Exploring the role of verbal category labels in flexible cognition

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Abstract

Recent research under the paradigm of the label feedback hypothesis has proposed a causal role for verbal labels in the online learning and processing of categories. Those categories learned along with names are learned faster, and are more robust after learning. The present study seeks to extend this research by considering the relationship between verbal label cues for categories and flexible categorization. Flexibility will be defined as the ability to dynamically activate and modify the cognitive processes of categorization in response to changing task demands. Flexibility is a key trait of human cognitive processes, and flexible categorization is important in creativity, problem solving, and other tasks. In the present study participants must learn to categorize between ‘friendly’ and ‘unfriendly’ aliens either with or without names during training. They then must learn to re-categorize the same stimuli set in one of three different transfer conditions. If labels do indeed act as material anchors upon which to hang categories, and in doing so play a role in maximizing selective attention, labels should also reduce flexibility. While the present study does show a role for selective attention in relearning, no effect of label was found for either category learning or relearning, with one exception; labels facilitated flexibility when a change in selective attention was not involved in the transfer. The inability to replicate previous findings of the role for verbal labels in category learning using similar methodologies raises interesting theoretical issues, questioning the extent to which this relationship applies to linguistic categorization.

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Introduction

Language, along with its use in communication, provides a symbolic system of representation through which a speaker contemplates the world around them. The emergence of the capacity for symbolic representation transformed human cognition (Deacon, 1997; DeLoache, 2004), permitting abstract thought and making possible cultural transmission of knowledge across generations. Yet the relationship between language and other cognitive processes is still controversial. For many of those who view language as a distinct mental module (Gleitman & Papafragou, 2005; Pinker, 1995), language is merely a formal medium that is used to describe mental representations, remaining independent of the concepts they express (Li & Gleitman, 2002). However, recent work in understanding the relationship between language and thought has provided evidence against this disassociation. Instead, these studies have revived interest in a bidirectional relationship between language and thought, suggesting that language is best understood as built upon domain general processes, and thus potentially in a mutually transformative relationship (Bowerman & Choi, 2001; Gumperz & Levinson, 1996).

With this discussion on the role of language in uniquely human cognitive abilities comes a renewed interest in the possibility that the structure language provides to the speaker's perceptual world may have a causal influence on the types of thoughts the speaker has. With habitual use of the specific set of conceptual symbolic representations afforded by a language, an individual may be restricted to these representations in problem-solving and other cognitive tasks. How a language may accomplish this is not well understood, and so the present study seeks to illuminate the influence of language on the ability to dynamically activate and modify online cognitive processes, those processes brought to bear on a particular situation or task, in response to changing task demands.

The ability to think and act adaptively and flexibly, while not a uniquely human trait, is a mental capacity uniquely well developed in human cognition and intelligent behavior (Deák, 2003). For example, in spatial reasoning tasks adult rats perform a spatial reorientation task through use of solely geometric information (Cheng, 1986), while adult humans relocate themselves more flexibly, by conjoining geometric and non-geometric information to help specify their location (Hermer & Spelke, 1994; Hermer-Vasquez & Spelke, 1999). Flexible cognition itself remains loosely defined, however, and in various studies it is seen as a specific cognitive ability found in specific tasks, a higher-order ability related to executive function, and a measure for divergent thinking (for review see: Ionescu, 2012). For the purposes of the current study, flexible cognition will be defined, following Deák (2003) and Ionescu (2012) as a property of the cognitive system, rather than a specific mechanism or process, on par with accuracy or efficiency, for example. Using this definition allows for the creation of a unified paradigm, drawing together research done using a wide variety of methodologies on a number of different cognitive processes. With flexibility considered as a property of a system, one can consider the interactions of different cognitive components. Here we will investigate flexible cognition in one particular interaction; that between categorization and language, specifically verbal labels.

Language and linguistic communication represent a key model of flexible cognitive system. This has been extensively demonstrated in language learning during development;

> “a child must have available a rich representational system and flexible ways of deciding between representations. The child [must] represent [an] intricate set of roles, positional patterns, cues, and conditions... [therefore] language [must]… utilize virtually every aspect of higher cognition’’ (Macwhinney, 1987, quote from Deák, 2003).

From early in development, language and the ability to flexibly make use of cognitive facilities appear to have a close-knit relationship.

Recent work lead by Gary Lupyan on the role of labels in categorization has demonstrated a special status afforded to verbal labels (Lupyan, Rakison, & McClelland, 2007; Lupyan & Thompson-Schill, 2011). Verbal labels participate in the learning of categories, facilitating learning and creating mental categories that are more robust than when the categories are learned without words because the labels become part of the category (Lupyan, Rakison, & McClelland 2007). Others, however, have argued that verbal labels are simply a more maximal form of feedback, and are therefore simple a form a facilitation, separate from the categories themselves (Maddox et al 2008). In order to tease these two views apart, the present study attempts to consider the role of verbal labels in flexible cognition, more specifically in the ability of individuals to flexibly adjust their categorization strategies. If the verbal labels do play a causal role in shaping and modulating mental representations or category structures, increasing the processes of selective attention and creating more robust categories, then labels should also reduce the ability to change these categories when required by feedback from the environment. On the other hand, if verbal labels are a form of feedback, and facilitate category learning without becoming a part of the categories themselves, labels should not negatively effect relearning, and indeed having labels may continue to positively influence category relearning.

