The Effect of Partial Exemplar Experience on Ill-Defined, Multi-modal Categories

by

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ABSTRACT

The purpose of this study was to investigate the effect of partial exemplar experience on category formation and use. Participants had either complete or limited access to the three dimensions that defined categories by dimensions within different modalities. The concept of "crucial dimension" was introduced and the role it plays in category definition was explained. It was hypothesized that the effects of partial experience are not explained by a shifting of attention between dimensions but rather by an increased reliance on prototypical values used to fill in missing information during incomplete experiences. Results indicated that participants (1) do not fill in missing information with prototypical values, (2) integrate information less efficiently between different modalities than within a single modality, and (3) have difficulty learning only when partial experience prevents access to diagnostic information.

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Chapter 1

THE EFFECT OF PARTIAL EXEMPLAR EXPERIENCE ON ILL-DEFINED, MULTI-MODAL CATEGORIES

When people go about their daily lives, they are subjected to a massive set of unique objects and experiences. For example, estimates of the number of discriminable colors run in the millions (Bruner et. al, 1956). While these experiences are unique they are often highly similar to one another, allowing observers to react to a complex set of possible environments with much simpler set of responses. Every successive day the sun strikes the surface of the earth at a different angle, having subtle effects on light in an environment, yet this has little effect on our ability to understand what we see. Even when analyzing an object beyond sight, e.g. in a pocket, there are a number of tactile inputs, all of which can give vital information about the world and how to interact with it: edges, textures, temperatures, etc. These inputs are highly sensitive, with fingertips being able to signify two different points of touch at less than a millimeter apart (Dellon, 1992). In order to survive in this complex world, people store new experiences we encounter into categories, defined by the similar features of its assigned members, and then use their knowledge of the categories (Bruner et al., 1956), or their knowledge of the categories' individual members (Nosofsky, 1992), to affect our behavior with experiences yet to come. These categories may be naturally defined, such as breeds of animals like dogs and cats, or subjectively defined much like different styles of architecture. Regardless of how it is defined, the features of the animal or building will determine how it is categorized and how we interact with it.

While there has been a great deal of research into the phenomenon of categorization abilities of both humans and animals, little investigation has been done on the impact of altered or restricted experiences with the items to be categorized. The concept of a restricted experience is simple: an experience in which less than full exemplar exposure is provided. This type of experience is not uncommon and is in fact pervasive throughout life. Often the total perception of an object is rendered incomplete either by an occlusion from other objects in the environment, the three dimensional nature of the object itself, or by limited or unavailable information from the multiple modalities needed to assess it, such as when a physician can view an organ but must also touch or palpate in order to accurately assess its health.

A recent inquiry into partial experience was provided by Taylor & Ross (2009), who investigated how experience with partial exemplars influences attention to nondiagnostic features. To begin, they defined diagnostic dimensions as detectable forms of information which can be used to reliably identify the correct category membership of an item while nondiagnostic dimensions have similar values in both categories and can only be used to identify a specific stimulus within a category rather than provide information about the stimulus' category membership. In their experiment, participants studied stimuli which were defined by 6 binary dimensions of which 4 were diagnostic and 2 were non-diagnostic. In the control condition full access to all dimensions was provided while in the partial condition the subject was denied access to two dimensions chosen at random. After training, those participants with partial experience gave higher category typicality ratings to items which included nondiagnostic information which was prototypical than participants who had full experience with all exemplars. Taylor & Ross concluded that this result occurred because participants with partial experience attended to additional nondiagnostic features, despite these features' inability to provide information which would identify the category of a given stimulus, to compensate for their inability to rely on the presence any one particular diagnostic feature or set of features. However, nondiagnostic information, as they defined it, was only informative of proximity of a stimulus to the prototype of the category to which it belongs and provided no information about the category to which the stimulus belonged. This may imply that partial experience increases dependence on the relation and similarity of the experienced dimensional values of stimuli to learned prototypical values. This possibility would have been undetected because the nondiagnostic dimensions of the stimuli had the same prototypical values regardless of category membership.

As is common in categorization research, Taylor and Ross (2009) used stimuli that were solely visual. While there is some basis for studying incomplete visual information brought about by objects obscuring the field of vision or the three dimensional nature of the stimuli themselves, sometimes vision or any sense alone cannot account for all information necessary to make a correct categorization judgment. Guessing at the contents of a sealed bag, which could contain a weighted box or a bowling ball, would be a much more successful venture if one is able to pick up the bag as well as see it as opposed to either of those sensations alone. Multimodal categorization is more complicated and time consuming than single modality research and it has not received much attention.

Regardless of its difficulties, the research community has not avoided analyses of multimodal experiences entirely. Cooke et al. (2007) investigated multimodal categorization and found evidence showing that the weight given to stimulus dimensions in similarity judgments was influenced by the modality used to experience the stimuli. They also found that the probability of category membership for a stimulus with another increased with its influenced similarity. Ultimately, this experiment still falls short of a complete analysis of multimodal categorization for two important reasons: (1) their participants engaged in a free sorting categorization task and not in a task in which categories were previously designated; and (2) the dimensions used to define the stimuli (macro geometry and micro geometry) were both accessible by both modalities of vision and touch. Perhaps as a result of this, a majority of their subjects used unidimensional rules in their category formations rather than using absolute similarity across both dimensions to make their category judgments. As well, the nature of the experiments allowed for no learning and transfer results, which precludes comparison to the vast collection of categorical studies.

This leads us to the overall proposition for the present experiment: to test the effects of partial and complete exemplar experience between two categories, defined in multiple dimensions and modalities, where separation among the categories could be achieved only by integration of the defining dimensions. To further analyze the effect of partial experience, participants were presented with two situations: a condition in which the dimension most necessary for successful integration and resulting categorization was (1) presented in the same modality as one of the other dimensions with which it must be integrated to form a separation of categories or (2) presented in a different modality than the other dimensions with which it must be integrated to form an effective separation of categories. This is a convoluted subject, but it is important to understand what it is and what it implies.

In previous research which required the integration of dimensions (Ashby & Gott, 1988) the typical number of dimensions presented was the minimum of two. As an example of this, Figure 1 shows the category structure used in some pilot research: two categories of ellipses as defined by two dimensions of length and width (Fig. 1). The rule for effective categorization, that Category A ellipses tend to be wider and shorter than those stimuli in Category B, required integration of dimensions. There is such a high degree of overlap between the categories in the values along either single dimension that, with a few exceptions, knowing only the length or width of a stimulus would not allow for an effective categorization. The relationship between the dimensions is what is important; integration of information from both dimensions is necessary for effectively separating stimuli into the two categories. It is important to note that while subjects can learn to integrate two dimensions effectively when the two dimensions are provided simultaneously, the task of learning the dimensional relationships would be much more difficult if the two dimensions were never presented simultaneously.

However, this difficulty may not necessarily be the case when categories are defined by multiple (more than two) dimensions. Given multiple dimensions, it becomes possible to have relationships between dimensions which provide an effective means to separate items into distinct categories and relationships between dimensions which do not.

