effects in some communication settings. However, the type of questions Tabatabai was concerned with was different from those which I am interested in. In this research I am concerned with how people communicate a target from an ambiguous set of items. The concept of relative similarity is important because in order to communicate a target, people have to distinguish the target first. People perceive different ways to cluster the target based on the relative similarity between the target and the other items.

2.6 Summary

In sum, although all the studies cited above are good contributions for the categorization literature, they all have a similar approach to the concepts of relative similarity, categories and attributes. It might be possible that in studies of categorization and cognition, such as those by Rosch and Mervis (1975), the categories formed are more stable or permanent. In that case, perception of an overall prototype would make sense. In the context of communication, however, the categories formed are not necessarily of the same sort, i.e., they do not need to be permanently learned.

In communication I would argue that categories are more *ad hoc* and goal oriented in the sense that they are formed by people to accomplish their immediate communication goals (Barsalou, 1983). For communication purposes, we do not need to process information coming from all the attributes. Since we can only refer to one thing at a time, if we were to communicate information based on an overall prototype representation, communication would not be efficient. Therefore, information is processed by paying attention only to the one attribute that allows for reducing the highest amount of uncertainty given a situation. To my knowledge, there is no literature investigating this issue.

In addition, most studies on how categories are formed, including those of Rosch, are conducted in ways that are disconnected from the communication context. For instance, a great amount of research on concepts has focused on the process of learning to categorize. Little exists on how people use categories and processes of categorization to communicate and process information. This current study aims to elaborate on this point.

In this research, I propose a different approach to relative similarity. I assume that when people have to communicate about stimuli that are not well defined, they use relative similarity to cluster items into smaller subsets. I propose that items are categorized based on perceived relative similarity, whereby similarity is maximized within categories and minimized between categories with respect to one attribute. Further, I postulate that when multiple attributes are involved, the sender perceives various ways of clustering the target item based on how similar/dissimilar it is with respect to the set of items. In addition, I postulate that when dealing with multiple perceived attributes, sender and receiver of the message have to choose the attribute that best distinguishes the target item from the other items in the set. I hypothesize that this attribute is the one that 1. maximizes the difference between the cluster which contains the target and the cluster of the other items, and 2. reduces the set as efficiently as possible to a subset of 1 (the target). These ideas will be developed in detail in the next sections.

Chapter 3

Research Framework

The research framework discusses how structure is developed in the context of communication; I draw on Communication Theory developed by Shannon (1948), which relates to information and uncertainty reduction in communication. This research also draws on Rosch and her associates' concept of relative similarity (or family resemblance, as in Rosch and Mervis, 1975). Shannon's Information Theory is used to analyze how information works to reduce uncertainty through the development of structure; I conceptualize this in terms of a system of categories. Relative similarity is used to explain the cognitive mechanisms involved in the development of those categories.

3.1 Communication and relative similarity

In this work, I apply Shannon's concepts of uncertainty and information to human communication. Shannon's Information Theory (1948) was developed to improve the transmission of a message from a sender to a receiver by both increasing channel capacity and decreasing noise of communication systems. Shannon's description of uncertainty can be understood as what a person experiences before learning the outcome of a probabilistic process and information as anything that reduces uncertainty. In Information Theory, information is measured in bits. One *bit* of information is the amount of information that reduces the number of equally likely outcomes by half. *Bits* are binary digits that can be represented by 1s or 0s.

According to Shannon, a message is selected from a set of possibilities. As human beings we do not organize the world through the use of 1s and 0s, we categorize. Our set of possibilities is therefore the way we categorize things. Categories allow uncertainty to be reduced in the same way that 1s and 0s do. As shown with the money in the box example in the introduction lefts and rights were equivalent to 1s and 0s in Information Theory. Each time the experimenter answered Yes/No for the participant question “whether or not the money was on the boxes on the left side?” uncertainty was reduced because half of the boxes was eliminated. The presence of categories reduces uncertainty regarding how to refer to one item within a set of items. However, categories are not always known. In human communication, categories are the pre-defined set of possibilities necessary for information to be conveyed and uncertainty to be reduced. Hence, if the set is not structured, i.e., if the categories are unknown, some structure has to be developed so that communication happens.

In addition to Shannon’s theory, in this research, I draw on Rosch and Mervis’ (1975) concept of relative similarity. I propose that when people have to communicate ambiguous stimuli they use relative similarity to develop categories, i.e., to create structure. Relative similarity refers to Rosch and Mervis’ (1975) concept of family resemblance. According to the authors, categories maximize perceived similarity among category members and minimize perceived similarity across contrasting category members. Rather than using the authors’ overall-similarity approach to categorization, in this research, relative similarity is defined with respect to a single attribute. By attribute I mean any basis for categorizing an item, which could include perceived overall similarity, or sharing just one perceived feature in common. Having categorized the item a certain way, this attribute then becomes a single dimension along which relative degrees of similarity for different items can be compared.

As mentioned in the literature review, Rosch and Mervis' theory of family resemblance was developed in the context of understanding cognitive processes involved in conceptual categorization. Categories in cognition are relatively stable and permanent. Therefore forming categories based on the overall-similarity of items in a category might make sense in the context of cognitive categorization, in which category structures are formed, stored, and are ready for retrieval repeatedly when needed. In this work I am not concerned with the repeated retrieval of information from a stable, permanent set of conceptual categories. This work investigates how people communicate one item from a set of ambiguous items for which a set of pre-conceived categories is not available. For this specific communication purpose, the use of categorization processes is different from that studied by Rosch and Mervis' (1975). I propose that people take advantage of the perceived structure of the ambiguous stimulus and form categories in a goal-oriented manner; this is done in order to distinguish the target item from other items in the set and to communicate these differences with greater efficacy. With this method of categorization, the categories developed might not be permanent. Judgments of similarities are used to create goal-directed categories that enable information processing by distinguishing the target from other items in the set. To form such goal-directed categories, people focus on whatever attributes best enable them to distinguish the target item from the others (Barsalou, 1983).

In this thesis, the words feature, attribute, dimension, and category are used interchangeably and with a broader meaning than usually given in the literature. Tversky (1977), for example states that features or attributes are characteristics of objects. Rosch (1978) defines categories as "a number of objects that are considered equivalent" usually designated by names such as dog, animal (p.4). Similar to Tversky, Rosch also considers attributes as characteristics of the categories. In this study category and attribute are understood as "analytically equivalent" (Ran and Duimering, 2007, p.159). A person decides to categorize items together based on some characteristic or attribute that makes them similar. In doing so, those items in the category have in common the fact that they all share the same attribute; the attribute becomes the definition of the category. Hence, attribute and category are analytically equivalent in how we use them for communication purposes. Moreover, a person perceives a similarity with respect to 'something'. The basis for that 'something' could be some sort of complicated overall similarity (computed across shared features), some holistic gestalt similarity or a single feature similarity. No matter what the basis is for this 'something', once it is perceived, that something becomes *the* attribute. Therefore, feature, attribute, dimension, and category are used as synonyms and refer not to an inherent property of an object but to any basis that can categorize or distinguish an item from a set of items. Whether someone compares items based on perceived overall similarity or similarity of a single feature, once the basis for comparison is perceived it becomes *the* attribute.

Note I am not arguing that possession of a specific attribute is identical to overall similarity between two items or a perceived resemblance between an item and some third thing such as a mental image, a category prototype etc. I am simply arguing that any of these bases for categorization can be used to draw distinctions among a set of ambiguous items for the purpose of information processing in communication. So as a short hand, I use the term attribute in general to refer to any of these various ways of drawing distinctions as a basis for categorization. I also use the word similarity in a general way to refer to various perceptual processes associated with perceiving such distinctions. For instance, perceiving that two or more ambiguous items may share a common feature or bare an overall resemblance to one another or a similarity to some thing else such as an image or an object in the world.

3.2 Communication and structure

3.2.1 Communicating an item from a structured set

The following shows a simplified example to explain the above concepts in a communication context. Suppose two people were given a structured set of cards, such as the triangles and circles of varying sizes shown in Figure 2 and one of them was asked to randomly select one of the items of the set and communicate that item to the other person. The sender of the message wants to communicate item 1. In this specific case, the sender has no problem selecting the item and in referring to it as a triangle while communicating to the other person. There is a definite set of items, 6 shapes; both people know how to refer to the different items – they are triangles or circles in different sizes. In other words, the categories (triangles/circles in their different sizes) needed for effective communication are already available to both people. I am calling this example structured because both sender and receiver can readily identify the subcategories based on the attributes of shape and size.

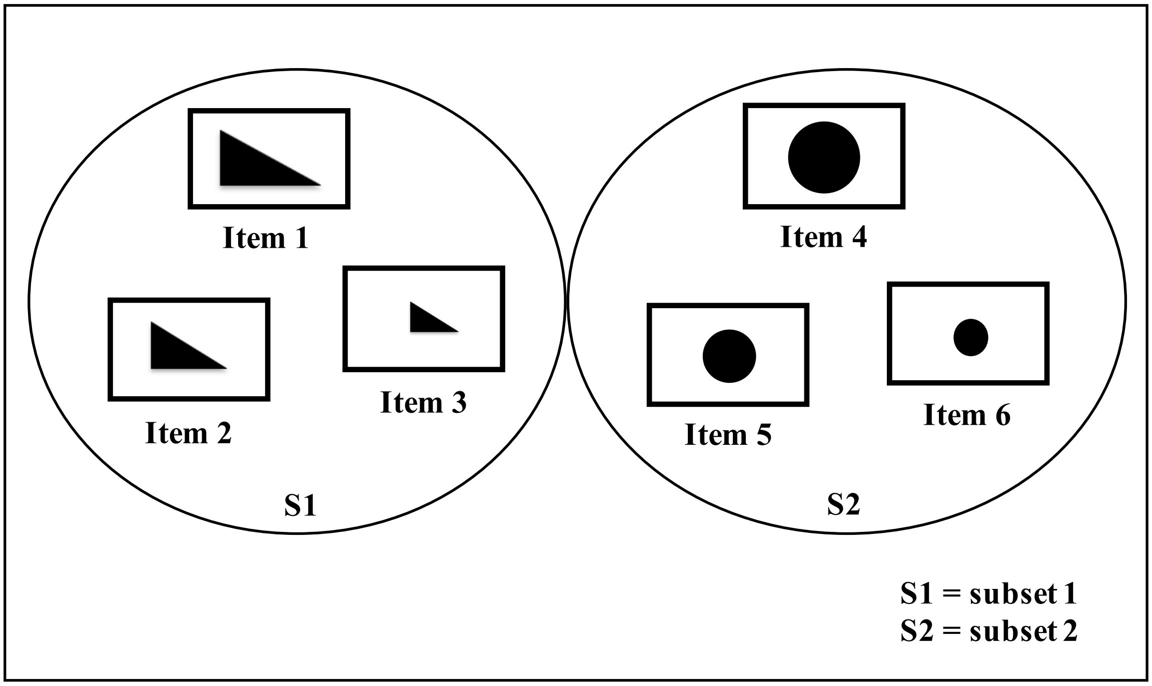


Figure 2 – Structured set

During the communication process, more structure means less uncertainty. Both people perceive without a doubt that there are certain shapes that are more similar to triangles and others that are not similar. The sender has no uncertainty regarding how to refer to an item. If s/he wants to communicate item 1, s/he refers to it as a triangle. On the other hand, the receiver has no uncertainty with respect to what a triangle is. All the cards one person perceives as triangles are the same ones the other person perceives as triangles. Due to the perception of a sharp distinction separating the two categories, there is no category overlap. The receiver uncertainty is only with respect to the outcome, i.e. which item within the possible items. The sender communicated a triangle. The receiver clusters their items into subsets of triangles (3 items) and non-triangles (3 items). According to Shannon, since the set decreased from 6 to 3, uncertainty was reduced by half. After the first attribute is used to reduce uncertainty and the two subcategories are formed, that attribute is of no further use to reduce the remaining uncertainty. To reduce the remaining uncertainty, the sender of the message must select a new attribute to base their similarity judgments on.

In general terms, when people have to communicate a target item from a set of items, as in Figure 2, they use judgments of similarity to categorize those items. In this study, relative similarity relates to the relative probability of an item being perceived as a member of a specific category. Given a certain attribute along which it is possible to evaluate the similarity of a set of items, similarity judgments can be represented as a probability distribution reflecting the relative probability of perceiving the item in a given category.

Suppose different individuals are looking at the set of items shown in figure 2. If we ask these individuals to judge similarity of those items based on the attribute triangle, we would expect these ratings to form a probability distribution similar to the one in Table 1 below, with a 100% chance of items 1-3 being grouped as triangles, because people perceive those items as highly similar to triangles, and 0% chance of the items 4-6 being grouped with the triangles, because people perceive circles as dissimilar from triangles.

Card Number	Probability (%)
1	100
2	100
3	100
4	0
5	0
6	0

Table 1 – Probability of items being perceived as a triangle

In this case, the boundary between the two categories (triangles and non-triangles) is very clear, with a very large gap separating them. I use the term 'gap' in this example to refer to the difference between the probability of people perceiving items 1, 2, and 3 as a triangle and the probability of people perceiving items 4, 5, 6 as a triangle. More specifically, the term gap is used in relation to probability distributions like the one in table 1 to refer to the difference in probability between the "least triangle" member of the triangle category (item 3 in this example) and the "most triangle" member of the non-triangle category (item 4 in this example). This will be more apparent in later examples where the boundaries between categories are not as sharply defined. In terms of perception, the gap relates to the individual perception of a sharp distinction between two clusters: triangles and non-triangles. In this specific example, the large gap (100%) corresponds with a person's perception of the items as clustering into two distinct subsets: triangles and circles. The perception of such a sharp, clear distinction can be interpreted as evidence of structure.

After clustering the items in figure 2 according to shape, we can say that the degree of similarity of the items within both subcategories is equally high (approximately the same), i.e. the triangles are very similar to one another and the non-triangles (circles) are also very similar to one another. On the other hand the similarity between the triangles and the circles is very low. Therefore, categorizing the items this way tends to maximize the similarity within the categories and minimize the similarity between categories.

According to Shannon's Information Theory, information conveyed in communication reduces uncertainty relative to a predefined set of possibilities. Hence, if there is no structure, information can only be conveyed and uncertainty reduced after some structure is created to define the set of possibilities. I draw on Rosch and Mervis' (1975) concept of relative similarity to propose that people use similarity judgments to create structure by dividing a complex unstructured stimulus into a set of categories.

More structure means less uncertainty when people communicate an item from a set of items. Structured sets are those in which both people perceive certain attributes and both know how to refer to them. People use judgments of relative similarity to categorize items of a set. They perceive, with respect to a certain attribute, that some items in a set share high similarity to each other and low similarity to others. During the communication process, the sender has no uncertainty with respect to which category the item belongs to. The receiver uncertainty, regarding which item within the set of possible items is the selected item, is also very little.

However, structured sets of items are rare. In the real world, people have to communicate ambiguous items. When sets are unstructured, the sender and receiver of the message may disagree regarding to which category an item belongs. Therefore, communicating unstructured sets will not be as easy as communicating structured sets.

3.2.2 Communicating an item from an unstructured set

The preceding example considers communication of an item from structured sets. The general idea suggests that to communicate one item, given an initial set of items, people will first create sub-categories based on judgments of similarity relative to one perceived attribute. Consider a new set of items such as in figure 3. Compared to the figure 2 set, this set has a different degree of structure, i.e. the gap separating one subset from the other does not allow for the same sharp distinction. Items within the set cannot be clustered discretely in triangles and circles (non-triangles) but instead there are overlapping categories. Suppose that, one person is asked to communicate item 7 to another person. The sender decides to refer to item 7 as a triangle. In order to identify which one of the 7 items is the referred triangle, the receiver clusters their items into triangles and non-triangles.

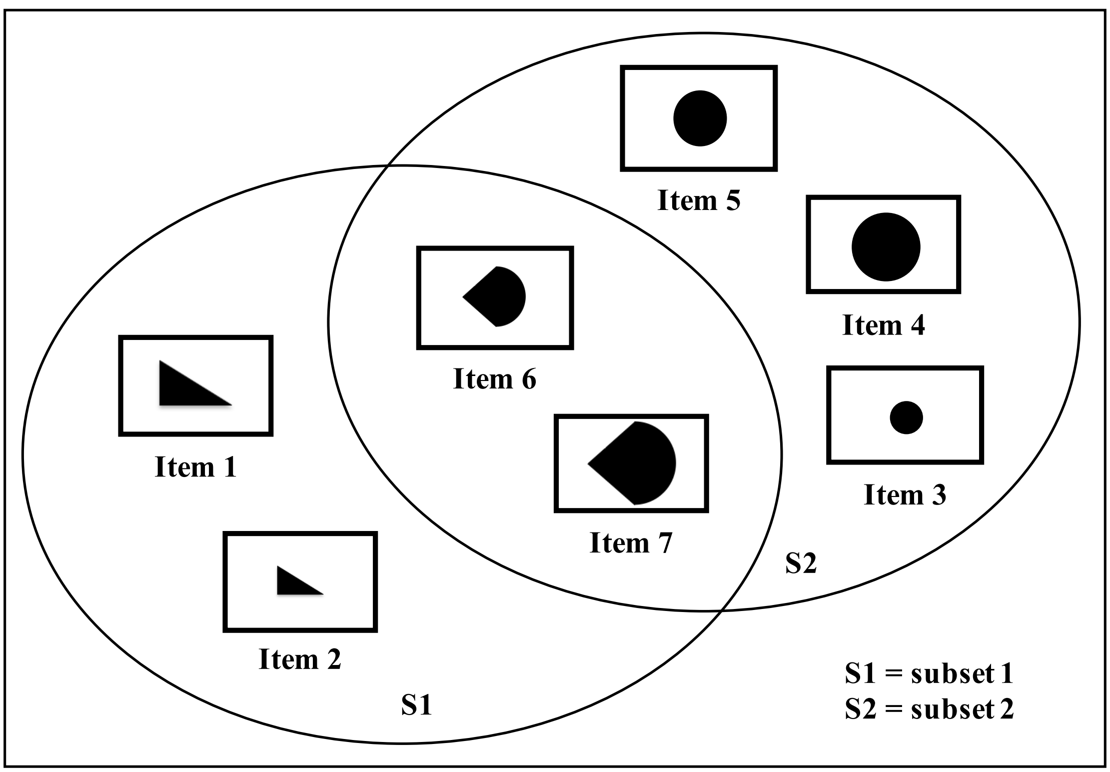


Figure 3 – Less structured set

Since the set of items contains triangles, circles, as well as boundary items that have attributes similar to both triangles and circles (straight lines forming an angle on one side, and curvilinear on the other side) the receiver might perceive item 7 as either a triangle or a circle. For the sake of the argument, suppose we have asked a group of people to judge the similarity of these items with respect to the attribute triangle. Since items 6 and 7 are boundary items, compared to the previous probability distribution, we would expect the following differences (see Table 2).

Card Number	Probability (%)
1	100
2	100
6	50
7	50
3	0
4	0
5	0

Table 2 – Probability of items being perceived as a triangle

In Table 1, there was a sharp gap, i.e. the difference between the probability of the least triangle being perceived as a triangle (100) and the probability of the most non-triangle being perceived as a triangle (0) was very clear (100 – 0). In Table 2 there is no clear gap between the triangles and non-triangles. Instead the two categories overlap. The probability of items 1 and 2 being perceived as a triangle is 100%, the probability of items 3, 4, and 5 being perceived as a triangle is 0%, and the probability of the boundary items 6 and 7 being perceived as a triangle is 50%. That is to say that the gap between the categories of triangles and non-triangles is not as sharp as it was before (now only a probability difference of 50% rather than 100%).

Therefore, less structure means more uncertainty. Individuals may not agree on whether or not an item belongs to the same category. For instance, if the sender describes item 7 as a triangle but the receiver perceives only items 1, and 2 as triangles miscommunication will result. When categories overlap the sender experiences uncertainty about how to refer to an item. In this case, the attributes of triangles and circles do not work as reliable codes anymore. The sender can refer to item 7 equally as triangle or circle. On the other hand, the receiver also experiences uncertainty regarding which item within the set of items is the one being referred to. Depending on the sender's choice of attribute, the receiver has also 50% probability of getting it right. Therefore, the level of uncertainty is much higher than in structured sets.

Although the size of gap is not as large as in the previous example, there is a certain amount of uncertainty being reduced. By communicating item 7 as a triangle, the initial set is reduced from 7 items to 4. 3 items (items 3, 4, and 5) are eliminated. People perceive the distinction between items 2 and 6, and between items 7 and 3, but there is some uncertainty about whether 6 and 7 are included in the triangle or the non-triangle categories.

In addition, this example raises the idea of the position of the gap, i.e., where the gap is located on the continuum. In the example in Figure 2, there was a sharp gap between triangles and non-triangles and a fixed location for the gap in the continuum. People perceived a clear distinction between triangles and non-triangles. In the Figure 3 example, the distinction is not obvious anymore. The boundaries are now fuzzy. There is uncertainty regarding where the gap should be located. By varying the gap position in the continuum, different amounts of uncertainty is reduced. Three out of the seven items are eliminated by one position and five out of the seven are eliminated by the other position.

The example above illustrates how the process of communication becomes more complex when attributes overlap.

3.2.3 Communication process and the development of structure

In the previous section I used simple examples to illustrate how communication is affected when people deal with sets with different degrees of structure. As we considered before, in structured sets the level of uncertainty is minimal because both the sender and receiver of the message know how to refer to the items. Categories are easily perceived, allowing for clustering and therefore reduction in the sender uncertainty regarding the best choice of attribute with which to encode the message. In these structured sets, the receiver has no difficulty in decoding the message regarding which item within the set is being communicated. In unstructured sets, however, both the sender and receiver experience uncertainty. The sender does not how to refer to the item. The receiver does not know which item from the set of items is the item being communicated. Since categories are not clear, the sender might encode an item as belonging to category A and the receiver might decode it as belonging to category B. To decrease the sender uncertainty, it is necessary to create smaller subsets or subcategories, in other words, to build structure. Therefore, communication is highly dependent on structure.

To better explain how structure in communication is developed, I will discuss the third experiment performed by participants during my Masters' Degree (Pimenta, 2011). I described the experiment in detail in the literature review. As I pointed out, during the communication process, it was very difficult for participants to refer to the set of items shown on Figure 4 given that the cards had only random lines drawn on them.

Participants did not have known or well-defined categories to rely on. They had to develop these structural categories step by step.

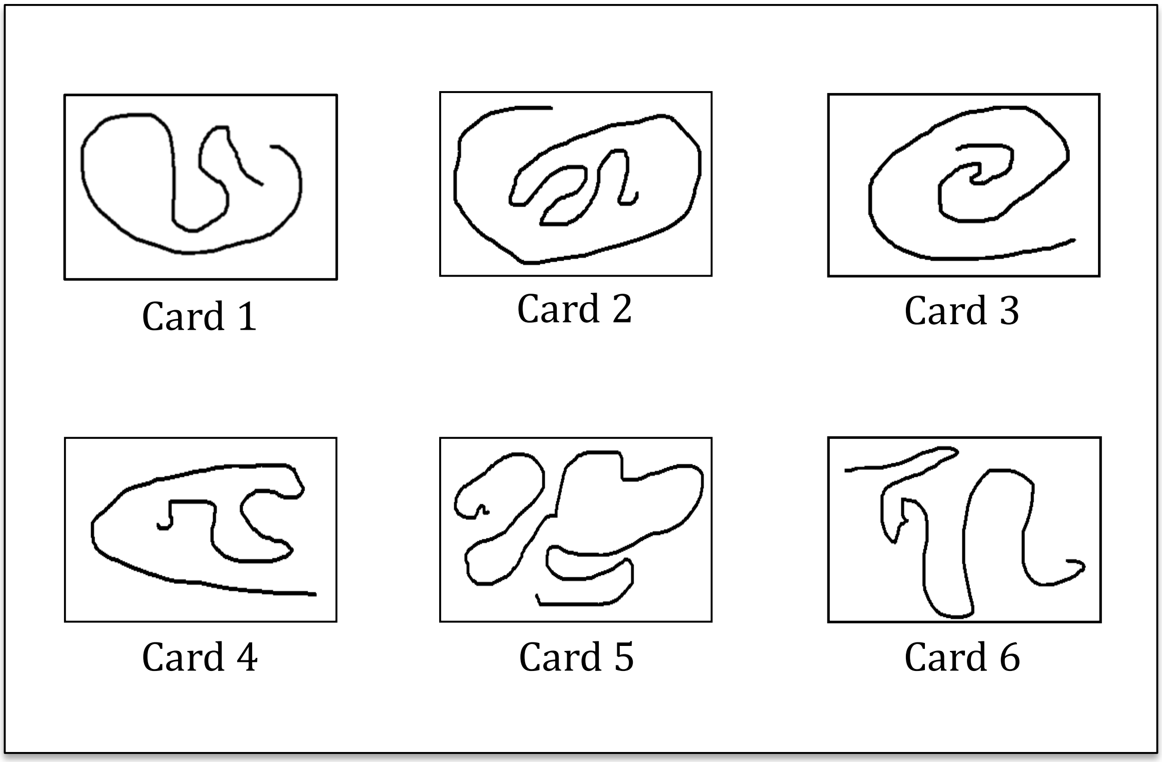


Figure 4 – Random lines numbered

Individuals performing the task perceived distinctive attributes on the cards by associating the entire drawing, or parts of it, with objects from the real world. For example, parts of two cards were identified as wrenches, some cards were identified as rounded, others were called boots, dogs, a fetus, and so on.

Each time the communicators judged their cards to be similar, they created the missing categories needed for effective communication. If both communicators identified the same card as the fetus, for instance, they broke the set of cards into two smaller subsets, the set of 1 fetus card and the set of 5 non-fetus cards. They could then use those categories effectively in their communication just as triangles and circles were used in the earlier examples. In other words, they created a structure that was not defined before. Both of them share the same structure of subcategories in this case, i.e. fetus and non-fetus.

However, the two people communicating did not always identify the same card as the fetus, that is, different people formed different structures. It was possible that the sender perceived card 1 as the fetus while the receiver identified card 2 as the fetus. In this case, although it might seem for both of them that they had two smaller subsets, fetus and non-fetus, their subsets or subcategories did not correspond. In a different situation, the sender might have perceived card 1 as the fetus while the receiver thinks that cards 1 and 2 are both fetus-like. Hence, the sender had a subset of 1 fetus and the receiver had a subset of 2 fetuses. Or yet, the receiver did not see any fetus – thus any of the 6 cards could be the fetus for the receiver. In all those cases, the sender and the receiver would not have the same subsets. As a consequence describing card 1 as "fetus" would not be effective.

Another example of how communicators grouped their cards into subcategories is the following. Participants perceived some of the cards as being circular or round. However, as with the fetus example, communicators differed on their judgments and in their perceptions of whether or not an item was round. Because there was no clear-cut boundary between round items and non-round items, some people found 2 cards more circular (any 2 among cards 1, 2, 3, 4), many saw 3 (any 3 among cards 1, 2, 3, 4), while others, 4 cards (cards 1, 2, 3, 4). Therefore, categories overlapped with respect to the attribute of roundness. The two people formed quite different subsets of cards, which means that they did not necessarily talk about the same card, though they thought they did.

It is worth comparing the current fetus and roundness examples to the earlier triangle and circle examples. In both cases I argue that judgments of relative similarity are used to reduce uncertainty by placing items into subcategories. In the first triangle/circle example, attributes were crisply structured and both people shared the same structure and had no difficulty categorizing the items. On the other hand, when attributes are unstructured, as with the boundary items in the second, less structured triangle/circle example and in the current fetus/roundness examples, categories overlap and uncertainty increases as communicators are unsure of how to refer to the items.

To summarize, when people have to refer to one item among a set of items they have to handle uncertainty. There are two sources of uncertainty associated with overlapping categories, the sender uncertainty regarding the encoding of the message and the receiver uncertainty regarding which item in the possible set of items is the one being referred to. Handling uncertainty in unstructured sets means not only dealing with the receiver uncertainty but also with the sender uncertainty. In the unstructured sets, clearly defined subcategories are not available. Therefore, judgments of relative similarity have to be used to develop those subcategories and build structure. The sender and the receiver uncertainty are reduced when subcategories are available.

In section 3.2.1, I have assumed that people attempt to maximize similarity within the category and minimize it between the categories when communicating structured sets. I argue that similarity is relative to the one perceived attribute that maximizes distinction between the subsets. Some basis for judging similarity is chosen to maximize the distinctiveness of the target item. This then becomes the single attribute used, both to refer to the item and to divide the set into subsets. In addition, relative similarity relates to the relative probability of an item being perceived as a member of a specific category. To illustrate relative similarity, I started with a two-dimensional structured set: i.e. a set of items in which only shapes and size were needed to communicate the items efficiently. I assumed that people would start dividing their cards into two subsets of different shapes (triangles/circles), not sizes (small/big). In other words, no choice between the two dimensions was taken into account[3]. However, when dealing with multiple dimensions, people deal with choice. For instance, if they have a set of items varying in terms of shape and colour, some people might choose to cluster items first in terms of color while others might choose to do so in terms of shape. In cases of unstructured sets in which attributes overlap and uncertainty is higher, both sender and receiver experience difficulty in choosing among multiple perceived attributes. The sender must choose the best alternative regarding how to refer to an item and the receiver has to choose the best alternative regarding which item within the possible items is the one being referred to. I propose that to reduce both types of uncertainty two different categorization logics operate: one related to the size of the gap, and another one related to the gap location in the similarity continuum.

[3] In section 3.2.2., I touched very briefly on the notion of choice of attributes while introducing the concept of gap position.

3.3 Categorization logics

As I pointed out earlier in the literature review as well as in the above examples, judgments of similarity are made with respect to one attribute. I also have mentioned that, during the communication of one item from a set of unstructured items, both sender and receiver of the message deal with uncertainty. The degree of uncertainty is higher when communicating an item from an unstructured set because the attributes overlap. Uncertainty is reduced when sender and receiver of the message perceive an attribute which allow them to cluster items through similarity judgments. I postulate that when dealing with multiple attributes the sender and receiver of a message have a choice of one attribute over others in order to reduce their uncertainties. In other words, when dealing with multiple attributes people will choose one that maximizes information processing.

When dealing with structured sets, people perceive that items are more similar to others and therefore in order to distinguish an item they create subcategories. Because the attributes are well defined, the sender of the message has no uncertainty regarding how to refer to an item. The receiver has little uncertainty regarding which item is referred to from the set of possible items. Therefore, in structured sets, the attribute reduces uncertainty regarding which category the item belongs to and regarding the item within the possible items being referred to. For example, when the sender of the message communicates a triangle, since the receiver knows what a triangle looks like, there is no uncertainty with respect to the subcategory being referred to. There is sharp distinction (i.e. a large gap) between the two subcategories (triangle/circle).

Unstructured sets might differ as uncertainty in those sets is higher. Different attributes might be associated with different methods of achieving maximal information processing. One attribute may be associated with creating two well-defined subcategories, and judging similarity based on that attribute allows for a nice, sharp gap along the continuum. On the other hand, the choice of another attribute might influence where the gap is located along the similarity continuum. In this case, the attribute chosen could allow the division of the set into subsets of different sizes. Information is transmitted because, each time there is a division into subsets, the number of items decreases. However, there is less information gain with respect to developing well-defined subcategories or structure to the set if the boundary between the resulting subsets is not sharply defined.

Both attributes “round” and “fetus” (see figure 4) are examples of information gain due to both the size of the gap and the position of the gap. However, the choice of “fetus” as the communicated attribute results in greater information gain (more uncertainty reduction) than the choice of the “round” attribute.

3.3.1 “Round” attribute

The sender wants to communicate card 1. As mentioned before, card 1 was perceived as “round” but it was also perceived as a “fetus”. The choice of one attribute is more efficient than the other. Let us consider each attribute option separately, starting with the attribute “round”.

By choosing to communicate it as round, the sender could have a subset of 4 cards similar to round (cards 1, 2, 3, 4) and two cards not similar to round (cards 5, 6).

For the sake of the argument, suppose we have asked a group of people to make similarity judgments of cards 1 to 6 with respect to how similar they were with respect to the attribute roundness and we have gotten the following probability distribution as a result (Table 3).

Card Number	Probability (%)
3	99
2	95
1	88
4	55
5	10
6	0

Table 3 – Probability of cards being perceived as round

Based on the probability distribution (Table 3) we would expect more agreement among people while judging cards 3, 2, and 1 with respect to the degree of roundness (a relatively continuous distribution), and would expect an amount of disagreement between cards 1 and 4 (a jump in the distribution), but not yet enough to say with certainty that card number 4 does not belong to the cluster anymore. A 55% chance means that the card is borderline, still similar enough to cause perceptual uncertainty.

The size of the gap between cards 3 and 2 varies by only 4% (99 – 95), between cards 2 and 1 by 7% (95 – 88). Finally, between cards 1 and 4 the gap size increases to 33% (88 – 55). In similarity terms it means that with respect to the attribute roundness, cards 3 and 2 share almost the same degree of similarity as cards 2 and 1. Then between cards 2 and 1 and cards 1 and 4, the similarity of the first pair is higher than the similarity of the second which indicates that people would have doubt whether or not to include card 4 in the subset.

Between cards 4 and 5 there is a gap of 35% (55 – 10). Because that variation is almost the same as the previous variation it does not help people to reduce their uncertainty about where the boundary is set (see Table 4). That is to say, if with respect to the attribute roundness people perceived card 5 as more similar to card 4, the boundary would be perceived after the third card, resulting in the subset of round (3, 2, 1) and non-round (4, 5, 6) cards. However, because the degree of similarity between cards 4 and 5 is almost the same as between cards 1 and 4, people still do not know in which subset card 4 goes. In this case there is no sharp gap that allows for a reliable separation along the continuum of round/non-round cards.

To summarize, the gap could be perceived as after card 3 or after card 4. In the first case, the subset round would contain cards 1, 2, and 3. In the second case, the subset round would have cards 1, 2, 3, and 4. With either, the size of the gap reduces some uncertainty – as cards 5 and 6 are eliminated from the initial set. But as a fuzzy boundary is perceived there is still uncertainty remaining.

Comparison between cards with respect to roundness

	Cards 3 and 2	Cards 2 and 4	Cards 4 and 1	Cards 1 and 5
Gap	0.04	0.07	0.33	0.35
Within similarity	High	High	Low	Low
Between similarity	Low	Low	High	High

Table 4 – Round cards with respect to gap and relative similarity

With respect to the position of the gap, since the perception of the boundary was fuzzy, there were two possible positions. The first resulted in information gain (uncertainty reduction) by eliminating 2 out of the 6 initial outcomes. The second, by eliminating 3 out of 6. Since the smaller the subset remaining, the more informative it is; the second option is better than the first.

To summarize, since the attribute round does not allow for perception of a sharp gap, there is no clear boundary between subcategories. The size of the gap reduces some uncertainty, but there is still remaining uncertainty. Based on the position of the gap, the initial subset can be decreased from 6 cards to 3, or from 6 to 4. Therefore, if the goal is to communicate card 1, by choosing the attribute “round” and creating two subcategories of 3 cards versus 3 cards, or 2 versus 4, a certain amount of uncertainty is reduced.

3.3.2 “Fetus” attribute

By choosing to communicate card 1 as a fetus, the sender has a subset of one card similar to a fetus (card 1) and another subset of five cards not similar to a fetus (cards 2, 3, 4, 5, 6). For the sake of the argument, suppose that we have asked a separate group of people to judge the degree of similarity of the 6 cards in Figure 6 with respect to a “fetus”, and as a result we obtained the probability distributions in Table 5. In this case most individuals perceive card 1 as most similar to a fetus. Some people found that card 2 resembled a fetus, but with a lower degree of similarity than card 1. According to the probability distribution in table 5, we would expect that with respect to the attribute fetus, the sender and the receiver would most likely perceive the boundary separating subsets between cards 1 and 2, creating the categories of fetus (card 1) and non-fetus (cards 2 to 6).