The ability to learn new categories is a critical part of flexibly accommodating to the speaker’s world. However, no study has looked directly at the influence of verbal labels on the perceptual and attentional processes that underlie conceptual flexibility. Similarly, while a number of studies have looked at how language aides in an individual’s ability to flexibly adjust the level of categorization, such as switching from taxonomic to thematic, for example categorizing a dog as an animal (taxonomic) or part of a hunting scene (thematic) (Blaye, Bernard-Peyron, Paour, & Bonthoux, 2006), far fewer research has investigated how verbal labels may influence individuals flexibility in adjusting their categorization strategies in regards to *the same domain on the same level,* focusing on relearning and restructuring of categories. Thus, the present investigation seeks to illuminate further the relationship between verbal labels and the cognitive processes underlying categorization. In developing an understanding of the role that verbal labels play in the construction and maintenance of categories, we further our understanding of the relationship between language and domain general cognitive processes, such as categorization, upon which language is built.

Background

Flexible Cognition

Flexible cognition forms the basis for problem solving, creativity, and a number of other traits that support human adaptability. Yet it is an elusive concept to pin down, and has only been studied in earnest since the 1990s (Deák, 2003). A variety of operational definitions have sprung up in the literature, ranging from studies of executive control, task switching, to the ability to process and switch between multiple representations. According to the cognitive flexibility theory, cognitive flexibility is the ability to restructure knowledge in multiple ways depending on the changing situational demands. Flexible thinking has also been thought of as a component of creativity, and has thus been considered an independent and stable trait that varies measurably across individuals (Simonton, 1996; Torrence, 1988; Runco, 1993). Diminished cognitive flexibility has been noted in a number of neuropsychiatric disorders, including attention deficit hyperactivity disorder (Etchepareborda & Mulas, 2004).

More recent studies in cognitive neuroscience have begun to explore the role of the brain in flexibility. These experiments have implicated the prefrontal cortex (PFC) as a localized area involved in the modulation of flexibility (Rougier, Noelle, Braver, Cohen & O'Reilly, 2005).

The PFC is involved in the active maintenance of patterns of neural activity over time, and also in adaptively updating these patterns by switching between active maintenance and rapid updating of new representations (O'Reilly, Braver, & Cohen, 1999). While many other areas in the brain have been demonstrated to be involved in flexibility, including interactions among frontal, parietal, and temporal areas (Robbins, 1998), the PFC's involvement in flexibility is of particular interest in that it also plays a key role in a wide range of language tasks (Gabrieli, Poldrack, & Desmond, 1998). The importance of this research paradigm is that the region plays a critical role in both flexibility and language processes, providing further motivation for exploring the relationship between the two.

For the purposes of the present study, flexible cognition will be defined following Deák (2003) as the "dynamic activation and modification of cognitive processes in response to changing task demands." Rather than being viewed as a specific cognitive skill (Colzato, Huizinga, & Hommel, 2009), or a higher-order ability such as executive control (Jacques & Zelazo, 2005), flexibility is best understood as a property of cognitive processes, comparable to accuracy or efficiency (Ionescu, 2012). This definition of flexibility in cognition allows for the unification of a large number of studies, including categorization, language use, problem solving, that have considered flexibility in a large number of different cognitive processes. This definition also allows for distinguishing between variability of behavior, that is making different responses in different situations, from true flexibility, which demands a switch or relearning of associations between stimuli and response (Deák 2003).

Flexibility in Categorization

Categorization, the process by which discriminably different things are classified into groups and thus responded to in kind, is a ubiquitous cognitive operation relevant to all aspects of daily human life. The literature on categorization is vast, stretching back to the classical model of concepts and categories proposed by Frege (1952). Modern theories of categorization typically can be divided between prototype and exemplar based models. Prototypes, first defined by Rosch (1973), represent the most central member of a given category. Prototype-based categorization theory posits that category learning involves learning the category prototype (Rosch 1973, 1975; Smith & Minda, 2002). In contrast, exemplar-based theories posit that upon encountering some stimuli, its similarity is measured to the memory of every previously encountered exemplar from each potentially relevant category. Some object will then be thought of as belonging to a particular category for which the sums of similarities is the greatest (see e.g. Nosofsky, 1986).

How categories are learned then is a key issue in understanding the relationship between verbal category labels and flexibility in cognition. A number of studies have demonstrated that the relationship between perceptual descriptions, how the category or concept is defined, and conceptual representations, such as verbal labels, are mutually influential (Goldstone, 2000; Lin & Murphys, 1997). It is widely accepted that adults tailor the categories they form to the current demands of the task or situation (Barsalou 1983), and can spontaneously group one object in several ways (Ross & Murphy, 1999). Categorical flexibility is thus a within-subject variable corresponding to the ability to switch, (or relearn), between different representations of a given object or set of objects. The development of this ability to switch between categorization strategies has been well documented through childhood (see e.g. Agnes et al, 2006). Children around three years of age demonstrate perseverative categorization following a switch in a card-sorting game, for example continuing to sort based on color after instructed that now the child was to sort by shape, (Zelazo, Frye, & Rapus, 1996). It is only later that children accurately and flexibly adjust to the switch in the rules of the game. Deák (2000) has shown that by the age of 4 years, children are able to associate different matches to the same stimuli when given instructions to do so (but see Blaye, et al, 2006 for an argument for the separation of response flexibility and categorical flexibility). Thus, flexibility in cognitive processes including categorization appears to develop sometime after the age of three.