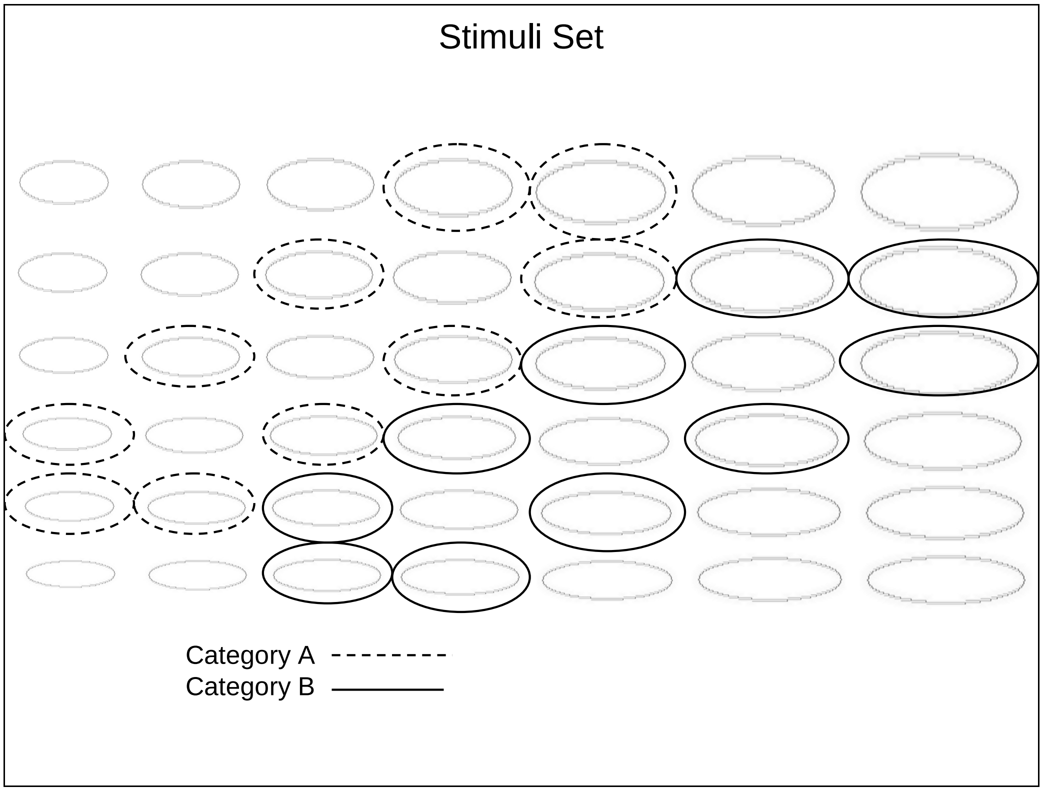
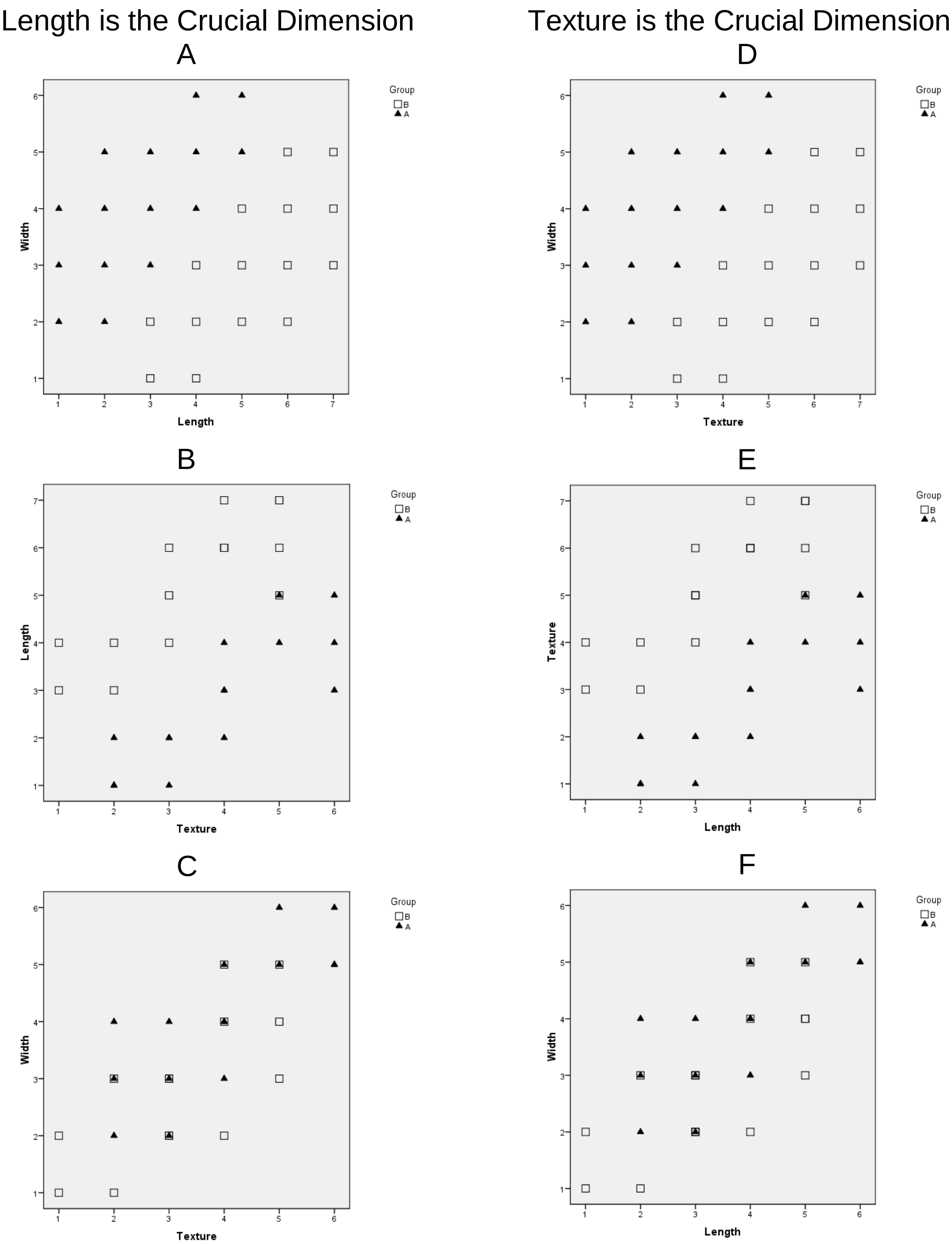


Figure 1. Example of Two Category Division by Multi-dimensional Rule.

Borrowing from the theme of diagnostic and nondiagnostic dimensions, one can conceive of this scenario thus: multidimensional categories can be defined by both diagnostic relationships and nondiagnostic relationships between the dimensions. In the present study, participants were provided with the opportunity to use a single dimension that, when integrated with one or both of two other dimensions, provided a diagnostic relationship that effectively separates the categories, while the other two dimensions had a nondiagnostic relationship. This dimension, which is most vital to effective category separation, is referred to as the "crucial dimension". The dimensions with which the crucial dimension must be integrated to form a diagnostic relationship are its “related dimensions”.