Card Number	Probability (%)
1	95
2	17
3	0
4	0
5	0
6	0

Table 5 – Probability of the cards being perceived as fetus

More specifically, there is a huge difference between the probability of people perceiving card 1 as being a fetus (95%) and people perceiving card 2 as a fetus (17%), a difference of 78%. The corresponding gap is much smaller between cards 2 and 3 (a probability difference of only 17%). It means that, with respect to the attribute fetus, cards 1 and 2 share lower similarity between them than cards 2 and 3 (see Table 6). Card 1 is perceived as highly similar to what a fetus is. Card 3 is not similar. People perceive a sharp distinction between cards 1 and 2. Because card 2 is very similar to card 3 with respect to the attribute fetus, i.e. they are both non-fetus, people perceive the boundary at the second card. We expect that, regarding the attribute “fetus”, people will cluster card 1 against all the other cards because between cards 1 and 2 there is a bigger, sharper gap along the fetus/non-fetus continuum than between cards 2 and 3 or cards 3 and 4 or any two other cards. The fetus cluster would have only one item – card number 1 – and all the other cards would be in the non-fetus cluster. The choice of fetus as an attribute for clustering the items into subsets allows for a large information gain by reducing the uncertainty regarding the categories. The large gap allows for a nice, crisp perceptual clustering through maximal distinctiveness.

Comparison between cards with respect to fetus

	Cards 1 and 2	Cards 2 and 3
Gap	0.78	0.17
Within similarity	High	Low
Between similarity	Low	High

Table 6 – Fetus cards with respect to gap and relative similarity

The attribute fetus brings yet additional information gain due to the position of the gap. By describing card 1 as a fetus, the sender clusters his initial set of items into two subsets: the subset of fetus-like cards and the subset of non-fetus-like cards. Because the subset of fetus contains only 1 card (card 1) maximal information gain is achieved. 5 of the 6 items from the original set have been eliminated so there is no remaining uncertainty to be reduced.

In summation, the choice of the attribute "fetus" over "round" is the result of judgments of relative similarity. People perceive a sharp distinction between cards 1 and 2 with respect to the attribute fetus. The attribute round does not allow for such a sharp distinction. In addition, the fetus subset has only 1 item – the target item; whereas the round subset will have either 3 or 4 items. Therefore by choosing fetus, both sender and receiver are better off. The sender knows how to refer to the target and the receiver knows which item is being referred to from the set of items. Maximal efficiency is achieved.

3.3.3 Hypotheses: Gap Size and Gap Position

If people want to communicate an item from a set of ambiguous items, I postulate that there is a choice of an attribute that best distinguishes the target item. The sender perceives different ways to cluster the target based on how similar/dissimilar it is from the other items in the set with respect to different attributes. The choice of the attribute that best distinguishes the target item comes from: 1. picking the attribute that results in the largest gap between clusters, and 2. picking the attribute that minimizes the sizes of the subset containing the target item, to reduce the set as efficiently as possible to a subset of 1 (the target). Based on this logic, the following hypotheses can be stated about how people choose between different attributes based on gap size and position.

***Hypothesis 1*: when communicating an item from a set of items, if people have to choose between one or more attributes, they will choose the one which maximizes the size of the gap, if position of the gap is controlled for.**

***Hypothesis 2*: when communicating sets of items, if people have to choose between one or more attributes, they will choose the one which results in a smaller subset size compared to the entire set, if the size of the gap is controlled for.**

3.4 Framework summary

In summation, the aim of this study is to investigate how information is processed and uncertainty is reduced when people communicate about ambiguous, unstructured. I argue that the degree of structure of the stimuli influences the amount and the source of uncertainty to be handled. Low degree of structure increases uncertainty, and therefore increases the need for information. I assume the use of perceived relative similarity as a mechanism of structuring the communication process. By relative similarity I refer to the perceptual phenomenon whereby similarity is maximized within categories and minimized between categories with respect to one attribute.

I argue that because relative similarity allows for clustering into subsets, it can be used to explain what happens when we communicate an item. During the communication process, if we want to refer to an item within a set of items we have to distinguish that item first. Distinguishing that item involves clustering. We cluster items that are similar to each other and leave out items that are dissimilar. Furthermore, I argue that judgments of relative similarity are made with respect to one attribute. Each time one attribute is perceived to create a cluster or a subset, uncertainty is reduced.

Furthermore, I postulate that when people have to communicate unstructured stimuli with a choice of attribute from multiple possible attributes, two categorical logics operate to reduce uncertainty: one that maximizes distinctiveness between categories by allowing for a larger gap (hypothesis 1) and one that maximizes the information gain by allowing the initial set to be clustered into smaller subsets (hypothesis 2). In terms of results, for the gap size, I expect people to choose the attribute corresponding with the larger perceived gap between two categories, resulting in a sharper distinction. For the gap position, I expect people to choose the attribute that would split the set into the smallest possible subset.

Chapter 4
Method

4.1 Overview of the experiments

Three experiments were designed to test the hypotheses. In all experiments, participants were presented a set of pictures or items and a corresponding set of attributes. Participants then performed a number of ranking tasks designed to emulate either the sender or the receiver perspective in a one-way communication situation. The sender tasks involved ranking a set of attributes based on the extent to which each attribute could be used to identify a specific target item from the set of items. The receiver tasks involved ranking a set of items given a single attribute based on the extent to which the attribute referred to the various items in the set.

In the first two experiments I used ambiguous stimuli in which there were no obvious gaps creating distinctions. Experiment 1 used random drawings and experiment 2 used Rorschach inkblots. The third experiment used a carefully designed two-dimensional stimulus in which the attributes shape and colour were varied in a controlled manner. This allowed for manipulation of the position and size of the gap with respect to the two attributes.

Three different one-way communication tasks were designed for the experiments. Experiments 1 and 2 each included all three tasks, while experiment 3 contained 2 of the tasks. All of the tasks involved participants ranking a presented set of items and attributes. For tasks 1 and 3, participants had to rank the attributes with respect to a target item. For task 2, they ranked items with respect to one specific attribute. The tasks were designed to reflect the sender's or receiver's point of view. Tasks 1 and 3 adopted the sender's point of view and task 2 the receiver's. In the sender's case, two methods of ranking were used – binary choice and direct ranking. Table 7 summarizes the three experiments and their respective tasks.

		Experiment 1	Experiment 2	Experiment 3
		Random Drawings	Rorschach Inkblots	Shapes/Colours
Task 1	sender, ranking descriptions (binary choice)	✔	✔	✔
Task 2	receiver, ranking items	✔	✔	✔
Task 3	sender, ranking descriptions	✔	✔	

Table 7 – Experiments and tasks

The two hypotheses described in the previous section deal with a communication situation in which a person is describing an item from a set of items so that another person can identify it. All three experiments operationalize the hypotheses in the same basic way. Given different dimensions or attributes that can be used to describe a set of items, when people use them to refer to an item they effectively cluster the stimulus items into subsets, one subset including the target item and another subset not including the target item.

The three tasks allow me to investigate the hypotheses as follows. Tasks 1 and 3 provided attributes to participants to describe a target item from a set of items to another person. Task 2 provided an attribute to participants to rank the set of items according to how another person had described the items. Hypothesis 1 deals with the extent to which attributes are selected based on the gaps created between the two subsets. According to the first hypothesis, given two attributes, one which allowed for a larger gap between two different categories, and another for a smaller gap, I expected people to choose the attribute with the larger gap. Hypothesis 2 deals with the extent to which attributes are selected based on the size of the subsets created. According to hypothesis two, if two attributes allow for grouping of subsets, I expected people to choose the attribute with the smallest subset containing the target item.

Each of the experiments and its respective stimulus and tasks are explained in detail in the following sections.

4.2 Experiment 1

Experiment 1 used an unstructured stimulus. By degree of structure I refer to the extent to which participants are likely to perceive a sharp gap with respect to an attribute allowing for a clear distinction of an item. The stimulus consisted of a set of six cards with random drawings on them (see Table 8). Participants performed a series of three tasks in which they were given sets of items and descriptions or attributes. In the next sections I describe the experimental stimulus, followed by descriptions of each of the tasks in detail.

4.2.1 Stimulus

As described in the literature review, during my Masters' I designed an experiment in which participants communicated about a set of 6 cards showing randomly drawn lines which I am also using as stimulus for this study. Data collected from that experiment allowed for the preparation of a list of attributes to be used in this study. Participants in the earlier experiment used many different descriptions to refer to the various cards. Out of these, I selected a set of 25 descriptions (9 per card) to use as attributes for describing the cards in the current study.

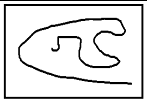
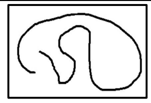
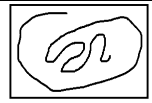
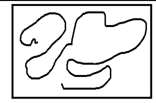
 Card A	 Card B	 Card C	 Card D	 Card E	 Card F
Unique Attributes					
looks like a bullet	looks like a function	looks like an “at” sign	looks like a fetus	has 2 and ½ fingers	looks like a heart
it’s an “A” if vertically oriented	lines start in opposite corners	looks like a tornado	tips very close to each other	has an “M”	looks like a cartoon character
ends with a straight line and a little hook	looks like a cactus	looks like an “e”	looks like a broken phone	it’s a monster going around its tail	looks like a turtle
Overlapping Attributes					
looks like a spiral	has a finger	looks like a spiral	it’s a wrench	it’s a wrench	looks like a hand
it’s a wrench	looks like a snake	looks like a snake	looks like a spiral	looks like a spiral	looks like a shoe
looks like a dinosaur	looks like a shoe	looks like a hand	looks like a dinosaur	looks like a dinosaur	looks like a dinosaur
Non-attributes					
has an “M”	looks like an “at” sign	looks like a cactus	ends with a straight line and a little hook	looks like a heart	has 2 and ½ fingers
looks like a function	looks like a turtle	it’s an “A” if vertically oriented	it’s a monster going around its tail	looks like an “e”	lines start in opposite corners
tips very close to each other	looks like a broken phone	looks like a fetus	looks like a cartoon character	looks like a tornado	looks like a bullet

Table 8 – List of pictures and attributes used in experiment 1

To select the attributes I chose the ones used most frequently by participants in the previous experiment. I also attempted to select attributes that would create variability in the extent to which the description would uniquely distinguish each of the 6 cards. Specifically, for each card I chose 3 descriptions that were used only for that card in the previous experiment (unique attributes), 3 that were used to describe sets of 2 or more cards (overlapping attributes), and 3 that had been used to designate 1 or more of the other cards from the set (non-attributes). The resulting set of attributes and cards used as stimulus for this experiment is shown in Table 8.

4.2.2 Method

Participants. 41 undergraduate students from a MSCI 311 class of the Management Science Department of the University of Waterloo participated in the study in exchange for a partial course credit.

Materials. A Microsoft protected file with 3 different tasks. As stimuli, the tasks had 6 cards with random drawings on them and some descriptions previously used to describe the cards. Table 8 shows the cards and their respective descriptions.

Procedure. Participants received an interactive Microsoft Word fillable survey form by e-mail. They were instructed to answer the survey and return the form via an Online dropbox. 46 students volunteered to participate in the study; 46 forms were sent out and 41 filled forms were returned. Each interactive form consisted of 12 pages including a cover page with the invitation to participate and general instructions, 10 pages with a set of five experimental tasks and specific instructions, and a final page with some words of gratitude for their participation (see Appendix A). 18 different versions of forms were developed. Each group of participants received a file with a different version. Participants performed 3 different tasks in this experiment. To control for the potential order effects the forms randomized the order of the tasks, the order of descriptions, and the order of the 6 card items within the set. To control for potential learning effects from one task to another and avoid common method bias the experiment was a between-subject design and none of the participants performed more than one task involving the same combination of target and descriptions. For example, if participants ranked descriptions for cards A and B in task 1, they would perform tasks 2 and 3 on a different set of cards.

Table 9 shows the different versions of the survey forms and the number of participants who completed each version.

Groups	Components	Stimulus randomization (order of items/ descriptions)	Task order randomization	Number of responses
1	Task 1 - Cards A & B Task 2 - 9 descriptions Task 3 - Cards C & D (5 tasks)	First	Form 1 (3C,3D,1A,1B,2)	3
			Form 2 (2,3C,3D,1A,1B)	2
			Form 3 (1A,1B,2,3C,3D)	1
		Second	Form 4 (3C,3D,1A,1B,2)	4
			Form 5 (2,3C,3D,1A,1B)	1
			Form 6 (1A,1B,2,3C,3D)	2
2	Task 1 - Cards C & D Task 2 - 8 descriptions Task 3 - Cards E & F (5 tasks)	First	Form 1 (3E,3F,1C,1D,2)	3
			Form 2 (2,3E,3F,1C,1D)	1
			Form 3 (1C,1D,2,3E,3F)	3
		Second	Form 4 (3E,3F,1C,1D,2)	1
			Form 5 (2,3E,3F,1C,1D)	2
			Form 6 (1C,1D,2,3E,3F)	3
3	Task 1 - Cards E & F Task 2 - 8 descriptions Task 3 - Cards A & B (5 tasks)	First	Form 1 (3A,3B,1E,1F,2)	2
			Form 2 (2,3A,3B,1E,1F)	2
			Form 3 (1E,1F,2,3A,3B)	3
		Second	Form 4 (3A,3B,1E,1F,2)	2
			Form 5 (2,3A,3B,1E,1F)	3
			Form 6 (1E,1F,2,3A,3B)	3

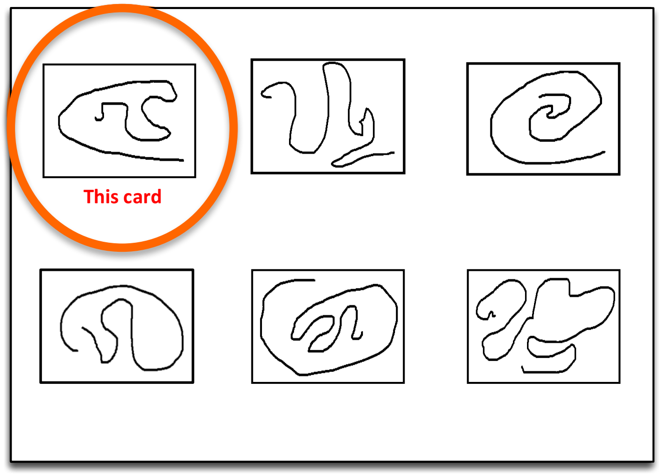
Table 9 – Experiment 1 design

Task 1. Participants were presented a set of 6 cards with a selected target item, as well as a set of 36 pairs of descriptions from the set of attributes shown in Table 8. They were asked to select the description that best described the target item. There were in total 36 pairs of descriptions for each target card. Those descriptions were composed of 9 different attributes[4]: 3 unique, 3 overlapping and 3 non-attributes. All participants performed this task twice using a different target item and different pairs of descriptions.

The following is an example of one version of task 1.

[4] The 36 descriptions are a combination of all the 9 types of attributes among them, i.e. unique-unique, unique-overlapping, overlapping-non-feature, non-feature-non-feature.

Imagine you were trying to get another person to select the card indicated below from the set of cards. Which of the following expressions would work best? For each pair choose one.



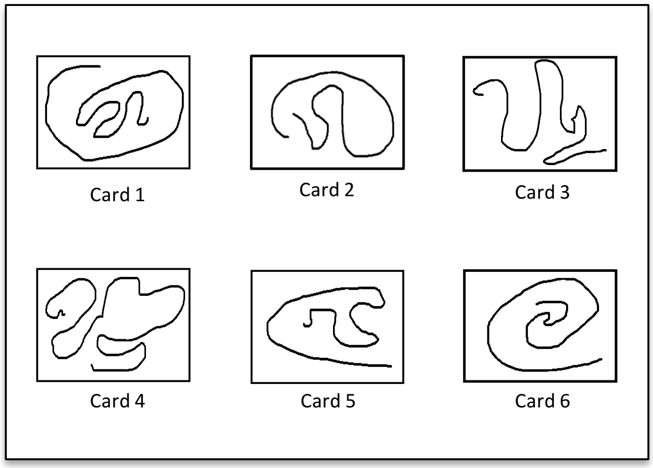
The following 36 pairs of expressions could be used to describe the circled card. **For each pair** please choose the expression that you think would work best to get the person to select the right card.

1.	☐ has a finger	☐ looks like a turtle
2.	☐ looks like a snake	☐ looks like a broken phone
3.	☐ looks like a cactus	☐ looks like an “at” sign
4.	☐ has a finger	☐ looks like an “at” sign
5.	☐ looks like a snake	☐ looks like a turtle
6.	☐ lines start in opposite corners	☐ looks like a shoe
7.	☐ looks like a function	☐ has a finger
8.	☐ looks like a cactus	☐ has a finger
9.	☐ looks like a snake	☐ looks like an “at” sign
10.	☐ lines start in opposite corners	☐ looks like a snake
11.	☐ looks like a turtle	☐ looks like a broken phone
12.	☐ looks like an “at” sign	☐ looks like a turtle
13.	☐ looks like a function	☐ looks like a cactus
14.	☐ has a finger	☐ looks like a shoe
15.	☐ looks like a function	☐ lines start in opposite corners
16.	☐ looks like a function	☐ looks like a snake
17.	☐ lines start in opposite corners	☐ has a finger
18.	☐ has a finger	☐ looks like a broken phone

19.	☐ looks like a shoe	☐ looks like a turtle
20.	☐ looks like a cactus	☐ looks like a broken phone
21.	☐ looks like a cactus	☐ looks like a shoe
22.	☐ looks like a function	☐ looks like a shoe
23.	☐ looks like a cactus	☐ looks like a turtle
24.	☐ looks like a function	☐ looks like a broken phone
25.	☐ looks like a shoe	☐ looks like an “at” sign
26.	☐ lines start in opposite corners	☐ looks like an “at” sign
27.	☐ looks like a cactus	☐ looks like a snake
28.	☐ looks like a function	☐ looks like an “at” sign
29.	☐ looks like an “at” sign	☐ looks like a broken phone
30.	☐ has a finger	☐ looks like a snake
31.	☐ lines start in opposite corners	☐ looks like a broken phone
32.	☐ lines start in opposite corners	☐ looks like a turtle
33.	☐ looks like a function	☐ looks like a turtle
34.	☐ looks like a shoe	☐ looks like a broken phone
35.	☐ looks like a snake	☐ looks like a shoe
36.	☐ lines start in opposite corners	☐ looks like a cactus

Task 2. Participants were given the same set of 6 cards and one of the 25 descriptions as shown in Table 8. Their goal was to correctly select a card by ranking the set of cards from 1 (most likely answer) to 6 (least likely answer) based on the given description. Following is one version of task 2.

Imagine you are communicating to a person in another room who has the following set of 6 cards. Your goal in this task is to correctly select cards based on descriptions provided by the other person. You will perform this task 9 times (for 9 different expressions).



Expression 1: The person describes one of these 6 items as **looks like a cartoon character**. Please rank the items from 1 to 6 in terms of which card the person is most likely referring to. (1 – most likely; 6 – least likely)

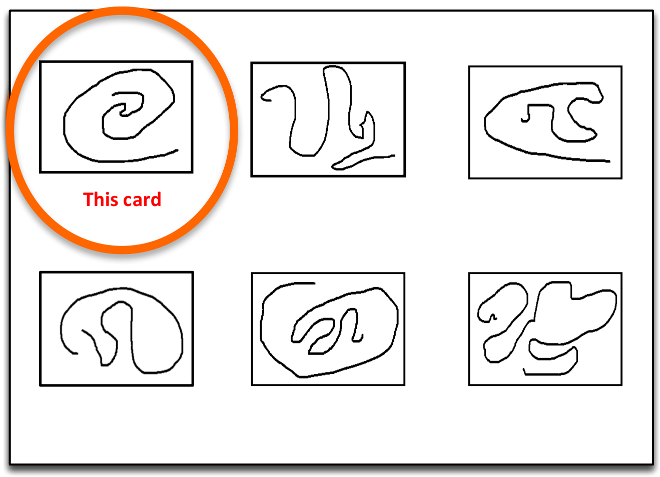
Card Number	Your Rank
1	
2	
3	
4	
5	
6	

All 25 different descriptions shown in the list of attributes were used as descriptions for the set of cards. Those 25 descriptions were assigned to 3 different groups of participants. Therefore, participants were either given 8 or 9 different descriptions with which to rank their cards.

Task 3. Participants received the set of 6 cards with a selected target item and 9 descriptions from the list of attributes (Table 8). Their goal was to rank the given descriptions from 1 to 9 in terms of which would most likely result in another person choosing the selected card. Each participant performed this task twice using a different target item and a different set of 9 descriptions.

The following is an example of this task.

Imagine you are communicating to a person in another room who has the following set of 6 cards. Your goal in this task is to get the other person to correctly select the card indicated below.



Please rank the following expressions from 1 to 9 in terms of which would most likely get the person to select the right card.

Expressions	**Your Rank**
looks like a fetus	
looks like an "e"	
looks like a tornado	
looks like a hand	
looks like a spiral	
looks like a snake	
looks like a cactus	
it's an "A" if vertically oriented	
looks like an "at" sign	

Measures. All three tasks used ranking as an indicator of participants' perceived similarity of a given item with respect to a given attribute/description. In tasks 1 and 3, participants ranked descriptions with respect to cards. Task 1 descriptions were ranked based on the binary choice of 36 pairs of descriptions for the target cards. Task 3 was based on the direct ranking of 9 descriptions with respect to the target cards. In task 2, participants ranked the 6 cards with respect to each specific description. Analysis of correlation coefficients were used to test whether or not task 2 relative ranks could be predicted by task 1 ranks and also separately by task 3 ranks. In other words, correlations methods were used to test the extent to which participants' perceptions of how to describe the items predicted which items were being identified by the given descriptions.

In both of these correlations, i.e. the correlation between tasks 1 and 2 and the correlation between tasks 3 and 2, I analyzed the entire data at once instead of focusing on the size or position of gaps associated with specific attribute-item pairs. This is because gap size and position were not directly controlled in the design of the experimental stimulus. The use of the pictures and descriptions from a previous experiment meant that gap sizes and positions were considered random variables in this experiment. Different rankings of attributes for a card reflect the variability of the perceived gap positions and gap sizes on the part of sender and receiver. Correlation coefficients capture the degree to which differences in sender similarity judgments influences receiver ability to identify items based on given attribute descriptions.

The data collected through experiment 1 is exclusively rank-based. Rankings show what items the participants perceived as most likely to be described by a given description and which descriptions were most descriptive of a given item. Section 1.1. of the framework defined and exemplified the gap in terms of probabilities. In this experiment, the relative probabilities are embedded in the ranks. Given a certain distribution of ranked descriptions with respect to a card, one can determine how likely the participants are to select that card based on the descriptions. With these correlation coefficients it is possible to examine whether the information conveyed by the sender, in terms of which attributes best describe a given item, is related to the receiver's interpretation in terms of which item is identified by given attributes.

In addition to the correlations, a regression analysis was used to compute the differences between the attributes rank of each card of task 1 and the cards rank of each attribute of task 2. They show how much the difference in ranking on task 1 affects the difference in ranking on task 2. The same analysis was repeated between the attributes rank of cards of task 3 and the cards ranks of task 2.

4.2.3 Results

As mentioned above, the data collected from the three tasks were all ranks. Task 1 was a series of binary choices between pairs of attributes as to which of each pair would best described the target item. Task 2 was a direct ranking of the 6 items with respect to a specific attribute. Task 3 was similar to task 1, but involved a direct ranking, where a set of 9 attributes was ranked with respect to a target item. The binary choice data from task 1 was converted into direct ranks by summing the number of times participants chose each of the 9 attributes for a given target item.

To examine whether or not task 2 relative ranks could be predicted by task 1 ranks, the following steps were taken. A matrix with all the 25 attributes and the attributes rank for the 6 cards was created for task 1 (see Table 10 columns 1 and 2 as example of the matrix for card A). A similar matrix was created for task 2 (see Table 10 column 3, showing the rank of card A for each attribute).

To determine whether the task 2 ranks could predict task 3, the same type of correlations between tasks 3 and 2 were also investigated. Therefore, the procedure described above was also used for task 3 (see Table 10 columns 1 and 3 for an example of card A).

Attributes	Task 1 attributes ranks for card A	Task 3 attribute ranks for card A	Task 2 card A's rank out of 6 for each attribute
it's an "A" if vertically oriented	1	1	1
ends with a straight line and a little hook	2	2	3
looks like a bullet	5	5	3
lines start in opposite corners			
looks like a cactus			
looks like a function	8	6	4
looks like an "e"			
looks like an "at" sign			
looks like a tornado			
looks like a fetus			
tips very close to each other	7	7	4
looks like a broken phone			
has 2 and ½ fingers			
it's a monster going around its tail			
has an "M"	6	8	3
looks like a heart			
looks like a cartoon character			
looks like a turtle			
looks like a spiral	9	9	3
looks like a dinosaur	4	3	2
it's a wrench	3	4	1
looks like a shoe			
has a finger			
looks like a snake			
looks like a hand			

Table 10 – Example of data used in correlations between task1/3 attribute ranks and task 2 card ranks for card A

Before testing the correlations, a chi-square of goodness of fit was used to examine whether or not task 2 relative ranks could be predicted by task 1 ranks. Given 25 attributes and 6 cards, the combinations of ranking tasks were such that each attribute was ranked for a minimum of 2 and a maximum of 4 cards. The average ranking shows whether the attribute was ranked higher or lower for each card. Thus allowing the prediction of how well a attribute can describe a given card. This relative prediction is then compared with actual scores from task 2, where all 6 cards were ranked against those attributes. If a task 2 ranking was consistent with the prediction, it was coded as "Yes". If inconsistent with the prediction, the ranking was coded as "No". Chi-square was then used to compare the prediction-coding relationship against a null-hypothesis of random chance. The result was significant, X^2 (1, *N* = 25) =16.43, p < 0.001. Task 1 ranking could be used to predict the relative rank in task 2. The same test was applied to examine the relationship between task 3 and task 2. Again the result was significant X^2 (1, *N* = 25) = 19.14, *p* < 0.001.

To have a more precise analysis, Pearson correlations' were performed to examine the extent to which participants' perception of how to describe the items correlated with which items are best identified by the given description. Strongly positive correlations among attribute ranks in task 1 and card ranks in task 2 were found for all 6 cards. Correlations were significant for cards A, B, C, D, and F at the 0.05 level but not significant for card E. Table 11 shows these results.

Correlations between task 1 ranks and task 2 ranks

Cards	*df*	*R*	*p (2-tailed)*
A	7	0.74	0.024
B	7	0.86	0.003
C	7	0.84	0.005
D	7	0.88	0.002
E	7	0.52	0.147
F	7	0.73	0.026

Table 11 – Correlations between task 1 attribute ranks and task 2 card ranks

Similar correlations were tested between task 3 attribute ranks and task 2 card ranks. As shown in table 12, strong positive correlations were found for all 6 cards. The correlations were significant at the 0.05 level for cards B, C, D, and F, and at the level of 0.1 for card A.

Correlations between task 3 ranks and task 2 ranks

Cards	*df*	*R*	*p (2-tailed)*
A	7	0.61	0.080
B	7	0.78	0.014
C	7	0.84	0.005
D	7	0.69	0.040
E	7	0.54	0.134
F	7	0.68	0.044

Table 12 – Correlations between task 3 attribute ranks and task 2 card ranks

It is not a surprise that both analyses (between tasks 1 and 2, and between tasks 3 and 2) show consistent correlations as the attribute rankings of task 1 and the attribute rankings of task 3 were also highly correlated (see Table 13). For both tasks, participants ranked the same attributes as the best descriptor of specific cards. This shows that the two methods for ranking cards – binary choices and direct ranking – are both reliable methods. Either is an appropriate method for detecting differences in items with respect to a given attribute. Ranking therefore can be used as a measure of the relative information conveyed by a given attribute to distinguish items. The high correlations between the attribute rankings of tasks 1 and 3 also suggest that the attributes were quite salient to participants.

Correlations between task 1 ranks and task 3 ranks

Cards	*df*	*R*	*p (2-tailed)*
A	7	0.92	0.001
B	7	0.83	0.005
C	7	1.00	0.001
D	7	0.83	< 0.001
E	7	0.83	0.005
F	7	0.85	0.004

Table 13 – Correlations between task 1 attribute ranks and task 3 attribute ranks

Following, I tested how much the difference ranking on task 1 affects the difference ranking on task 2. Again a matrix with the 27 attributes and the 6 cards was created for tasks 1 and 2 (Table 14 columns 1 and 2 is an example for card A). Scores from the raw data were used for this measurement. For Task 1, the score was calculated as the sum of how many times participants chose a specific attribute divided by the sum of all the attributes chosen for the same card. For example, for card A, participants chose the attribute in binary choice selection “it is an ‘A’ vertically oriented” 87 times. Participants made a total of 448 binary choices selections of descriptions in total for card A. Hence, 87 divided by 448 equals 0.194 (as observed in row 2, column 2 in Table 14). For Task 2, each participant ranked 9 descriptions with respect to the set of 6 cards. I used the average among the total of participants ranks as the score (see Table 14 column 4).

A simple linear regression was calculated to predict the difference in ranking on task 2 based on difference in ranking on task 1. A significant regression equation was found $F(1, 52) = 81.965$, $p < 0.001$, with an R^2 of 0.612, standardized β= -0.782. In other words, one unit decrease in the task 1 scores corresponds to a 0.782 increase in rank in task 2. The standardized beta coefficient is negative because when task 1 attributes for each of the cards were transformed into a score they became inversely proportional to task 2 average means. In other words, while task 1 attributes with the highest scores were the best descriptors for a specific card, in task 2 an attribute best description had the smallest numerical rank.

Task 3 and task 2 were also tested in the same way. For task 3, I used average attributes rank (see Table 14 column 3 as example for card A). A simple linear regression was calculated to predict the difference in ranking on task 2 based on difference in ranking on task 3. A significant regression equation was found $F(1, 52) = 75.203$, $p < 0.001$, with an R^2 of 0.591, standardized β= 0.769. In other words, for each unit of difference in ranking in task 3 here are 0.769 units of difference in ranking in task 2.

Those differences are an indication of participants' perception of how much a given attribute better describes one card over other cards. High correlations in these differences suggest that participants perceived certain attributes as being better descriptors than others. This difference shows that participants did indeed perceive certain attributes as showing greater distinctiveness of a target card, thus allowing for a choice of an attribute that best distinguished the item, which is consistent with hypotheses.

Attributes	Task 1 attributes ranks for card A	Task 3 attribute ranks for card A	Task 2 card A's rank out of 6 for each attribute
it's an "A" if vertically oriented	0.194	2.67	2.00
ends with a straight line and a little hook	0.167	3.73	3.08
looks like a bullet	0.094	4.60	3.25
lines start in opposite corners			
looks like a cactus			
looks like a function	0.058	6.13	2.92
looks like an "e"			
looks like an "at" sign			
looks like a tornado			
looks like a fetus			
tips very close to each other	0.063	6.20	4.13
looks like a broken phone			
has 2 and ½ fingers			
it's a monster going around its tail			
has an "M"	0.071	6.73	3.08
looks like a heart			
looks like a cartoon character			
looks like a turtle			
looks like a spiral	0.042	6.80	3.46
looks like a dinosaur	0.147	4.20	2.92
it's a wrench	0.163	4.27	1.33
looks like a shoe			
has a finger			
looks like a snake			
looks like a hand			

Table 14 – Example of computed scores used in regression analyses between tasks 1/3 attribute ranks and task 2 cards ranks for card A

4.2.4 Discussion

Hypothesis 1 states that during the communication process if people have a choice among multiple attributes to communicate an item they will choose the attribute that maximizes the size of gap. Hypothesis 2 says that a person will choose the attribute that decreases the size of the subset the most, resulting in the smaller subset as possible regarding gap position.

Unfortunately the design of experiment 1 was not able to directly measure the effects of gap size and gap position. As described in the measures section, the data collected was rank-based. Ranking gives information about which attributes best distinguish one item from a set of items. The ranks provide an indicator of overall similarity judgments of attributes with respect to items and items with respect to attributes. However, they do not directly measure gap size or gap position. The two hypotheses were measured indirectly through determining correlations between each attributes rank in different tasks.

Results from the first two analyses – between tasks 1 and 2 attribute rankings and between tasks 3 and 2 attribute rankings – show very high correlations. In task 2, participants adopted the view of the receiver of the message and in tasks 1 and 3 the adopted view was that of a sender. High correlation of the rankings indicates that the sender uncertainty, with respect to how to refer to an item, and the receiver uncertainty, of how to identify the item selected, were both reduced. Specifically, the information conveyed by the sender in terms of which attributes best described a given item influenced the interpretation of the receiver in terms of which items were identified by a given attribute.

The results from the regression equations were also significant. The tests indicated to what degree participants perceived a given attribute to be similar to a target card. The evidence showed that participants perceived differences between attributes, i.e.

they perceived one attribute being more similar to a card than another attribute. Because participants perceived a difference, there was a higher likelihood of selecting the target card.

Although hypotheses 1 and 2 were not directly tested, the results are consistent with what would be expected if the hypotheses were true. The evidence shows that attributes that are more distinctive from the point of view of the sender also end up being more selective from the point of view of the receiver, which is consistent with the argument of gap position and gap size, as hypothesized. Nonetheless it is theoretically possible to obtain similar correlation and regression results based on a general similarity-based judgment process rather than the more specific gap size and position theory proposed here. .

4.3 Experiment 2

Experiment 2 replicated experiment 1 using as stimulus the well-known Rorschach inkblots, which were originally developed by Hermann Rorschach in 1921 as a projection technique in clinical psychology (Exner, 2003). In psychotherapy the examiner presents the inkblots to a client whose task is to describe what they see on each inkblot. Exner (2003) has compiled evidence showing the descriptions that people commonly use to describe each of the pictures; from this I selected a set of pictures and descriptions to use in this experiment.

From Rorschach's original 10 inkblots, I selected 6 to use as stimuli (see Figure 5), so as to be consistent with experiment 1 which also used 6 cards. The 6 pictures in figure 5 were chosen because they were the 6 most described pictures from the Exner report. A large number of different descriptions was important to match the same variability among the descriptions as in experiment 1.

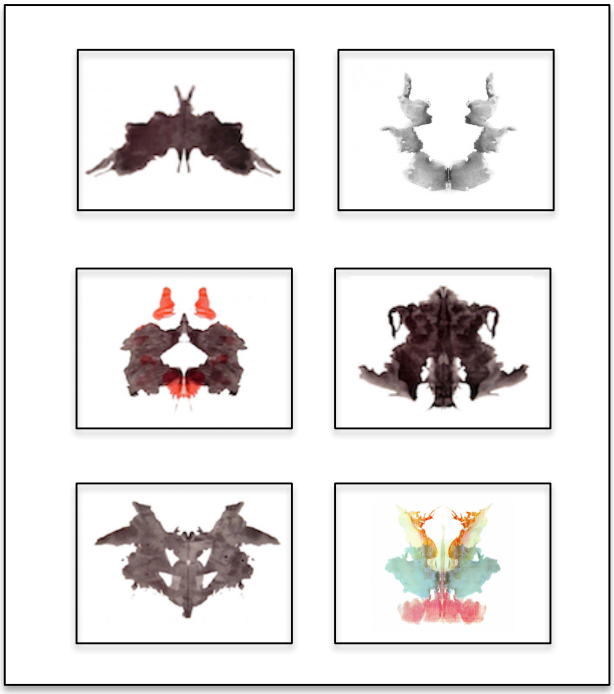


Figure 5 – Experiment 2 stimulus

4.3.1 Stimulus

I followed a similar approach to that used in experiment 1 in selecting a set of 17 attributes from the descriptions compiled by Exner (2003) (see Table 15). I selected some descriptions which were unique to a single picture, and some that were overlapping, in that people had used them to describe more than one picture. Descriptions that were unique for one of the figures were also paired up with other pictures as “non-attributes” to create a set of attributes for each picture that varied in the extent to which the descriptions uniquely distinguished any of the 6 pictures. Because some of the descriptions reported by Exner (2003) referred to small details of the pictures (e.g. hats, legs, etc), I decided to used only descriptions that referred to the whole picture or to a large portion of a picture. It was not possible to replicate experiment 1 with respect to the number of attributes per picture because Exner's list did not include enough "unique" and "overlapping" descriptions to match the design precisely. Therefore instead of using 3 of each type of attribute I used only two, for a total of 17 attributes.