Studies that directly consider categorical flexibility in adults are less common. Maintenant and colleagues (2011) have recently demonstrated reduced ability to flexibly use taxonomic relations in older populations (see also Smiley & Brown, 1979). Other related work has focused on the way that prior categorization experience influences perceived similarities (e.g., Goldstone, Lippa, & Shiffrin, 2001). According to these studies, conceptual and categorical flexibility must be accompanied by flexibility in perceptual and attentional processes (Goldstone 1998). In a study on conceptual flexibility of object categories, (in this case faces), Goldstone & Steyvers (2001) considered two mechanisms for perceptual category flexibility: selective attention and differentiation of dimensions. Selective attention refers to the process by which, in categorization learning, individuals will learn to attend to some features of the objects to be categorized and ignore irrelevant features. Dimensional differentiation refers to the psychological process by which previously unified dimensions become perceptually and cognitively distinct. Attentionial shifts in regards to the dimensions of a stimulus require that the different dimensions that make up a stimulus can be attended to individually. In order to study these mechanisms, Goldstone & Steyvers (2001) applied a learning/transfer task, wherein subjects first learned to distinguish between two categories, and then at transfer had to relearn the categories based on altered relevance of dimensions. Thus, dimensions that were previously diagnostic for categorization may become unimportant, or the reverse, allowing for a measure of the role of selective attention. Similarly, new dimensions may exist in the transfer stimuli set that did not exist in the training set, allowing a separate measure of dimensional differentiation. The authors teased apart selective attention and dimensional differentiation through transfer conditions that required relearning involving previously learned dimensions, (i.e. those that have been differentiated), in contrast with those that introduce novel, and therefore non-differentiated dimensions at transfer. They found that the cost of transfer away from the selectively attended dimension was partially alleviated when the dimensions involved were those that the participants had learned to isolate from one another.

Categorizing objects requires that stable characteristics of a set of objects are perceived as invariant. In order to represent this invariance, which allows for inferences and appropriate responses to be made, the representation must highlight some properties and ignore others (Harnad, 2005). Selective attention has been demonstrated vividly in the development of shape-biases in object learning by children (Landau, Smith, & Jones, 1988; Soja, Carey, & Spelke, 1991; Imai & Gentner, 1997), where a general strategy of focusing on shape demonstrates a broad-range implementation of selective attention towards those features while ignoring dimensions such as color and texture. Selective attention is key to models of categorization such as Nosofksy's (1986, 1991) exemplar model, in which an object is measured in similarity compared to a stored category member in a multidimensional space. The distances between objects along dimensions within this space compress and expand depending on the categorization required and the attention given to particular dimensions. In this way perceptual categorization becomes adapted to specific tasks and environments by increasing attention paid to those features and dimensions that have proven useful during category learning, while at the same time reducing the perceptual salience of those features and dimensions that have proven unimportant

(Goldstone & Steyvers, 2001). When these shifts in attentional weighting are inappropriate to a subsequent task, it is highly likely that performance will suffer (Goldstone, 1994).

Dimension differentiation is the mechanism by which dimensions that are originally psychologically fused together become separated and isolated (Garner 1976, 1978, Goldstone & Steyvers 2001, but see Love & Markman 2003 for an argument for the non-independence of stimulus dimensions). Dimension differentiation plays a role in learning and may characterize child-to-adult development and novice-to-expert training, with a general trend of movement from integral dimensions to perceptually and cognitively isolated. For example, Melcher & Schooler (1996) provided evidence that expert, but not novice, wine tasters isolate independent perceptual features, discrete points along a particular dimension, in wine.

The present study will investigate the relationship between selective attention and flexibility with a focus on just one subset of the demonstrably wide range of categorization literature; that of rule-based perceptual categories. Rule-based categories are those that are learned and reasoned with in an explicit fashion (Maddox, Love, Glass, & Filoteo, 2008; Feldman, 2003). The rule-based category's diagnostic processes are consciously accessible, and verbally expressible, meaning that the category learners should be able to explicitly explain their categorization strategies. This type of category structure is particular useful for a study of transfer in that typically only one perceptual dimension is relevant for categorization at a time. The task of the learner is then to discover this relevant dimension and map the dimensional values to the relevant categories (Ashby & Maddox 2005).

Categorization and Verbal Labels

The processes of selective attention and dimensional differentiation in categorization lead stimuli to be considered more similar when in the same category, and more easily distinguishable when in different categories (Harnad 1987). Recent studies have demonstrated that verbal labels may influence these processes, speeding up the attentional processes that focus on diagnostic properties of categorized objects. It has been suggested that simply sharing a label, (which will be defined as a name for a category), causes two objects to be perceived as more similar than those that do not.

The role of linguistic development in shaping conceptual development has been well established in the literature (Casasola 2005, Gentner & Goldin-Meadow 2003, Gumperz & Levinson 1996, Levinson 1997, Lupyan, Rakison, & McClelland 2007, Spelke & Tsivkin 2001, Waxman & Markow 1995, Yoshida & Smith 2005). A lively discussion currently exists in the field as to the extent of this causal relationship, especially in consideration of cross-linguistic differences in semantic categorization in such diverse areas as color (Winawer et al, 2007), space (Majid et al, 2004), and metaphor comprehension (Boroditsky, 2001). For many researchers, verbal labels are simply that, names that get attached to categories that do not play a role in category learning or maintenance (see e.g. Hespos & Spelke, 2004).

However, recent research has pointed to a more bi-directional relationship, with category labels acting as top-down feedback in perceptual category learning. Verbal labels have been shown to aide in the learning of novel object categories (Lupyan, Rakison, & McClelland 2007). There are a number of explanations for this relationship. Some researchers have provided evidence that labels work to provide a more maximally informative feedback during categorization learning, making rule-based categories, categories that are learned explicitly with diagnostic rules that are easily verbalized (Ashby & Maddox 2005), easier to learn (Maddox et. al 2008). Others consider labels as physical, external symbols upon which our categories are hung, creating a unique category structure qualitatively different than categories without labels

(Clark 2006, Lupyan, Rakison, & McClelland 2007). In this sense, language is viewed as a self-constructed cognitive niche, with words providing the material scaffolding required to promote abstract thought and reason, by providing a target for more basic capacities such as statistical and associative learning (Clark 2006). These latter theories have been generalized by Lupyan as part of a new Label Feedback Hypothesis framework (Lupyan, 2007).