Figure 2 shows the stimulus population for the two categories used in this experiment, and it should be clear what makes the crucial dimensions vital to the process of separating the categories. Figures 2A through 2C depict the stimulus dimensions of the condition in which length is the crucial dimension. A clear linear separation exists between the two categories when information is integrated from the dimensions of length and width (Fig. 2A) or length and texture (Fig. 2B) but not between texture and width (Fig. 2C) and as such length is the dimension most necessary to distinguishing between the two groups. Likewise, figures 2D through 2F depict the stimulus dimensions of the condition in which texture is the crucial dimension. In this condition, is important to note that there is little distinction between the two groups when analyzed by the dimensions of width and length (Fig. 2F), and therefore it is impossible for one to correctly distinguish between the groups using only visual information.

While the crucial dimension is of importance in itself, its value in category separation may be best realized if one tampers with the experience of it. Using the context of partial exemplars, what would be the effect of disconnecting the experience of the crucial dimension from the experience from both of its related dimensions as opposed to the disconnection of one? To clarify, two examples about cookies are



Note. Any item represented by a square filled with a triangle represents an item from both categories that share the same values.

Figure 2. Stimulus Dimensions.

presented: first, imagine someone is trying to determine what kind of cookie is present within a container. There are two possible kinds of cookie: triple chocolate chip, their favorite, and oatmeal raisin, their least favorite. In this example, both types of cookie are defined by their color (black to white), size (big to small), and smell (strong to subtle). For the first example, both types of cookies are highly similar in color and smell, yet the preferred cookie is generally larger, yet when making comparisons simply choosing the larger cookie does not always result in making the preferred choice. Therefore, in order to pick the preferred cookie it is necessary to pick the cookie that is not only large but is also either darker in color or stronger in scent. In this example one can easily identify the desired cookie simply by experiencing the visual dimensions. Due to simultaneous access to both the crucial dimension of size and a related dimension of color the chooser's ability to pick the correct cookie would not be seriously affected if one was unable to smell the cookies. However, in the second example, both types of cookies are highly similar in their color and size, yet the preferred cookie has a smell that is stronger. Similar to the first example, simply choosing the stronger smelling cookie does not always result in the preferred choice and it is therefore necessary to also know the color or size of the cookie or both. As such, if the person was blindfolded, their ability to choose the preferred cookie would be seriously hampered. They would access to the crucial dimension of scent, but their inability to simultaneously access either of the related dimensions of color or size would prevent integrating that information and therefore prevent an effective separation of categories.

When we combine the manipulation of crucial dimensions with the variable of partial or complete exemplar experience, we end with four separate groups to be compared against one another: complete experience with length as the crucial dimension, complete experience with texture as the crucial dimension, partial experience with length as the crucial dimensions, and partial experience with texture as the crucial dimension.

It was the general hypothesis that when an item is examined, but one or more dimensions are missing, the participant will know that the missing dimension must have some value and will therefore attempt to fill in the missing information with a prototypical value from memory. This would result in predictable deviation of the observer defined value of the missing dimension from the actual value. This, in turn, should result in predictable changes in behavior of participants who have incomplete experiences in object recognition and categorization. The specific predictions given this hypothesis and the alternative hypothesis proposed by Taylor and Ross (2009) follow.

Learning Hypotheses

First, it is hypothesized that the modality of the crucial dimension should have no effect in learning if all dimensions are presented simultaneously. Ernst (2007) showed that normally non-related experiences of vision and touch, namely luminance and resistance to pressure, can be integrated "if the value of one variable was informative about the value of the other" by showing that participants who experienced the two dimensions as being correlated, had a lower threshold to discriminate stimuli with correlated dimensions than stimuli with non-correlated dimensions. Therefore, it was predicted that there should be no difference in learning categorization performance between participants in the length and texture crucial dimension conditions if participants have full experience with the learning stimuli. If there is a difference we would assume participants in the texture crucial dimension condition would perform worse in categorization tests across learning and transfer than subjects who studied stimuli with length as the crucial dimension due to a potential difficulty resulting from forcing participants in the texture as the crucial dimension condition to integrate across modalities.

Second, when texture is the crucial dimension there should be reliable differences in categorization performance across learning trials and transfer between subjects in the partial and complete experience conditions. The integration of the crucial dimension with its related dimensions should become more difficult, if not impossible, if the related dimensions are not simultaneously provided with the crucial dimension, as when texture is the crucial dimension, as opposed to if one of the related dimensions is provided simultaneously with the crucial dimension, as when length is the crucial dimension (See Fig. 2). As such, for participants with partial experience, those that studied categories with texture as the crucial dimension should have worse categorization performance in learning compared to participants whose crucial dimension was length.

These two predictions would result in little difference in categorization accuracy across learning trials between participants with full experience and length as their crucial dimension, participants with partial experience and length as their crucial dimension, and participants with full experience and texture as their crucial dimension, yet all three of those groups of participants would perform very differently across learning trials from participants with partial experience and texture as their crucial dimension. These results would be evidenced by a series of planned analyses: (1) a three way interaction between the repeated measure of test number and the between subject variables of experience and crucial dimension and (2) several repeated measures ANOVAs will be done to assess the differences between unique sets of conditions. The second set of analyses will be conducted to further analyze the results of the first to see if the results follow the predictions above.

Recognition Hypothesis

Next, it was the general hypothesis of this study that participants would fill in missing information with prototypical values in learning. This should result in an increased prototype effect during transfer categorization tasks. However, this result would also be indicative of the theory put forth by Taylor and Ross (2009). In order to assess if participants were filling in missing information with prototypical values, participants were given a forced choice recognition test immediately after the learning trials. The participants were asked to identify the stimuli they had previously experienced from a group which contained the old stimulus that they had already studied and two other stimuli, near exact copies of the old stimulus, which had been altered along a single dimension to be either more prototypical or were given a random value; a value randomly selected from the set of values the participants had experienced in learning. If participants with partial experience were filling in missing information with prototypical values they would be more likely to falsely recognize the prototypical stimuli as the old stimulus than a stimulus with a random value. We would therefore predict that participants in the partial experience condition would show a significant increase in incorrect selection of the more prototypical stimuli than participants which had full experience. However, if participants are simply dividing attention when information is missing, as hypothesized by Taylor & Ross (2009), participants with partial experience would have no stored memory of missing dimensional values from learning and would, therefore, be just as likely to falsely recognize the stimulus with a randomized value as one with a prototypical value. In addition, participants with complete experience should be just as likely to falsely recognize the prototypical stimulus as the random stimulus as these choices would be errors and errors should have no bias.

Transfer Hypotheses

At the onset of this experiment, it was unknown what effects partial experience would have on categorization accuracy at transfer. Following our predictions from the learning trials, there were several predictions made. First, the three-way interaction predicted across learning trials would be present as an interaction between experience and crucial dimension conditions in regards to the old stimuli at transfer: there would be little difference in categorization accuracy between participants with full experience and length as their crucial dimension, participants with partial experience and length as their crucial dimension, and participants with full experience and texture as their crucial dimension, yet all three of those groups of participants would perform much better than participants with partial experience and texture as their crucial dimension. This result is uncertain because participants would have full experience with the stimuli at transfer regardless of their experience during the testing blocks, which may negate the impact of experience at transfer. Second, if participants with partial experience in learning are replacing missing information with prototypical information, they should be more likely to correctly identify prototypes than participants who had full experience with all stimuli in learning. Other possible analyses about categorization performance at transfer may have interest, but it was unclear how partial experience and its interaction with crucial dimension would impact performance beyond the two prior predictions. Still, some exploratory analyses were done assessing the impact of the relative similarity of a stimulus to the category prototypes on categorization accuracy.