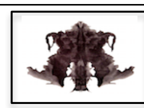
 **Picture 1**	 **Picture 2**	 **Picture 3**	 **Picture 4**	 **Picture 5**	 **Picture 6**
Unique Attributes					
looks like a garden	looks like an eagle	looks like elves	looks like boots	looks like a vampire	looks like fire and smoke
looks like a vase	looks like a spinal vertebrae	looks like a cloud	looks like a coat hanged	looks like a dancer in costume	looks like bears
Overlapping Attributes					
looks like a mask	looks like a mask	looks like two people	looks like a butterfly	looks like a butterfly	looks like two people
looks like an art/statue	looks like a butterfly	looks like an art/statue	looks like animal skin	looks like animal skin	looks like an art/statue
Non-attributes					
looks like a spiral vertebrae	looks like bears	looks like a coat hanged	looks like elves	looks like boots	looks like an eagle
looks like a cloud	looks like vase	looks like a vampire	looks like a garden	looks like fire and smoke	looks like a dancer in costume

Table 15 – List of pictures and attributes used in experiment 2

4.3.2 Method

Participants. 105 undergraduate students from a MSCI 211 class at the University of Waterloo participated in the study in exchange for partial course credit.

Materials. Experiments 2 and 3 were performed simultaneously in a single survey. The material was similar to that used in experiment 1, a Microsoft protected file, however this time each participant performed 5 different tasks. Experiments 2 and 3 were included on the same file. Experiment 2 had 3 tasks, similar to the tasks performed in experiment 1, while experiment 3 consisted of 2 tasks. I will explain experiment 3 in the following section. As stimuli for experiment 2, the tasks used the 6 Rorschach inkblots and their respective attributes as shown in table 15.

Procedure. Similar to experiment 1, participants received an interactive Microsoft Word fillable form by e-mail. They were instructed to answer the survey and return the form via an Online dropbox. 249 forms were sent out to the MSCI 211 undergrad students and 107 forms were returned. 1 of the files could not be opened, and another one was blank and therefore both were discarded, resulting in 105 completed forms. Each interactive form consisted of 30 pages containing one first page with the consent of participation and a second page with general instructions, 12 pages with a task from experiment 3, three tasks from experiment 2, an additional 12 pages with the second task from experiment 3, and one page with words of gratitude for their participation (see Appendix B).

12 different versions of the survey form were designed. To control for order effects, forms varied with respect to the order of tasks, order of descriptions, and order of stimuli within the set of items. In addition, to control for learning effects the survey forms were designed in a way that participants did not perform any task with repeat target items from the stimulus or with repeated sets of descriptions. To avoid common method bias experiment 2 was a between-subject design. Experiment 3 was a within-subject design and will be discussed in section 4.5. Table 16 shows how the two experiments were designed and performed.

Groups	Components	Task Type	Stimulus Randomization (order of items/ descriptions)	Task Order Randomization	Number of responses
1	Task 1 - One Dimension I	Ranking	First	Form 1 (tasks 1,2,3,4,5)	9
	Task 2 - Card A	Binary Choice			
	Task 3 - 3 Descriptions	Ranking			
	Task 4 - Card E	Ranking	Second	Form 2 (tasks 5,2,3,4,1)	9
	Task 5 - Rotation 1	Binary Choice			
2	Task 1 - One Dimension II	Ranking	First	Form 3 (tasks 1,2,3,4,5)	11
	Task 2 - Card B	Binary Choice			
	Task 3 - 3 Descriptions	Ranking			
	Task 4 - Card F	Ranking	Second	Form 4 (tasks 5,2,3,4,1)	10
	Task 5 - Rotation 2	Binary Choice			
3	Task 1 - Rotation 2	Ranking	First	Form 5 (tasks 1,2,3,4,5)	9
	Task 2 - Card C	Binary Choice			
	Task 3 - 3 Descriptions	Ranking			
	Task 4 - Card A	Ranking	Second	Form 6 (tasks 5,2,3,4,1)	8
	Task 5 - Rotation 3	Binary Choice			
4	Task 1 - Rotation 1	Ranking	First	Form 7 (tasks 1,2,3,4,5)	7
	Task 2 - Card D	Binary Choice			
	Task 3 - 3 Descriptions	Ranking			
	Task 4 - Card B	Ranking	Second	Form 8 (tasks 5,2,3,4,1)	8
	Task 5 - Rotation 4	Binary Choice			
5	Task 1 - Rotation 3	Ranking	First	Form 9 (tasks 1,2,3,4,5)	9
	Task 2 - Card E	Binary Choice			
	Task 3 - 3 Descriptions	Ranking			
	Task 4 - Card C	Ranking	Second	Form 10 (tasks 5,2,3,4,1)	10
	Task 5 - One Dimension I	Binary Choice			
6	Task 1 - Rotation 4	Ranking	First	Form 11 (tasks 1,2,3,4,5)	8
	Task 2 - Card F	Binary Choice			
	Task 3 - 2 Descriptions	Ranking			
	Task 4 - Card D	Ranking	Second	Form 12 (tasks 5,2,3,4,1)	6
	Task 5 - One Dimension II	Binary Choice			

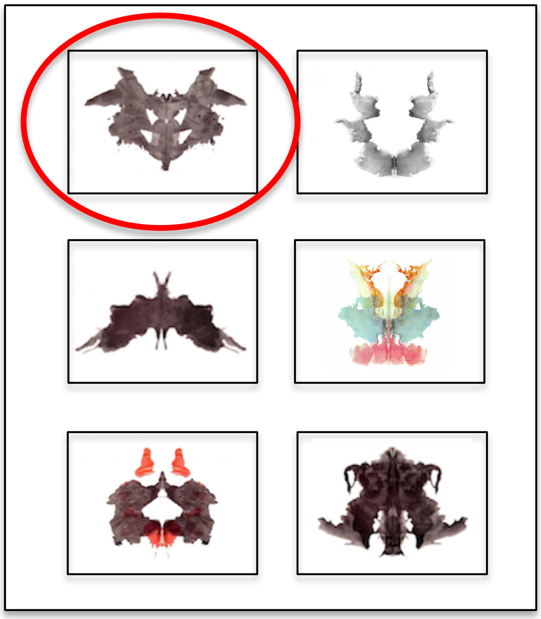
Table 16 – Experiment 2 design

Task 1. Participants were presented with a set of 6 Rorschach pictures and 15 pairs of descriptions from the list of attributes (see Table 15). The descriptions were composed of 6 different attributes[5]: 2 unique, 2 overlapping and 2 non-attributes. The aim was to rank the best description with respect to the selected target picture.

[5] The 15 descriptions are a combination of all the 6 types of attributes among them, i.e. unique-unique, unique-overlapping, overlapping-non-feature, non-feature-non-feature.

The following is an example of this task.

For this task, imagine you were trying to get another person to select the picture indicated from the set of pictures shown at the left.



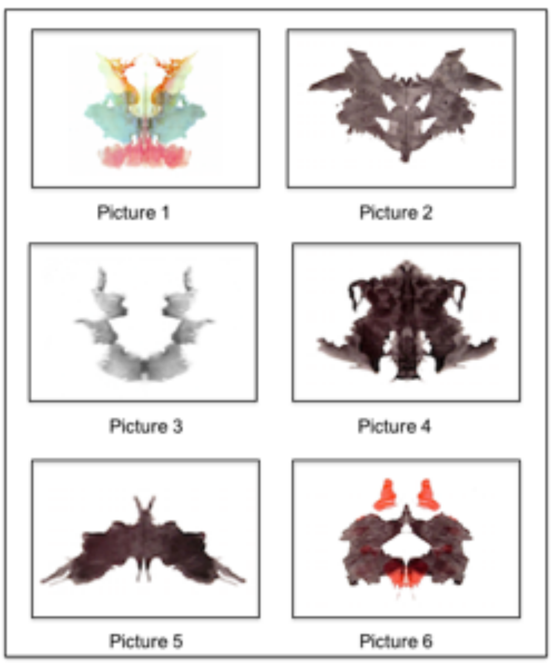
The following 15 pairs of descriptions could be used to describe the circled picture. **For each pair** please choose the description that you think would work best to get the person to select the right picture.

1	☐ looks like an eagle	☐ looks like a mask
2.	☐ looks like a spinal vertebrae (disc)	☐ looks like a vase
3.	☐ looks like a mask	☐ looks like a vase
4.	☐ looks like a spinal vertebrae (disc)	☐ looks like a mask
5.	☐ looks like an eagle	☐ looks like bears
6.	☐ looks like a spinal vertebrae (disc)	☐ looks like an eagle
7.	☐ looks like a spinal vertebrae (disc)	☐ looks like bears
8.	☐ looks like an eagle	☐ looks like a butterfly
9.	☐ looks like a butterfly	☐ looks like a vase
10.	☐ looks like a butterfly	☐ looks like bears
11.	☐ looks like bears	☐ looks like a vase

12.	☐ looks like an eagle	☐ looks like a vase
13.	☐ looks like a mask	☐ looks like bears
14.	☐ looks like a butterfly	☐ looks like a mask
15.	☐ looks like a spinal vertebrae (disc)	☐ looks like a butterfly

Task 2. Participants were given the set of 6 Rorschach pictures and one of the 17 descriptions shown in the list of attributes (Table 15). Their task was to rank the pictures from 1 to 6 based on which was most likely being described by the given description. The following version is an example of task 2.

Now, imagine you are communicating to a person in another room who has the set of 6 pictures shown at the left. Your goal is to select pictures based on descriptions provided by the other person. For each of the following descriptions please rank the items from 1 to 6 in terms of which picture the person is most likely referring to (1 – most likely; 6 – least likely).

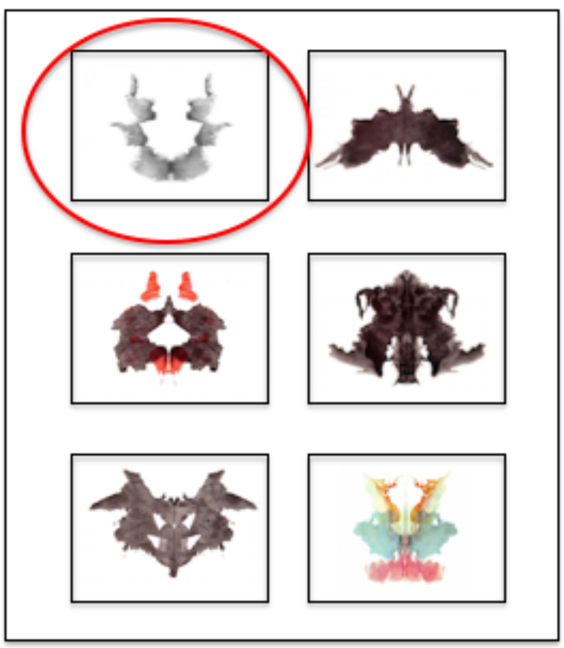


The other person uses the description **"looks like an animal skin"**	
Picture Number	Your Rank
1	
2	
3	
4	
5	
6	

All 17 descriptions shown in the list of attributes were used to rank the set of Rorschach pictures. Those 17 descriptions were assigned to 6 different groups of participants. Therefore, participants were either given 2 or 3 different descriptions with which to rank their pictures.

Task 3. Participants received the set of 6 Rorschach pictures with a target card and 6 descriptions from the list of attributes (Table 15). The goal of this task was to rank the given descriptions from 1 to 6 based on which would most likely get another person to select the targeted picture.

Imagine you are communicating to a person in another room who has set of 6 pictures at the left. Your goal in this task is to get the other person to correctly select the picture indicated. Please rank the following descriptions from 1 to 6 in terms of which would most likely get the person to select the right picture.



Description	Your Rank
looks like a cloud	
looks like art/statues	
looks like a coat hanged	
looks like two people	
looks like a vampire	
looks like elves	

Measures. As previously mentioned, experiment 2 was a replication of experiment 1 using different stimuli. Therefore experiment 2 replicated experiment 1 measures.

Ranking was used in all three tasks. Task 1 was a binary choice of attributes and tasks 2 and 3 used direct ranking. In task 1 and 3 participants ranked descriptions with respect to pictures and in task 2, they ranked pictures with respect to one description. These rankings were analyzed using correlation methods. The first correlation examined the extent to which participants' perception of how to describe the items of the set correlated with which items are best identified by the given description. As in experiment 1, correlations between tasks 1 and 2 and between tasks 3 and 2 were examined. As mentioned in the experiment 1 measures section, in both of these tests I analyzed the two hypotheses at once. Ranking data gives information about how descriptive items are. Since both hypotheses predict that people will choose the attribute which maximizes information gain, correlation between those ranks is a good measure to test both hypotheses.

A regression analysis was used to show how much the difference ranking on task 1 affects the difference ranking on task 2. A similar effect between tasks 3 and 2 was also tested with a second regression analysis. Those additional tests indicated how much participants perceived a given attribute to be similar with respect to a target card.

4.3.3 Results

To examine whether or not task 1 attribute ranks could be predicted by task 2 pictures rank, the same steps were followed as in experiment 1. A matrix with all attributes and their rankings for the 6 pictures was created for task 1 (see Table 17 columns 1, 2 as example of the matrix for picture A). A similar matrix was created for task 2 (see Table 17 columns 1 and 4, as example of the matrix for picture A). As it can be observed from the table, only the column for task 2 attributes was complete. Task 1 and 3 attributes of experiment 2 were limited to the 6 attributes previously identified from Exner's (2003) table of descriptions.

The same type of relationship between tasks 3 and 2 was also investigated. That is, a correlation method was used to examine whether or not task 3 attribute ranks could be predicted by task 2 pictures ranks (see Table 17 columns 1 and 3 for an example of picture A).

Attributes	Task 1 attributes ranks for card A	Task 3 attribute ranks for card A	Task 2 pictures A's rank out of 6 for each attribute
looks like an animal skin			
looks like bears	5	4	1
looks like a coat hanged			
looks like a butterfly	3	3	2
looks like boots			
looks like a spinal vertebrae (disc)	4	1	3
looks like art/statues			
looks like a vampire			
looks like a garden			
looks like a mask	1	2	1
looks like elves			
looks like a vase	6	6	4
looks like an eagle	2	5	1
looks like a cloud			
looks like fire and smoke			
looks like two people			
looks like a dancer in costume			

Table 17 – Example of data used in correlations between tasks 1/3 attribute ranks and task 2 pictures ranks for picture A

Before testing the correlations, a chi-square goodness of fit test was used to examine whether or not task 2 relative ranks could be predicted by task 1 ranks. Given that there were 17 attributes and 6 pictures, the combinations of ranking tasks were such that each attribute was ranked for a minimum of 2 and a maximum of 3 pictures. The task 1 and 3 rankings show whether the attribute is ranked higher or lower for a given picture, that is, how good an attribute is as a descriptor of a given picture. The rankings from tasks 1 and 3 were then compared with how the attributes scored on task 2, where all 6 pictures were ranked against those attributes. If the predicted and actual scores were consistent they were coded as "Yes" if they were not consistent they were coded as "No". The result for tasks 1 and 2 was not significant, X^2 (1, N = 25) = 25.09, *p* = 0.157. According to the goodness of fit test, task 1 rank could not be used to predict the relative ranks of task 2. The same test was applied to examine the relationship between task 3 and task 2. The result was also not significant, X^2 (1, *N* = 25) = 29.56, *p* = 0.090.

Next, I examined the extent to which participants' perception of how to describe the items of the set correlated with which items are best identified by the given description. Task 1 attribute ranks for each picture were correlated to task 2 pictures ranks for each picture. The correlations coefficients were all strong (R > 0.3). Correlations were significant at 0.05 level for pictures B and D, but not for pictures A, C, D, F. Table 18 shows the results.

Correlations between task 1 ranks and task 2 ranks

Pictures	*Df*	*R*	*p (2-tailed)*
A	4	0.68	0.140
B	4	0.90	0.014
C	4	0.31	0.546
D	4	0.83	0.043
E	4	0.59	0.215
F	4	0.49	0.326

Table 18 – Correlations between task 1 attribute ranks and task 2 picture ranks

Similar correlations were tested between task 3 attribute ranks and task 2 pictures ranks. As shown in table 19, except for picture A, all results were also strongly correlated. Correlations were significant at 0.05 level for pictures D and F, at the level 0.01 for card B, and not significant for cards A, C, E.

Correlations between task 3 ranks and task 2 ranks

Pictures	*Df*	*R*	*p (2-tailed)*
A	4	0.17	0.749
B	4	0.77	0.075
C	4	0.47	0.344
D	4	0.83	0.043
E	4	0.55	0.255
F	4	0.81	0.049

Table 19 – Correlation between task 3 attribute ranks and task 2 picture ranks

Tasks 1 and 3 exemplified two different methods for ranking pictures with respect to descriptions. Table 20 summarizes the correlations between attribute ranks obtained in tasks 1 and 3. The results show strong positive correlations between task 1 rankings and task 3 rankings. The high correlations suggest that the attributes were quite salient to participants. Thus the two methods for ranking pictures were both good methods for detecting differences in similarity between items with respect to a given attribute. Ranking therefore could be used as a measure of the relative information conveyed by a given attribute to distinguish items.

Correlations between task 1 ranks and task 3 tasks

Pictures	*df*	*R*	*p (2-tailed)*
A	**4**	**0.43**	**0.397**
B	**4**	**0.77**	**0.072**
C	**4**	**0.93**	**0.008**
D	**4**	**0.94**	**0.005**
E	**4**	**0.88**	**0.020**
F	**4**	**0.83**	**0.042**

Table 20 – Correlations between task 1 picture ranks and task 3 picture ranks

I tested how much the difference ranking on tasks 1 and 3, respectively, affect the difference ranking on task 2 through regression analyses. A matrix with all the attributes and pictures used in the experiment was created for all three tasks (see Table 21 as an example for picture A). The same kind of scoring used in experiment 1 was used in experiment 2. For Task 1, I determined the sum of how many times participants used the same attribute divided by the sum of all attributes for the same picture (see table 21 column 2 is an example for picture A). For tasks 2 and 3, average ranks across participants were used (see Table 21 columns 3 and 4).

A simple linear regression was calculated to predict the difference in ranking for task 2 based on difference in ranking on task 1. A significant regression equation was found: $F(1,34) = 9.248$, $p = 0.005$, R^2 of 0.214, standardized β=-0.464. In other words, one unit decrease in the task 1 scores corresponds to a 0.464 increase in rank in task 2. The standardized beta coefficient is negative because when task 1 attributes for each of the pictures were transformed into a score they became inversely proportional to task 2 average ranks.

Task 3 and task 2 were tested in the same way. As with task 2, I used average attributes ranks for task 3 (see table 21 column 3 as example for picture A). A simple linear regression was calculated to predict the difference in ranking on task 2 based on difference in ranking on task 3. A significant regression equation was found: $F(1,34) = 7.510$, $p = 0.010$, R^2 of 0.181, standardized β= 0.425. In other words, for each unit of difference in ranking in task 3 there are 0.425 units of difference in ranking in task 2.

These differences are an indication of participants' perception of how much a given attribute better describes one picture than others. In other words, how sharp the gap is. High correlations suggest that certain descriptions allowed participants perception of a sharp gap, as predicted by my hypothesis.

Attributes	Task 1 attributes ranks for card A	Task 3 attribute ranks for card A	Task 2 pictures A's rank out of 6 for each attribute
looks like an animal skin			
looks like bears	0.145	3.53	2.72
looks like a coat hanged			
looks like a butterfly	0.176	3.12	2.48
looks like boots			
looks like a spinal vertebrae (disc)	0.154	2.53	3.43
looks like art/statues			
looks like a vampire			
looks like a garden			
looks like a mask	0.256	3.06	2.80
looks like elves			
looks like a vase	0.084	4.47	3.53
looks like an eagle	0.185	3.65	2.50
looks like a cloud			
looks like fire and smoke			
looks like two people			
looks like a dancer in costume			

Table 21 – Example of computed scores used in correlations between tasks 1/3 attribute ranks and task 2 picture ranks for picture A

4.3.4 Discussion

Experiment 2 was a replication of experiment 1. Therefore the results of the experiment were also consistent with hypotheses 1 and 2. Hypothesis 1 states that during the communication process if people have a choice among multiple attributes to communicate an item they will choose the attribute that maximizes the size of gap. Hypothesis 2 says that they will choose the attribute that decreases the size of the subset the most, resulting in the smaller subset as possible regarding the gap position.

Because data collected for experiment 2 was rank-based, a direct measure for gap position and gap size was not developed. Ranking gives information about which attributes best distinguish one item from a set of items. The ranks provide an indicator of overall similarity judgments of attributes with respect to items and items with respect to attributes. However, they do not directly measure gap size or gap position. The two hypotheses were measured indirectly through correlations between attributes ranks from different tasks.

Although results for the first set of correlations – correlation between tasks 1 attribute ranks and tasks 2 pictures ranks and correlation between task 3 attribute ranks and task 2 pictures ranks – were not as high as in experiment 1, they were still considerably high. In part, the differences in the correlation results can be explained due to having a smaller number of attributes. For instance, in experiment 1 there were 9 data points being correlated while in experiment 2 there were only 6 data points. The smaller number of data points being correlated makes the test very strict. Despite those differences the results were consistent across the two experiments.

Tasks 1 and 3 reflect the sender's view and task 2 reflects the receiver's view. Strong correlations between sender and receiver ranks is an indication that the sender's uncertainty with respect to how to refer to an item and the receiver's uncertainty of which item an attribute refers to were both reduced. More specifically, the information conveyed by the sender in terms of which attributes best described a given item influenced the interpretation of the receiver in terms of which items were identified by a given attribute.

The results for the regression equations were also quite strong. Those additional tests indicated how much participants perceived a given attribute to be similar to a target picture. Those results were evidence that participants perceived differences between attributes, i.e. they perceived one attribute being more similar to a picture than another attribute. Because they perceived that difference, their chance of selecting the right picture was increased.

Since experiment 2 was a replication of experiment 1, hypotheses 1 and 2 were not tested directly either. Still the same conclusions are valid. Taken together, the results provide evidence that attributes that are more descriptive from the point of view of the sender also end up being more selective from the point of view of the receiver, which is consistent with the argument of gap position and gap size in the hypotheses. Nonetheless it is theoretically possible to obtain similar correlation and regression results based on a general similarity-based judgment process rather than the more specific gap size and position theory proposed here.

4.4 Experiments 1 and 2: General Discussion

Results from experiments 1 and 2 gave evidence consistent with hypotheses 1 and 2. Similarity judgments of the items were measured in terms of ranking attributes with respect to pictures (task 1 and 3) and in terms of ranking items with respect to the attributes (task 2). Tasks 1 and 3 give participants the point of view of the sender, and in doing so, predict the receivers view. Similarity judgments of the items by the sender, as measured in terms of ranking given attributes, allow prediction of a receivers' point of view. The senders' perceptions of similarity of the item were strongly correlated with that of the receivers' perceptions. The strong correlation gives evidence that participants had a preference for certain attributes over other attributes.

Perception of differences between items with respect to a given attribute was also strongly correlated with differences in the likelihood of participants selecting a target item given an attribute. Taken together those results provide evidence supporting the hypotheses; attributes that are more diagnostic from the point of view of the sender also end up being more selective from the point of view of the receiver, which is consistent with the argument of gap position and gap size in the hypotheses.

Although the correlations and regressions results were consistent with what would be expected if the hypotheses were true, they were not a direct test of the hypotheses. As stated previously it is possible to imagine a situation where similar results could be obtained based on a more general similarity judgment process rather the specific gap size and position theory proposed here. For example, if one considers the probability distribution tables (Table 3 and Table 5) presented earlier in the framework section, one could imagine a distribution in which item probabilities differed from one another by equal discrete amounts. In such a case, there would be no sharp gap separating any possible subsets of the items despite consistent similarity judgments across participants. Thus it is possible that people use general similarity judgments of items relative to attributes (and attributes relative to items) to process information in communication without necessarily using perceived gaps.

Experiments 1 and 2 were designed with some characteristics that allowed certain achievements while also causing certain limitations. For example, both experiments were designed with ambiguous or unstructured stimuli. Unstructured stimuli are multidimensional. In theory, given a multidimensional stimulus, people can perceive an infinite variety of attributes that they can use to cluster items and create distinctions. In other words, there are no limits in how people differentiate dimensions to cluster items. Therefore, in order to use the random drawings and the Rorschach inkblots as stimuli, I had to create a finite set of dimensions or attributes.

The list of attributes was created based on descriptions used by real people to describe the same items in previous circumstances. This was both an advantage and a limitation. It was an advantage because the data was not fictitious. However, it was also a limitation because I did not have the same data collected for all three tasks. In both experiments 1 and 2, task 2 was the only one in which participants ranked all the items with respect to all the attributes. In tasks 1 and 3 participants ranked certain attributes with respect to certain items. In other words, not all attributes were used to describe all the items. Certain attributes were used uniquely to describe a specific item, while other attributes were used for two or three items.

Another potential disadvantage of using naturalistic descriptions is that they vary in complexity. For example, some of the descriptions referred to one object and some referred to more complex images (e.g. “wrench” vs. “it’s a monster going around its tail”, in experiment 1). More complex descriptions raise the question of how many attributes were actually associated with a given description. For instance does the participant perceive a monster going around its tail as a single holistic image or as do they process it as a sequence of attributes, e.g. “monster”, “tail”, “going around”, etc.?

In addition, the degree of similarity varied depending on which attribute they identified. An attribute could result in a very sharp distinction, thereby reducing uncertainty with respect to how to refer to an item and by reducing the size of the subset at the same time. Another attribute could result in a less sharp distinction since there was no perception of a sharp gap but uncertainty was reduced due to the position of the gap by decreasing the size of the subset.

Finally, unstructured stimuli did not allow for control in terms of the gap size and gap position. In multidimensional stimuli, there is random variation in the size and position of the gap for any of the dimensions.

4.5 Experiment 3

Experiment 3 was designed to address some of the limitations of experiments 1 and 2. The experiment was designed with a two-dimensional stimulus as shown in Figure 6. The use of two dimensions limited what participants were paying attention to, and allowed for manipulation of the similarity of the items in different ways along the two dimensions.

The two dimensions used in experiment 3 were shape and colour. Shape varied from triangle to circle and colour varied from red to yellow. Thus each of the items in figure 6 could be described by any of the four attributes “red”, “yellow”, “triangle”, and “circle”. Moreover, the shapes and colours varied in a 5x5 grid[6] (see figure 6). Due to their relative positions in the grid, different items varied in degree of similarity with respect to the two dimensions by fixed and discrete amounts.

The two-dimensional grid allowed for direct control of the gap size and gap position by using different stimulus designs consisting of different sets of items selected

[6] The 5x5 grid was drawn by Kristen Duimering.

from the 25 items in figure 6. Moreover, since the variables were discrete, they allowed for a different type of measure. Pairwise comparisons rather than correlations are appropriate to handle discrete variables. I am directly comparing one stimulus design with a given gap size with another stimulus design with another gap size, for instance.

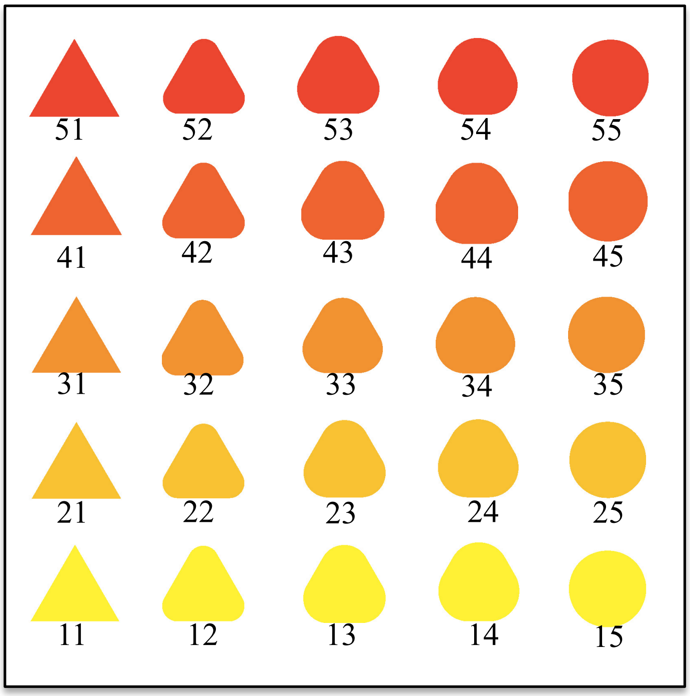


Figure 6 – Experiment 3 stimulus

As mentioned in section 2, experiments 2 and 3 were performed simultaneously as part of the same survey with the same participants. Participants performed two tasks in experiment 3, each consisting of the four attributes (red, yellow, triangle, and circle) and a set of items selected from the 25 grid positions in figure 6. In task 1, the participants use binary choices to select the best attribute to describe a target item with respect to the set of items. In task 2, the participants ranked the items with respect to each of the four attributes. Therefore, experiment 3 addressed the issue of incomplete data mentioned in the above section by ranking all items against all four attributes in each case.

All of those aspects of experiment 3 design will be explained in detail in the next sections.

4.5.1 Stimulus design

In the 5x5 grid, shape varied from triangle to circle on the horizontal axis, and colour varied from yellow to red on the vertical axis. For each set of items used in experiment 3, the target was always the item in the middle of the grid (item 33), which theoretically could be identified equally well using any of the four attributes, triangle, circle, red, or yellow.

The main goal of a structured design, in which items would have a fixed position, was to control for the two categorical logics and better test the two hypotheses. Hypothesis 1 referred to the gap size. It states that when people communicate unstructured stimuli, and can choose among multiple attributes to describe items, they will choose the one which maximizes the gap size between the category containing the target item and the category containing the remaining items. Reflecting the gap position, hypothesis 2 says that when people have to communicate unstructured stimuli and they have a choice among alternative attributes, they will chose the one which will maximize information gain, by minimizing the size of the category containing the target item.

For the design of the stimulus sets, in each case I selected a set of 4 to 6 items from the grid, including the target item (33). The sets were presented to participants in randomly ordered arrangements to avoid conveying to them the idea that the items were selected from an organized grid. Depending on the chosen set of items it is possible to create several stimulus conditions such that the target is more or less similar to the other items in the set and the gap size and position can be varied in a controlled manner.

The example shown in Figure 7A was one of four “baseline” stimulus designs that were used as the control conditions for the experiment. It consisted of the five items 42, 43, 33, 34, and 24. The item in the middle is the target (item 33). Items 42 and 43 are 1 distance unit away from the target in the colour dimension (i.e., 1 unit more red) and items 34 and 24 are 1 distance unit away from the target in the shape dimension (i.e., 1 unit more circular). Several other stimulus designs were created from the baseline design by replacing one or more of items 42, 43, 34, and 24 with other items from the 5x5 grid, to manipulate gap size, gap position, or both gap size and position simultaneously with respect to the shape and colour dimensions.

The assumption in the design is that the perceived similarity between items should correlate closely with distance between items in the 5x5 grid. For example, an item 1 unit away from the target (e.g. items 32 or 23) should be perceived as more similar to the target than an item that is 2 units away (e.g. items 13 or 31). Although I take the grid distance between two items as an indicator of their similarity, it is evident that people are likely to perceive the similarity of items in ways that do not correspond directly to grid distances. It is important to note, however, that I only consider relative differences in similarity from one stimulus condition to another, not the absolute similarity of items for any single stimulus. In the baseline stimulus design, for instance, if human similarity perceptions were identical to grid distances, I would expect participants to describe the target as either a triangle or yellow with equal frequency (because the target item is equal distance from pure triangle and pure yellow). However, if perceptual judgments of similarity differed from grid distances, for example such that people described the target as a triangle 60% of the time and as yellow only 40% of the time, then any changes in gap size or position should vary from this 60:40 base rate in the direction predicted by the hypotheses. Thus, although similarity perceptions do not correspond directly to grid distances, it seems reasonable to assume that the relative degree of perceived similarity should be correlated with relative distances within the grid.

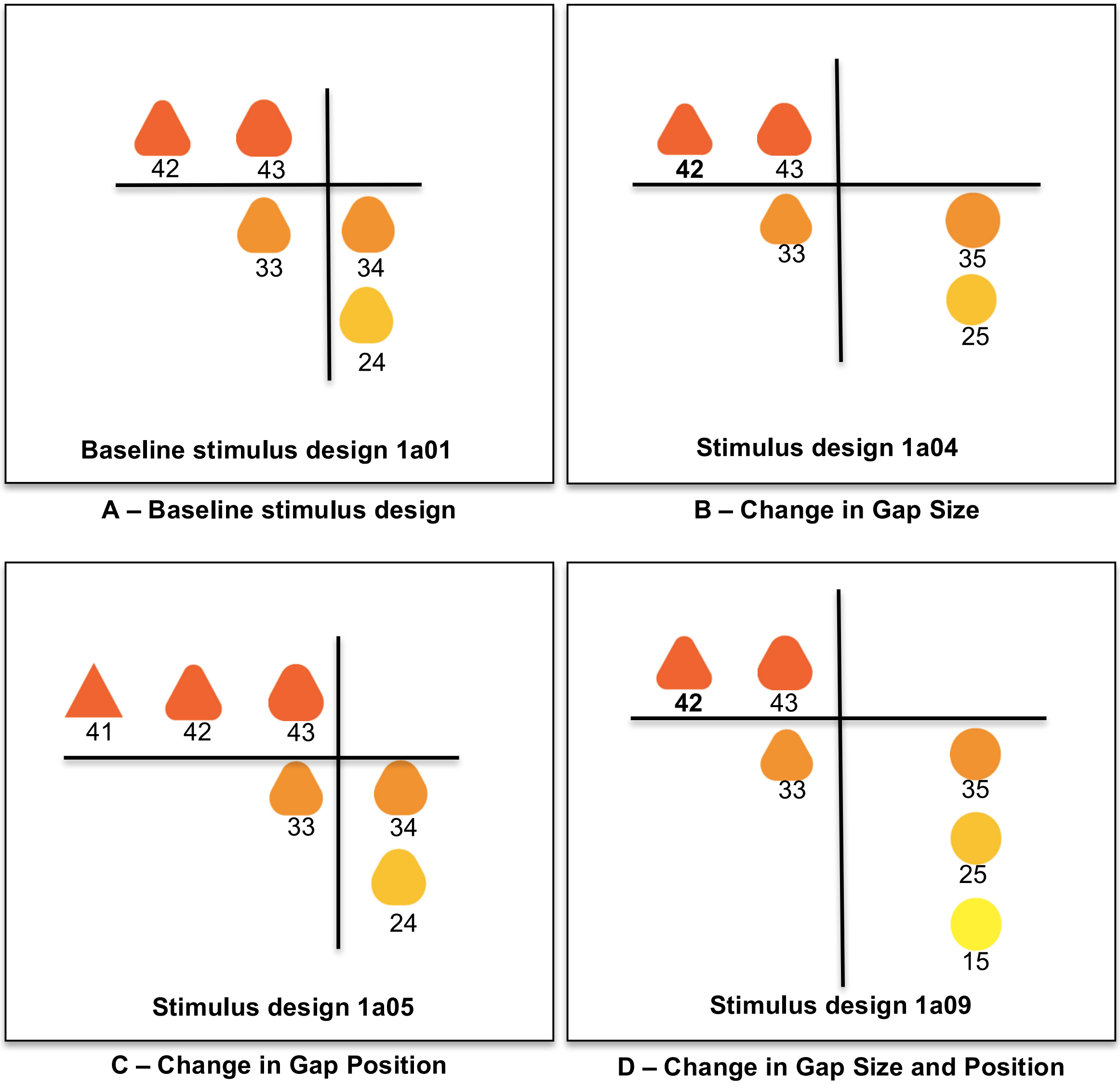


Figure 7 – Example of baseline stimulus design and different manipulations

In the next sections I explain how gap size and gap position were varied in different stimulus conditions. Since they all varied in several different ways, I will explain one example of each. All the examples given are based on the binary choice of describing the target item (33) as either a triangle or as yellow. Because all stimulus designs were created by modifying the baseline stimulus design, the baseline design is explained first.