The Label Feedback Hypothesis (LFH) states that in learning to associate category names with entities, labels become associated with the distinctive features or dimensions of the labeled category. Upon activation, the label produces top-down modulation of lower-level perceptual representations, influencing bottom-up activity such as the perception of a visual stimulus. Labels interact with category learning, with named categories becoming more ‘categorical’, or more abstract, and less idiosyncratic. According to Lupyan “by virtue of the learned associations between words and their referents, words participate in the creation of categories they denote, and function on-line to selectively shape the perceptual representations that underlie our conceptual knowledge” (Lupyan, 2007 pg. 2). Thus, labels have been shown to influence the perceptual processes of selective attention and dimensional differentiation explored in the previous section.

This has been demonstrated experimentally a number of times. Lupyan and colleagues (2007) had participants learn to distinguish between two categories of alien exemplars, either with or without the additional presentation of a label, (either *leebish* or *grecious*), during feedback. Participants given arbitrary labels learned to distinguish between the two types of aliens significantly faster than participants who did not receive labels during training. A later study by Lupyan and Thompson-Schill (2011) demonstrated, making use of a picture identification paradigm, that this positive correlation between labels and effective category learning is not extended to words that do not directly refer to an object or to non-speech sounds (such as 'meowing' for the category <cat>, or the sound of a cat meowing), providing evidence that conceptual representations activated by words have a cognitively special status above those activated through nonverbal or non-labeled means.

Labels have been implicated in the development of categories, but what of their maintenance and adjustment? Lupyan, Rakison, and McClelland (2007) also provided evidence that categories associated with verbal labels are not only learned faster, but are maintained more robustly after initially training. If one of the main uses of language is the creation of associations between concepts and words in such a way that the labeled concepts are learned fast and remain more robust, it is possible that a verbal label will also reduce the categorical flexibility by strengthening selective attention to a diagnostic dimension. The present study explores this possibility.

Learning new concepts has been shown to be a critical part of our ability to flexibly accommodate to the world in which we interact, on a number of different levels, from perceptual to abstract (Goldstone & Steyvers, 2001; Gershkoff-Stowe et al,1997; Markman & Makin, 1998). Less work has been done considering the role of language beyond development in modifying the selection and encoding of information based on a dynamically changing environment, in regards to contextual demands and previous experience. Given the relationship between language and cognitive flexibility (Deák, 2003), the present study explores the role of label on the ability to flexibly adjust one's categorization patterns to match changes in the environment. If, as suggested by Maddox et al (2008), labels simply aid in categorization of rule-based categories by providing a more maximally informative feedback mechanism, it is possible that labels may also affect positively categorical flexibility, or at least will not play a role in reducing flexibility. However, categories, especially those for objects, seem to abstract away from the specifics of exemplars and focus attention on the historically predicative features that indicate category membership. If this is true, then verbal labels for object categories may reduce the ability to flexibly modify one's representations and behavioral responses to changing stimuli or task demands. If labels work as a sort of material symbol on which we hang our concepts and categories (Clark 2006), or in some other way stabilize abstract ideas (Lupyan et al, 2007), than it is quite possible that verbal labels will reduce categorical flexibility by facilitating this abstraction. Given the number of studies that demonstrate linguistic label's effect on similarity judgments (Davidoff, 2001; Goldstone, Lippa, & Shiffrin 2001) and negative effect on non-typical categorization strategies (Brojde, Porter, & Colunga, 2011), it seems likely to be the case that verbal labels in some way reduce the ability to flexibly adjust the categorization processes involved. These studies indicate that category names modulate item representations online through top-down feedback; as a label is paired with individual exemplars, it becomes associated with features most reliably associated with the category. A third possibility also exists; namely, that labels, whether or not they aid in category learning, will not affect flexibility in categorization.

The Current Investigation

The present study seeks to add to the literature on labels and categorization by investigating the rigidity of categorization strategies both with verbal labels and in their absence. Previous literature supports the possibility of three different outcomes. It is possible that labels acting as maximal feedback in category learning with a benefit of faster and better learning in such a way that if a change is required by the environment, the use of labels will lead to faster adaptability. However, if labels build stronger categories in such a way that the cognitive salience of non-defining features are inhibited, it is quite possible that these labeled categories would be more resistant to change than those ‘weaker’ categories developed without categories. Thus, to support this hypothesis, I would expect to find a main effect of label in the data, but also an interaction between label type and phase, (whether before or after transfer), moving in opposite directions; a positive effect of label during training, as has been shown previously, and a negative effect of label after transfer. A third possibility is that labels do not influence flexibility in recategorization in any way. Given the role that selective attention plays in category development, it seems likely that a verbal label strengthens the focus on the particular diagnostic dimension salient for determining category membership. The goal of the present experiment is to test whether this relationship between verbal labels and the reinforcement of attention to salient dimensions also works to reduce the ability to flexibly shift one’s categorization strategy in response to changing task demands in the environment. When an individual needs to restructure the categorical divisions of a particular domain, especially when this restructuring requires a shift in attention to a previously non-diagnostic dimension, having verbal labels for categories already established could slow down the relearning curve.

The influence of verbal labels on learned sensitivity to dimensions was tested using a category-learning paradigm in which participants received an initial and transfer category learning task. As with the Lupyan et al (2007), participants learned to approach one type of alien and retreat from another. The stimulus domain consisted of gabor patches varying on the orientation of lines, and their frequency, or thickness (see *Materials* below for more detail), that appeared as the aliens’ eyes. They then had to relearn the categorization in one of three conditions: 0, 90, and 180 degree transfers (see figure 1 for a visualization of the transfer conditions). The 0 degree transfer condition, also called the *identification* condition, will have no change between the training and testing, and so will be the base condition upon which the other transfer conditions will be measured. In this transfer condition, the relevant dimension during learning, orientation, stays relevant after transfer. In the 90 degree transfer condition, the diagnostic dimension itself will switch from dimension A to dimension B, and so half of each category learned during the first phase will be part of the new categories during transfer testing. Participants in this condition learn to categorize based on the frequency of the lines during learning, and then must change their strategy to categorize based on orientation at transfer. Lastly, for the 180 degree transfer condition, the diagnostic dimension will remain the same from training to transfer, but the escape/approach responses will switch categories. In this transfer condition, as with the 0 degree transfer condition the relevant dimension does not change, however the participants must learn to switch behavioral responses. See figure 3 below for visualization of conditions. Thus there were 6 conditions in total (see table 1). By observing transfer categorization performance, equivalent across conditions, we can access how the initial learning process, both with and without labels and across relevant dimensions, influence subsequent categorization tasks. Having all conditions transfer to the same categorization allows for a clear relationship between how initial categorization influences participants’ ability to relearn categorization strategies flexibly (see e.g. Goldstone & Steyvers, 2001)