Chapter 2
METHODS

Participants

Participants were 60 undergraduate students from the ASU 101 Introductory Psychology research pool and they received 1 hour of research credit for their participation in the experiment.

Stimuli

Learning and Transfer

Stimuli were 30 ellipses that varied in length, width, and texture. The texture dimension was determined by the grade of sandpaper placed on the back of the objects. The stimulus populations for the two crucial dimension conditions are shown in Tables 1 and 2, with the stimuli's level presented in the given dimension: 1 through 6 for Width with each increase in level representing a 15% increase in width, 1 through 7 for Length with each increase in level representing a 15% increase is length, and 1 through 7 with each increase in level representing an increase in grade of sandpaper from the previously given grades. Seven grades of sandpaper were used that were discriminable: 36, 80, 180, 220, 320, 800, and 1600.

Forced Choice Recognition

The forced choice recognition test described later made use of multiple non-studied stimuli of varying dimensional values. These approximately twenty new stimuli (Table 3 & 4) were generated by altering a dimensional value of an old stimulus to a new value: one which had the differing dimension set to a prototypical value (a Prototypical stimulus) and

Table 1

Stimuli and Their Dimensions

Length is Crucial Dimension

Group A				**Group B**			
Stimulus	Width	Length	Texture	Stimulus	Width	Length	Texture
A1	2	1	3	B1	1	3	2
A2	2	2	2	B2	1	4	1
A3	3	1	2	B3	2	3	1
A4	3	3	4	B4	2	5	3
A5	4	2	3	B5	3	4	2
A6	4	4	4	B6	3	6	3
A7	5	3	6	B7	4	5	5
A8	5	5	5	B8	4	7	4
A9	6	4	5	B9	5	6	4
A10	6	5	6	B10	5	7	5
A Proto.	4	3	4	B Proto.	3	5	3
A11	3	2	4	B11	2	4	3
A12	5	4	4	B12	4	6	3
A13	5	1	2	B13	1	6	1
A14	6	2	6	B14	2	7	5

Table 2

Stimuli and Their Dimensions

Texture is Crucial Dimension

Group A				**Group B**			
Stimulus	Width	Length	Texture	Stimulus	Width	Length	Texture
A1	2	3	1	B1	1	2	3
A2	2	2	2	B2	1	1	4
A3	3	2	1	B3	2	1	3
A4	3	4	3	B4	2	3	5
A5	4	3	2	B5	3	2	4
A6	4	4	4	B6	3	3	6
A7	5	6	3	B7	4	5	5
A8	5	5	5	B8	4	4	7
A9	6	5	4	B9	5	4	6
A10	6	6	5	B10	5	5	7
A Proto.	4	4	3	B Proto.	3	3	5
A11	3	4	2	B11	2	3	4
A12	5	4	4	B12	4	3	6
A13	5	2	1	B13	1	1	6
A14	6	6	2	B14	2	5	7

Table 3

Forced Choice Recognition Stimuli

Dimension Levels of Stimuli in the Length as Crucial Dimension Condition

Category A			Category B		
Original	Prototypical	Random	Original	Prototypical	Random
1v 2-1-3	2-1-4	2-1-2	1v 1-3-2	1-3-3	1-3-1
2tw 2-2-2	3-2-2	1-2-2	2tl 1-4-1	1-5-1	1-6-1
3v 3-1-2	3-1-4	3-1-1	3v 2-3-1	2-3-3	2-3-4
4tw 3-3-4	4-3-4	6-3-4	4tw 2-5-3	-	-
5v 4-2-3	4-2-4	4-2-5	5v 3-4-2	3-4-3	3-4-4
6tl 4-4-4	-	-	6tl 3-6-3	3-5-3	3-2-3
7v 5-3-6	5-3-4	5-3-2	7v 4-5-5	4-5-3	4-5-7
8tl 5-5-5	5-3-5	5-1-5	8tl 4-7-4	4-5-4	4-6-4
9v 6-4-5	6-4-4	6-4-3	9v 5-6-4	5-6-3	5-6-5
10tl 6-5-6	6-3-6	6-7-6	10tw 5-7-5	3-7-5	6-7-5

Note. Stimuli dimensions are presented in order of width-length-texture. “v” denotes stimuli studied visually only in the partial conditions, “t” denotes stimuli studied haptically only. ”w” and “l” denote the dimension that is altered (width and length) for those stimuli studied haptically only.

- denotes stimuli which have been removed from the test.

Table 4

Forced Choice Recognition Stimuli

Dimension Levels of Stimuli in the Texture as Crucial Dimension Condition

A			B		
Original	Prototypical	Random	Original	Prototypical	Random
1v 2-3-1	2-3-3	2-3-5	1v 1-2-3	1-2-5	1-2-7
2tw 2-2-2	4-2-2	1-2-2	2tw 1-1-4	3-1-4	4-1-4
3v 3-2-1	3-2-2	3-2-6	3v 2-1-3	2-1-5	2-1-4
4tw 3-4-3	4-4-3	5-4-3	4tw 2-3-4	3-3-4	5-3-4
5v 4-3-2	4-3-3	4-3-1	5v 3-2-4	3-2-5	3-2-3
6tl 4-4-4	-	-	6tl 3-3-6	-	-
7v 5-6-3	-	-	7v 4-5-5	-	-
8tl 5-5-5	5-4-5	5-3-5	8tl 4-4-7	4-3-7	4-5-7
9v 6-5-4	6-5-3	6-5-7	9v 5-4-6	5-4-5	5-4-2
10tl 6-6-5	6-4-5	6-2-5	10tl 5-5-7	5-3-7	5-2-7

Note. Stimuli dimensions are presented in order of width-length-texture. “v” denotes stimuli studied visually only in the partial conditions, “t” denotes stimuli studied haptically only. ”w” and “l” denote the dimension that is altered (width and length) for those stimuli studied haptically only.

- denotes stimuli which have been removed from the test.

one which had the differing dimension set to a random value (a Random stimulus). For each of these stimuli, the altered dimension for the

Prototypical and Random stimuli was within the inexperienced modality for their original stimulus, i.e. a stimulus which was explored visually but not haptically would have its texture altered. For those original stimuli studied haptically either length or width were altered. These stimuli were also used in the complete experience conditions.

Procedure

Learning

Participants went through six blocks of test trials in which the 20 learning stimuli were presented random order. Depending upon their experience condition participants studied the stimuli either completely or partially. Participants in the complete experience condition were allowed to see the front of the ellipse and were allowed to touch its back simultaneously. In the partial experience condition, participants were restricted in their experience with individual stimuli: for items with odd numbers (A1, B1, etc.) participants were only allowed to see the stimuli and therefore could only assess the dimensions of length or width, and for items with even numbers (A2, B2, etc.) the stimuli were hidden behind a curtain and participants were only allowed to touch the back of the stimuli and asses the texture of the stimuli. After experiencing a stimulus by whatever means they were allowed, participants then gave a category assignment for that stimulus and received feedback on whether their assignment was correct. After completing a test block, a new test block began using the same stimuli presented in another random order.