A. Baseline stimulus design

As noted above, Figure 7A (stimulus design 1a01)[7] shows a baseline stimulus design consisting of the target item 33 along with items 42, 43, 34, and 24. The black lines are used to represent how participants were expected to structure the stimulus into two subsets, or clusters, by describing the target item (33) as either a triangle or as yellow. For instance, by describing item 33 as a triangle, participants group 33 together with items 42 and 43 (other triangles), while 34 and 24 become "non-triangles". By describing item 33 as yellow, participants group 33 together with items 34 and 24 (other yellow items), while items 42 and 43 become "non-yellow". Because the subset sizes of triangle and yellow are the same in this case (3 items each) the position of the gap is equal for both dimensions. Similarly, the distance in the grid between item 33 and items 34 and 24 (i.e., between triangles and non-triangles) is the same as the distance between item 33 and items 42 and 43 (i.e., between yellow and non-yellow items), the gap size is also equal for both dimensions (1 unit distance each).

B. Gap size

The gap size was increased by shifting items away from the target in the direction of the colour or in the direction of the shape. Figure 7B is an example of a stimulus design in which gap size varied (stimulus design 1a04). In this case there is a gap of 2 units in the shape dimension (between triangles and non-triangles) and 1 unit in the colour dimension (between yellow and non-yellow items), as indicated by the black vertical and horizontal lines respectively. The larger gap for the shape dimension suggests that a sharper

[7] A coding scheme was used to refer to the various stimulus designs. The scheme will be explained later in section 4.5.2

distinction can be drawn, and more uncertainty reduced, by describing the target item (33) as a triangle than as yellow. As a result, compared to the baseline stimulus design, I expected that people would shift their choices toward triangle, the attribute with the larger gap.

In addition to the example in figure 7B the two stimulus designs in Figure 8 were also included as examples of changes in gap size relative to the baseline design.

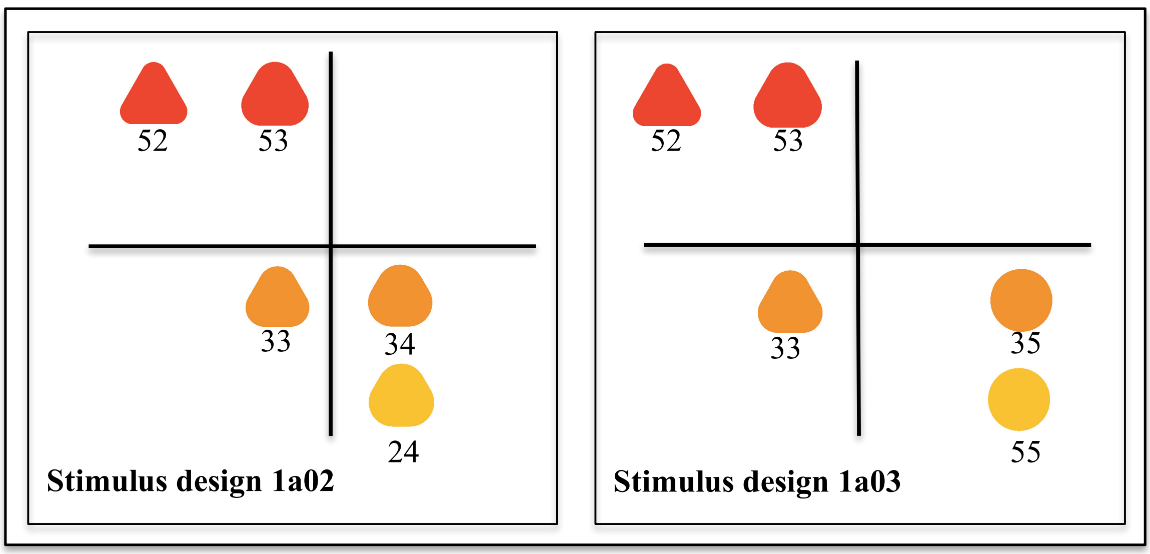


Figure 8 – Gap size changes

C. Gap position

Gap position refers to the relative size of the subsets associated with describing the target with respect to a particular attribute. The gap position was changed by either adding an item to, or deleting an item from, the baseline stimulus. Figure 7C is an example of a change in gap position, achieved by adding item 41 to the baseline design (stimulus design 1a05). Compared to the baseline stimulus design, the addition of item 41 increases the triangle subset but leaves the subset of yellow items unchanged (4 triangles vs. 3

yellow items). The smaller subset for yellow implies that more uncertainty can be reduced by describing the target item (33) as yellow than as a triangle. Therefore from hypothesis 2, I expected that people would shift their choices towards yellow, the attribute with the smaller subset.

In addition to the example in figure 7C, the following three stimulus designs were also included as examples of changes in gap position.

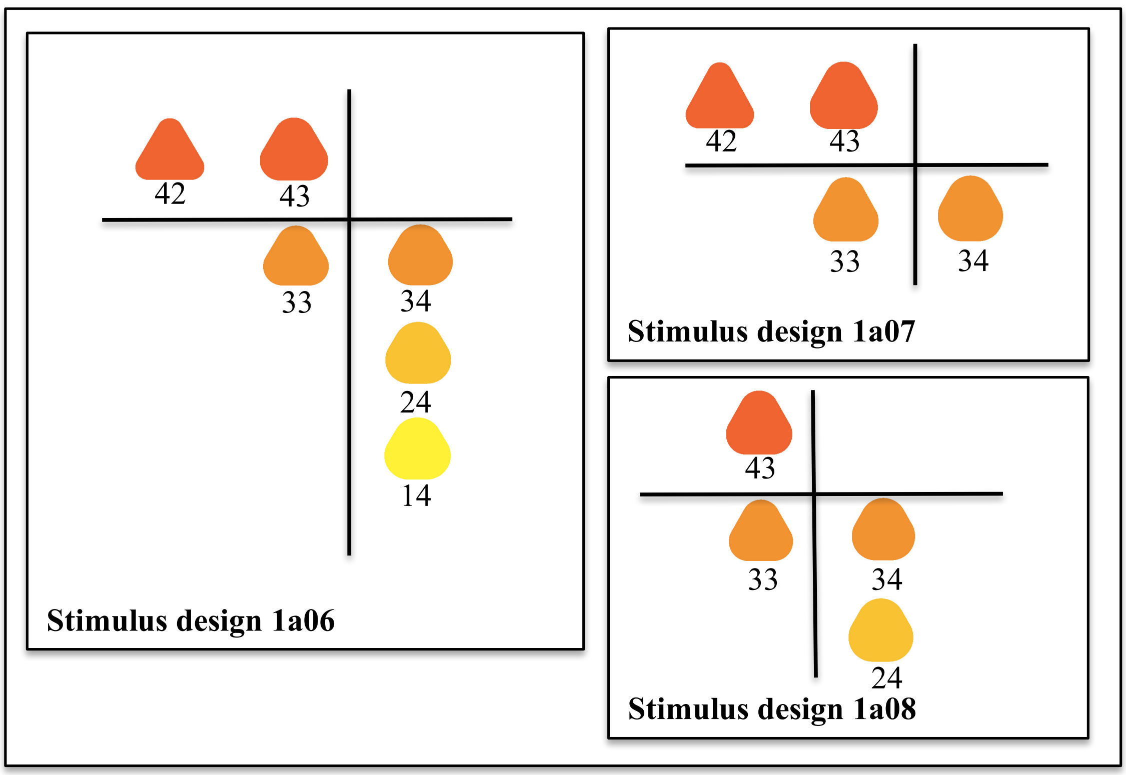


Figure 9 – Gap position changes

D. Both position and gap size

Although I did not have a specific hypothesis dealing with both position and gap size simultaneously, 4 conditions were created to investigate potential interactions between the two variables. Stimulus design 1a09 is an example (Figure 7D). It was composed of items 42, 43, 33, 35, 25, and 15. As can be observed from the comparison between Figures 7A and 7D, to achieve both changes, items were shifted away 1 unit in the direction of shape and item 15 was added simultaneously. In the baseline case (Figure 7A), referring to the target (item 33) as either triangle or yellow corresponded with equal gap size (1unit distance) and position (subset size of 3 items each). Due to the changes, in Figure 7D it is possible to perceive a larger gap size for triangle (2 units distance) and an increased subset size for yellow (4 items vs. 3 for triangle). In this example, both the larger gap and the smaller subset for triangle imply that more uncertainty can be reduced by describing the target item (33) as a triangle than as yellow. Therefore, from hypothesis 1 I expected that people would shift their choices toward triangle, the attribute with the larger gap. From hypothesis 2 I also expected that people would shift their choices toward triangle, the attribute with the smaller subset. Thus, the combined effect of both variables was expected to be larger in magnitude than the corresponding effects of either variable alone.

In addition to the example in Figure 7D the following three stimulus designs were also included as examples of changes in both gap size and position.

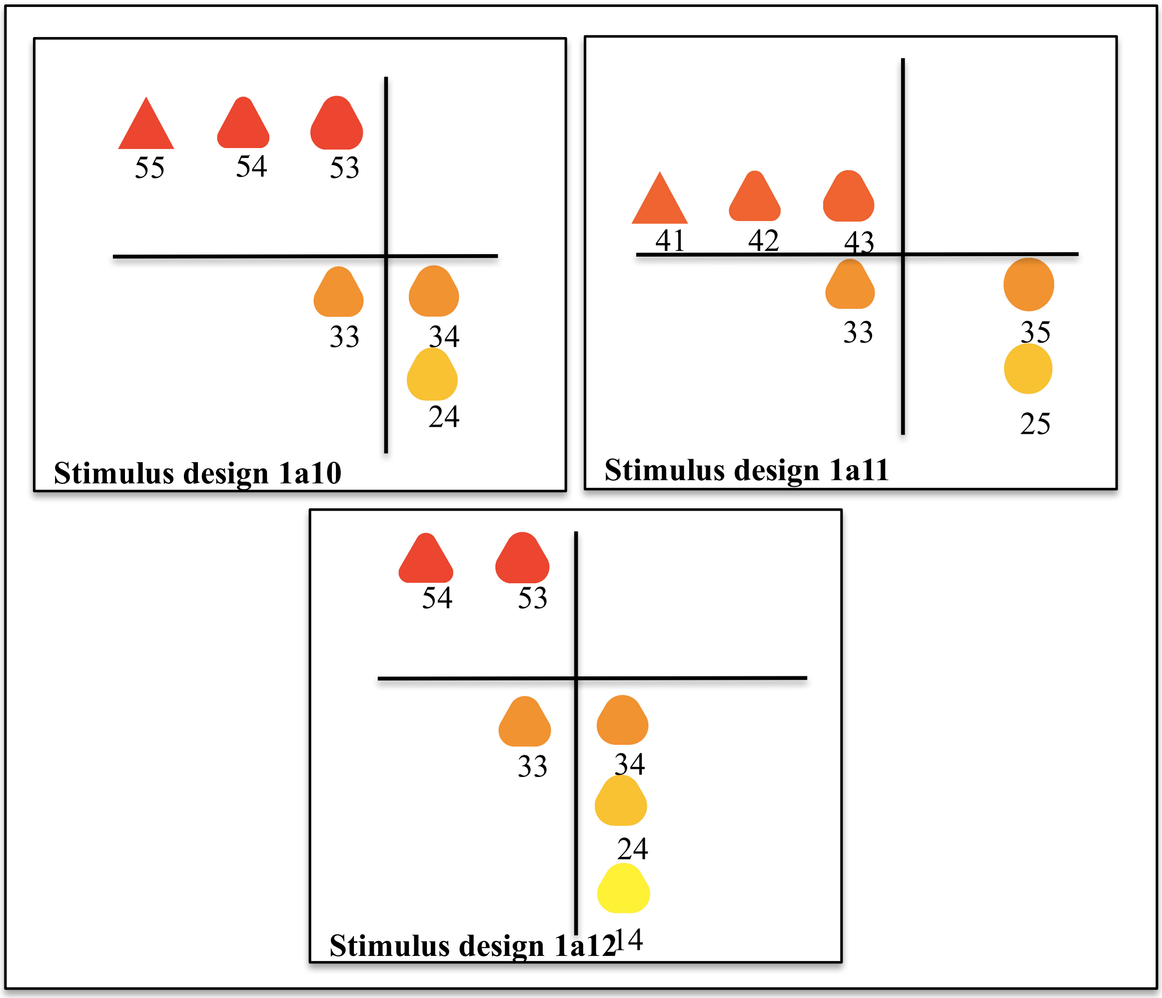


Figure 10 – Gap size and position changes

4.5.2 Families of stimulus designs and a coding scheme

The previous examples, shown in Figures 7-10, constitute one complete family of stimulus designs: one baseline stimulus design and 11 different stimulus designs manipulated from the baseline. Because the entire experimental stimulus design is based on a two-dimensional grid, I was able to create 3 other families of stimuli with equivalent structures by rotating the grid 90, 180, and 270 degrees. For example, Figure 11 shows the baseline stimulus design described earlier, as well as three additional baseline stimulus designs of equivalent structure, that were obtained by rotation around the grid.

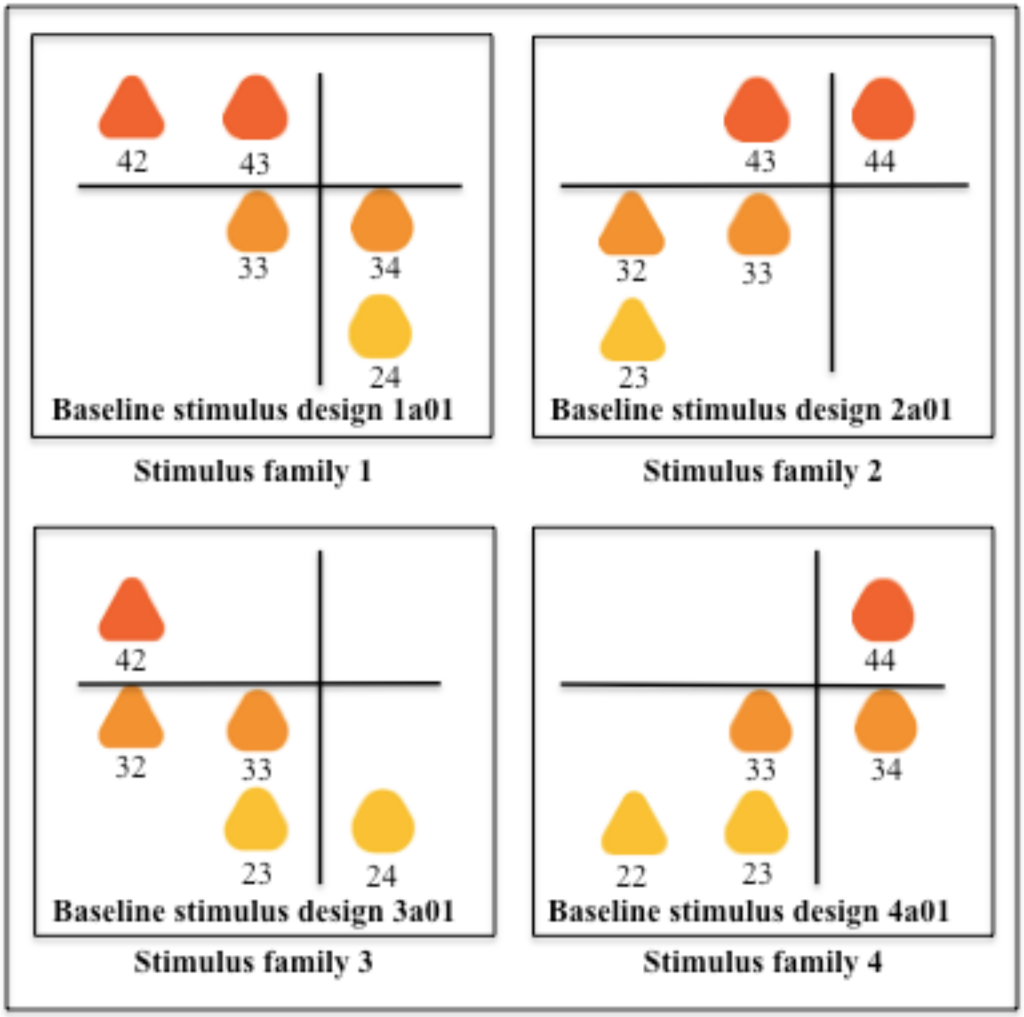


Figure 11 – Families of stimulus designs

Similarly, I rotated each of the 11 stimulus designs described above to obtain three additional complete families of stimulus designs. Each family included designs with the same structures previously described: a baseline stimulus design, 3 designs with changes in gap size, 4 designs with changes in gap position, and 4 designs with changes in both gap size and position simultaneously. All together, the four families add up to 48 different stimulus designs representing various manipulations of gap size and position.

A coding scheme was used to label each of the various stimulus designs. I coded the first baseline stimulus (Figure 7A) as design 1a01. The first digit in the code (1 in this case) referred to the rotation on the 5x5 grid. Since there were 4 different rotations, the first digit varied from 1 to 4. The last two digits referred to the different stimulus designs, which manipulated gap size and position in various ways. For instance, the two digits "01" identified a baseline stimulus design; 02 to 04 referred to changes in gap size only; 05 to 08 referred to changes in gap position only; and 09 to 12 referred to changes in both gap size and gap position simultaneously.

A letter ("a" in this example) was also included in the code to designate a particular combination of the various binary choices presented to participants in task 1 of the experiment. Specifically, there were six different binary choices for task 1 (red vs. yellow; triangle vs. circle; triangle vs. red; yellow vs. triangle; circle vs. yellow; and circle vs. red). However, because each stimulus design was rotated around the 5x5 grid, there were four different versions of each design, and a given binary choice in one rotation corresponded with a different binary choice in a different rotation. For instance, the binary choice triangle vs. yellow in rotation 1 was structurally equivalent to circle vs. yellow in rotation 2, circle vs. red in rotation 3, and triangle vs. red in rotation 4. Thus, 6 sets of structurally equivalent binary choices were defined, coded with the letters "a" – "f". Each set designated four structurally equivalent binary choices (one for each of the four rotations of the stimulus designs around the grid) for one of the six binary choices in task 1.

Figure 12 summarizes the correspondence between different binary choices across the four rotations of the baseline stimulus. The four rows in the table represent the four rotations. The six columns, coded a-f, represent sets of structurally equivalent binary choices across the four rotations. Although only the baseline stimulus design is shown in Figure 12, the same logic applies for all of the 12 stimulus designs in each family.

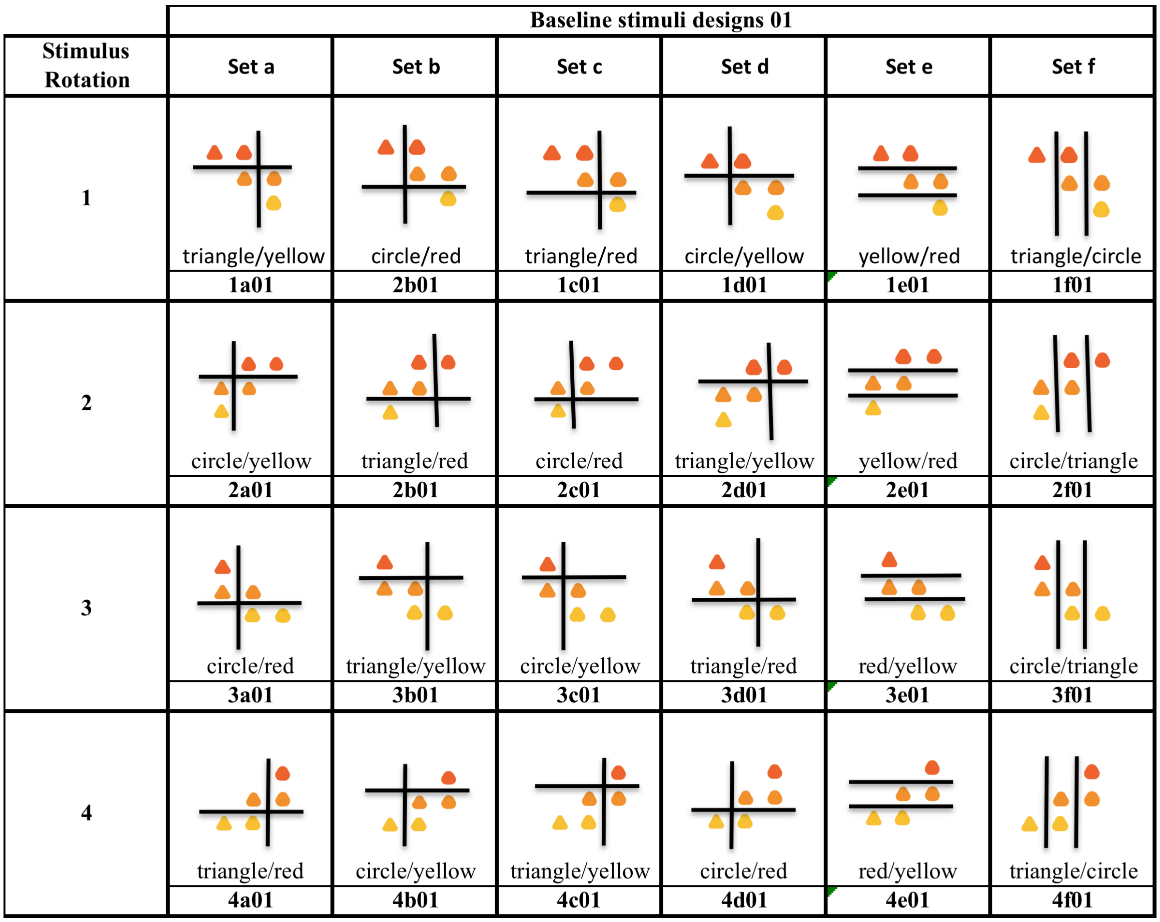


Figure 12 – Six sets of equivalent binary choices structures for baseline stimulus conditions 01 for rotations 1, 2, 3, and 4

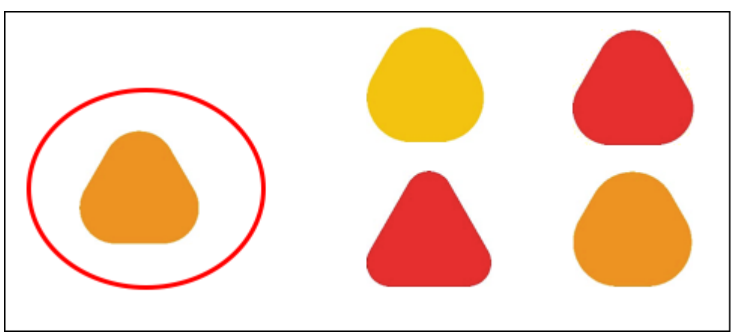
In addition to the four stimulus design families described above, I also designed two other families of designs which included various manipulations starting from a different baseline stimulus design. Although data were collected for these two families along with the other four, I decided not to report the results in the dissertation. Furthermore, I also decided not to report the results for stimulus designs involving simultaneous changes in both gap size and position in this dissertation. All the stimulus design families (including those whose results are not being reported) and their respective codes are included in Appendix C.

4.5.3 Method

As mentioned in Section 4.3.2, experiments 2 and 3 were conducted simultaneously using a single survey. Therefore, the experimental procedure, materials and participants were the same as those described earlier for experiment 2.

Task 1. For task 1, participants were presented with a set of items and descriptions. Their goal was to rank the descriptions with respect to the items. Below is a sample of task 1.

For this task, imagine you were trying to get another person to select the item indicated from the set of items shown below.
The following 6 pairs of descriptions could be used to describe the circled item. **For each pair** please choose the description that you think would work best to get the person to select the indicated item.

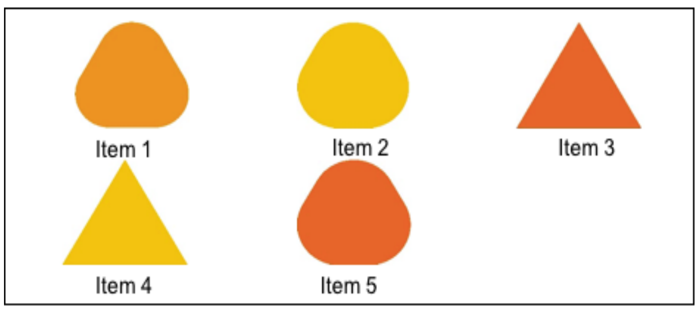


1. ☐ looks red ☐ looks yellow
2. ☐ looks like a triangle ☐ looks like a circle
3. ☐ looks like a triangle ☐ looks red
4. ☐ looks yellow ☐ looks like a triangle
5. ☐ looks like a circle ☐ looks yellow
6. ☐ looks like a circle ☐ looks red

Participants performed the above task 12 times in relation to 12 different stimulus designs.

Task 2. Participants were given a set of items and one description. The objective was to rank the items with respect to the description. The following task is an example of task 2.

Imagine you are communicating to a person in another room who has the following set of items. Your goal in this task is to correctly select items from the set based on descriptions provided by the other person. For each of the descriptions provided below please rank the items based on which one the person is most likely referring to (where rank of 1 is the "most likely"). This task will be repeated 12 times altogether (with 12 different sets of Items).



The other person uses the description "looks red"	
Item Number	**Your Rank**
1	
2	
3	
4	
5	

The other person uses the description "looks like a circle"	
Item Number	**Your Rank**
1	
2	
3	
4	
5	

The other person uses the description ”looks yellow”	
Item Number	**Your Rank**
1	
2	
3	
4	
5	

The other person uses the description ”looks like a triangle”	
Item Number	**Your Rank**
1	
2	
3	
4	
5	

Participants performed the above task 12 times in relation to 12 different stimulus designs.

Measures. In experiment 3, gap size and position were directly controlled in the design of the experimental stimulus. Hence, pairwise comparisons methods were used to examine differences between how participants responded to different stimulus designs with different sized gaps or different gap positions. The experiment was a within-subject design. To test for the effect of gap size, paired sample t-tests were used to examine differences in participant responses between the baseline stimulus design (gap 1 unit distance) and other stimulus designs with a larger gap size (gap size of 2 units distance). To test for the effect of gap position, paired sample t-tests were used to examine differences in participant responses between the baseline stimuli designs (with given subsets sizes of items) and other stimulus design with different subsets sizes (smaller subsets vs. larger subsets).

More specifically, in task 1, participants performed a series of binary choices between pairs of attributes, as to which of each pair would best describe the target item. To compare participants' attribute choices between different stimulus conditions, the binary choice data were converted into ratios by summing the number of times participants chose each of the 4 attributes for a given target item. These ratios were used in the pairwise comparisons.

In task 2, participants ranked the set of items with respect to each specific attribute description, and how participants ranked the target item against other items in the set were compared across different conditions. To compare ranks across different stimulus conditions with different numbers of items, the rank of the target item for each participant was converted into a standardized score by dividing the rank-value by the number of items in the set. These standardized ranks were used in the t-tests.

4.5.4 Results

Task 1

A. Gap Size

To test for the effect of gap size, paired sample t-tests were used to examine differences between participants' choices of attributes between the baseline stimulus designs, with a gap size of 1 unit distance within the 5x5 grid, and other stimulus designs with gap sizes of 2 units. Gap size was manipulated with respect to both the size and shape dimensions of the 5x5 grid. Stimulus designs coded 02 used a gap of 2 units for the colour dimension (i.e., with respect to either red or yellow); designs coded 04 used a gap of 2 units for the shape dimension (i.e., either triangle or circle). See Appendix C for details of each stimulus design. In each case, only some of the six binary choices were relevant for hypothesis testing, while others were not. For instance, if the attribute changing from 1-unit to 2-unit gap size was yellow, only binary choices that included the attribute yellow were relevant (i.e., “yellow vs. red”, “yellow vs. triangle”, and “yellow vs. circle”), whereas other binary choices were irrelevant. In total, there were 6 binary choices relevant for hypothesis testing: 3 for the colour dimension (reported in Table 23) and 3 for the shape dimension (reported in Table 24).

For each of the 6 relevant binary choices, the t-test was used to compare ratios of participant choices for the attribute with the larger gap in the 2-unit gap condition, against ratios of choices for the same attribute in the baseline (1-unit gap) condition. As explained earlier, for any binary choice between two attributes there were four structurally equivalent choices, corresponding to the four rotations of the stimulus designs around the 5x5 grid (see columns “a”-“f” in Figure 12). Thus, for each t-test, n=4 ratios for an attribute with a 1-unit gap in the baseline stimulus design were compared against n=4 ratios for the same attribute with a 2-unit gap in a different stimulus design. Because the same participants performed the binary choices in both stimulus conditions, this is a within-subjects experimental design, and paired sample t-tests were used.

As an illustration, the ratios for one set of equivalent attribute binary choices (set “a”) for the 4 rotations of the baseline stimulus are shown in Table 22. The first column refers to the four different rotations of the baseline stimulus design. The second column identifies the equivalent binary choices of attributes for each rotation (labeled attribute 1 and 2 to identify structurally equivalent attributes across the four rotations). The third and fourth columns indicate the number of participants who chose each of the two attributes, and the last two columns give the corresponding ratios of choices for each attribute. In the t-tests, one of the two ratios (ratio 1 or 2) would be used for pair-wise comparison between two stimulus conditions, depending on which ratio corresponded with the attribute with manipulated gap size.

Baseline sets

Family-rotations	Binary choice: attributes 1 and 2	Votes for attribute 1	Votes for attribute 2	ratio for attribute 1	ratio for attribute 2
1a01	triangle/yellow	10	6	0.62	0.38
2a01	circle/yellow	8	10	0.44	0.56
3a01	circle/red	11	7	0.61	0.39
4a01	triangle/red	11	4	0.73	0.37

Table 22 – Example of an aggregated stimulus design with similar dimensional structure

Table 23 summarizes paired samples t-test results for the three cases in which gap size was manipulated with respect to colour attributes (either red or yellow). In the table, gap 1 means (M) and standard deviations (SD) refer to the baseline stimulus designs with a gap size of 1 unit. Gap 2 M and SD refer to the four stimulus designs ending in 02 (for instance, 1a02, 2a02, 3a02, 4a02) with a gap size of 2 units. From Hypothesis 1, when people communicate about unstructured stimuli and they can choose among multiple attributes to describe the item, they are expected to choose the attribute that maximizes the gap size. Thus, I expected people to shift in their choices towards the attribute with the larger gap. Because this is a directional hypothesis, I expected gap 2 means to be greater than gap 1 means, and used 1-tailed probabilities to evaluate t-test results. The results were significant for all sets of the manipulations of gap size with respect to colour attributes, except for set d.

	Gap 1 (Baseline, 1 unit)		Gap 2 (Design 02, 2 units)					
Sets	M*	SD*	M*	SD*	*df*	*t*	*p (1-tailed)*	Decision
Sets a01, a02	0.4250	0.0904	0.5100	0.1386	3	-2.72	0.036	S
Sets d01, d02	0.5575	0.1859	0.6375	0.1746	3	-1.86	0.080	NS
Sets e01, e02	0.6250	0.1516	0.7675	0.1133	3	-3.57	0.041	S

*M and SD based on the ratio of choices for the attribute with the larger gap

Table 23 – T-tests results for the baseline designs 01 and gap size stimulus designs 02 with respect to colour

Table 24 summarizes paired samples t-test results for the three cases in which gap size was manipulated with respect to shape attributes (either triangle or circle). The result was significant for sets a. For sets c and f, the results were not significant using a 1-tailed test.

	Gap 1 (Baseline, 1 unit)		Gap 2 (Design 04, 2 units)					
Sets	M*	SD*	M*	SD*	*df*	*t*	*p (1-tailed)*	Decision
Sets a01, a04	0.5750	0.0904	0.6750	0.0785	3	-7.39	0.003	S
Sets c01, c04	0.5600	0.2045	0.7800	0.0753	3	-1.88	0.079	NS
Sets f01, f04	0.6525	0.1957	0.7125	0.2304	3	-0.95	0.206	NS

*M and SD based on the ratio of choices for the attribute with the larger gap

Table 24 – T-tests results for the baseline designs 01 and gap size stimulus designs 04 with respect to shape

B. Gap Position

To test for the effect of gap position, paired sample t-tests were used to examine differences between the ratios of participants' attribute choices between the baseline stimulus design and other designs with either larger or smaller subsets of items for a given attribute. Stimulus designs coded 05 and 06 differed from the baseline design by adding an item to one of the attributes. Designs coded 07 and 08 differed from the baseline design by deleting an item from one of the attributes. There were 8 relevant cases of manipulations to gap position, as shown in Tables 25-28. See Appendix C for details of the relevant design variations.

Hypothesis 2 stated that when people have to communicate unstructured stimuli and they have a choice among alternative attributes to describe the item they would chose the one which maximizes information gain by choosing the attribute that minimizes the subset size containing the target item. Thus, in any of the pairwise comparisons I expected people to shift in their choices toward the attribute with the smaller subset size, referred to as “position 2” in Tables 25-28 (“position 1” refers to the baseline design). Because this is a directional hypothesis, I expected position 2 means to be greater than position 1 means, and used 1-tailed probabilities to evaluate t-test results. As shown in Tables 25-28, the results were not significant for the manipulations of gap position with respect to the addition of an item (designs ending in 05 and 06) but they were significant for those with respect to the deletion of an item (designs ending in 07 and 08).

	Position 1 (baseline)		**Position 2 (05)**					
Sets	**M***	**SD***	**M***	**SD***	***df***	***t***	***p (1-tailed)***	**Decision**
Sets a01, a05	0.4000	0.1197	0.5650	0.2133	3	-1.73	0.091	NS
Sets b01, b05	0.6100	0.0993	0.6875	0.2243	3	-0.71	0.265	NS

*M and SD based on the ratio of choices for the attribute with the smaller subset

Table 25 – T-tests results for the baseline stimulus designs 01 and gap position stimulus designs 05, by addition of an item

	Position 1 (baseline)		**Position 2 (06)**					
Sets	**M***	**SD***	**M***	**SD***	***df***	***t***	***p (1-tailed)***	**Decision**
Sets a01, a06	0.6025	0.1204	0.6025	0.1902	3	0.00	0.500	NS
Sets b01, b06	0.3900	0.0993	0.4775	0.1429	3	-1.29	0.145	NS

*M and SD based on the ratio of choices for the attribute with the smaller subset

Table 26 – T-tests results for the baseline stimulus designs 01 and gap position stimulus designs 06, by addition of an item

	Position 1 (baseline)		**Position 2 (07)**					
Sets	**M***	**SD***	**M***	**SD***	***df***	***t***	***p (1-tailed)***	**Decision**
Sets a01, a07	0.4000	0.1197	0.6300	0.1364	3	-10.12	0.001	S
Sets b01, b07	0.6100	0.0993	0.7175	0.1323	3	-6.51	0.004	S

*M and SD based on the ratio of choices for the attribute with the smaller subset

Table 27 – T-tests results for the baseline stimulus designs 01 and gap position stimulus designs 07, by deletion of an item

	Position 1 (baseline)		Position 2 (08)					
Sets	**M***	**SD***	**M***	**SD***	***df***	***t***	***p (1-tailed)***	**Decision**
Sets a01, a08	0.6025	0.1204	0.6700	0.0653	3	-2.35	0.005	S
Sets b01, b08	0.3900	0.0993	0.5175	0.0619	3	-2.21	0.057	S

*M and SD based on the ratio of choices for the attribute with the smaller subset

Table 28 – T-tests results for the baseline stimulus designs 01 and gap position stimulus designs 08, by deletion of an item

Task 2

For task 2, participants were given a set of items and four attributes or descriptions: triangle, circle, yellow, and red. Their goal was to rank the items with respect to each attribute, based on the likelihood that the attribute was referring to each of the items. Therefore, the data collected from task 2 was a direct rank of the items with respect to each attribute, for each stimulus design. As in Task 1, the various stimulus designs manipulated either gap size or gap position. The following results summarize the effects of gap size and position on how the target item was ranked by participants with respect to the four attributes. Specifically, paired sample t-tests compared participants' ranks of the target item with respect to each attribute for the baseline stimulus design, against the corresponding target item ranks for the other stimulus designs.

As noted earlier, I used standardized rank scores because the number of items in the different stimulus designs varied from 4 to 5 depending on the stimulus. As with task 1, stimulus designs of equivalent dimensional structure, based on different rotations of the stimulus around the 5x5 grid, were aggregated together for analysis of task 2. In addition, however, because the data for task 2 consisted of each individual's ranks (rather than ratios of all participants' choices in task 1) the sample sizes were large enough to also conduct separate t-tests for each of the 4 stimulus rotations, rather than just a single aggregate test for a given design using the combined data from all 4 rotations. Thus, five t-tests were conducted for each pairwise comparison between participants' rankings of the target item for a given attribute for the baseline stimulus vs. another stimulus design: one for each of the four rotations separately, and one for the aggregate responses of the four rotations together.