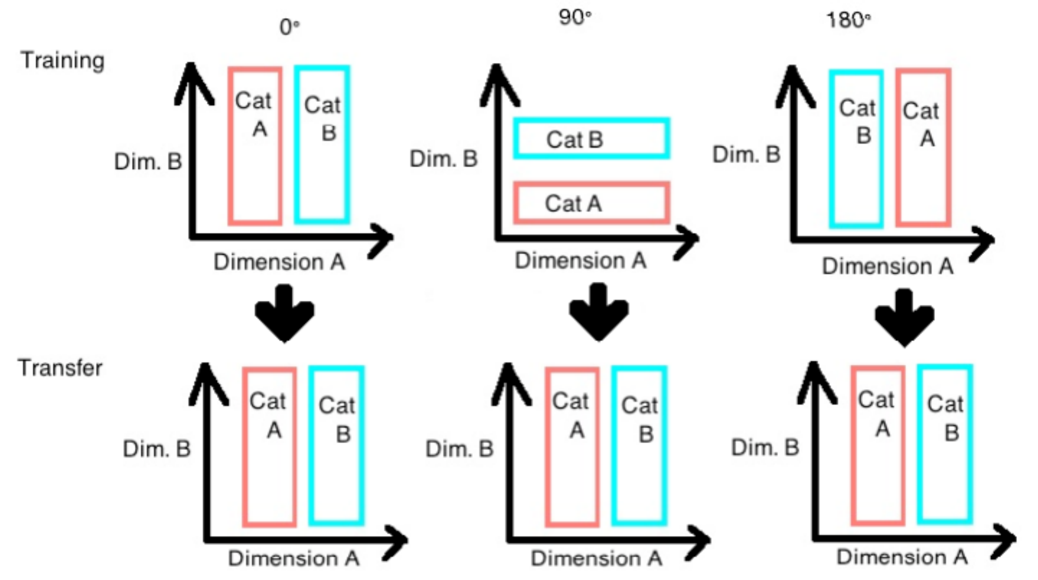

Figure 1: Visualization of training condition and the three transfer conditions. Dimension B represents the frequency of the lines of the aliens' eyes, Dimension A their orientation.

Condition 1	Label	0 degree transfer
Condition 2	Label	180 degree transfer
Condition 3	Label	90 degree transfer
Condition 4	No Label	0 degree transfer
Condition 5	No Label	180 degree transfer
Condition 6	No Label	90 degree transfer

Table 1: Condition matrix.

Methodology

Subjects

174 participants were drawn from the undergraduate psychology subject pool at the University of Colorado, Boulder, in exchange for course credit. Subjects were randomly assigned to either *label* or *no label* training conditions and *0 degree*, *90 degree*, and *180 degree* rotation transfer conditions, giving six groups of participants (n = 29).

Materials

In an attempt to replicate previous findings on the effect of verbal labels for shape-based categories in a new domain (Lupyan, Rakison, & McClelland, 2007), categorization strategies will be organized based on the non-shape features of the object. To this end, 36 gabor patches were created, varying along the dimensions of frequency and orientation (see figure 2 for examples, Appendix D for all stimuli), and were then implanted into the eyes of a novel aquatic alien (figure 3). The code and dimensional values of the entire set may be found in the appendices below. The use of the gabor matches is motivated by previous research; gabor patches have a long history of use for visual categorization, and stimuli similar to the gabor patches, single lines varying along the dimensions of orientation and length, have been used previously in a study that demonstrated a positive effect of label on category learning (Maddox et al, 2008).