Forced Choice Recognition

Following the 6th test block, subjects underwent two final tests. First they underwent a forced choice recognition test. Subjects were instructed at the beginning of the test that one of the three stimuli with which they were presented was one they had experienced in the previous learning trials and that their task was to select the one they believed was old. For each trial, subjects were presented with the three stimuli, old, prototypical, and random, (Tables 3 and 4) one at a time. They were allowed to explore these stimuli both visually and haptically and were allowed to study the stimuli as many times as they needed to make their judgment. The order of presentations of these stimuli within the group (Old, Prototypical, and Random) was random and the groups (e.g. A1, B3, etc.) were presented in a random order.

Two issues arose in this test: first, in the length crucial dimension condition there are four old stimuli, A4, A6, B4, and B6, for which their Prototypical stimuli would have been exactly alike (Table 3). This could result in a false sense of recognition or, conversely, a feeling of recognition could result in awareness of the stimuli as being “new” by presenting the same stimulus twice during the course of the test. In order to avoid either outcome, only one of each pair was presented: A4 and B6. Second, for participants in the texture crucial dimension there were four stimuli whose generated Prototypical stimulus was the same as the old stimulus: A6, A7, B6, and B7. There was no way to resolve this, so all four stimuli, and their accompanying stimuli were omitted in this test.

Transfer Classification

After the forced choice recognition test, subjects received a transfer test that included all old and six sets of new stimuli (two for each category): a prototype constructed to possess the mean values of the three dimensions of the stimuli in their assigned categories, two exemplars situated within the learned category boundaries (A11, A12, B11, B12), and two exemplars situated outside the category but more similar to a certain category than the other (A13, A14, B13, B14). The new exemplars within the categories are defined as *low distortion* exemplars because they are highly similar to their category's prototype and the new exemplars outside the categories are defined as *high distortion* exemplars. For the dimensional values of these stimuli view Table 1. Subjects were allowed to explore all stimuli both visually and haptically. The stimuli were presented randomly, and the subject made a judgment if each stimulus belonged to category A or B. Subjects did not receive feedback on their responses.

Design

The major dependent measures on the learning and transfer tests were the accuracies in participants' classification judgments and recognition choices in the force choice recognition test. Experience condition (complete, partial) and crucial dimension (texture, length) were manipulated as between subject variables and test number was a within-subjects variable.

Learning

The measure of learning was the classification accuracy of stimuli across the learning test trials. As such, the comparisons of interest are between the groups with different experience conditions and crucial dimension conditions and a repeated measure of test number. A repeated measures ANOVA was conducted with the fixed factors of experience and crucial dimension. Further repeated measures ANOVA contrast analyses determined whether each group of participants had a significant linear trend.

Forced Choice Recognition Test

The measure of this test was tracking which stimulus of the three in the presented group (Original, Prototypical, and Random) that a participant chose as the old stimulus. These choices were translated into probabilities of selection, e.g. when presented with the three stimuli associated with stimulus A1, participants had a probability of 0.50 of choosing the Original stimulus, 0.40 of choosing the Prototypical stimulus, and 0.10 of choosing the Random stimulus. Comparisons of choices will be made between experience and crucial dimension conditions through a set of t tests: (1) a set of independent samples t-tests comparing choice of stimuli (old, random, prototypical) between groups with full and partial experience and (2) crucial dimension as well as (3) a set of paired sample t-tests for groups of participants to assess the changes in recognition choices between conditions.

Transfer Classification

The measure of this test was correct category assignment of stimuli into groups A or B. Comparisons in classification performance between the experience and crucial dimension conditions were made on the basis of two factors: (1) stimulus type, e.g. old and (2) relative similarity of the stimulus to the two group prototypes. For comparisons of stimulus type between conditions, the classification performance of varying types of stimuli were averaged across participants of the given condition: old stimuli (A1 through A10 and B1 through B10), new outside category stimuli (A13, A14, B13, B14), new within category stimuli (A11, A12, B11, B12), and the two group prototypes.

The other analysis of interest involved the similarity of stimuli to the prototypes of both groups: the stimulus' relative prototype similarity. When comparing stimuli according to their relative prototype similarity, a measure of similarity was created by measuring the distance of the stimuli to the two prototypes in the constructed dimensional space and then subtracting the smaller value, the distance of the given stimulus to the prototype of its own category, from the larger value, the distance of the given stimulus to the prototype of the opposite category. The higher the value of this relative similarity for a given stimulus, the more similar to its own prototype and dislike the other prototype it was. As such, a stimulus in category A which is both highly similar to its prototype while also highly similar to the other will have a lower score than another stimulus in category A which is just as similar its category's prototype as the first stimulus but is less similar to the prototype of category B. For the purpose of analysis, the stimuli were broken into three groups based upon their relative similarities to the two prototypes: strong stimuli (12 stimuli in total) had the highest scores, medium stimuli (9 stimuli in total) had the second highest, and weak stimuli (9 stimuli in total) had the lowest scores.

Chapter 5

RESULTS

Learning

Figure 3 shows the mean proportion correct across the six training blocks as a function of the four learning conditions. Overall, there was a significant increase in categorization performance across tests, $F(5,280) = 27.680$, $p<0.001$, $\eta^2=0.331$. Follow up analyses revealed that there were significant linear trends across learning trials regardless of conditions: (1) when participants had full experience with length as CD, $F(1,14)=25.184$, $p<0.001$, $\eta^2=0.643$; (2) with partial experience and length as CD, $F(1,14)= 58.497$, $p<.001$, $\eta^2=0.807$; (3) with full experience and texture as CD, $F(1,14)=15.476$, $p=.001$, $\eta^2=0.525$; and (4) when participants had partial experience with texture as CD, $F(1,14)=7.138$, $p=.018$, $\eta^2=0.338$. As predicted, there was a three way interaction between test number, experience condition, and crucial dimension (Fig. 3), $F(5,280)=2.440$, $p=.035$, $\eta^2=0.042$. The three way interaction reveals that, across learning trials, there was little difference in categorization accuracy between partial and full experience when length was the crucial dimension, but there was a significant difference between partial and full experience when texture was the crucial dimension. In the latter contrast, participants with full experience improved in categorization accuracy faster than participants with partial experience.