A. Gap Size

To test for the effect of gap size, paired sample t-tests were used to examine differences between participants' target item rankings between the baseline stimulus designs with a gap size of 1 grid distance unit, and other stimulus designs with gap sizes of 2 units. As explained for task 1, gap size was manipulated with respect to both the size and shape dimensions of the 5x5 grid. Stimulus designs coded 02 used a gap of 2 units for the colour dimension (i.e., with respect to either red or yellow); designs coded 04 used a gap of 2 units for the shape dimension (i.e., either triangle or circle). See Appendix C for details of each stimulus design. The t-test results for 02 designs are reported in Table 29 and the results for 04 designs are reported in Table 30.

For the gap size manipulations, I expected people to shift toward the attribute with the larger gap size. In terms of how participants ranked the target item, this corresponds with an expectation of relatively lower numerical ranks for the attribute with the larger gap size. Because the hypothesis is directional, one-tailed t-tests were used to assess the results.

With respect to manipulations of gap size for colour attributes, Table 29 shows that there was not a significant difference in any of the cases tested.

			Gap 1 (baseline, 1unit)		Gap 2 (design 02, 2 units)						
Sets	Changed Dimension/ Attribute	Rotations	M*	SD*	M*	SD*	*df*	*t*	*p (1-tailed)*	Decision	*Sign Test****
Sets a01, a02	yellow	1	0.4400	0.0828	0.5200	0.1265	14	-1.87	0.041	NS	-
Sets a01, a02	yellow	2	0.5000	0.2309	0.5125	0.1258	15	-0.18	0.420	NS	-
Sets a01, a02	red	3	0.4947	0.1223	0.5158	0.1922	18	-0.62	0.271	NS	-
Sets a01, a02	red	4	0.6000	0.2000	0.5692	0.1601	12	0.49	0.318	NS	+
Sets a01, a02	colour	all	0.5048	0.1717	0.5270	0.1537	62	-0.85	0.196	NS	-

*M and SD based on the standardized rank of the target item with respect to the given dimension/attribute

*** Sign test result, fraction of cases in predicted direction (1/4), p = 0.375

Table 29 – Task 2 t-tests results for the baseline design 01 vs. gap size stimulus design 02 with respect to colour

Table 30 shows the t-test results for manipulations of gap size for shape attributes. Results were significant for two of the four separate rotations and for the rotations aggregated.

			Gap 1 (baseline, 1unit)		Gap 2 (design 04, 2 units)						
Sets	Changed Dimension/ Attribute	Rotations	M*	SD*	M*	SD*	*df*	*t*	*p (1-tailed)*	Decision	*Sign Test****
Sets a01, a04	triangle	1	0.5200	0.1656	0.4933	0.1280	14	0.49	0.317	NS	+
Sets a01, a04	circle	2	0.5875	0.1708	0.4500	0.1549	15	2.20	0.022	S	+
Sets a01, a04	circle	3	0.4842	0.1803	0.4632	0.1499	18	0.42	0.341	NS	+
Sets a01, a04	triangle	4	0.6923	0.1321	0.5231	0.1013	12	4.43	0.001	S	+
Sets a01, a04	shape	all	0.5270	0.1619	0.4794	0.1370	62	1.81	0.038	S	+

*M and SD based on the standardized rank of the target item with respect to the given dimension/attribute

*** Sign test result, fraction of cases in predicted direction (4/4), p = 0.125

Table 30 – Task 2 t-tests results for the baseline design 01 vs. gap size stimulus design 04 with respect to shape

B. Gap position

To test for the effect of gap position, paired sample t-tests were used to examine differences in participants' ranking of the target item between the baseline stimulus design and other designs with either larger or smaller subsets of items for a given attribute. As explained for task 1, there were four different stimulus designs that manipulated gap position by either adding or deleting an item with respect to one of the attribute subsets. For each of 05-08 designs, the gap position manipulations resulted in two sets of structurally equivalent stimuli (sets “a” and “b” as shown in Figure 12), so the results for the two sets are reported separately below (two Tables for each stimulus design). For each set of stimulus designs to be compared with the baseline design, four separate t-tests were conducted for each rotation of the stimulus, as well as one test for the four aggregated rotations. All together, this resulted in a total of 80 t-tests, as shown in Tables 31-34. See Appendix C for details of the relevant design variations.

From hypothesis 2, I expected people to shift toward the attribute corresponding with the smaller subset containing the target item. In terms of how participants ranked the target item, this corresponds with an expectation of relatively lower numerical ranks for the attribute with the smaller subset. Because the hypothesis is directional, one-tailed t-tests were used to assess the results.

As shown in table 31, for the baseline stimulus design and stimulus design 05, there was significant difference between the single family-rotation 4 set a for red but not for triangle and there was also a significant difference for the single family-rotation 4 set b for both yellow and circle. There was also a significant difference for the sets b shape aggregated stimuli designs.

			Position 1 (baseline)		Position 2 (05)							
Sets	**Changed Dimension/ Attribute**	**Rotations**	**M***	**SD***	**M***	**SD***	**Expected Change in target rank for position 2**	***df***	***t****	***p (1-tailed)***	**Decision**	***Sign Test***
Separate analysis for each rotation												
Sets a01, a05	yellow	1	0.4400	0.0828	0.4773	0.1383	Decrease	14	-0.93	0.184	NS	-
Sets a01, a05	triangle	1	0.5200	0.1652	0.6113	0.1498	Increase	14	-1.46	0.084	NS	+
Sets b01, b05	red	1	0.6667	0.1633	0.6540	0.2387	Increase	14	0.16	0.440	NS	-
Sets b01, b05	circle	1	0.6400	0.1352	0.6013	0.1396	Decrease	14	0.84	0.214	NS	+
Sets a01, a05	yellow	2	0.5000	0.2309	0.4888	0.1892	Decrease	15	0.22	0.415	NS	+
Sets a01, a05	circle	2	0.5875	0.1708	0.5219	0.2176	Increase	15	0.93	0.185	NS	-
Sets b01, b05	red	2	0.7000	0.1633	0.7294	0.1792	Increase	15	-0.55	0.295	NS	-
Sets b01, b05	triangle	2	0.7125	0.2062	0.6775	0.2235	Decrease	15	0.60	0.280	NS	+
Sets a01, a05	red	3	0.4947	0.1224	0.5253	0.1597	Decrease	18	-0.76	0.230	NS	-
Sets a01,ab05	circle	3	0.4842	0.1803	0.5353	0.2130	Increase	18	-0.67	0.255	NS	-
Sets b01, b05	yellow	3	0.6947	0.1545	0.6684	0.1109	Increase	18	0.64	0.267	NS	-
Sets b01, b05	triangle	3	0.6842	0.1803	0.5895	0.1616	Decrease	18	1.60	0.064	NS	+
Sets a01, a05	red	4	0.6000	0.2000	0.3692	0.7455	Decrease	12	3.49	0.002	S	+
Sets a01, a05	triangle	4	0.5231	0.1013	0.5785	0.0882	Increase	12	-1.56	0.077	NS	+
Sets b01, b05	yellow	4	0.5692	0.1797	0.7438	0.0830	Increase	12	-3.70	0.002	S	+
Sets b01, b05	circle	4	0.6923	0.1321	0.5792	0.1468	Decrease	12	2.51	0.014	S	+
Aggregate analysis for all rotations												
Sets a01, a05	color	all	0.5048	0.1717	0.4724	0.1569	Decrease	62	1.19	0.119	NS	+
Sets a01, a05	shape	all	0.5270	0.1619	0.5589	0.1802	Increase	62	-0.95	0.174	NS	+
Sets b01, b0!	color	all	0.6635	0.1678	0.6960	0.1642	Increase	62	-1.11	0.137	NS	+
Sets b01, b0!	shape	all	0.6825	0.1671	0.6125	0.1725	Decrease	62	2.59	0.006	S	+

*M and SD based on the standardized rank of the target item with respect to the given dimension/attribute

** t is negative if position 2 mean is greater than position 1 mean

Table 31 – Task 2 t-tests results for the baseline stimulus design 01 vs. gap position stimulus design 05, by addition of an item

For gap position between the baseline stimulus design 01 and gap position 06, with respect to the single rotations, as shown in table 32, some results were significant for family-rotations 1, and 3. Result was also significant for three of the aggregated rotations. All other results were not significant.

Sets	Changed Dimension/ Attribute	Rotations	M*	SD*	M*	SD*	Expected Change in target rank for position 2	*df*	*t***	*p (1-tailed)*	Decision	*Sign Test*
Separate analysis for each rotation												
Sets a01, a06	yellow	1	0.4400	0.0828	0.5453	0.1721	Increase	14	-2.17	0.024	S	+
Sets a01, a06	triangle	1	0.5200	0.1652	0.3880	0.1509	Decrease	14	3.16	0.004	S	+
Sets b01, b06	red	1	0.6667	0.1633	0.6233	0.1840	Decrease	14	0.76	0.231	NS	+
Sets b01, b06	circle	1	0.6400	0.1352	0.6447	0.1772	Increase	14	-0.10	0.461	NS	+
Sets a01, a06	yellow	2	0.5000	0.2309	0.5431	0.1685	Increase	15	-0.64	0.267	NS	+
Sets a01, a06	circle	2	0.5875	0.1708	0.5200	0.1602	Decrease	15	1.63	0.063	NS	+
Sets b01, b06	red	2	0.7000	0.1633	0.6250	0.1660	Decrease	15	1.41	0.089	NS	+
Sets b01, b06	triangle	2	0.7125	0.2062	0.6463	0.2105	Increase	15	0.98	0.172	NS	-
Sets a01, a06	red	3	0.4947	0.1224	0.5716	0.0862	Increase	18	-1.96	0.033	S	+
Sets a01, a06	circle	3	0.4842	0.1803	0.4737	0.1516	Decrease	18	0.27	0.394	NS	+
Sets b01, b06	yellow	3	0.6947	0.1545	0.5626	0.1163	Decrease	18	3.76	0.001	S	+
Sets b01, b06	triangle	3	0.6842	0.1803	0.5968	0.2178	Increase	18	1.73	0.051	NS	-
Sets a01, a06	red	4	0.6000	0.2000	0.5915	0.1122	Increase	12	0.11	0.457	NS	-
Sets a01, a06	triangle	4	0.5231	0.1013	0.4723	0.1782	Decrease	12	0.73	0.240	NS	+
Sets b01, b06	yellow	4	0.5692	0.1797	0.6046	0.0861	Decrease	12	-0.57	0.289	NS	-
Sets b01, b06	circle	4	0.6923	0.1321	0.6415	0.1496	Increase	12	0.86	0.205	NS	-
Aggregate analysis for all rotations												
Sets a01, a06	color	all	0.5048	0.1717	0.5622	0.1361	Increase	62	-2.03	0.023	S	+
Sets a01, a06	shape	all	0.5270	0.1619	0.4648	0.1625	Decrease	62	2.64	0.005	S	+
Sets b01, b06	color	all	0.6635	0.1678	0.6016	0.1428	Decrease	62	2.39	0.010	S	+
Sets b01, b06	shape	all	0.6825	0.1671	0.6300	0.1908	Increase	62	1.88	0.033	NS	-

*M and SD based on the standardized rank of the target item with respect to the given dimension/attribute

** t is negative if position 2 mean is greater than position 1 mean

Table 32 – Task 2 t-tests results for the baseline stimulus design 01 vs. gap position stimulus design 06, by addition of an item

The position of the gap was manipulated twice by deleting an item from the baseline stimulus design. Since I tested the two types of manipulations for the two different sets, sets a and b, there are also 2 t-tests for each of the stimuli designs that were grouped together and 2 tables of t-tests for each of the single rotations. As shown in Tables 33 and 34, some of the scores between rotations conditions showed significant differences, others did not. From the single family-rotations, 14 results were significant and 18 were not significant. With respect to the aggregated rotations, 5 results were significant and 3 were not significant.

			Position 1 (baseline)		Position 2 (07)							
Sets	**Changed Dimension/ Attribute**	**Rotations**	**M***	**SD***	**M***	**SD***	**Expected Change in target rank for position 2**	***df***	***t*****	***p (1-tailed)***	**Decision**	***Sign Test*****
					Separate analysis for each rotation							
Sets a01, a07	yellow	1	0.4400	0.0828	0.3500	0.1268	Decrease	14	2.66	0.010	S	+
Sets a01, a07	triangle	1	0.5200	0.1652	0.7000	0.1402	Increase	14	-3.43	0.002	S	+
Sets b01, b07	red	1	0.6667	0.1633	0.8167	0.1759	Increase	14	-2.72	0.009	S	+
Sets b01, b07	circle	1	0.6400	0.1352	0.5833	0.122	Decrease	14	0.03	0.031	S	+
Sets a01, a07	yellow	2	0.4933	0.2375	0.4333	0.2403	Decrease	15	0.73	0.238	NS	+
Sets a01, a07	circle	2	0.5867	0.1767	0.5833	0.1809	Increase	15	0.04	0.484	NS	-
Sets b01, b07	red	2	0.7067	0.1668	0.7667	0.2403	Increase	15	-0.89	0.194	NS	+
Sets b01, b07	triangle	2	0.7200	0.2111	0.7167	0.2289	Decrease	15	0.04	0.484	NS	+
Sets a01, a07	red	3	0.4947	0.1224	0.4079	0.2077	Decrease	18	1.40	0.089	NS	+
Sets a01, a07	circle	3	0.4842	0.1803	0.6579	0.1710	Increase	18	-2.70	0.008	S	+
Sets b01, b07	yellow	3	0.6947	0.1545	0.8289	0.2507	Increase	18	-2.07	0.027	S	+
Sets b01, b07	triangle	3	0.6842	0.1803	0.6711	0.1456	Decrease	18	0.29	0.389	NS	+
Sets a01, a07	red	4	0.6000	0.2000	0.4808	0.1234	Decrease	12	1.83	0.046	S	+
Sets a01, a07	triangle	4	0.5231	0.1013	0.6538	0.1626	Increase	12	-2.48	0.015	S	+
Sets b01, b07	yellow	4	0.5692	0.1797	0.8654	0.1297	Increase	12	-4.43	0.001	S	+
Sets b01, b07	circle	4	0.6923	0.1321	0.5962	0.1266	Decrease	12	1.65	0.063	NS	+
					Aggregate analysis for all rotations							
Sets a01, a07	color	all	0.5032	0.1727	0.4153	0.1863	Decrease	62	2.83	0.003	S	+
Sets a01, a07	shape	all	0.5258	0.1629	0.6492	0.1661	Increase	62	-3.73	< 0.001	S	+
Sets b01, b07	color	all	0.6645	0.1689	0.8185	0.2083	Increase	62	-4.66	< 0.001	S	+
Sets b01, b07	shape	all	0.6839	0.1681	0.6452	0.1666	Decrease	62	1.39	0.085	NS	+

*M and SD based on the standardized rank of the target item with respect to the given dimension/attribute

** t is negative if position 2 mean is greater than position 1 mean

*** Sign test result, fraction of cases in predicted direction (15/16), p = 0.000

Table 33 – Task 2 t-tests results for the baseline stimulus design 01 vs. gap position stimulus design 07, by deletion of an item

			Position 1 (baseline)		Position 2 (08)							
Sets	**Changed Dimension/ Attribute**	**Rotations**	**M***	**SD***	**M***	**SD***	**Expected Change in target rank for position 2**	***df***	***t*****	***p (1-tailed)***	**Decision**	***Sign Test*****
Separate analysis for each rotation												
Sets a01, a08	yellow	1	0.4400	0.0828	0.6333	0.1858	Increase	14	-4.23	0.001	S	+
Sets a01, a08	triangle	1	0.5200	0.1652	0.4667	0.0898	Decrease	14	1.13	0.240	NS	+
Sets b01, b08	red	1	0.6667	0.1633	0.6333	0.1600	Decrease	14	0.51	0.314	NS	+
Sets b01, b08	circle	1	0.6400	0.1352	0.8167	0.1997	Increase	14	-3.32	0.003	S	+
Sets a01, a08	yellow	2	0.5000	0.2309	0.5156	0.1700	Increase	14★	-0.18	0.430	NS	+
Sets a01, a08	circle	2	0.5875	0.1708	0.4219	0.1760	Decrease	14★	3.90	0.001	S	+
Sets b01, b08	red	2	0.7000	0.1633	0.6094	0.1573	Decrease	14★	1.55	0.071	NS	+
Sets b01, b08	triangle	2	0.7125	0.2062	0.6719	0.2183	Increase	14★	0.47	0.322	NS	-
Sets a01, a08	red	3	0.4947	0.1224	0.6447	0.1517	Increase	18	-3.90	0.001	S	+
Sets a01, a08	circle	3	0.4842	0.1803	0.4605	0.1912	Decrease	18	0.41	0.342	NS	+
Sets b01, b08	yellow	3	0.6947	0.1545	0.6447	0.1268	Decrease	18	1.16	0.132	NS	+
Sets b01, b08	triangle	3	0.6842	0.1803	0.6579	0.2077	Increase	18	0.47	0.322	NS	-
Sets a01, a08	red	4	0.6000	0.2000	0.6731	0.1201	Increase	12	-0.94	0.184	NS	+
Sets a01, a08	triangle	4	0.5231	0.1013	0.4231	0.1201	Decrease	12	2.50	0.014	S	+
Sets b01, b08	yellow	4	0.5692	0.1797	0.5769	0.1201	Decrease	12	-0.10	0.461	NS	-
Sets b01, b08	circle	4	0.6923	0.1321	0.7500	0.1443	Increase	12	-1.42	0.091	NS	+
Aggregate analysis for all rotations												
Sets a01, a08	color	all	0.5048	0.1717	0.6151	0.1670	Increase	61★	-3.46	0.001	S	+
Sets a01, a08	shape	all	0.5270	0.1619	0.4444	0.1519	Decrease	61★	3.29	0.001	S	+
Sets b01, b08	color	all	0.6635	0.1678	0.6190	0.1410	Decrease	61★	1.52	0.067	NS	+
Sets b01, b08	shape	all	0.6825	0.1671	0.7183	0.2033	Increase	61★	-1.10	0.139	NS	+

*M and SD based on the standardized rank of the target item with respect to the given dimension/attribute

** t is negative if position 2 mean is greater than position 1 mean

*** Sign test result, fraction of cases in predicted direction (13/16), p = 0.011

★ one participant did not respond

Table 34 – Task 2 t-tests results for the baseline stimulus design 01 vs. gap position stimulus design 08, by deletion of an item

Because the results of the t-tests were not as good as I was expecting I decided to conduct sign tests to investigate whether or not the cases studied were at least in the direction predicted by the hypotheses. The sign tests were run for both tasks 1 and 2.

In task 1, I conducted sign tests in all the aggregated cases for all rotations. I aggregated all the cases of changes in gap size related to colour attribute (aggregated designs 02) and all the cases related to shape attribute (aggregated designs 04). Next I aggregated colour and shape attributes together. Therefore the final sign test result is an aggregation of all the manipulations of gap size. Gap position was aggregated in a similar way but with an additional step. First the aggregated designs 05 were put together. Then the aggregated designs 06. In parallel, designs 07 and 08 were treated similarly. Next, designs 05 and 06 were put together because both of them were manipulation of gap position by addition of an item. Being manipulation of gap position by deletion of an item, designs 07 and 8 were also aggregated. Finally, all of those gap position manipulation designs were aggregated.

Due to the different nature of task 2 data collection, I conducted sign tests for both the aggregated cases across designs and the aggregated cases for all rotations. The aggregated cases for all the rotations is similar to the explained above for task 1. In addition, however, because the data for task 2 consisted of each individual's ranks, t-tests were run for each single design, rather than just a single aggregate test for a given design using the combined data from all 4 rotations. Therefore, I also aggregated those cases across designs and conduct sign tests as observed in Table 35.

The vast majority of the cases studied were in the right direction as predicted by the hypotheses. In task 1, the sign test for both gap size and position were significant, with p = 0.031, and p = 0.008, respectively. In task 2, with respect to the aggregated analysis across designs, the gap position results were statistically significant, p < 0.001, and, although the gap size results were not statistically significant, 5 out of 8 of the cases were in the right direction. With respect to the aggregated analysis for all rotations, 1 out of 2 cases for the gap size were in the right direction and gap position was statistically significant, p = 0.001 (see Table 35).

Tasks	Hypotheses	Stimuli		Cases in predicted direction	*p*	Cases in predicted direction	*p*	Cases in predicted direction	*p*
Task 1				**Aggregated analysis for all rotations**					
	Gap Size	color	02	3/3	NS	6/6	0.031		
		shape	04	3/3	NS				
	Gap Position	addition of an item	05	2/2	NS	4/4	NS	8/8	0.008
			06	2/2	NS				
		deletion of an item	07	2/2	NS	4/4	NS		
			08	2/2	NS				
Task 2				**Single Design**		**Aggregated across designs**			
	Gap Size	color	02	1/4	NS	5/8	NS		
		shape	04	4/4	NS				
	Gap Position	addition of an item	05	11/16	NS	22/32	0.050	50/64	< 0.001
			06	11/16	NS				
		deletion of an item	07	15/16	< 0.001	28/32	< 0.001		
			08	13/16	0.021				
				Aggregated analysis for all rotations					
	Gap Size	color	02	0/1	NS	1/2	NS		
		shape	04	1/1	NS				
	Gap Position	addition of an item	05	4/4	NS	7/8	0.070	15/16	0.001
			06	3/4	NS				
		deletion of an item	07	4/4	NS	8/8	0.008		
			08	4/4	NS				

Table 35 - Sign tests on fraction of cases in predicted directions across all conditions in tasks 1 and 2

4.5.5 Discussion

Hypothesis 1 states that during the communication process if people have a choice among multiple attributes to describe an item, they will choose the attribute that maximizes the size of gap. Hypothesis 2 says that they will choose the attribute that minimizes the size of the subset containing the target item. In general, the results of experiment 3 gave inconsistent support for hypotheses 1 and 2. For task 1, the t-test results indicated that the effects of both gap size and gap position on participants' attribute choices were significant in 50% of the cases. For task 2, the results supported the gap size hypothesis in 3 out of 10 t-tests and the gap position hypothesis in 30 out of 80 t-tests. The vast majority of the sign tests cases were in the direction predicted by the hypotheses.

Because experiments 1 and 2 were consistent with the hypotheses and the sign tests cases pointed to the right direction, the following considerations are made, in an attempt to account for the present findings.

First, I want to point out that an important advantage to the stimulus design in experiment 3 is that it allowed for manipulation and control of gap size and gap position independently. The use of the 5x5 grid as a basis for the design allowed for a more precise way of controlling changes in the two variables, compared to the stimuli used in experiments 1 and 2, which depended on naturally occurring variation in the two variables. The hope, therefore, was that the 5x5 grid design would provide a tighter way of testing the hypotheses. Unfortunately there were also certain drawbacks to the structured stimulus design, which may have contributed to the inconsistent results.

One potential drawback is that the design may have lacked sufficient measurement precision, due to limited variability in the stimulus designs or in the choices given to participants. In task 1, for example, participants made binary choices between pairs of attributes to describe a target item in relation to the other items in the set. However, because there were only four attributes (triangle, circle, red, yellow), there were not many possible variations available to participants to rank the items. Task 2 was a direct ranking task, in which the participants ranked a set of items with respect to one attribute. The number of items in a set varied from 4 to 6 items, again providing relatively little room for variable ranking responses on the part of participants. In both case, the lack of variability in response might have limited the measurement precision for detecting small differences in participants' preferences or perceptions between different stimulus conditions. The lack in variability perhaps could explain why the hypotheses were not supported in some of the t-tests, although the sign tests indicated that they are in the direction predicted by the hypotheses. I discuss possible solutions to these issues under future research.

Another measurement precision issue was due to the small sample sizes used in the t-tests for task 1. Because task 1 involved binary choices, the t-tests were run on sets of only 4 ratios, where each ratio was an aggregate indicator of all participants' choices for one rotation of a given stimulus design. With a sample size of only 4, the t-test becomes very conservative, making it difficult to achieve statistical significance when there is any inconsistency in the data. Task 2 was analyzed at the level of individual participant rankings, with larger samples sizes, and more of the results did come out significant.

Finally, another aspect to be considered is that in some of the stimulus designs, especially those in which gap size was increased, there might have been an additional factor operating besides the hypothesized effects due to gap size and position. The gap size hypothesis predicted that people would shift their choices toward the attribute with a larger gap. That is, the stimulus design operationalizes the categorization logic by creating a gap between the category containing the target item and the category containing the remaining items, which is larger for one attribute than for another attribute. However, in addition to creating a difference in gap size between the two attributes, stimulus designs that varied gap size also had the effect of varying the internal degree of similarity (or homogeneity) within the two attribute categories. For example, by creating a larger gap between the triangle and non-triangle categories, an additional effect might be to reduce the degree of similarity of items in the yellow category compared to items in the triangle category. That is an additional effect, not predicted by the hypothesis, which could not be controlled in the current design of the stimulus, and may have influenced the results independently from the effects of gap size and position.

Chapter 5

General Discussion

This work investigated how people communicate about ambiguous, unstructured stimuli. Problems arise in many empirical communication settings, such as learning, research, innovation, or new product development, where people must develop some form of structure to communicate effectively about ambiguous new ideas, product concepts, and so on.

I investigated the cognitive mechanisms that people use to identify and describe a specific ambiguous item from among a set of ambiguous items during communication. According to Shannon's information theory (1948), uncertainty is reduced and information conveyed in communication with respect to a predefined set of possibilities. Therefore an unstructured stimulus can be communicated only after some structure has been established which can be used to distinguish among a set of possibilities. This amounts to a categorization process, whereby a set of ambiguous items are divided into subsets based on similarity judgments. I proposed that people use judgments of similarity to create structure by drawing distinctions between items, with respect to perceived dimensions or attributes, by which the items can be compared to one another. More specifically, I proposed that items are categorized based on perceived relative similarity, whereby similarity is maximized within categories and minimized between categories with respect to one attribute.

Assuming a one-way communication from sender to receiver, I postulated that when multiple attributes are available for describing a target item, the sender perceives various ways of clustering the target item based on how similar/dissimilar it is to the other items with respect to the various attributes, and chooses the attribute/description that best distinguishes the target from the other items in the set. Similarly, given a certain attribute as a description of an item (i.e., as a message) the receiver uses similarity judgments to select the cluster, or subset, of items that are best described by that attribute. I hypothesized that the chosen attribute is the one that most reduces uncertainty by 1. maximizing the difference between the cluster containing the target and the cluster of the other items, and, 2. minimizing the size of the subset containing the target item (i.e., by eliminating as many of the non-target items as possible). I have used the term gap to refer to the difference in perceived relative similarity between the subset containing the target item and the subset of remaining items. The first hypothesis deals with the size of the gap and the second deals with its position with respect to the particular attribute used as the basis for similarity judgments.

Three experiments were conducted to test the hypotheses. In two of the experiments I used unstructured stimuli (random line drawings and Rorschach inkblots) and in one of them I used a structured stimulus (items of varying shape and colour based on a 5x5 grid). The unstructured stimuli were multidimensional, so participants could perceive a diverse variety of attributes that could be used to cluster the items and draw distinctions between them. The attributes/descriptions used in these experiments were realistic, in the sense that they were based on how people had actually described the items in prior experimental or therapeutic settings. With respect to the hypotheses, the multidimensional stimuli provide random variation in the size and position of the gap for any of the dimensions.

The structured stimulus was designed with two dimensions (shape and colour), which allowed for controlled manipulation of gap size and position to test the hypotheses. Specifically, because each item had a fixed position in the 5x5 grid, the relative similarity of items could be varied by discrete amounts with respect to the four attributes triangle, circle, red, and yellow, where the assumption in the design is that perceived similarity should correlate closely with distances between items in the grid.

The results from experiments 1 and 2 gave evidence consistent with what would be expected if hypotheses 1 and 2 were true. Both experiments consisted of three tasks. Tasks 1 and 3 took the communication sender's point of view and participants were asked to rank various attributes in terms of how descriptive they were of the target item with respect to the set of items. Task 2 took the receiver point of view and participants were asked to rank the set of items with respect to one specific description. Correlation and regression analyses were used to examine the relationship between the senders' attribute rankings (tasks 1 and 3) and the receivers' item rankings (task 2). The results showed strong correlations between the two kinds of rankings, suggesting attributes that are more descriptive from the point of view of senders are also more selective from the point of view of receivers. The regression results further showed that differences in attribute ranks by senders had large, statistically significant effects on differences in item ranks by receivers. The results of experiments 1 and 2, using two different kinds of stimuli, were very consistent and therefore provided strong evidence for generalizability of the observed effects.

With respect to the gap position hypothesis, higher ranked attributes should narrow the set of items down to relatively small subsets containing the target item, whereas lower ranked attributes do not give much reduction in the subset size. In terms of the gap size hypothesis, increases (decreases) in an attribute's rank by senders should correspond with increased (decreased) selectivity of the attribute for receivers. The correlation and regression results are consistent with both of these hypotheses. However, they are also consistent with a more general process of similarity judgment rather than the specific gap size and position theory proposed. Furthermore I could not measure gap position and size directly in experiments 1 and 2, so experiment 3 was designed as a more direct test.

In experiment 3, gap size and position were directly controlled for in the design of the experimental stimulus. Hence, the two hypotheses were tested directly through pairwise comparisons methods. Participants performed two tasks. In task one they took the role of communication sender and performed a series of binary choices, rating different attributes with respect to which would best describe the target item. In task two they took the role of communication receiver and ranked a set of items with respect to which was best described by the four attributes triangle, circle, red, and yellow. Hypothesis testing was based on differences between stimulus conditions with different gap sizes and positions, in how participants described the target item in task one and how they ranked the target item in task two. To test for the effect of gap size, paired-sample t-tests were used to examine differences between the baseline stimulus designs (gap size of 1 unit distance within the grid) and other stimulus design with a larger gap size (of 2 units distance). To test for the effect of gap position, paired-sample t-tests were used to examine differences between the baseline stimulus designs (with given subset sizes of items) and other stimulus design with different subset sizes (smaller subsets sizes of items vs. larger subsets sizes of items).

Unfortunately, the results of experiment 3 gave inconsistent support for hypotheses 1 and 2. For task one, 50% of the results from the t-tests for differences in gap size and 50% of the results for differences in gap position were significant. For task two 30% of the t-tests for differences in gap size and about 40% of the t-tests for differences in gap position came out statistically significant. Therefore, in general, the results for hypotheses 3 were inconsistent. Sign tests were therefore used to aggregated the various specific cases to test whether the overall direction of responses were consistent with the hypotheses. The vast majority of the cases studied were in the right direction as predicted by the hypotheses. In task 1, the sign test for both gap size and position were significant, with $p = 0.031$, and $p = 0.008$, respectively. In task 2, with respect to the aggregated analysis across designs, the gap position results were statistically significant, $p < 0.001$, and, although the gap size results were not statistically significant, 5 out of 8 of the cases were in the right direction. With respect to the aggregated analysis for all rotations, 1 out of 2 cases for the gap size were in the right direction and gap position was statistically significant, $p = 0.001$.

In the previous sections I suggested two potential shortcomings of the experimental design that may have accounted for the inconsistent results: first, the lack in variability, that is, the 5x5 grid did not allow for enough complexity in the stimuli designs; and, second, the sample size was not large enough to detect differences in task one. Because the results of the unstructured stimuli in experiments 1 and 2 were consistent with the hypotheses and the majority of the sign tests in experiment 3 pointed in the right direction of the hypotheses more investigation is needed for a definite conclusion.

5.1 Contributions

This study brings valuable contributions to the fields of categorization and communication in terms of both theory and research methods. The current literature in the field of categorization and communication is very limited, and Markman and Ross (2003) noted a lack of connection between these fields. Very little work has investigated how humans process unstructured stimuli to communicate about it. This dissertation makes a direct connection between categorization and communication by focusing on how we use categorization processes, including perceptions of similarity and difference with respect to an item's perceived attributes, to communicate unstructured information. In this work I used Shannon's information theory (Shannon, 1949) to analyze how information works to reduce uncertainty through the development of structure, which I conceptualized in terms of a system of categories. I also used Rosch's and her associates (1978) concept of relative similarity to explain the cognitive mechanisms involved in the development of those categories.

This study also points to a new way of understanding of the concept "feature" or "attribute". In the literature, "feature" typically means a property or characteristic possessed by members of a category (Tversky, 1977, Rosch, 1978). In this work, I use the terms "feature" or "attribute" to mean any basis for categorizing an item, which could include perceived overall similarity or the sharing of one property in common. By having categorized the item a certain way, this then becomes a single attribute along which relative degrees of similarity of different items can be compared.

Note I am not arguing that possession of a specific attribute is identical to overall similarity between two items or a perceived resemblance between an item and some third thing such as a mental image, a category prototype etc. I am simply arguing that any of these bases for categorization can be used to draw distinctions among a set of ambiguous items for the purpose of information processing in communication. So I use the term attribute in general to refer to any of these various ways of drawing distinctions as a basis for categorization.

This work also points to a new understanding of "relative similarity", in which two entities are relatively similar to one another with respect to "one" attribute. In Rosch and Mervis' studies (1975), relative similarity (or what they called "family resemblance") refers to overall similarity of category members vs. non-members, measured in terms of the relative number of features in common, from a set of attributes that are characteristic of the category. Such an approach may account for the structure of categories associated with a person's conceptual structure, reflecting concept knowledge that is relatively stable over time. By contrast, this research investigates how people communicate one item from a set of ambiguous items for which a set of preconceived conceptual categories is not available. For this specific communication purpose, the use of categorization processes is different from that studied by Rosch and Mervis (1975). I propose that people take advantage of the perceived structure of the ambiguous stimulus and form categories, in a goal-directed manner

(Barsalou, 1983), in order to distinguish the target item from other items in the set and communicate the message. The categories developed might not be permanent. Similarity judgments are used to create *ad hoc* goal-directed categories that enable information processing with respect to specific communication goals in specific communication situations. To form such goal-directed categories, people focus on whatever attributes best enable them to distinguish the target item from the others (Barsalou, 1983). Given a different communication goal of distinguishing a different target item, people will focus on different attributes and form different categories.

Note that I use the word similarity also in a general way to refer to various perceptual processes associated with perceiving distinctions. For instance, perceiving that two or more ambiguous items may share a common feature or bare an overall resemblance to one another or a similarity to some thing else such as an image or an object in the world. The new ways of understanding attributes and relative similarity developed in this thesis are both contributions to the field of categorization itself.

This dissertation has also made methodological contributions. I have introduced methods that utilize both structured and unstructured stimuli in a communication setting. I developed two of the stimuli-drawings, (the structured grid and the unstructured random drawings), and used Rorschach inkblots for the second unstructured stimulus. I developed a series of three one-way communication tasks. Two of them had the sender’s view and one had the receiver’s view of communication. Moreover, those tasks were designed with two different ranking methods, in two tasks I used a direct rank method, and in one task I used a binary choice method. Moreover, for the two unstructured stimuli, to come up with lists of attributes to describe the items, I used real descriptions that had actually been used by people to refer to the items in previous communication situations. The use of ambiguous stimuli drawn from realistic previous communication situations contributes to the generalizability of the results to our daily experience with real life information processing of ambiguous stimuli and can facilitate other exploratory studies.

5.2 Limitations

There are limitations to this research. Some of those limitations were methodological and might have affected hypotheses results. In experiments 1 and 2, the use of unstructured stimuli was an advantage but also brought some limitations. One of those limitations, as already mentioned, was incomplete data, whereby each item was ranked with respect to specific attributes but not all attributes were ranked with respect to all items. As mentioned, the attributes that I used were drawn from real descriptions of the stimulus items in previous communication settings. People had seen the pictures and had used some descriptions to identify similarities and dissimilarities among those cards/pictures. For the tasks in the experiments, I selected some of those attributes. However, some of the attributes were only applicable to one of the pictures; others were descriptive of two or three of the pictures; none had been previously used to describe all the different pictures. Although it would have been possible to select a fixed set of attributes and arbitrarily use them across all items in experiments 1 and 2, this would have reduced the realism of the task by asking participants to rate items with respect to unrelated attributes. The length of time needed for participants to complete the survey was also taken into account in the decision. For instance, task 1 in experiment 1 contained 36 binary choices and each participant had to perform two of those tasks. If each attribute had been used for all of the 6 cards in this task, the amount of work would not be reasonable.