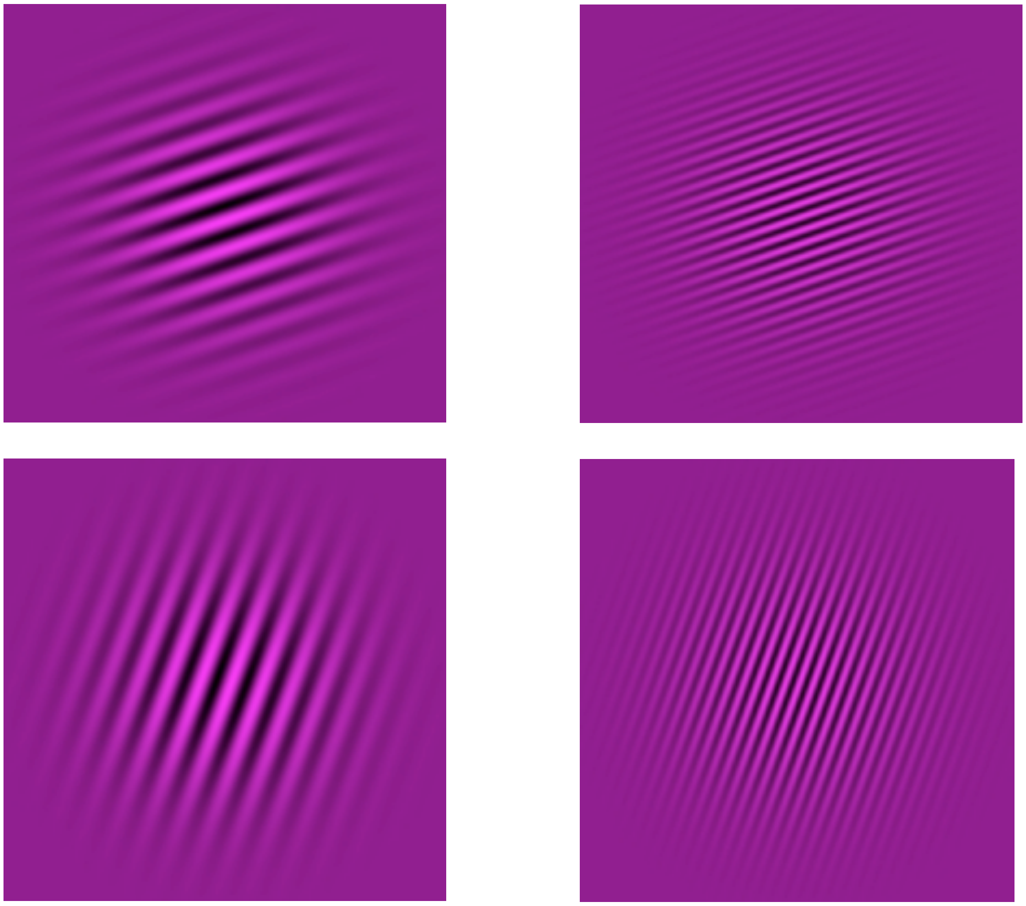

Figure 2: Exemplar gabor patches demonstrating the highest and lowest values of frequency and orientation for the stimuli sets.

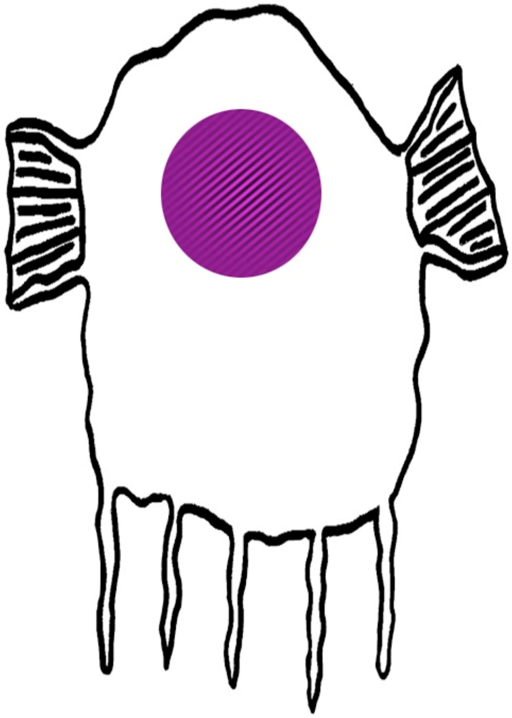

Figure 3: Sample alien exemplar (not actual size).

Training Procedure

Participants will be told that they are to take part in a NASA training program before traveling to a newly found planet. They were told that previous explorers to the planet had discovered two aquatic alien species, one of which was friendly and could be approached, and one that was dangerous and should be avoided. In the *label* conditions, the participants were also told that the previous researchers had found it useful to name the aliens, and that the friendly aliens were named '*Gowachi'*, while the dangerous aliens were named '*Caleba'*. Thus, participants were asked to learn to distinguish between two categories for a set of novel stimuli. Individual trials began with a fixation marker in the middle of the screen, presented for 500 milliseconds. For each trial, an alien will be presented briefly, (500 ms), before a scuba diver appears in one of four locations; above, below, or on either side of the alien. The participant must then decide whether to approach or escape the alien using the directional keys on a standard keyboard. For example, if a scuba diver appeared on the left of a friendly alien, the participant should press the "right" key to move the scuba diver closer, whereas if the scuba diver appeared above an unfriendly alien, the participant should press the "up" key to move the scuba diver away. After a response is made, feedback will be provided in either minimal (a chime for correct, a buzz for incorrect) or maximal (chime/buzz + correct category label) conditions. If the participant waits for longer than 3 seconds, feedback was given without response. After the feedback, the alien and scuba diver remained on the screen for additional 800 ms before the start of the next trial and the representation of the fixation marker. Each unique alien + diver trial was presented once in random order, for a total of 144 trials of training (36 alien exemplars x 4 diver locations). All subjects received the same number of categorization learning trials and had equal exposure to the stimuli across conditions.

Transfer Training

After training was completed, the participants were told that they were now ready to travel to the Planet Teeb. In all but two conditions (the *0 degree transfer* conditions), upon arrival on the planet the participants were alerted that something has gone wrong, and that the aliens are not behaving as they should, (see figure 4). The participants were then presented again with the same 144 trials from training, in random order. During the transfer phase trial, only minimal feedback (chime or buzz) were given in all conditions, irrespective of whether the participants had been trained in the label or no-label condition. In all other regards, each individual trial proceeded identically to a training trial. When the participant had completed the randomly presented 144 transfer trials, they were told that their journey was complete and were asked to answer a short post-study questionnaire regarding the study using paper and pencil (see appendix A).

Figure 4: Transfer warning for all non-identification

Results

Trials were grouped into blocks of 36, giving four blocks each for training and transfer phases. Each correct trial was scored as 1, each incorrect trial as 0, and each trial in which the participant did not answer was dropped. Accuracy in each block was then calculated. 20 participants that did not reach at least 50% accuracy by the end of training were dropped, leaving 79 participants in the label condition, 73 in the no label condition, with 47 participants in the 0 degree transfer condition, 46 in the 180 transfer condition, and 59 in the 90 degree transfer condition.