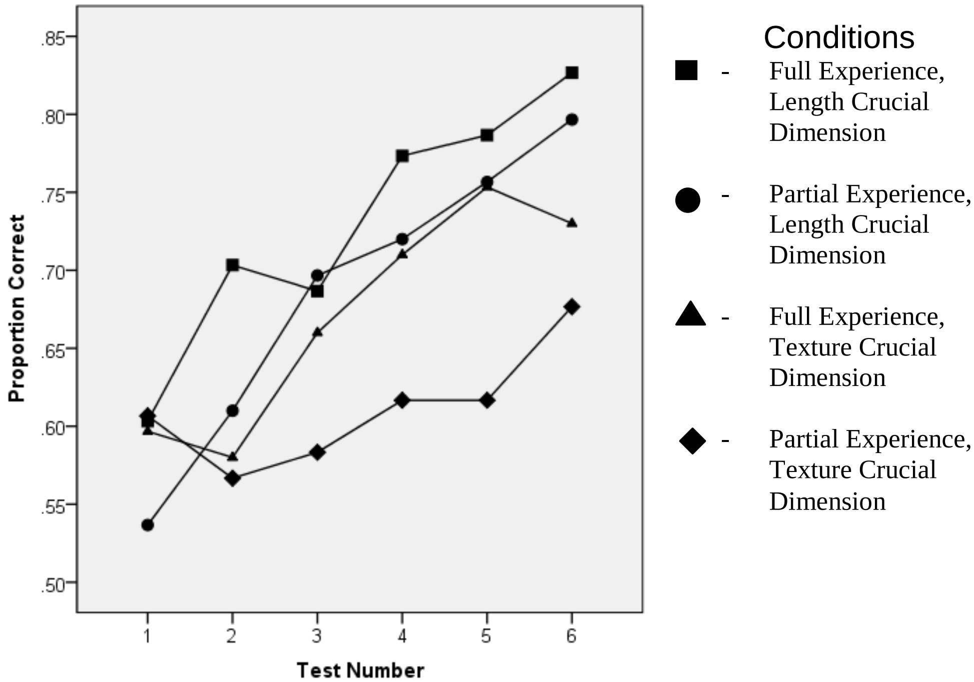


Figure 3. Categorization Accuracy over Learning Trials by Unique Conditions.

Forced Choice Recognition

Figure 4 shows the mean proportion of 'old' responses during the forced choice recognition test as a function of type of stimulus (Old, Random, and Prototypical) and training condition. The first analysis revealed that participants with full experience were more likely to correctly recognize the old stimulus than participants with partial experience, $t(58)=2.242$, $p=0.029$. The next set of analyses separated the participant groups based upon their conditions and compared their overall choice preference. Participants with full experience and length as crucial dimension correctly recognized the old stimulus more than the randomized

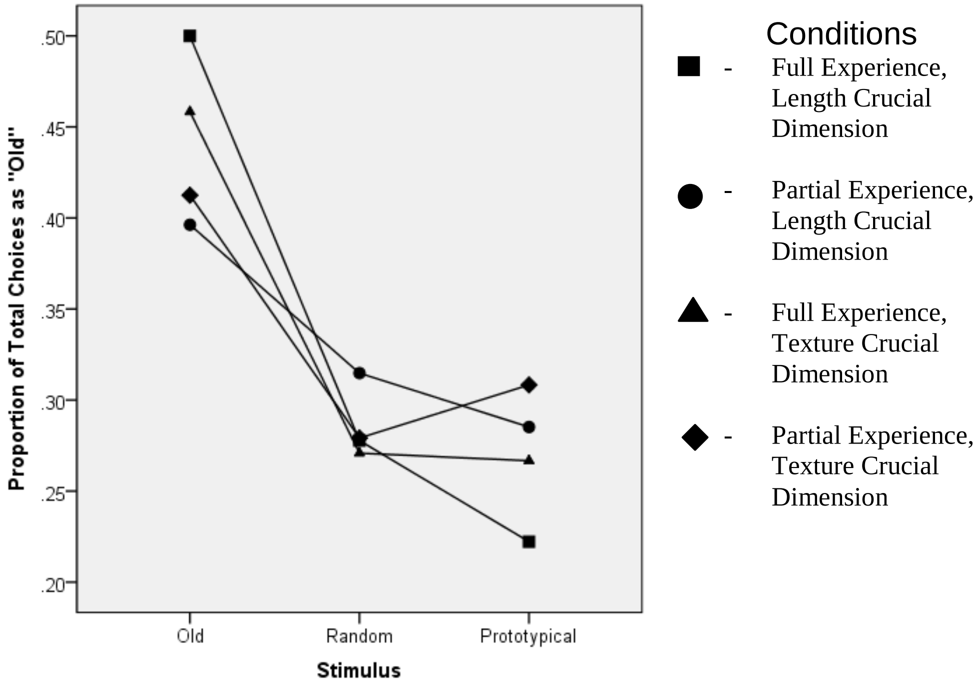


Figure 4. Proportion of Identification of Stimuli as “Old” in a Forced Choice Recognition Test.

stimulus, $t(14)=4.765$, $p<0.001$, and the prototypical stimulus, $t(14)=4.885$, $p<0.001$; they did not differ in their selection of the randomized or prototypical stimulus as old, $t(14)=1.146$, $p=0.271$. Participants with partial experience and length as CD did not correctly recognize the old stimulus more than the randomized stimulus, $t(14)=1.280$, $p=0.221$, but did correctly identify the old stimulus more than the prototypical stimulus, $t(14)=2.624$, $p=.020$, and they did not differ in their incorrect recognition of the randomized or prototypical stimuli, $t(14) = 0.541$, $p=0.597$. Participants with full experience and texture as CD correctly recognized the old stimulus more than the randomized stimulus, $t(14)=2.553$, $p=0.023$, and the prototypical stimulus, $t(14)=3.003$, $p=0.009$, and they did not differ in their incorrect recognition of the randomized or prototypical stimulus, $t(14)=0.069$, $p=0.946$. Participants with partial experience and texture as CD correctly recognized the old stimulus more often than the randomized stimulus, $t(14)=3.264$, $p=0.006$, but did not correctly identify the old stimulus more than the prototypical stimulus, $t(14)=1.609$, $p=0.130$, and they did not did not differ in their incorrect recognition of the randomized or prototypical stimuli, $t(14)=-0.594$, $p=0.562$.

Transfer Categorization

Results from the transfer task were further broken down into two different analyses: item types (old, prototype, etc.) and relative distance of stimuli from the prototypes.

Item Type

Figure 5 shows the proportion correct classifications on the transfer test as a function of stimulus type (prototype, old, new-low distortion, and new-high distortion) as a function of learning condition. The initial analysis evaluated the effect of training condition and transfer stimulus on classification accuracy. Overall, the effect of crucial dimension was significant, $F(1,56) = 7.06$, $p = 0.01$, $\eta^2 = 0.112$, with performance significantly higher when length (0.856) rather than texture (0.759) was the crucial dimension. Performance significantly differed on the various stimulus types, $F(3,168) = 6.13$, $p = 0.001$, $\eta^2 = 0.10$,. Mean performance on the old, new-low, new-high, and prototype stimuli were 0.753, 0.796, 0.892, and 0.808, respectively. Neither the effect of experience (full = 0.825, partial = 0.806) nor any of the interactions was significant, all ps > 0.05.