Other potential limitations were related to the design of the 5x5 grid used in experiment 3. On one hand the grid allowed for a fixed location of each item, allowing for controlled and consistent manipulation of gap size and of gap position. Because the stimulus designs were all based on a small 5x5 grid, they could have a variability issue in terms of the limited ranking options available to participants, making it difficult to detect small differences between different stimulus designs. The design was based on the assumption that the perceived similarity between items should correlate closely with distance between items in the 5x5 grid. Each stimulus design contained the target item (item 33) and 3 to 5 other items from the grid depending on the different manipulations. Because the grid allowed for only five positions in either dimension, the use of rank measures (vs., continuous scales etc.) meant that opportunities for participants to rank the target differently from one condition to the next were limited.

Finally, it is also possible that the survey data collected in the experiments contained some degree of noise. The participants received their survey by e-mail and completed their tasks at places and times of their own convenience. Although instructions were provided in the forms, it is possible that some participants did not complete their tasks with care. When it was possible to identify with a high degree of certainty that a task had not been completed correctly, the participant's responses were removed from the dataset. Otherwise, it was considered as random error. To address the problem, the surveys could be perhaps reduced in length so that participants would spend less time answering them. In addition, instead of being surveyed at home without supervision, individuals or small groups of individuals could be invited to complete the survey in a central lab location, in the presence of the researcher.

5.3 Future research

There are some promising directions for future research that emerged from this study. First, future research could investigate the problem of structuring ambiguous stimuli in other communication contexts. For instance, an organization in which various different departments are involved with the development of a new process or product would be a good setting to study the issue, using case study or other field methodologies.

There are also potential future research directions related to addressing some of the methodological limitations of the current study. As mentioned before the two hypotheses could not be directly tested with the unstructured stimuli in experiments 1 and 2 because they did not allow for direct manipulation and control of gap size and gap position. Experiment 3 used a two-dimensional 5x5 grid to provide more precise manipulation and control of the two variables, but it may have lacked sufficient variability in the choices available to participants to detect small changes in their similarity judgments. One possible way to deal with the issue would be to enlarge the 5x5 grid. By using a 10x10 grid, for instance, one would be increasing the complexity of the stimuli designs. The differences between adjacent items would decrease, therefore there would be more variability among them. Despite the change, I would still be able to efficiently manipulate and control for the two variables.

Another possible solution for the variability problem would be to add more dimensions to the design as distractors (or noise). Participants would have more dimensions to pay attention to, which increases the complexity of the design. A possible downside to this kind of solution is that it could decrease the accuracy of the manipulation and control of the variables. A third possible way to handle the variability issue is to use a Likert scale measure instead of the simple binary choices. The binary choices allow the participant to choose between two attributes, for instance, triangle or yellow, but does not allow the participant to say how yellow an item is. The use of a scale would introduce more variability allowing participants to express small changes in perceived similarity that are missed by the simpler binary choice measurement approach.

In conclusion, because the two hypotheses could not be appropriately tested there is still some doubt about their validity. I would like to test their veracity before anything else. If the hypotheses are correct, other ideas could be explored. For instance, although I developed experiment 3 stimulus designs that manipulated both, gap size and position simultaneously I decided not to test them in this dissertation. Additional stimuli designs were created, by manipulating only one of the dimensions (shape or colour) at a time. Those were not included in this research either.

Chapter 6

Conclusions

This work investigated the cognitive mechanisms involved in developing a suitable structure for communication about ambiguous stimuli. Shannon's information theory (Shannon, 1948) was very useful to explain how communication is structure dependent. That is, human information processing works to reduce uncertainty through the development of structure. Structure was conceptualized in terms of a system of categories and Rosch and her associates' concept of relative similarity (or family resemblance, as in Rosch and Mervis, 1975) was used to explain the cognitive mechanisms involved in the development of the categories during the communication process.

I assumed that when people have to communicate categories that are not well defined, they use relative similarity to cluster items into smaller subsets. I proposed that people use similarity judgments to create structure by dividing a complex unstructured stimulus into a set of categories. More specifically, items are categorized based on perceived relative similarity, whereby similarity is maximized within categories and minimized between categories with respect to one attribute. Further, I postulated that when multiple attributes are involved, the sender perceives various ways of clustering the target item based on how similar/dissimilar it is with respect to the set of items. In addition, I postulated that when dealing with multiple perceived attributes, the sender of the message chooses the attribute that best distinguishes the target item from the other items in the set. Similarly, the receiver must identify the subset of items that are best distinguished by the given attribute. I hypothesized that the chosen attribute is the one that reduces uncertainty by 1. maximizing the difference between the cluster which contains the target and the cluster of the other items, and 2. minimizing the size of the subset containing the target item (i.e. by eliminating as many of the non-target items as possible). The receiver receives the message (i.e., attribute) designating the subset or cluster. S/he experiences uncertainty regarding which item(s) is(are) best described by that message. Based on similarity judgments, the receiver creates clusters that best match their understanding of the sender's intended clustering. Therefore, structure is built based on how both people, sender and receiver, perceived similarity between various attributes/clusterings and used the varying messages to communicate their perceived clusterings.

The reported experiments provided partial support for the above conceptualization, showing that attributes that are more descriptive from the point of view of the sender also end up being more selective from the point of view of the receiver, which is consistent with the argument of gap position and gap size, as it is showed in the hypotheses. Unfortunately, the direct tests for the hypotheses in experiment 3 were not conclusive.

The present research has developed a framework for a problem not addressed before in the literature. Although the literature addresses the development of more permanent and stable structures, which can be further retrieved from memory and used to make comparisons, it does not address the development of goal-directed categories, i.e. temporary categories used to select the message to be communicated. When two people are given an ambiguous set of items and must communicate one item from that set, they make use of categorization processes to distinguish among the items. They perceive various attributes that allow them to judge relative similarity among the items and describe the target item in terms of the attribute that best distinguishes it from the others. This results in two goal-directed subcategories; one that contains the target item and one that does not. Because these categories are formed on the fly, based on specific communication goals, once the item has been communicated they may serve no further purpose for the person, and might even be forgotten.

In addition to the main theoretical contribution, this work makes three other potential theoretical and methodological contributions. First, the research framework puts together two large fields of knowledge, categorization and communication. Communication is structure dependent and structure is created through the development of a system of categories. Second, a substantial method was developed. The method contained unstructured and structured stimuli allowing for manipulation and control of the variables. The one-way communication tasks used two different types of ranking tasks and two different perspectives, the sender's view and the receiver's view of the message. Finally, it offered theoretical contributions to the categorization theory by providing a new way of looking to the concepts of "attribute" and "relative similarity".

Appendix A

Experiment 1 Surveys

Following is one sample survey for experiment 1. All together there were 18 different survey versions as described in the method section.

Consent of Participant

By signing this consent form, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

I have read the information presented in the information letter about the study conducted by Geovania Pimenta under the supervision of Professor Rob Duimering, Department of Management Sciences, University of Waterloo. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted. I am aware that I may withdraw from the study without penalty at any time by advising the researchers of this decision. I am also aware that I may still be granted the 4 bonus-mark in the MSCI 311 final exam by completing and submitting the alternative assignment by April 20, 2015.

This project 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. 36005.

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

By submitting the completed survey online, I hereby agree to the above.

Print Name:

UW ID #:

Dated at Waterloo, Ontario:

Experiment participation for MSCI 311

You are invited to participate in a research experiment dealing with communication of simple drawings. If you decide to complete the survey below you will receive 4 bonus marks added to your final exam score. (Note: Bonus marks will only be granted if it is clear that you have taken the tasks seriously.)

Please complete the survey within Microsoft Word and submit your completed survey in the Dropbox on the MSCI 311 Learn site. The deadline for submission is Monday, April 20th by 5pm.

General instructions

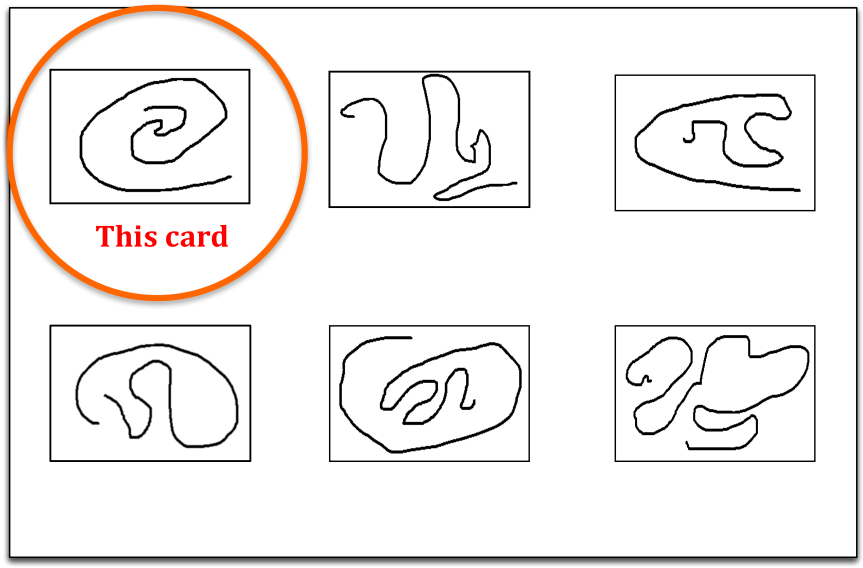
You will be completing 3 kinds of communication tasks involving the description of drawings on cards (13 tasks altogether). Please read and follow the specific instructions for each task. If you have any questions about these tasks, or about the research in general, please contact me at gdpimenta@uwaterloo.ca.

Thanks for your participation,

Geovania Pimenta

Task 1 – a

Imagine you are communicating to a person in another room who has the following set of 6 cards. Your goal in this task is to get the other person to correctly select the card indicated below.

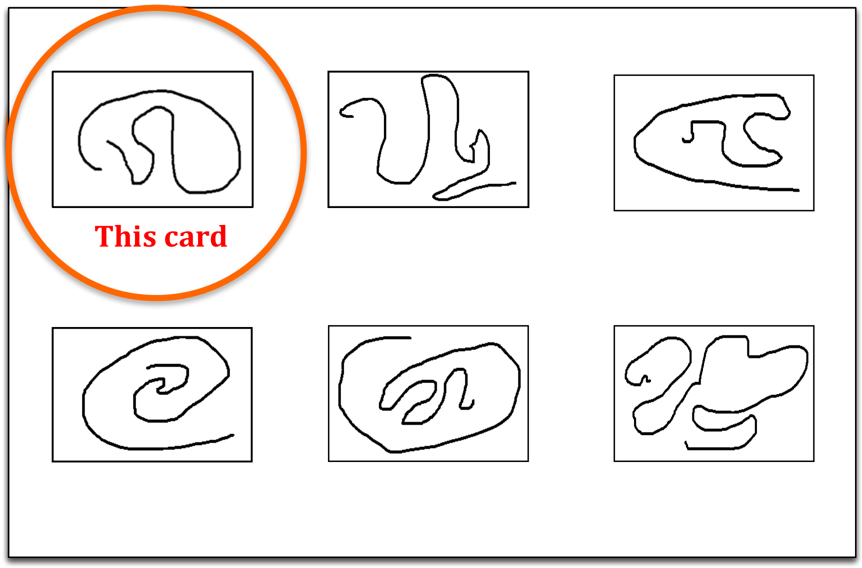


Please rank the following expressions from 1 to 9 in terms of which would most likely get the person to select the right card.

Expressions	Your Rank
looks like a fetus	
looks like an "e"	
looks like a tornado	
looks like a hand	
looks like a spiral	
looks like a snake	
looks like a cactus	
it's an "A" if vertically oriented	
looks like an "at" sign	

Task 1 – b

Imagine you are communicating to a person in another room who has the following set of 6 cards. Your goal in this task is to get the other person to correctly select the card indicated below.

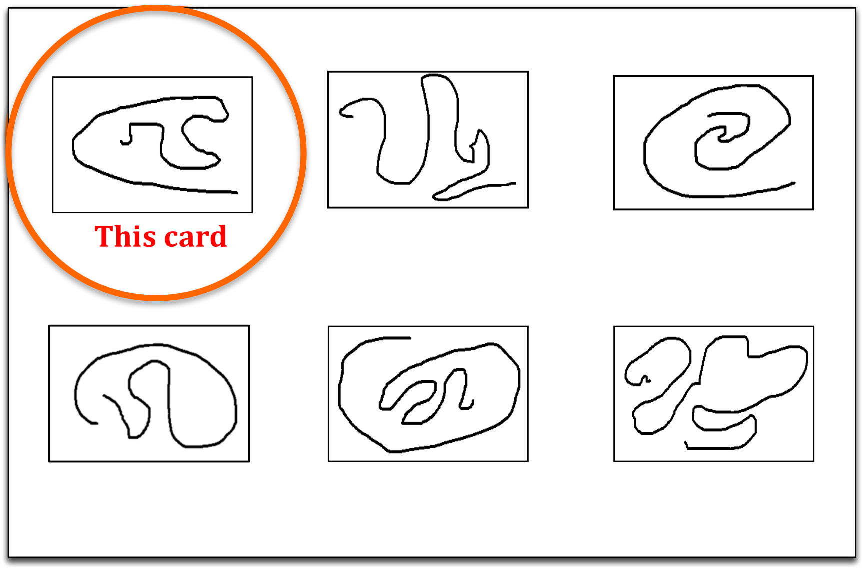


Please rank the following expressions from 1 to 9 in terms of which would most likely get the person to select the right card.

Expressions	**Your Rank**
ends with a straight line and a little hook	
it's a monster going around its tail	
looks like a dinosaur	
tips very close to each other	
has a finger	
looks like a fetus	
looks like a broken phone	
looks like a cartoon character	
looks like s spiral	

Task 2 – a

Imagine you were trying to get another person to select the card indicated below from the set of cards. Which of the following expressions would work best? For each pair choose one.



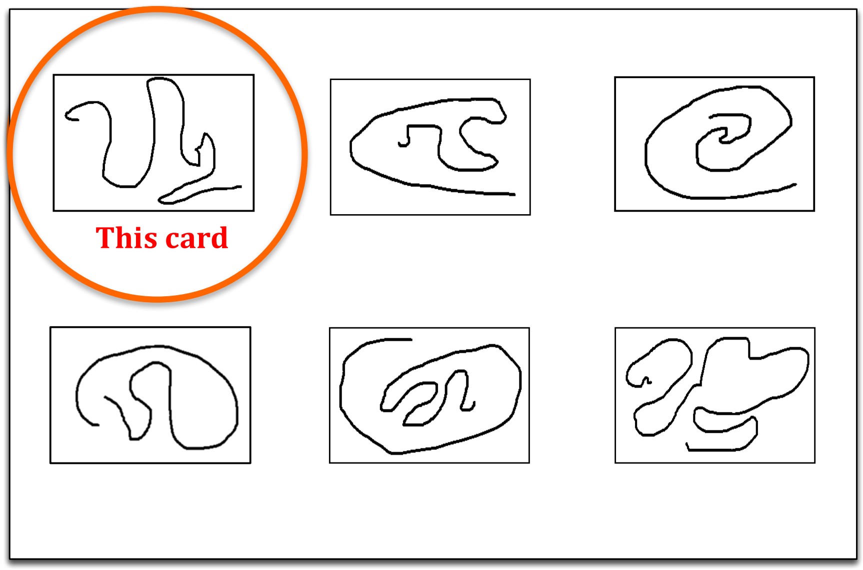
The following 36 pairs of expressions could be used to describe the circled card. **For each pair** please choose the expression that you think would work best to get the person to select the right card.

1.	☐	looks like a bullet	☐	tips very close to each other
2.	☐	looks like a dinosaur	☐	has an "M"
3.	☐	ends with a straight line and a little hook	☐	looks like a spiral
4.	☐	ends with a straight line and a little hook	☐	looks like a function
5.	☐	it's an "A" if vertically oriented	☐	ends with a straight line and a little hook
6.	☐	looks like a dinosaur	☐	looks like a function
7.	☐	it's an "A" if vertically oriented	☐	looks like a function
8.	☐	looks like a dinosaur	☐	tips very close to each other
9.	☐	ends with a straight line and a little hook	☐	it's a wrench

10.	☐ it's an "A" if vertically oriented	☐ tips very close to each other
11.	☐ ends with a straight line and a little hook	☐ looks like a dinosaur
12.	☐ ends with a straight line and a little hook	☐ tips very close to each other
13.	☐ it's a wrench	☐ has an "M"
14.	☐ looks like a function	☐ tips very close to each other
15.	☐ looks like a bullet	☐ it's an "A" if vertically oriented
16.	☐ looks like a spiral	☐ it's a wrench
17.	☐ looks like a bullet	☐ ends with a straight line and a little hook
18.	☐ has an "M"	☐ looks like a function
19.	☐ it's an "A" if vertically oriented	☐ looks like a spiral
20.	☐ looks like a spiral	☐ looks like a dinosaur
21.	☐ it's a wrench	☐ looks like a function
22.	☐ looks like a bullet	☐ looks like a spiral
23.	☐ has an "M"	☐ tips very close to each other
24.	☐ it's an "A" if vertically oriented	☐ it's a wrench
25.	☐ looks like a spiral	☐ has an "M"
26.	☐ it's an "A" if vertically oriented	☐ looks like a dinosaur
27.	☐ ends with a straight line and a little hook	☐ has an "M"
28.	☐ looks like a bullet	☐ it's a wrench
29.	☐ it's a wrench	☐ tips very close to each other
30.	☐ looks like a bullet	☐ looks like a dinosaur
31.	☐ looks like a bullet	☐ has an "M"
32.	☐ looks like a spiral	☐ looks like a function
33.	☐ looks like a spiral	☐ tips very close to each other
34.	☐ it's a wrench	☐ looks like a dinosaur
35.	☐ looks like a bullet	☐ looks like a function
36.	☐ it's an "A" if vertically oriented	☐ has an "M"

Task 2 – b

Imagine you were trying to get another person to select the card indicated below from the set of cards. Which of the following expressions would work best? For each pair choose one.



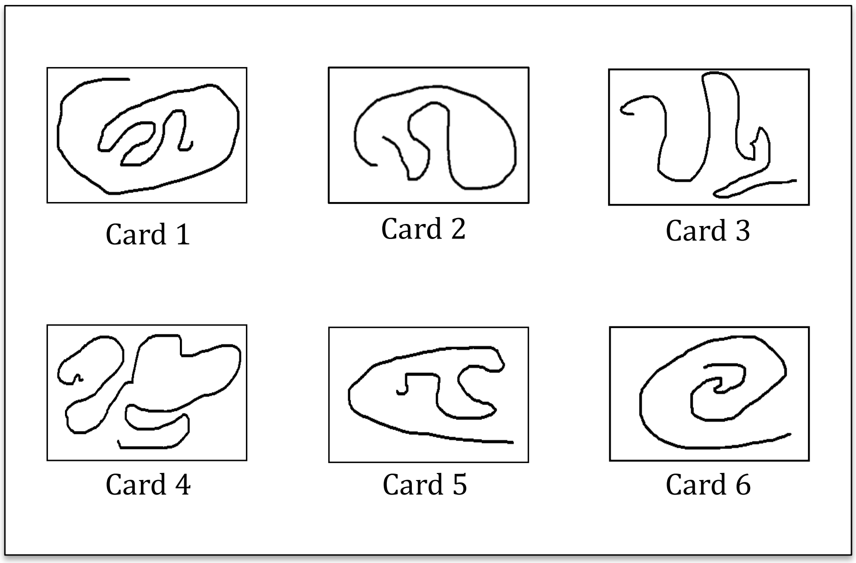
The following 36 pairs of expressions could be used to describe the circled card. **For each pair** please choose the expression that you think would work best to get the person to select the right card.

1.	☐ has a finger	☐ looks like a turtle
2.	☐ looks like a snake	☐ looks like a broken phone
3.	☐ looks like a cactus	☐ looks like an “at” sign
4.	☐ has a finger	☐ looks like an “at” sign
5.	☐ looks like a snake	☐ looks like a turtle
6.	☐ lines start in opposite corners	☐ looks like a shoe
7.	☐ looks like a function	☐ has a finger
8.	☐ looks like a cactus	☐ has a finger
9.	☐ looks like a snake	☐ looks like an “at” sign
10.	☐ lines start in opposite corners	☐ looks like a snake

11.	☐ looks like a turtle	☐ looks like a broken phone
12.	☐ looks like an “at” sign	☐ looks like a turtle
13.	☐ looks like a function	☐ looks like a cactus
14.	☐ has a finger	☐ looks like a shoe
15.	☐ looks like a function	☐ lines start in opposite corners
16.	☐ looks like a function	☐ looks like a snake
17.	☐ lines start in opposite corners	☐ has a finger
18.	☐ has a finger	☐ looks like a broken phone
19.	☐ looks like a shoe	☐ looks like a turtle
20.	☐ looks like a cactus	☐ looks like a broken phone
21.	☐ looks like a cactus	☐ looks like a shoe
22.	☐ looks like a function	☐ looks like a shoe
23.	☐ looks like a cactus	☐ looks like a turtle
24.	☐ looks like a function	☐ looks like a broken phone
25.	☐ looks like a shoe	☐ looks like an “at” sign
26.	☐ lines start in opposite corners	☐ looks like an “at” sign
27.	☐ looks like a cactus	☐ looks like a snake
28.	☐ looks like a function	☐ looks like an “at” sign
29.	☐ looks like an “at” sign	☐ looks like a broken phone
30.	☐ has a finger	☐ looks like a snake
31.	☐ lines start in opposite corners	☐ looks like a broken phone
32.	☐ lines start in opposite corners	☐ looks like a turtle
33.	☐ looks like a function	☐ looks like a turtle
34.	☐ looks like a shoe	☐ looks like a broken phone
35.	☐ looks like a snake	☐ looks like a shoe
36.	☐ lines start in opposite corners	☐ looks like a cactus

Task 3

Imagine you are communicating to a person in another room who has the following set of 6 cards. Your goal in this task is to correctly select cards based on descriptions provided by the other person. You will perform this task 9 times (for 9 different expressions).



Expression 1: The person describes one of these 6 items as **<u>looks like a cartoon character.</u>** Please rank the items from 1 to 6 in terms of which card the person is most likely referring to. (1 – most likely; 6 – least likely)

Card Number	Your Rank
1	
2	
3	
4	
5	
6	

Expression 2: The person describes one of these 6 items as **<u>has 2 and ½ fingers.</u>** Please rank the items from 1 to 6 in terms of which card the person is most likely referring to. (1 – most likely; 6 – least likely)

Card Number	Your Rank
1	
2	
3	
4	
5	
6	

Expression 3: The person describes one of these 6 items as **<u>looks like a shoe.</u>** Please rank the items from 1 to 6 in terms of which card the person is most likely referring to. (1 – most likely; 6 – least likely)

Card Number	Your Rank
1	
2	
3	
4	
5	
6	

Expression 4: The person describes one of these 6 items as **<u>it's a monster going around its tail.</u>** Please rank the items from 1 to 6 in terms of which card the person is most likely referring to. (1 – most likely; 6 – least likely)

Card Number	Your Rank
1	
2	
3	
4	
5	
6	

Expression 5: The person describes one of these 6 items as **looks like a tornado.** Please rank the items from 1 to 6 in terms of which card the person is most likely referring to. (1 – most likely; 6 – least likely)

Card Number	Your Rank
1	
2	
3	
4	
5	
6	

Expression 6: The person describes one of these 6 items as **looks like a hand.** Please rank the items from 1 to 6 in terms of which card the person is most likely referring to. (1 – most likely; 6 – least likely)

Card Number	Your Rank
1	
2	
3	
4	
5	
6	

Expression 7: The person describes one of these 6 items as **has an "M".** Please rank the items from 1 to 6 in terms of which card the person is most likely referring to. (1 – most likely; 6 – least likely)

Card Number	Your Rank
1	
2	
3	
4	
5	
6	

Expression 8: The person describes one of these 6 items as **ends with a straight line and a little hook.** Please rank the items from 1 to 6 in terms of which card the person is most likely referring to. (1 – most likely; 6 – least likely)

Card Number	Your Rank
1	
2	
3	
4	
5	
6	

Expression 9: The person describes one of these 6 items as **looks like a spiral.** Please rank the items from 1 to 6 in terms of which card the person is most likely referring to. (1 – most likely; 6 – least likely)

Card Number	Your Rank
1	
2	
3	
4	
5	
6	

Thank you for completing the tasks!

Make sure you have saved all your answers!

Please submit it to the Learn Dropbox until April 20th, 5pm.

Thanks!! Enjoy your summer!

Geovania Pimenta

Student Name :

Student ID:

Appendix B

Experiments 2 and 3 Surveys

Following is one sample survey for experiment 2. All together there were 12 different survey versions as described in the method section.

Consent of Participant

By signing this consent form, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

I have read the information presented in the information letter about the study conducted by Geovania Pimenta under the supervision of Professor Rob Duimering, Department of Management Sciences, University of Waterloo. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted. I am aware that I may withdraw from the study without penalty at any time by advising the researchers of this decision. I am also aware that I may still be granted the 1 bonus-mark in MSCI 211 by completing and submitting the alternative assignment by August 10, 2015.

This project 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. 36005.

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

By submitting the completed survey online, I hereby agree to the above.

Print Name:

UW ID #:

Dated at Waterloo, Ontario:

☐ Male ☐ Female

General instructions

Thank you for agreeing to participate in this study.

You will be completing 5 kinds of communication tasks involving the description of pictures. The tasks are quite simple but please read and follow the specific instructions for each task. For example, you will be asked to choose which descriptions better describe a specific item within a set of items, or to rank a set of items with respect to one description. You will be granted 1 bonus-mark in MSCI 211 after submission of your responses. (Please note that students whose survey responses indicate that they have not taken the survey seriously will not be granted the bonus-mark.)

If you have any questions about these tasks, or about the research in general, please contact me at gdpimenta@uwaterloo.ca.

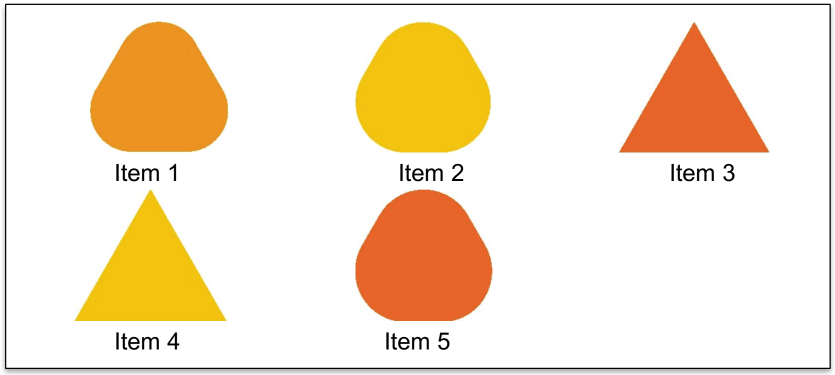
Thanks for your participation,

Geovania Pimenta

Part 1

Imagine you are communicating to a person in another room who has the following set of items. Your goal in this task is to correctly select items from the set based on descriptions provided by the other person. For each of the descriptions provided below please rank the items based on which one the person is most likely referring to (where rank of 1 is the "most likely"). This task will be repeated 12 times altogether (with 12 different sets of Items).

Set 1



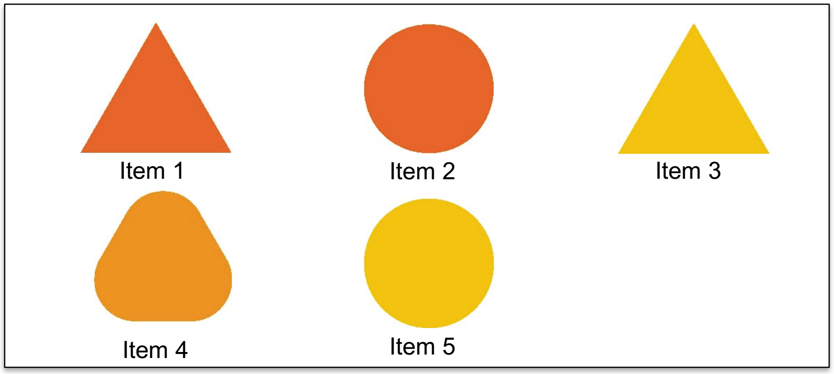
The other person uses the description **"looks red"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

The other person uses the description **"looks like a circle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

The other person uses the description **"looks yellow"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

The other person uses the description **"looks like a triangle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

Set 2



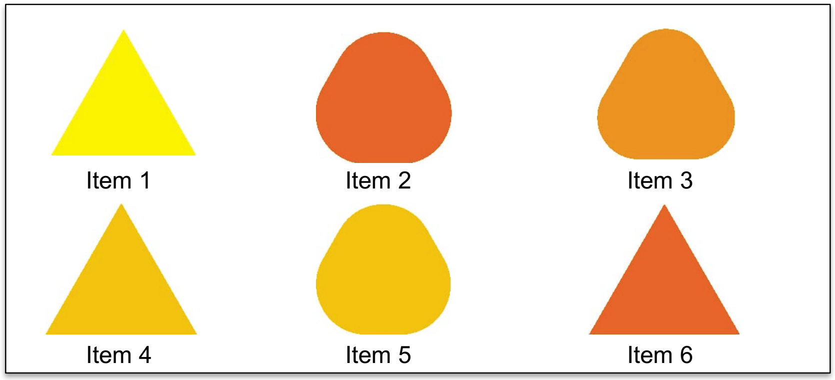
The other person uses the description **"looks yellow"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

The other person uses the description **"looks like a triangle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

The other person uses the description **"looks red"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

The other person uses the description **"looks like a circle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

Set 3



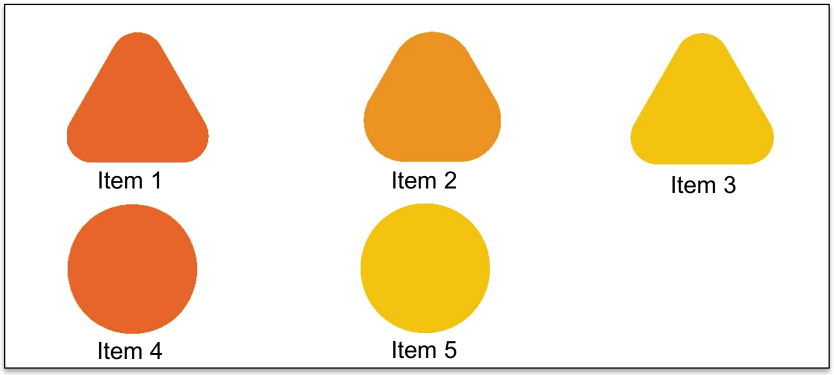
The other person uses the description **"looks red"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks yellow"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks like a triangle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks like a circle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

Set 4



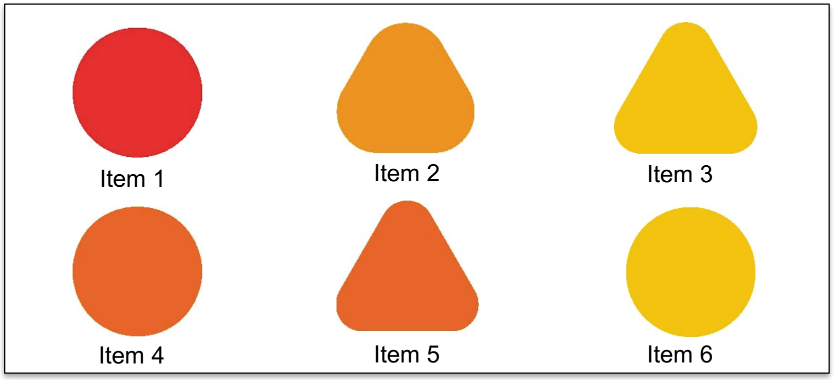
The other person uses the description **"looks red"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

The other person uses the description **"looks yellow"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

The other person uses the description **"looks like a circle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

The other person uses the description **"looks like a triangle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

Set 5



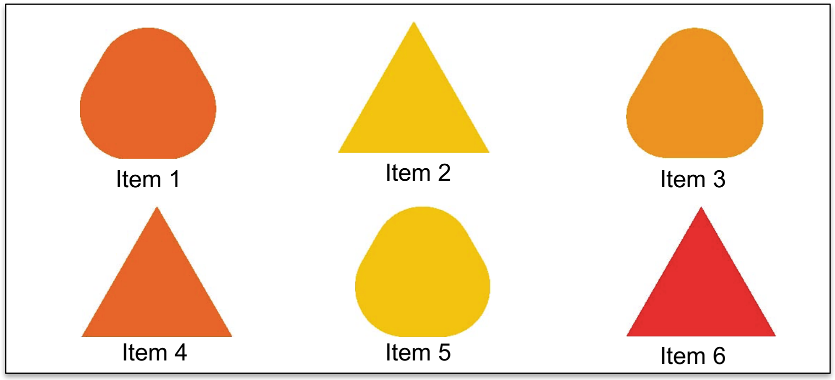
The other person uses the description **"looks yellow"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks red"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks like a circle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks like a triangle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

Set 6



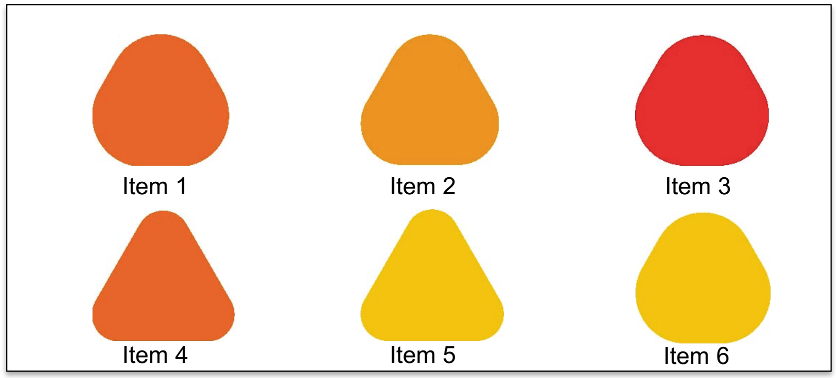
The other person uses the description **”looks like a triangle ”**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **”looks red”**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **”looks like a circle”**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **”looks yellow”**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

Set 7



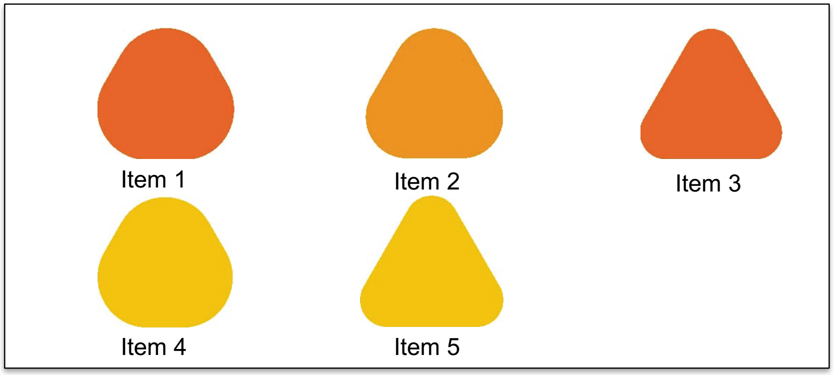
The other person uses the description **"looks like a circle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks red"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks like a triangle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks yellow"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

Set 8



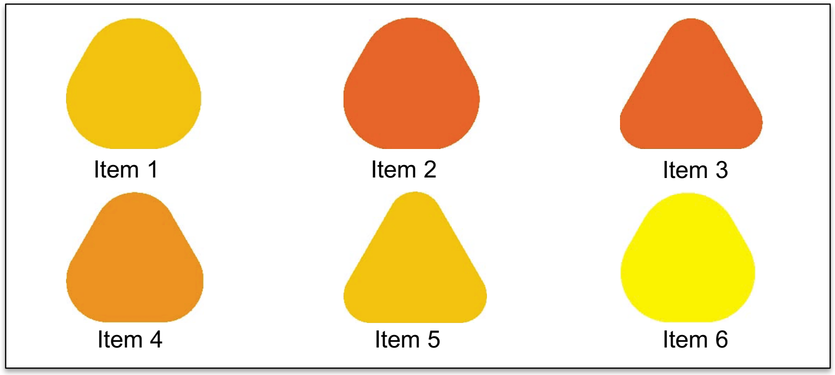
The other person uses the description **"looks red"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