All results were first analyzed using repeated measures mixed-design analysis of variance (ANOVA), with label type (label vs. no label) and transfer type (0, 90, 180) as between-subject factors and phase (training vs. transfer) and block (1, 2, 3, 4) as within-subject factors. The first question addressed by this analysis is whether participants learned the novel categories. Accuracy performance improved over time in both the training and transfer phases, as shown by a main effect of block, *F*(3, 438) = 103.42, *p* < .001. However, the trajectory of category learning differed depending on whether the participant was in the learning phase or the transfer phase, as evidenced by a significant Block x Phase interaction, *F*(3, 438) = 32.562, *p* < .001. Thus, the learning trajectory in the training phase demonstrated a larger growth in accuracy over the four blocks compared to the four blocks of transfer, where learning continued, but at a slower pace, (see figure 5). The next question addressed was how labels influence category learning and transfer. The participants in the label condition did not learn to categorize significantly faster than those who learned without label, either before or after transfer, as revealed by a non-significant Label Type x Block x Phase interaction *F*(3, 438) = 1.031, *p* = .379. Thus, previous findings of the facilitation of categorization learning by label (Lupyan et al, 2007) were not replicated. Similarly, it was shown that label does not have an effect on category relearning, either positively or negatively.

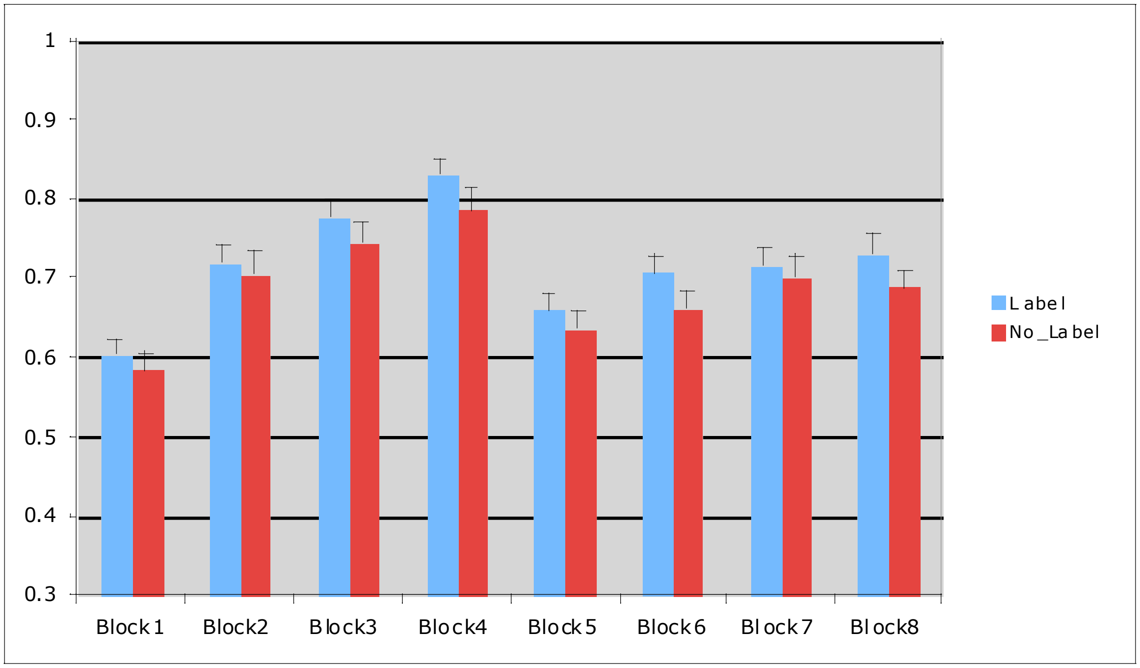

Figure 5: Average accuracy of the four blocks of training and the four blocks of transfer, collapsing across the three transfer conditions. Label did not have a significant affect on the accuracy of any block of training or transfer.

Next I explored the role of transfer type and selective attention. The analysis revealed that the type of transfer influenced performance in a significant Transfer Type x Phase interaction, $F(2, 146) = 80.553$, $p < .001$. Figure 6 shows the training and transfer trajectories of all six conditions. The results illustrate both an advantage among participants who learned to categorize by frequency during training, and a subsequent disadvantage for categorization relearning during the transfer phase among the same group. During training, these participants showed an advantage for learning to categorize by frequency when compared to the two other transfer type groups, for whom the diagnostic dimension was orientation. During transfer, these participants showed a disadvantage for categorization relearning, which required them to change attention from the dimension of frequency to the dimension of orientation. These distinct learning patterns among participants in the 90 degree transfer group were confirmed in two further analyses, with two repeated measure ANOVAs revealing a main effect of transfer type for both the training phase, *F*(2, 146) = 18.289, *p* < .001, and for the transfer phase, *F*(2, 146) = 14.694, *p* < .001.