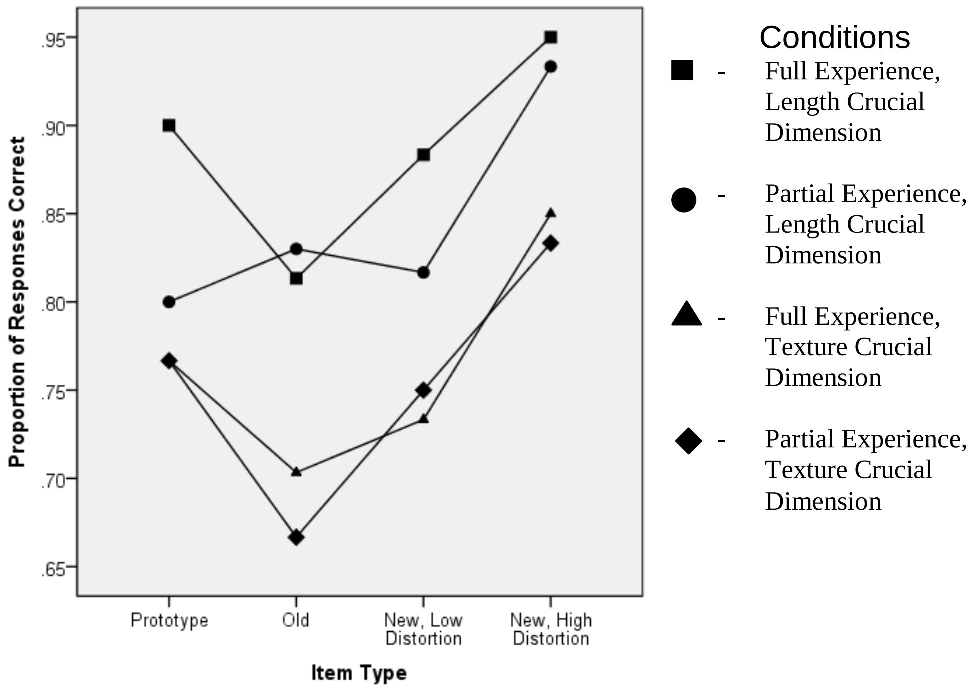


Figure 5. Categorization Performance of Item Types at Transfer.

Several ANOVA tests revealed that participants did not differ in their ability to correctly categorize prototypical stimuli, $F(3,56)=0.687$, $p=0.564$; new, low distortion stimuli, $F(3,56)=1.774$, $p=0.163$; or new, high distortion stimuli, $F(3,56)=0.954$, $p=0.421$; but they did differ in how well they categorized old stimuli, $F(3,56)=6.294$, $p=0.001$ (Fig. 5). A follow up univariate ANOVA revealed that participants with length as the crucial dimension performed better at categorizing old stimuli than participants with texture as the crucial dimension, $F(1,56)=18.096$, $p<0.001$, $\eta^2 = 0.244$

but categorization of old stimuli was not affected by experience, $F(1,56)=0.097$, $p=0.757$, $\eta^2 = 0.002$. There was no significant interaction between the two manipulations, $F(1,56)=0.689$, $p=0.410$, $\eta^2 = 0.012$.

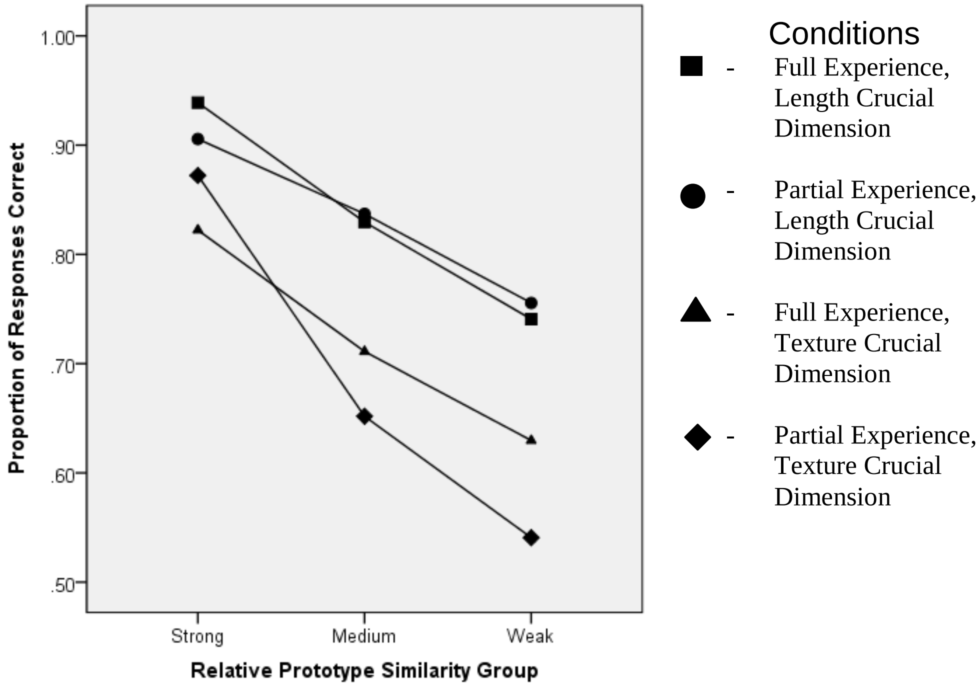


Figure 6. Categorization Accuracy at Transfer by Relative Prototype Similarity.

Relative Prototype Similarity

Figure 6 illustrates the proportion of categorization responses at transfer that were correct as a function of relative prototype similarity. The higher a stimulus' relative prototype similarity the more likely a participant was to correctly categorize it, $F(2,112)=68.792$, $p<0.001$, $\eta^2=0.551$. There was a significant main effect of crucial dimension with participants in the length crucial dimension condition outperforming participants in the texture crucial dimension condition, $F(1,56)=15.473$, $p<.001$, $\eta^2=0.216$, and there was a significant interaction between relative prototype similarity and crucial dimension, $F(2,112)=3.289$, $p=.041$, $\eta^2=0.055$. There was neither a significant main effect of experience condition, $F(1,56)=.304$, $p=0.584$, $\eta^2=0.005$, nor a significant interaction between relative prototype similarity and experience condition, $F(2,112)=.802$, $p=.451$, $\eta^2=0.014$. There was a three way interaction between relative prototype similarity, crucial dimension, and experience condition: categorization accuracy across relative prototype similarities was not affected by experience when length was the crucial dimension, but when texture was the crucial dimension performance decreased faster as relative prototype similarity decreased for participants with partial experience than for participants with full experience, $F(2,112)=3.515$, $p=.033$, $\eta^2=0.059$.

Chapter 6

DISCUSSION

The results indicate multiple effects of partial experience most of which are straightforward while others are more curious. First, the hypotheses regarding category learning were largely confirmed: partial experience had almost no impact on category learning when the crucial dimension was simultaneously presented with one or more of the related dimensions but had a pronounced impact on performance when the crucial dimension was presented alone. In essence, partial experience should not be expected to truly hinder the learning of categories until it interferes with access to necessary information; so long as a diagnostic combination of information is available, participants can learn to distinguish between different categories. While this statement is intensely obvious, it has important implications for other findings of this study.