The other person uses the description **"looks like a circle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

The other person uses the description **"looks yellow"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

The other person uses the description **"looks like a triangle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	

Set 9



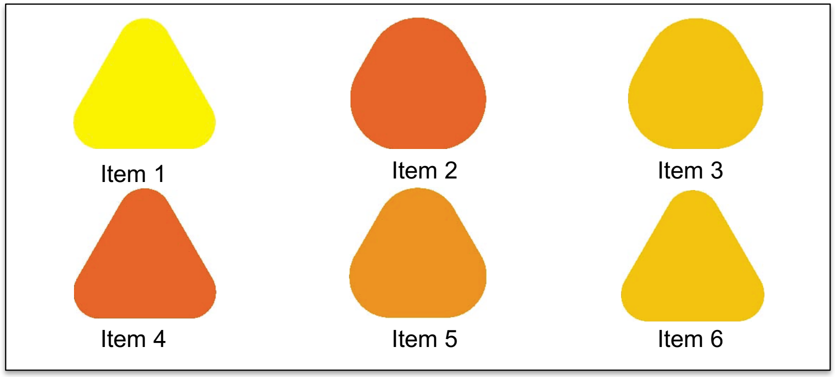
The other person uses the description **"looks red"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks like a circle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks yellow"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks like a triangle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

Set 10



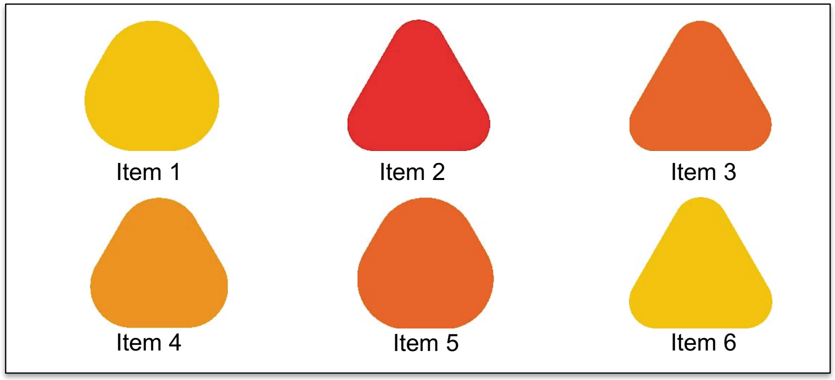
The other person uses the description **"looks like a triangle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks yellow"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks red"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks like a circle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

Set 11



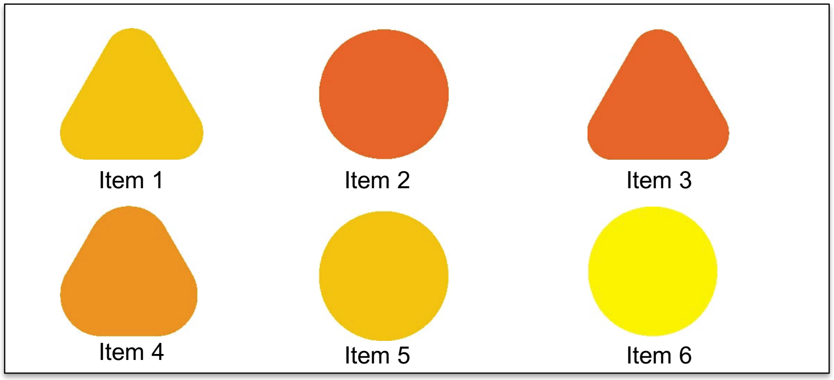
The other person uses the description **”looks red”**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **”looks like a circle”**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **”looks yellow”**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **”looks like a triangle”**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

Set 12



The other person uses the description **"looks red"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

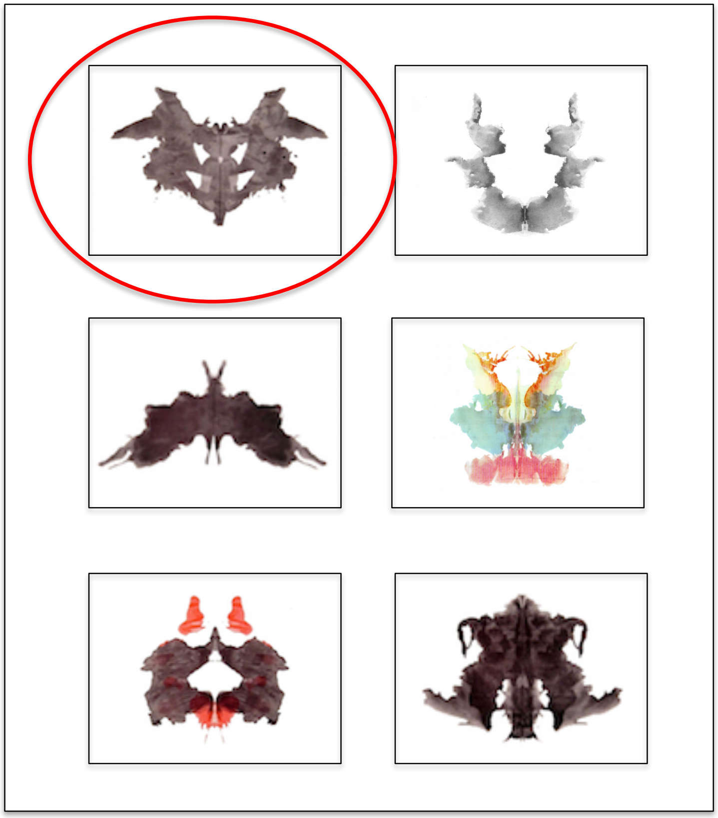
The other person uses the description **"looks yellow"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks like a triangle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks like a circle"**	
Item Number	Your Rank
1	
2	
3	
4	
5	
6	

Part 2

For this task, imagine you were trying to get another person to select the picture indicated from the set of pictures shown at the left.
The following 15 pairs of descriptions could be used to describe the circled picture. **For each pair** please choose the description that you think would work best to get the person to select the right picture.



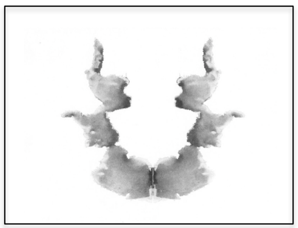
1	☐ looks like an eagle	☐ looks like a mask
2.	☐ looks like a spinal vertebrae (disc)	☐ looks like a vase
3.	☐ looks like a mask	☐ looks like a vase
4.	☐ looks like a spinal vertebrae (disc)	☐ looks like a mask
5.	☐ looks like an eagle	☐ looks like bears
6.	☐ looks like a spinal vertebrae (disc)	☐ looks like an eagle
7.	☐ looks like a spinal vertebrae (disc)	☐ looks like bears
8.	☐ looks like an eagle	☐ looks like a butterfly
9.	☐ looks like a butterfly	☐ looks like a vase
10.	☐ looks like a butterfly	☐ looks like bears
11.	☐ looks like bears	☐ looks like a vase
12.	☐ looks like an eagle	☐ looks like a vase
13.	☐ looks like a mask	☐ looks like bears
14.	☐ looks like a butterfly	☐ looks like a mask
15.	☐ looks like a spinal vertebrae (disc)	☐ looks like a butterfly

Part 3

Now, imagine you are communicating to a person in another room who has the set of 6 pictures shown at the left. Your goal is to select pictures based on descriptions provided by the other person. For each of the following descriptions please rank the items from 1 to 6 in terms of which picture the person is most likely referring to (1 – most likely; 6 – least likely).

Picture 1

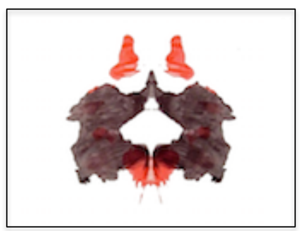
Picture 2



Picture 3

Picture 4

Picture 5



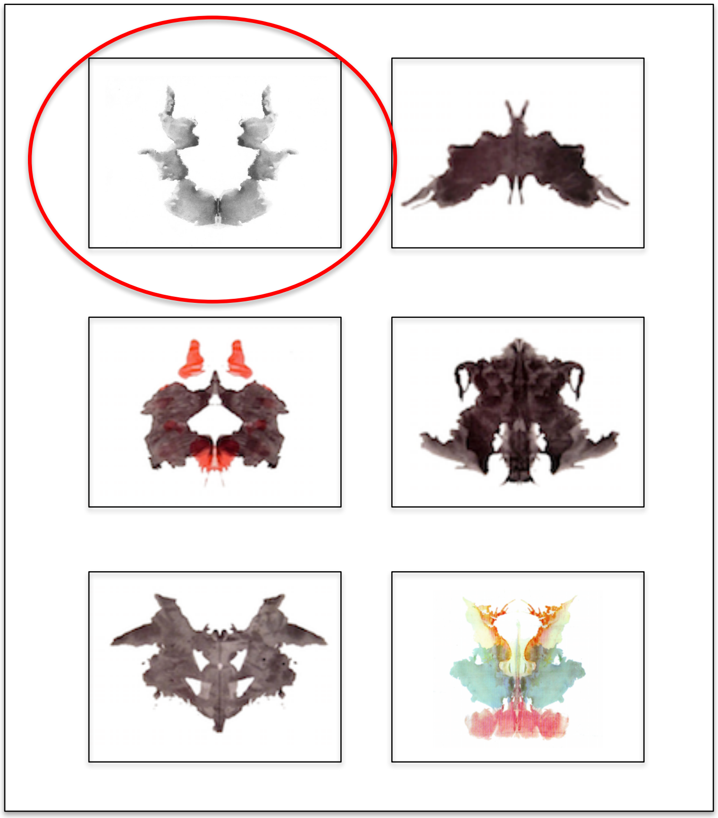
Picture 6

The other person uses the description **"looks like an animal skin"**	
Picture Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks like bears"**	
Picture Number	Your Rank
1	
2	
3	
4	
5	
6	

The other person uses the description **"looks like a coat hanged"**	
Picture Number	Your Rank
1	
2	
3	
4	
5	
6	

Part 4



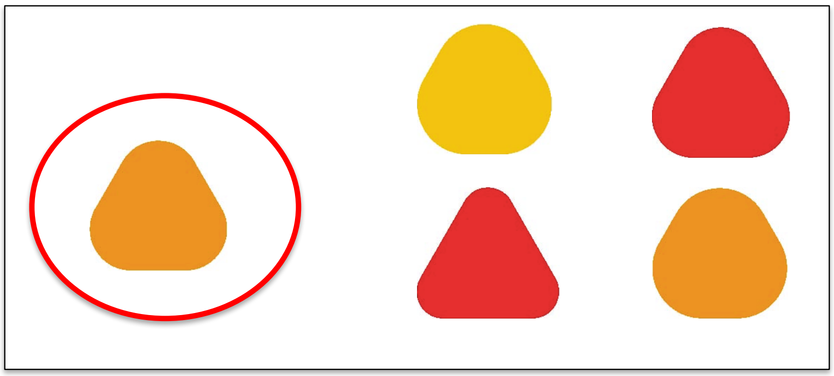
Imagine you are communicating to a person in another room who has set of 6 pictures at the left. Your goal in this task is to get the other person to correctly select the picture indicated. Please rank the following descriptions from 1 to 6 in terms of which would most likely get the person to select the right picture.

Description	Your Rank
looks like a cloud	
looks like art/statues	
looks like a coat hanged	
looks like two people	
looks like a vampire	
looks like elves	

Part 5

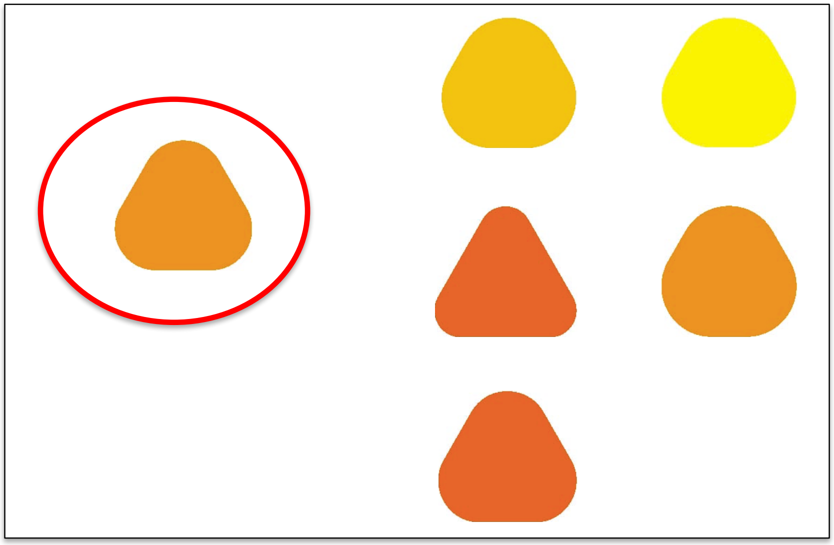
For this task, imagine you were trying to get another person to select the item indicated from the set of items shown below.
The following 6 pairs of descriptions could be used to describe the circled item. **For each pair** please choose the description that you think would work best to get the person to select the indicated item.

Example 1



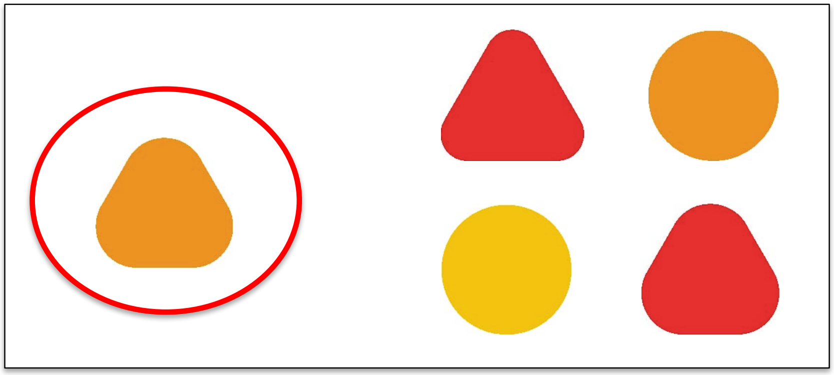
1. ☐ looks red ☐ looks yellow
2. ☐ looks like a triangle ☐ looks like a circle
3. ☐ looks like a triangle ☐ looks red
4. ☐ looks yellow ☐ looks like a triangle
5. ☐ looks like a circle ☐ looks yellow
6. ☐ looks like a circle ☐ looks red

Example 2



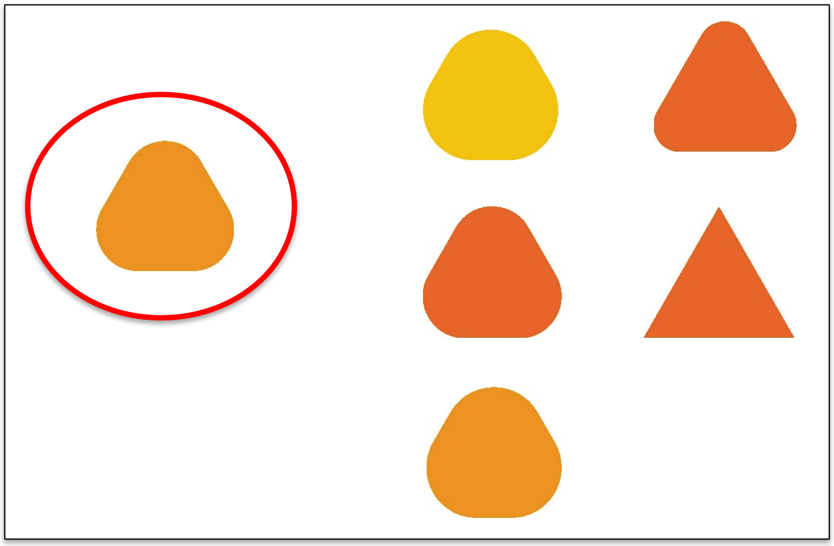
1.	☐ looks like a circle	☐ looks red
2.	☐ looks like a triangle	☐ looks red
3.	☐ looks like a triangle	☐ looks like a circle
4.	☐ looks yellow	☐ looks red
5.	☐ looks like a circle	☐ looks yellow
6.	☐ looks yellow	☐ looks like a triangle

Example 3



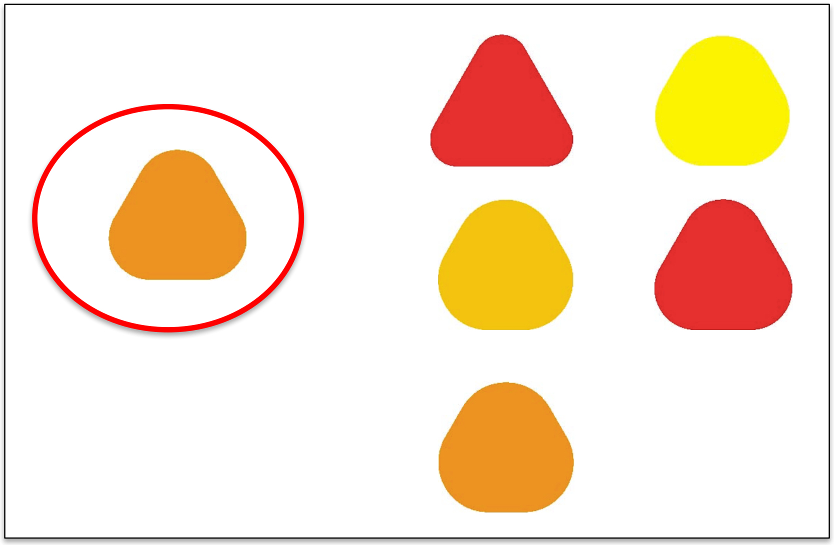
1.	☐	looks like a triangle	☐	looks like a circle
2.	☐	looks like a circle	☐	looks red
3.	☐	looks yellow	☐	looks like a triangle
4.	☐	looks like a triangle	☐	looks red
5.	☐	looks like a circle	☐	looks yellow
6.	☐	looks red	☐	looks yellow

Example 4



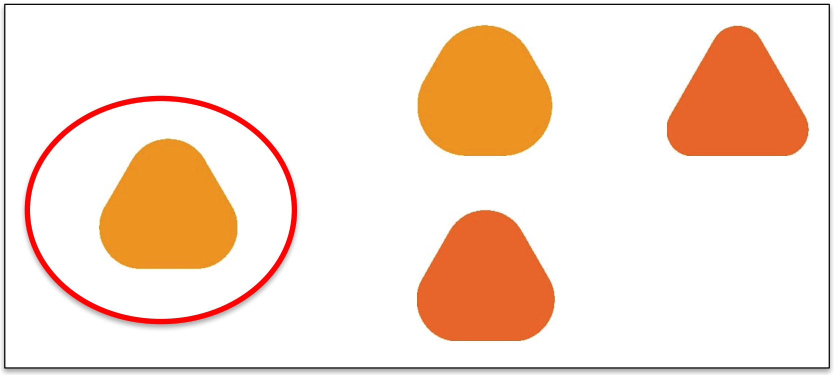
1.	☐ looks yellow	☐ looks like a triangle
2.	☐ looks red	☐ looks yellow
3.	☐ looks like a circle	☐ looks yellow
4.	☐ looks like a triangle	☐ looks like a circle
5.	☐ looks like a triangle	☐ looks red
6.	☐ looks like a circle	☐ looks red

Example 5



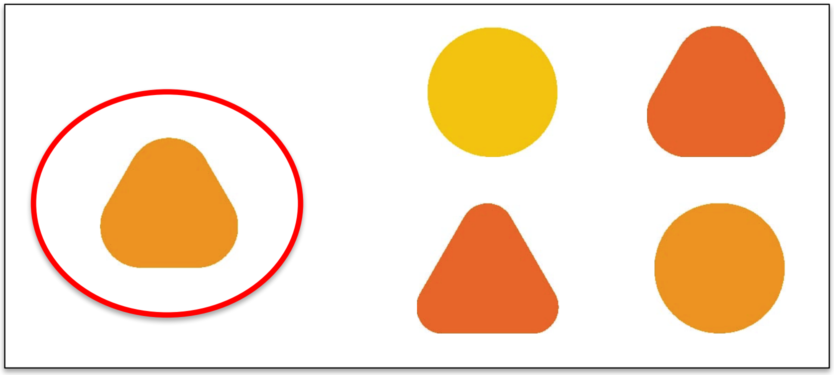
1.	☐	looks like a triangle	☐	looks like a circle
2.	☐	looks like a circle	☐	looks red
3.	☐	looks like a triangle	☐	looks red
4.	☐	looks like a circle	☐	looks yellow
5.	☐	looks red	☐	looks yellow
6.	☐	looks yellow	☐	looks like a triangle

Example 6



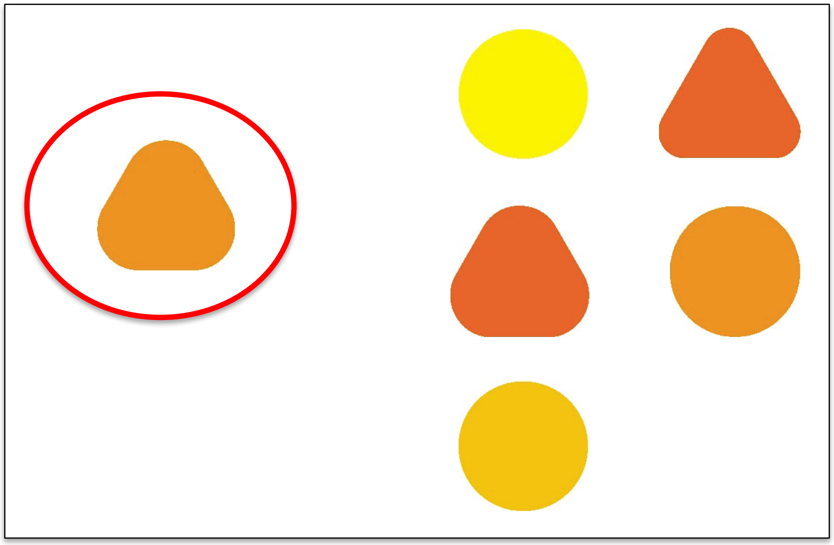
1.	☐ looks like a circle	☐ looks red
2.	☐ looks yellow	☐ looks like a triangle
3.	☐ looks red	☐ looks yellow
4.	☐ looks like a triangle	☐ looks like a circle
5.	☐ looks like a circle	☐ looks yellow
6.	☐ looks like a triangle	☐ looks red

Example 7



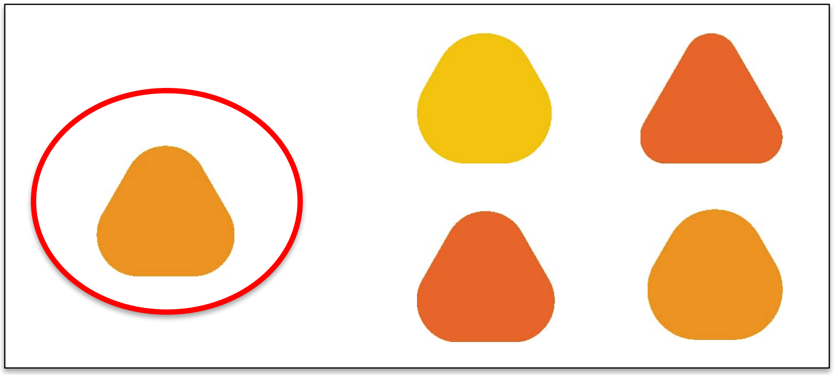
1.	☐ looks like a triangle	☐ looks red
2.	☐ looks like a circle	☐ looks yellow
3.	☐ looks like a circle	☐ looks red
4.	☐ looks like a triangle	☐ looks like a circle
5.	☐ looks red	☐ looks yellow
6.	☐ looks yellow	☐ looks like a triangle

Example 8



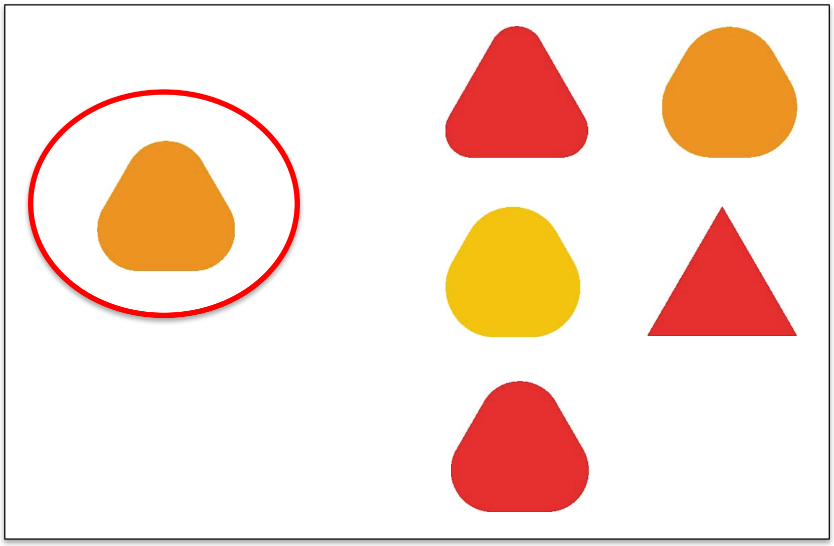
1. ☐ looks like a triangle ☐ looks like a circle
2. ☐ looks red ☐ looks yellow
3. ☐ looks yellow ☐ looks like a triangle
4. ☐ looks like a triangle ☐ looks red
5. ☐ looks like a circle ☐ looks red
6. ☐ looks like a circle ☐ looks yellow

Example 9



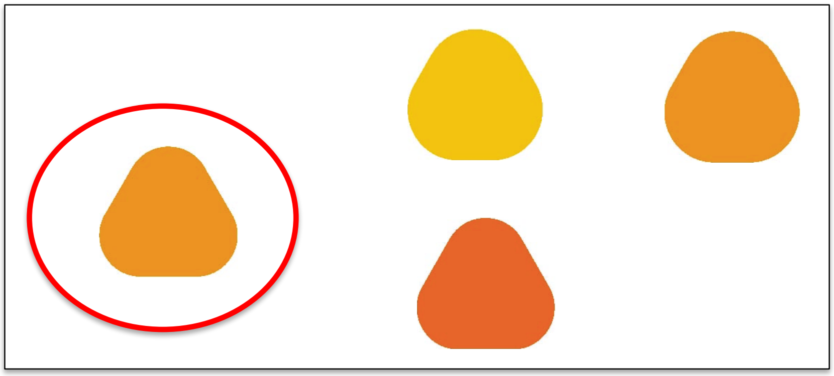
1.	☐	looks like a triangle	☐	looks like a circle
2.	☐	looks red	☐	looks yellow
3.	☐	looks like a triangle	☐	looks red
4.	☐	looks like a circle	☐	looks red
5.	☐	looks like a circle	☐	looks yellow
6.	☐	looks yellow	☐	looks like a triangle

Example 10



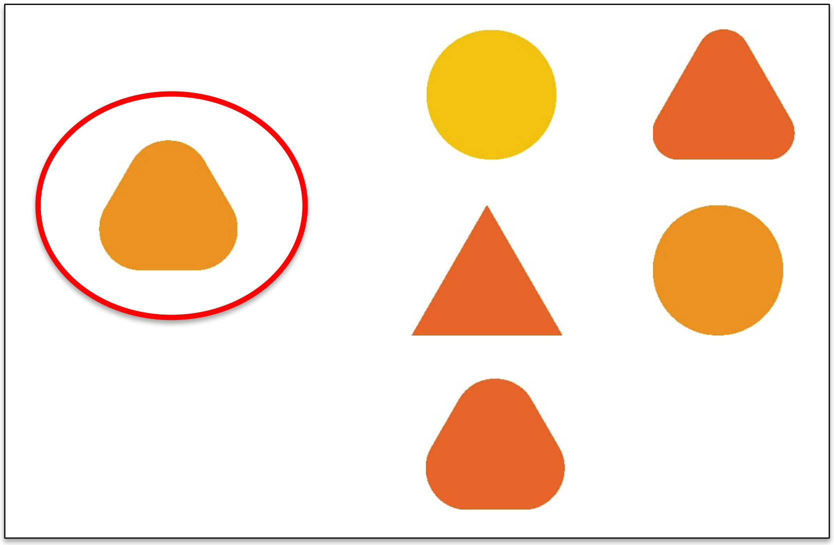
1.	☐	looks yellow	☐	looks like a triangle
2.	☐	looks like a triangle	☐	looks like a circle
3.	☐	looks like a circle	☐	looks yellow
4.	☐	looks red	☐	looks yellow
5.	☐	looks like a circle	☐	looks red
6.	☐	looks like a triangle	☐	looks red

Example 11



1.	☐	looks like a circle	☐	looks yellow
2.	☐	looks like a circle	☐	looks red
3.	☐	looks yellow	☐	looks like a triangle
4.	☐	looks like a triangle	☐	looks red
5.	☐	looks red	☐	looks yellow
6.	☐	looks like a triangle	☐	looks like a circle

Example 12



1.	☐	looks like a triangle	☐	looks like a circle
2.	☐	looks like a circle	☐	looks red
3.	☐	looks like a triangle	☐	looks red
4.	☐	looks red	☐	looks yellow
5.	☐	looks yellow	☐	looks like a triangle
6.	☐	looks like a circle	☐	looks yellow

Thank you for completing the tasks!

Make sure you have saved all your answers!

Please submit it to the Learn Dropbox until August 10, 2015.

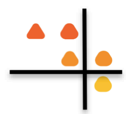
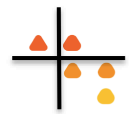
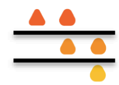
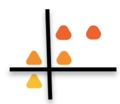
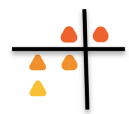
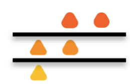
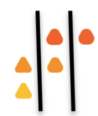
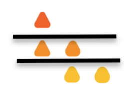
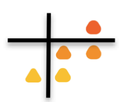
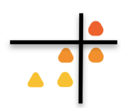
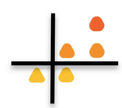
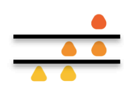
Thanks!!

Geovania Pimenta

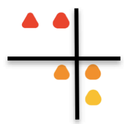
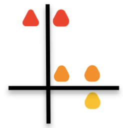
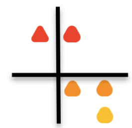
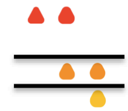
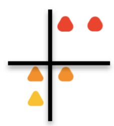
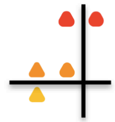
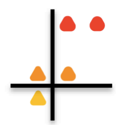
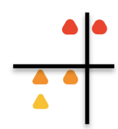
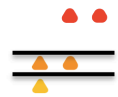
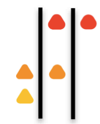
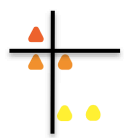
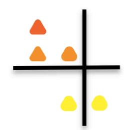
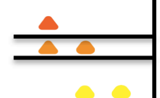
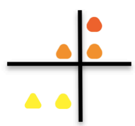
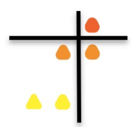
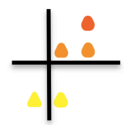
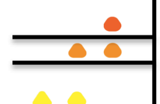
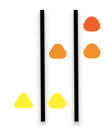
Appendix C

Reported Stimulus Designs

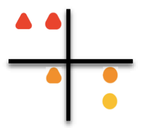
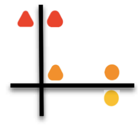
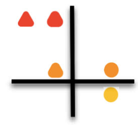
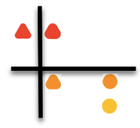
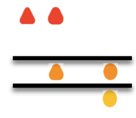
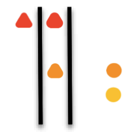
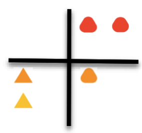
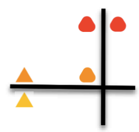
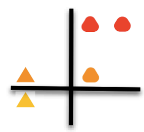
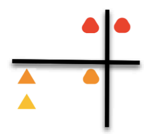
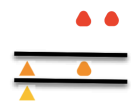
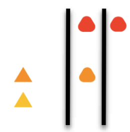
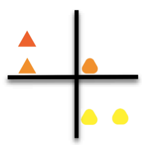
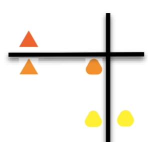
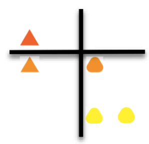
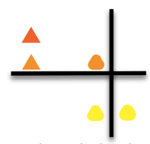
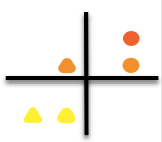
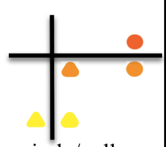
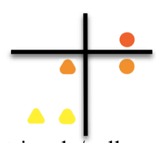
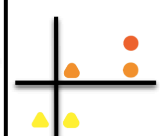
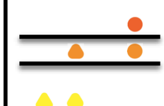
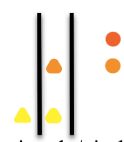
Baseline stimulus designs – 01

Baseline stimuli designs 01						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
1	 triangle/yellow **1a01**	 circle/red **1b01**	 triangle/red **1c01**	 circle/yellow **1d01**	 yellow/red **1e01**	 triangle/circle **1f01**
2	 circle/yellow **2a01**	 triangle/red **2b01**	 circle/red **2c01**	 triangle/yellow **2d01**	 yellow/red **2e01**	 circle/triangle **2f01**
3	 circle/red **3a01**	 triangle/yellow **3b01**	 circle/yellow **3c01**	 triangle/red **3d01**	 red/yellow **3e01**	 circle/triangle **3f01**
4	 triangle/red **4a01**	 circle/yellow **4b01**	 triangle/yellow **4c01**	 circle/red **4d01**	 red/yellow **4e01**	 triangle/circle **4f01**

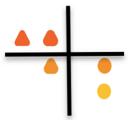
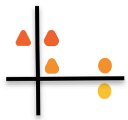
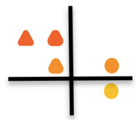
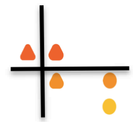
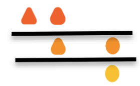
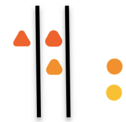
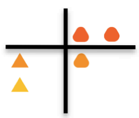
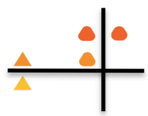
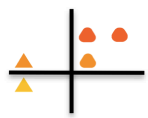
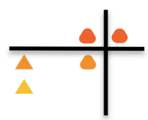
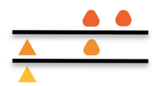
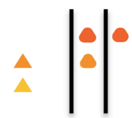
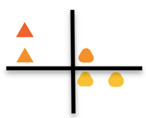
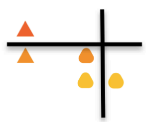
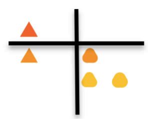
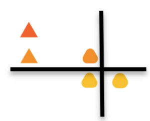
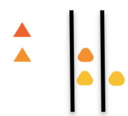
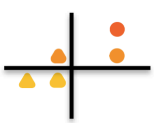
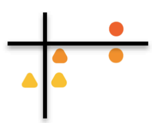
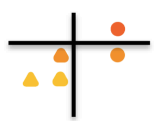
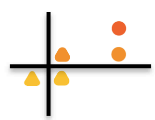
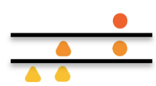
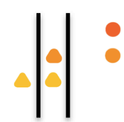
Gap Size Manipulation – Stimulus designs 02

Gap size stimuli designs 02 (by increasing the distance from the baseline sets from 1 unit to 2 units with respect to colour)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
1	 triangle/yellow **1a02**	 circle/red **1b02**	 triangle/red **1c02**	 circle/yellow **1d02**	 yellow/red **1e02**	 triangle/circle **1f02**
2	 circle/yellow **2a02**	 triangle/red **2b02**	 circle/red **2c02**	 triangle/yellow **2d02**	 yellow/red **2e02**	 circle/triangle **2f02**
3	 circle/red **3a02**	 triangle/yellow **3b02**	 circle/yellow **3c02**	 triangle/red **3d02**	 red/yellow **3e02**	 circle/triangle **3f02**
4	 triangle/red **4a02**	 circle/yellow **4b02**	 triangle/yellow **4c02**	 circle/red **4d02**	 red/yellow **4e02**	 triangle/circle **4f02**