Second, participant choices made during the forced choice recognition test allow us to make definite conclusions on our hypothesis that participants with partial experience would fill in missing information with prototypical values and they would therefore be more likely to choose the Prototypical stimulus in the forced choice recognition test than participants with complete experience. The alternative hypothesis, based upon the conclusion of Taylor & Ross (2009), was that participants with partial experience would divide their attention amongst available dimensions which would result with participants with partial experience having no bias in their false recognitions and they would choose the Prototypical stimuli just as much as the Randomized stimuli. The general findings of the present experiment were that (1) partial experience interfered with correct recognition of old stimuli, (2) partial experience had no impact on incorrect recognition of the prototypical stimulus, and (3) there were some small changes resulting from crucial dimension in participants' recognition choices. These results indicate that participants do not supply prototypical values for missing information, disconfirming the proposed hypothesis, and instead they support the conclusion of Taylor & Ross (2009).

There are other interesting conclusions regarding the results of this test. The first, conclusion was that partial experience interferes with correct recognition of old stimuli. Correct recognition in a forced choice recognition test demands that participants have, in memory, knowledge of each of the distinct dimensional levels of a previously experienced stimulus in order to distinguish it from its two distracters. As evidence of the difficulty of this task, even participants with full experience did not correctly recognize the old stimulus from all groups. Not surprisingly, the follow up analyses reveal that participants with full experience, regardless of crucial dimension, correctly identified the old stimulus as the stimulus they had previously experienced more than they falsely identified either the prototypical or randomized stimulus. However, there was a split in behavior between participants with partial experience depending upon their crucial dimension condition: those that studied categories with the crucial dimension of texture did not differ in their preference for the old stimuli and the prototypical stimuli while participants that studied categories with a crucial dimension of length did not differ in their preference for the old stimuli and the randomized stimuli. This seems to indicate that there may be differences in how partial exemplars are stored, depending upon the nature of the participants' partial experience. This result must be taken with a fair amount of doubt as, regardless of crucial dimension, participants with partial experience did not differ in their rates of false recognition of the prototypical and randomized stimuli. Regardless, these results indicate that some questions may remain regarding the effects of partial experience on recognition.

The initial predictions for transfer test categorization accuracy were that (1) the three way interaction present in learning would carry over into the transfer test as a two way interaction of experience and crucial dimension for the categorization of old stimuli and (2) participants with partial experience would correctly categorize prototypes more than participants with full experience. The first prediction is based upon the prediction for the learning tests, that there would be a three way interaction between experience and crucial dimension conditions and test trial number: there would be little difference in categorization performance across learning trials between participants with complete or partial experience when the crucial dimension was length but there would be a difference across learning trials between participants with complete experience and participants with partial experience when the crucial dimension was texture. This would arise because participants with partial experience and texture as a crucial dimension would not have access to a diagnostic relationship, preventing them from distinguishing the two categories from one another, while the other conditions would. The prediction was that this would result in a two way interaction between experience and crucial dimension conditions at transfer. Participants with partial experience and texture as the crucial dimension should have been as ineffective at distinguishing the categories at transfer as they were in the test trials.

This prediction, while based upon the same logic as the predictions for the learning test results, was incorrect: there was no interaction between experience and crucial dimension for the categorization of old stimuli at transfer. Instead, only the crucial dimension affected performance as participants with texture as the crucial dimension performed worse at categorizing old stimuli than participants with length as the crucial dimension. It is a possibility that the lack of impact on categorization performance by partial experience may have been caused by the number of trials. Given enough trials, participants may have achieved some form of categorization accuracy ceiling effect for their given crucial dimension. A visual inspection of Figure 3 supports this, as it can be seen that subjects with texture as the crucial dimension slowed in their learning when compared to participants with length as their crucial dimension, even when participants had full experience. Still, the exact reason for this result is ultimately unclear and may be of interest to future research in partial experience.

The second prediction regarding item types at transfer was that participants with partial experience would be more likely to correctly categorize prototypes. This was based upon our general prediction that participants with partial experience would fill in missing information with prototypical information. As our analysis of the forced choice recognition test shows, this hypothesis was incorrect. It is not surprising, then, that this prediction was also incorrect and there was no difference between experience conditions on categorization of prototypes.

The other exploratory analysis of the transfer test involved the relative prototype similarity of stimuli. This revealed an interesting result where relative prototype similarity had a significant impact on how well a participant could categorize a stimulus, with accuracy decreasing about 0.22 across the gradient (from strong, to medium, to weak relative similarity to the prototypes). Interestingly, this gradient was far steeper for the texture-crucial, partial exploration condition, in which accuracy decreased by 0.32; for the remaining conditions, this decrease was about 0.20. This interaction may reflect the interaction found in learning, in which learning of the category structure was mitigated for the texture-crucial, partial exploration, compared to the other conditions. If length was the crucial dimension, participants were able to learn effective category structures regardless of their partial experience because the potentially separate texture information did not need to be experienced and integrated with the visual dimensions in order to construct a diagnostic relationship. Partial experience had a more significant impact when texture was the crucial dimension. In order to learn the category structure, participants with texture as the crucial dimension had to experience and integrate information from the visual dimensions. This was impossible when participants had partial experience, and therefore had no ability to simultaneously experience and thereby integrate the texture of a stimulus with its length or width making it extremely difficult for participants with texture as the crucial dimension to learn the category structure if they had partial experience with the stimuli. Therefore, it is safe to conclude that the effects of experience and crucial dimension on relative prototype similarity at transfer are the result of the effects of experience and crucial dimension on participants’ learning of category structure.

While it is tempting to look at this last conclusion and look for implications into the categorization theory, it is unwise to do so without in-depth modeling. The most obvious reason for this is that relative prototype similarity, while a clear measure involving the proximity of a stimulus to the two prototypes, can easily be conflated with multiple proposed methods of categorization such as decision boundaries (Ashby & Gott, 1988), exemplar similarity (Nosofsky, Kruschke, & McKinley, 1992), and prototype similarity (Homa, Cross, Cornell, Goldman, & Schwartz, 1973). Still, these results show that new issues regarding partial experience must be addressed by these different approaches, such as how to represent missing information in a computational formula. A more specific model analysis is required before making any conclusions on the impact of partial experience in regards to these theories and this is beyond the scope of this study.

In conclusion, the omission of information did not impact either learning or transfer when there was a reliable diagnostic relationship still available such as when length was the crucial dimension. However, when texture was the crucial dimension, learning was negatively affected by partial experience but not transfer performance. While the cause of this is not yet clear, in both learning and transfer participants with texture as the crucial dimension performed worse at categorizing stimuli. This supports the possibility that, overall, it was more difficult for participants to integrate information between the modalities of touch and sight than integrating information present in sight alone. Also, for all conditions, relative prototype similarity strongly influenced the classification accuracy of stimuli at transfer, particularly when texture was the crucial dimension and exploration was partial. Most importantly, little support was found for the hypothesis that subjects would be more likely to recognize the category prototype on a forced choice test. In fact, subjects generally selected the old stimulus, and, when incorrect, selected a stimulus altered randomly as often as a stimulus altered to be more prototypical, regardless if participants' exploration was full or partial and whether length or texture was the crucial dimension. This lends support to the conclusion of Taylor & Ross (2009), that participants divide their attention amongst available information when the presentation of diagnostic information is unreliable.

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