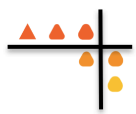
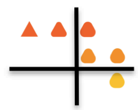
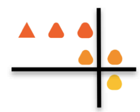
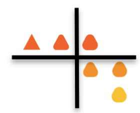
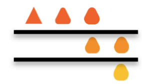
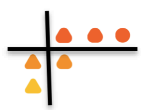
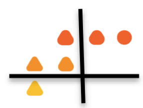
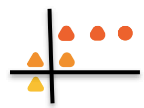
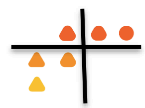
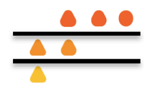
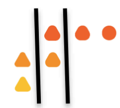
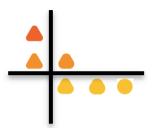
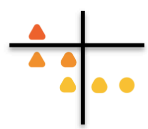
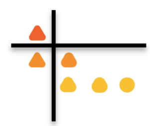
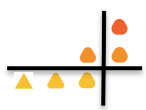
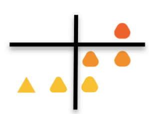
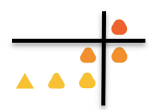
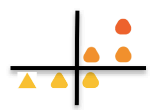
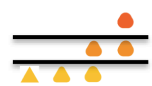
Gap Size Manipulation – Stimulus designs 03

Gap size stimuli designs 03 (by increasing the distance from the baseline sets from 1 unit to 2 units with respect to both shape and colour)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
1	 triangle/yellow **1a03**	 circle/red **1b03**	 triangle/red **1c03**	 circle/yellow **1d03**	 yellow/red **1e03**	 triangle/circle **1f03**
2	 circle/yellow **2a03**	 triangle/red **2b03**	 circle/red **2c03**	 triangle/yellow **2d03**	 yellow/red **2e03**	 circle/triangle **2f03**
3	 circle/red **3a03**	 triangle/yellow **3b03**	 circle/yellow **3c03**	 triangle/red **3d03**	 red/yellow **3e03**	 circle/triangle **3f03**
4	 triangle/red **4a03**	 circle/yellow **4b03**	 triangle/yellow **4c03**	 circle/red **4d03**	 red/yellow **4e03**	 triangle/circle **4f03**

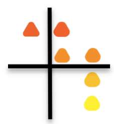
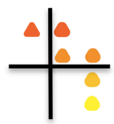
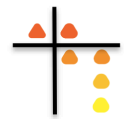
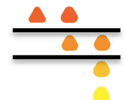
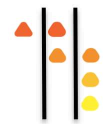
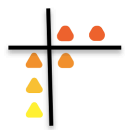
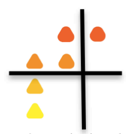
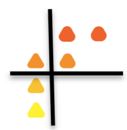
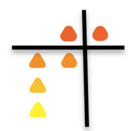
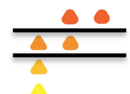
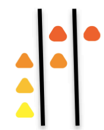
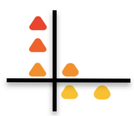
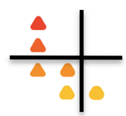
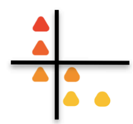
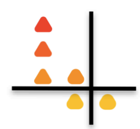
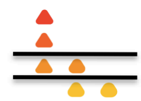
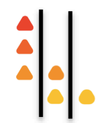
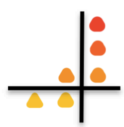
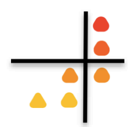
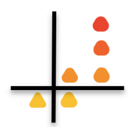
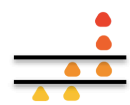
Gap Size Manipulation – Stimulus designs 04

Gap size stimuli designs 04 (by increasing the distance from the baseline sets from 1 unit to 2 units with respect to shape)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
1	 triangle/yellow **1a04**	 circle/red **1b04**	 triangle/red **1c04**	 circle/yellow **1d04**	 yellow/red **1e04**	 triangle/circle **1f04**
2	 circle/yellow **2a04**	 triangle/red **2b04**	 circle/red **2c04**	 triangle/yellow **2d04**	 yellow/red **2e04**	 circle/triangle **2f04**
3	 circle/red **3a04**	 triangle/yellow **3b04**	 circle/yellow **3c04**	 triangle/red **3d04**	 red/yellow **3e04**	 circle/triangle **3f04**
4	 triangle/red **4a04**	 circle/yellow **4b04**	 triangle/yellow **4c04**	 circle/red **4d04**	 red/yellow **4e04**	 triangle/circle **4f04**

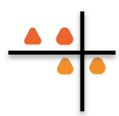
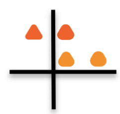
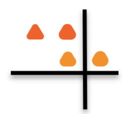
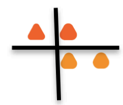
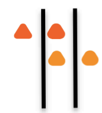
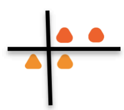
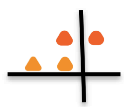
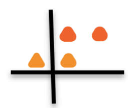
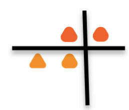
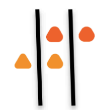
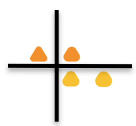
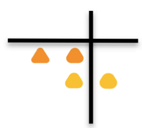
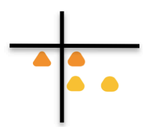
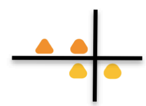
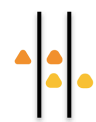
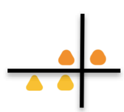
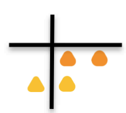
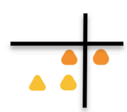
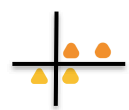
Gap Position Manipulation – Stimulus designs 05

Gap position stimuli designs 05 (by adding an item to the baseline sets)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
1	 triangle/yellow **1a05**	 circle/red **1b05**	 triangle/red **1c05**	 circle/yellow **1d05**	 yellow/red **1e05**	 triangle/circle **1f05**
2	 circle/yellow **2a05**	 triangle/red **2b05**	 circle/red **2c05**	 triangle/yellow **2d05**	 yellow/red **2e05**	 circle/triangle **2f05**
3	 circle/red **3a05**	 triangle/yellow **3b05**	 circle/yellow **3c05**	 triangle/red **3d05**	 red/yellow **3e05**	 circle/triangle **3f05**
4	 triangle/red **4a05**	 circle/yellow **4b05**	 triangle/yellow **4c05**	 circle/red **4d05**	 red/yellow **4e05**	 triangle/circle **4f05**

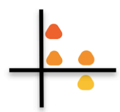
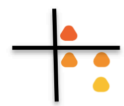
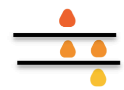
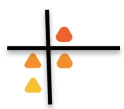
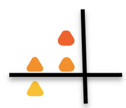
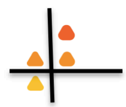
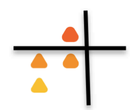
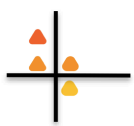
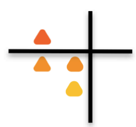
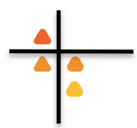
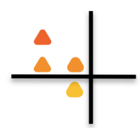
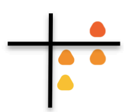
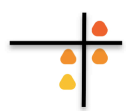
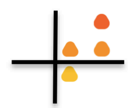
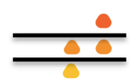
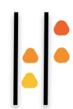
Gap Position Manipulation – Stimulus designs 06

Gap position stimuli designs 06 (by adding an item to the baseline sets)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
1	 triangle/yellow **1a06**	 circle/red **1b06**	 triangle/red **1c06**	 circle/yellow **1d06**	 yellow/red **1e06**	 triangle/circle **1f06**
2	 circle/yellow **2a06**	 triangle/red **2b06**	 circle/red **2c06**	 triangle/yellow **2d06**	 yellow/red **2e06**	 circle/triangle **2f06**
3	 circle/red **3a06**	 triangle/yellow **3b06**	 circle/yellow **3c06**	 triangle/red **3d06**	 red/yellow **3e06**	 circle/triangle **3f06**
4	 triangle/red **4a06**	 circle/yellow **4b06**	 triangle/yellow **4c06**	 circle/red **4d06**	 red/yellow **4e06**	 triangle/circle **4f06**

Gap Position Manipulation – Stimulus designs 07

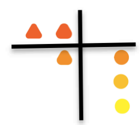
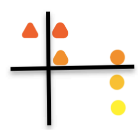
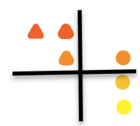
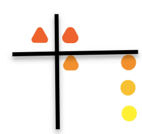
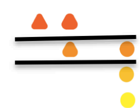
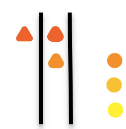
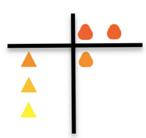
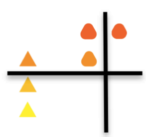
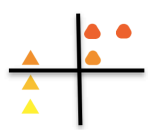
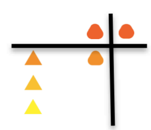
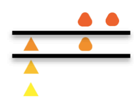
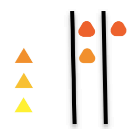
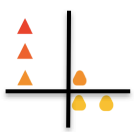
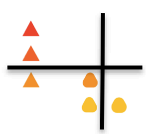
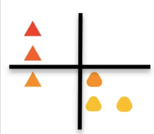
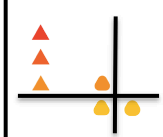
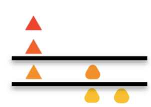
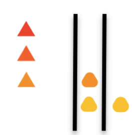
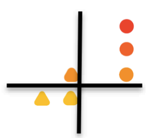
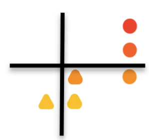
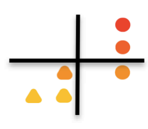
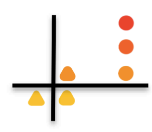
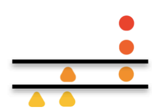
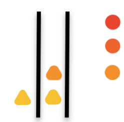
Gap position stimuli designs 07 (by deleting an item to the baseline sets)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
1	 triangle/yellow **1a07**	 circle/red **1b07**	 triangle/red **1c07**	 circle/yellow **1d07**	 yellow/red **1e07**	 triangle/circle **1f07**
2	 circle/yellow **2a07**	 triangle/red **2b07**	 circle/red **2c07**	 triangle/yellow **2d07**	 yellow/red **2e07**	 circle/triangle **2f07**
3	 circle/red **3a07**	 triangle/yellow **3b07**	 circle/yellow **3c07**	 triangle/red **3d07**	 red/yellow **3e07**	 circle/triangle **3f07**
4	 triangle/red **4a07**	 circle/yellow **4b07**	 triangle/yellow **4c07**	 circle/red **4d07**	 red/yellow **4e07**	 triangle/circle **4f07**

Gap Position Manipulation – Stimulus designs 08

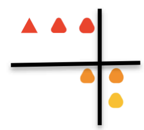
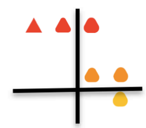
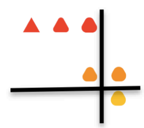
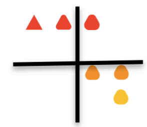
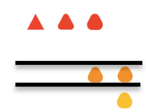
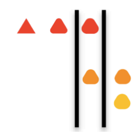
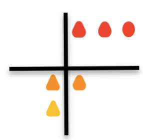
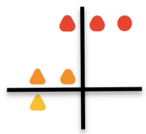
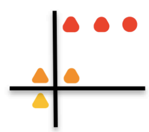
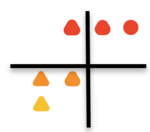
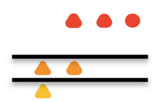
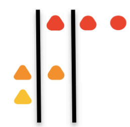
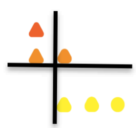
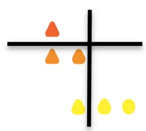
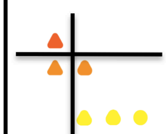
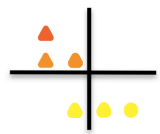
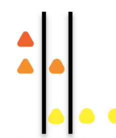
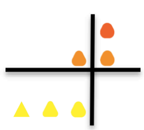
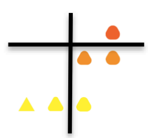
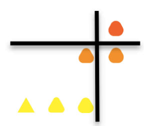
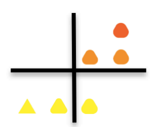
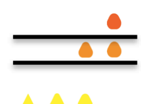
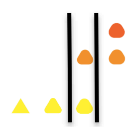
Gap position stimuli designs 08 (by deleting an item to the baseline sets)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
1	 triangle/yellow **1a08**	 circle/red **1b08**	 triangle/red **1c08**	 circle/yellow **1d08**	 yellow/red **1e08**	 triangle/circle **1f08**
2	 circle/yellow **2a08**	 triangle/red **2b08**	 circle/red **2c08**	 triangle/yellow **2d08**	 yellow/red **2e08**	 circle/triangle **2f08**
3	 circle/red **3a08**	 triangle/yellow **3b08**	 circle/yellow **3c08**	 triangle/red **3d08**	 red/yellow **3e08**	 circle/triangle **3f08**
4	 triangle/red **4a08**	 circle/yellow **4b08**	 triangle/yellow **4c08**	 circle/red **4d08**	 red/yellow **4e08**	 triangle/circle **4f08**

Appendix C B – Non-Reported Stimulus Designs

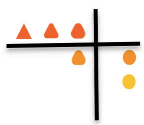
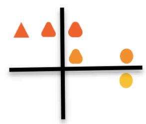
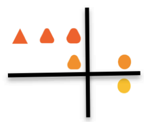
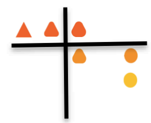
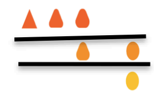
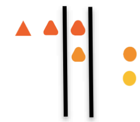
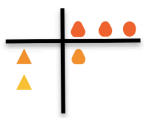
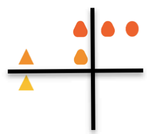
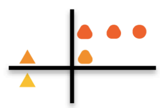
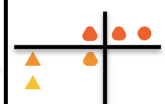
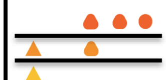
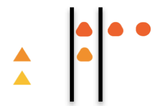
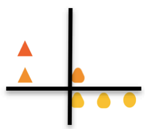
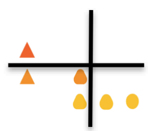
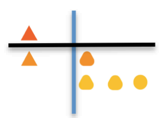
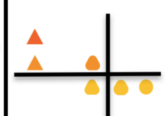
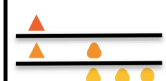
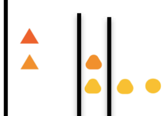
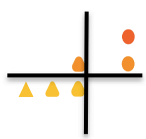
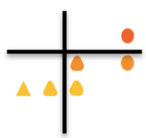
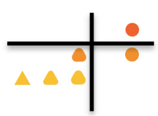
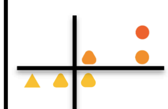
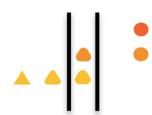
Gap Size and Position Manipulation – Stimulus Designs 09

Gap size and position stimuli designs 09 (by increasing the gap size from 1 unit to 2 units and adding an item to the baseline sets simultaneously)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
1	 triangle/yellow **1a09**	 circle/red **1b09**	 triangle/red **1c09**	 circle/yellow **1d09**	 yellow/red **1e09**	 triangle/circle **1f09**
2	 circle/yellow **2a09**	 triangle/red **2b09**	 circle/red **2c09**	 triangle/yellow **2d09**	 yellow/red **2e09**	 circle/triangle **2f09**
3	 circle/red **3a09**	 triangle/yellow **3b09**	 circle/yellow **3c09**	 triangle/red **3d09**	 red/yellow **3e09**	 circle/triangle **3f09**
4	 triangle/red **4a09**	 circle/yellow **4b09**	 triangle/yellow **4c09**	 circle/red **4d09**	 red/yellow **4e09**	 triangle/circle **4f09**

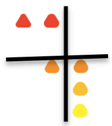
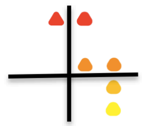
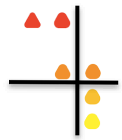
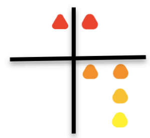
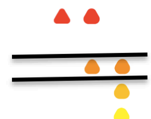
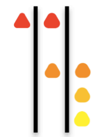
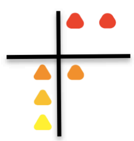
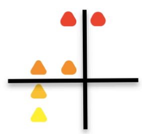
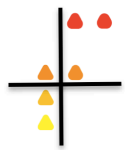
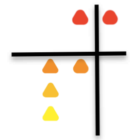
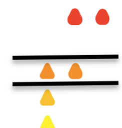
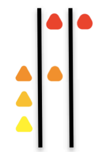
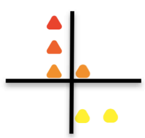
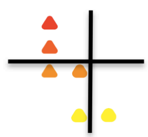
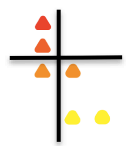
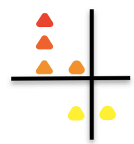
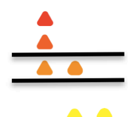
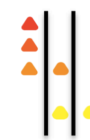
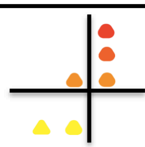
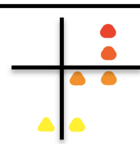
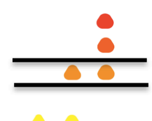
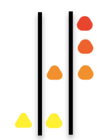
Gap Size and Position Manipulation – Stimulus Designs 10

Gap size and position stimuli designs 10 (by increasing the gap size from 1 unit to 2 units and adding an item to the baseline sets simultaneously)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
1	 triangle/yellow **1a10**	 circle/red **1b10**	 triangle/red **1c10**	 circle/yellow **1d10**	 yellow/red **1e10**	 triangle/circle **1f10**
2	 circle/yellow **2a10**	 triangle/red **2b10**	 circle/red **2c10**	 triangle/yellow **2d10**	 yellow/red **2e10**	 circle/triangle **2f10**
3	 circle/red **3a10**	 triangle/yellow **3b10**	 circle/yellow **3c10**	 triangle/red **3d10**	 red/yellow **3e10**	 circle/triangle **3f10**
4	 triangle/red **4a10**	 circle/yellow **4b10**	 triangle/yellow **4c10**	 circle/red **4d10**	 red/yellow **4e10**	 triangle/circle **4f10**

Gap Size and Position Manipulation – Stimulus Designs 11

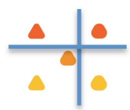
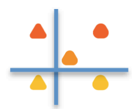
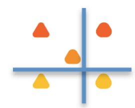
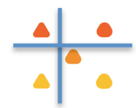
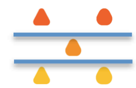
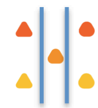
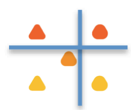
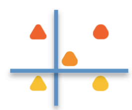
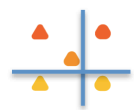
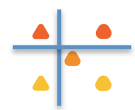
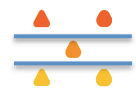
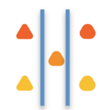
Gap size and position stimuli designs 11 (by increasing the gap size from 1 unit to 2 units and adding an item to the baseline sets simultaneously)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
1	 triangle/yellow **1a11**	 circle/red **1b11**	 triangle/red **1c11**	 circle/yellow **1d11**	 yellow/red **1e11**	 triangle/circle **1f11**
2	 circle/yellow **2a11**	 triangle/red **2b11**	 circle/red **2c11**	 triangle/yellow **2d11**	 yellow/red **2e11**	 circle/triangle **2f11**
3	 circle/red **3a11**	 triangle/yellow **3b11**	 circle/yellow **3c11**	 triangle/red **3d11**	 red/yellow **3e11**	 circle/triangle **3f11**
4	 triangle/red **4a11**	 circle/yellow **4b11**	 triangle/yellow **4c11**	 circle/red **4d11**	 red/yellow **4e11**	 triangle/circle **4f11**

Gap Size and Position Manipulation – Stimulus Designs 12

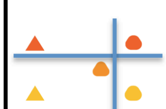
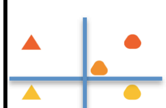
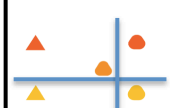
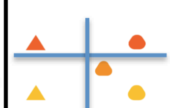
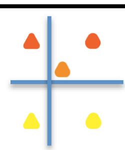
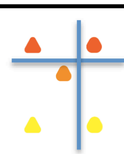
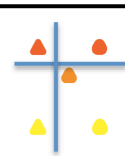
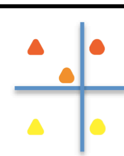
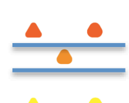
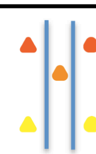
Gap size and position stimuli designs 12 (by increasing the gap size from 1 unit to 2 units and adding an item to the baseline sets simultaneously)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
1	 triangle/yellow **1a12**	 circle/red **1b12**	 triangle/red **1c12**	 circle/yellow **1d12**	 yellow/red **1e12**	 triangle/circle **1f12**
2	 circle/yellow **2a12**	 triangle/red **2b12**	 circle/red **2c12**	 triangle/yellow **2d12**	 yellow/red **2e12**	 circle/triangle **2f12**
3	 circle/red **3a12**	 triangle/yellow **3b12**	 circle/yellow **3c12**	 triangle/red **3d12**	 red/yellow **3e12**	 circle/triangle **3f12**
4	 triangle/red **4a12**	 circle/yellow **4b12**	 triangle/yellow **4c12**	 circle/red **4d12**	 red/yellow **4e12**	 triangle/circle **4f12**

One Dimensional Stimuli Designs Family-Rotations

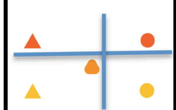
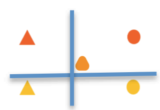
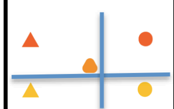
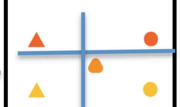
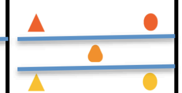
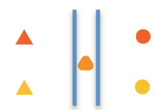
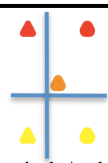
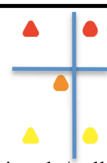
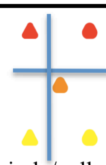
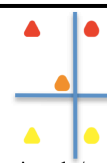
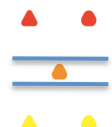
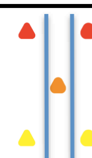
Baseline Stimuli Designs 01

Stimulus Rotation	Set a	Set b	Set c	Set d	Set e	Set f
5	 triangle/yellow **5a01**	 circle/red **5b01**	 triangle/red **5c01**	 circle/yellow **5d01**	 yellow/red **5e01**	 triangle/circle **5f01**
6	 circle/red **6a01**	 triangle/yellow **6b01**	 circle/yellow **6c01**	 triangle/red **6d01**	 red/yellow **6e01**	 circle/triangle **6f01**

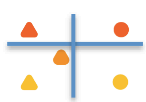
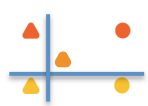
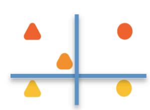
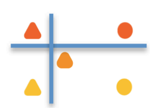
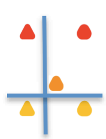
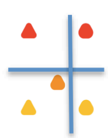
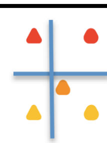
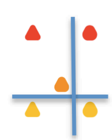
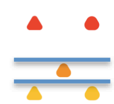
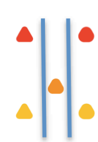
Gap Size Manipulation – Stimulus designs 02

Gap size stimuli designs 02 (by increasing the distance from the baseline sets from 1 unit to 2 units with respect to colour)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
5	 triangle/yellow **5a02**	 circle/red **5b02**	 triangle/red **5c02**	 circle/yellow **5d02**	 yellow/red **5e02**	 triangle/circle **5f02**
6	 circle/red **6a02**	 triangle/yellow **6b02**	 circle/yellow **6c02**	 triangle/red **6d02**	 red/yellow **6e02**	 circle/triangle **6f02**

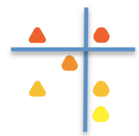
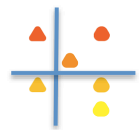
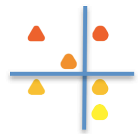
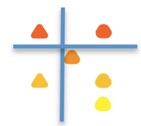
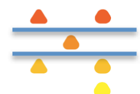
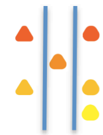
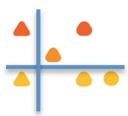
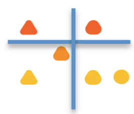
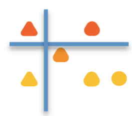
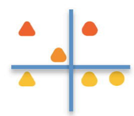
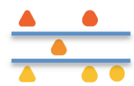
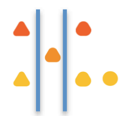
Gap Size Manipulation – Stimulus designs 03

Gap size stimuli designs 03 (by increasing the distance from the baseline sets from 1 unit to 2 units with respect to both shape and colour)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
5	 triangle/yellow **5a03**	 circle/red **5b03**	 triangle/red **5c03**	 circle/yellow **5d03**	 yellow/red **5e03**	 triangle/circle **5f03**
6	 circle/red **6a03**	 triangle/yellow **6b03**	 circle/yellow **6c03**	 triangle/red **6d03**	 red/yellow **6e03**	 circle/triangle **6f03**

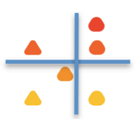
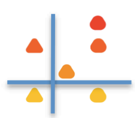
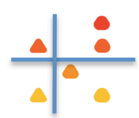
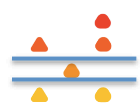
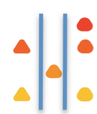
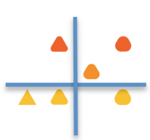
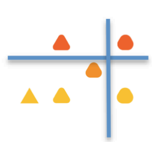
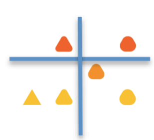
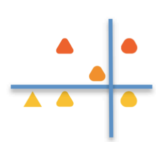
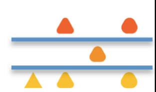
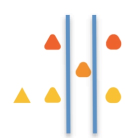
Gap Size Manipulation – Stimulus designs 04

Gap size stimuli designs 04 (by increasing the distance from the baseline sets from 1 unit to 2 units with respect to shape)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
5	 triangle/yellow **5a04**	 circle/red **5b04**	 triangle/red **5c04**	 circle/yellow **5d04**	 yellow/red **5e04**	 triangle/circle **5f04**
6	 circle/red **6a04**	 triangle/yellow **6b04**	 circle/yellow **6c04**	 triangle/red **6d04**	 red/yellow **6e04**	 circle/triangle **6f04**

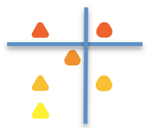
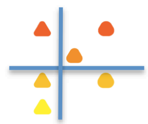
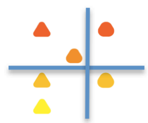
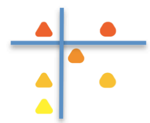
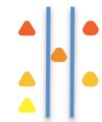
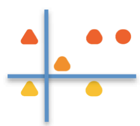
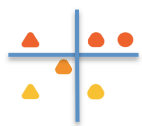
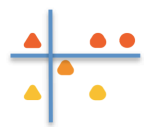
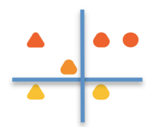
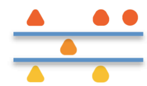
Gap Position Manipulation – Stimulus designs 05

Gap position stimuli designs 05 (by adding an item to the baseline sets)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
5	 triangle/yellow **5a05**	 circle/red **5b05**	 triangle/red **5c05**	 circle/yellow **5d05**	 yellow/red **5e05**	 triangle/circle **5f05**
6	 circle/red **6a05**	 triangle/yellow **6b05**	 circle/yellow **6c05**	 triangle/red **6d05**	 red/yellow **6e05**	 circle/triangle **6f05**

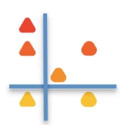
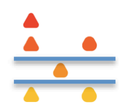
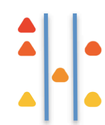
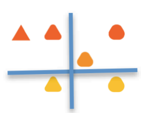
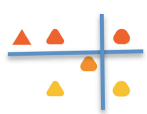
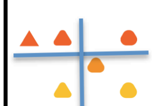
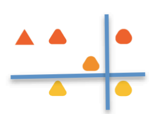
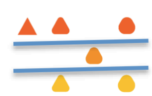
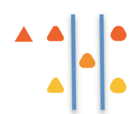
Gap Position Manipulation – Stimulus designs 06

Gap position stimuli designs 06 (by adding an item to the baseline sets)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
5	 triangle/yellow **5a06**	 circle/red **5b06**	 triangle/red **5c06**	 circle/yellow **5d06**	 yellow/red **5e06**	 triangle/circle **5f06**
6	 circle/red **6a06**	 triangle/yellow **6b06**	 circle/yellow **6c06**	 triangle/red **6d06**	 red/yellow **6e06**	 circle/triangle **6f06**

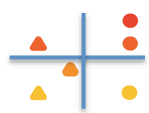
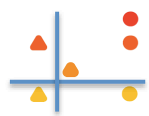
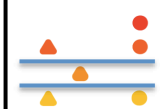
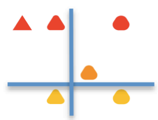
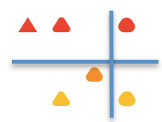
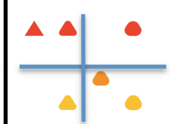
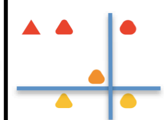
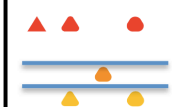
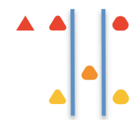
Gap Position Manipulation – Stimulus designs 07

Gap position stimuli designs 07 (by deleting an item to the baseline sets)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
5	 triangle/yellow **5a07**	 circle/red **5b07**	 triangle/red **5c07**	 circle/yellow **5d07**	 yellow/red **5e07**	 triangle/circle **5f07**
6	 circle/red **6a07**	 triangle/yellow **6b07**	 circle/yellow **6c07**	 triangle/red **6d07**	 red/yellow **6e07**	 circle/triangle **6f07**

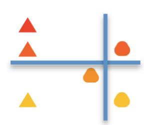
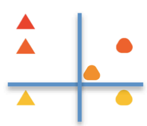
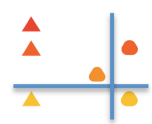
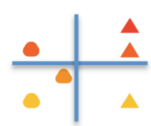
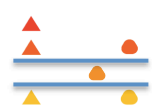
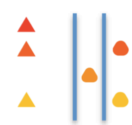
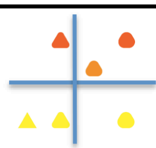
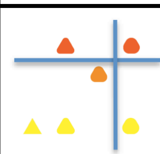
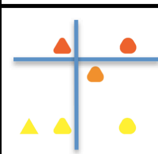
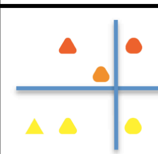
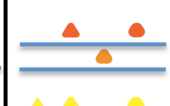
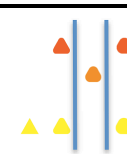
Gap Position Manipulation – Stimulus designs 08

Gap position stimuli designs 08 (by deleting an item to the baseline sets)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
5	 triangle/yellow **5a08**	 circle/red **5b08**	 triangle/red **5c08**	 circle/yellow **5d08**	 yellow/red **5e08**	 triangle/circle **5f08**
6	 circle/red **6a08**	 triangle/yellow **6b08**	 circle/yellow **6c08**	 triangle/red **6d08**	 red/yellow **6e08**	 circle/triangle **6f08**

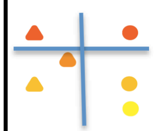
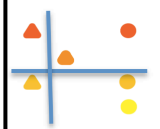
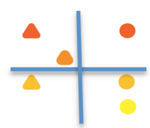
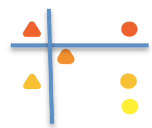
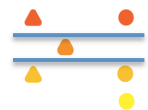
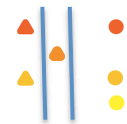
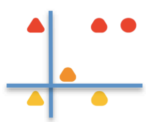
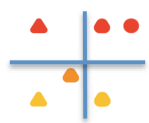
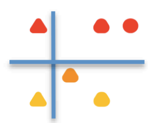
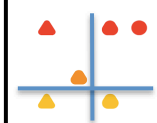
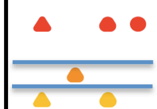
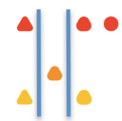
Gap Size and Position Manipulation – Stimulus Designs 09

Gap size and position stimuli designs 09 (by increasing the gap size from 1 unit to 2 units and adding an item to the baseline sets simultaneously)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
5	 triangle/yellow **5a09**	 circle/red **5b09**	 triangle/red **5c09**	 circle/yellow **5d09**	 yellow/red **5e09**	 triangle/circle **5f09**
6	 circle/red **6a09**	 triangle/yellow **6b09**	 circle/yellow **6c09**	 triangle/red **6d09**	 red/yellow **6e09**	 circle/triangle **6f09**

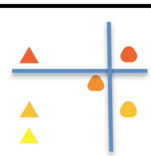
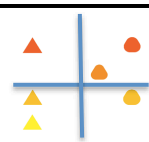
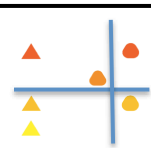
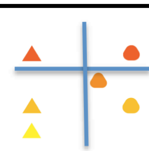
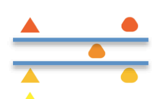
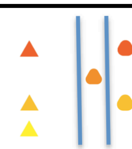
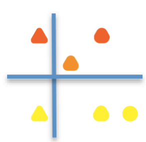
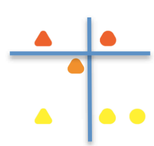
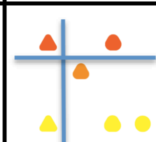
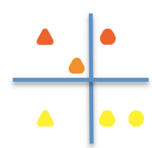
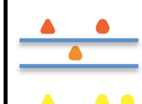
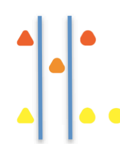
Gap Size and Position Manipulation – Stimulus Designs 10

Gap size and position stimuli designs 10 (by increasing the gap size from 1 unit to 2 units and adding an item to the baseline sets simultaneously)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
5	 triangle/yellow **5a10**	 circle/red **5b10**	 triangle/red **5c10**	 circle/yellow **5d10**	 yellow/red **5e10**	 triangle/circle **5f10**
6	 circle/red **6a10**	 triangle/yellow **6b10**	 circle/yellow **6c10**	 triangle/red **6d10**	 red/yellow **6e10**	 circle/triangle **6f10**

Gap Size and Position Manipulation – Stimulus Designs 11

Gap size and position stimuli designs 11 (by increasing the gap size from 1 unit to 2 units and adding an item to the baseline sets simultaneously)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
5	 triangle/yellow **5a11**	 circle/red **5b11**	 triangle/red **5c11**	 circle/yellow **5d11**	 yellow/red **5e11**	 triangle/circle **5f11**
6	 circle/red **6a11**	 triangle/yellow **6b11**	 circle/yellow **6c11**	 triangle/red **6d11**	 red/yellow **6e11**	 circle/triangle **6f11**

Gap Size and Position Manipulation – Stimulus Designs 12

Gap size and position stimuli designs 12 (by increasing the gap size from 1 unit to 2 units and adding an item to the baseline sets simultaneously)						
Stimulus Rotation	**Set a**	**Set b**	**Set c**	**Set d**	**Set e**	**Set f**
5	 triangle/yellow **5a12**	 circle/red **5b12**	 triangle/red **5c12**	 circle/yellow **5d12**	 yellow/red **5e12**	 triangle/circle **5f12**
6	 circle/red **6a12**	 triangle/yellow **6b12**	 circle/yellow **6c12**	 triangle/red **6d12**	 red/yellow **6e12**	 circle/triangle **6f12**

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