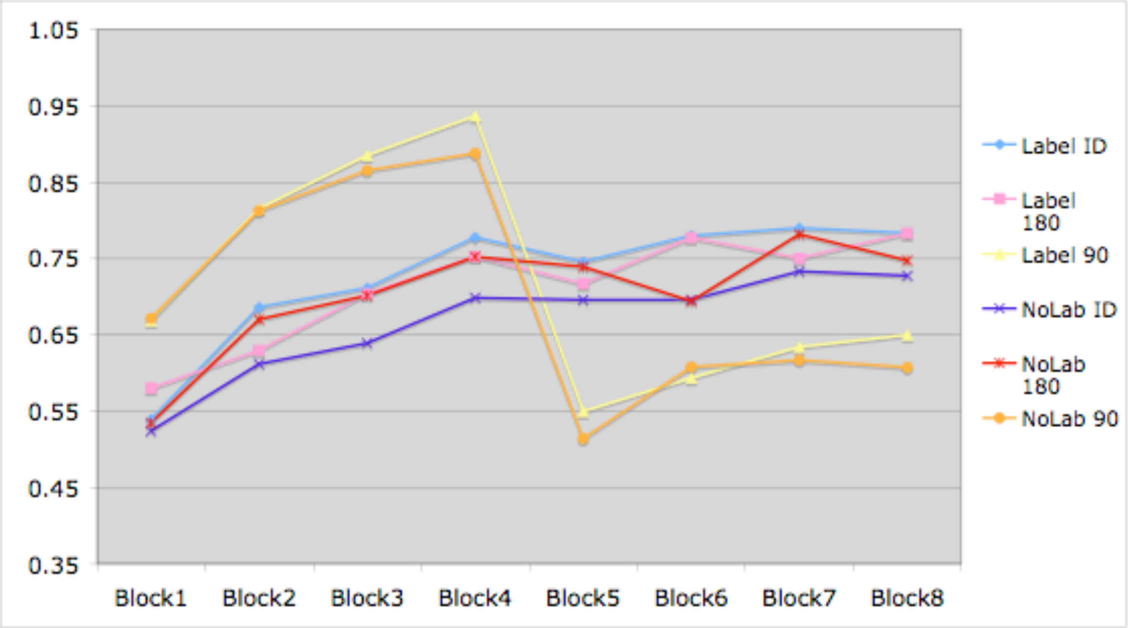

Figure 6: This graph shows the trajectories of each of the six conditions, with the transfer conditions matched with colors; 0 degree transfer condition is light blue (label) and dark blue (no label), 180 degree transfer condition is pink (label) and red (no label), and finally the 90 degree transfer condition is yellow (label) and orange (no label).

In order to consider further the effect of transfer across dimensions, a second repeated measures mixed factor ANOVA was implemented with block as a within-subject factor and label type and transfer type as between subject factors, with just the data from the four blocks of training from the identification, or 0 degree transfer condition and the four blocks of transfer from the 90 degree transfer condition. This was done in order to compare learning trajectories of the same category structure; for both, orientation was the diagnostic dimension and responses were matched to the categories as well. Those participants learning this categorization strategy after first learning that frequency, not orientation, was the diagnostic dimension showed a reduced ability to learn to categorize based on orientation, despite being more experienced with the stimuli set then novels approaching the task for the first time, (see figure 7), with a significant Block x Transfer Type interaction, *F*(3, 306), = 4.19, *p* < .05.

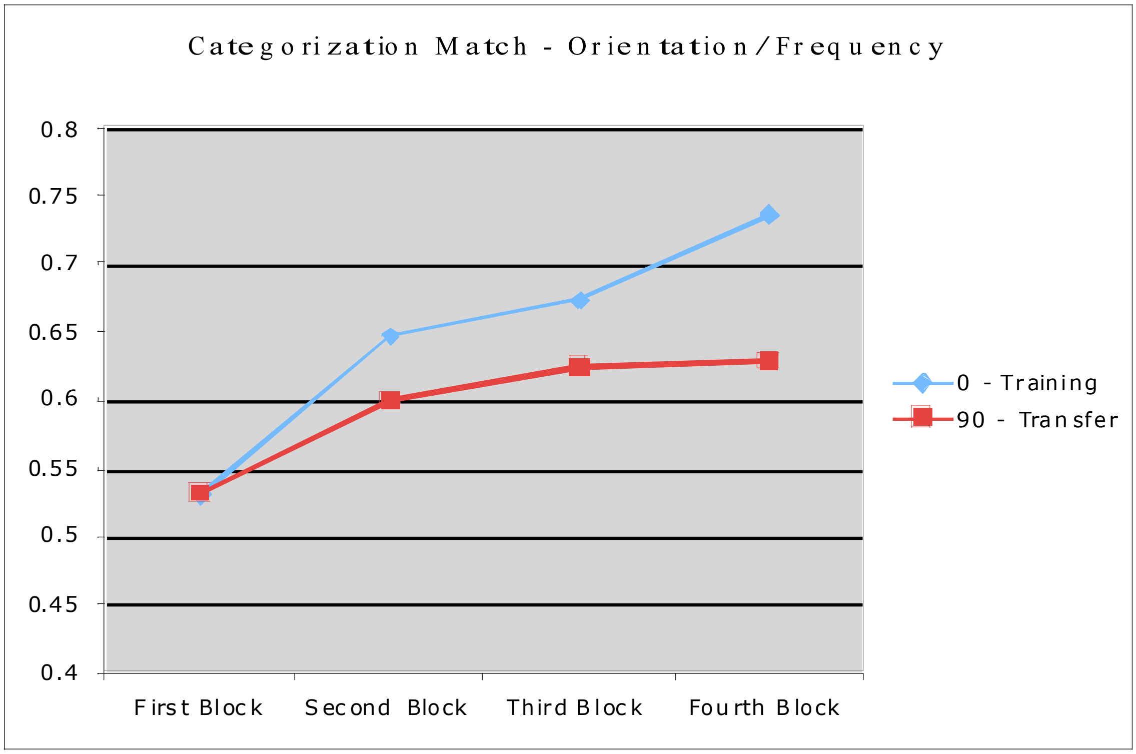

Figure 7: This table shows the reduced learning curve after transfer for participants in the 90 degree transfer condition, compared to the matched categorization of the four blocks of training for participants in the 0 degree transfer condition, illustrating that selective attention reduces flexibility in categorization.

Of final interest is a significant four-way interaction between phase, block, label type, and transfer type, *F*(6, 438) = 2.18, *p* < .05. As this was the only significant interaction involving label, this interaction was analyzed further, with data from the three transfer type conditions entered into separate repeated measures mixed-design ANOVAs. For the 0 degree transfer condition and the 90 degree transfer condition, no significant interaction involving label was found. However, in the 180 degree transfer condition a significant interaction of Phase x Block x Label Type was found, *F*(3, 132) = 4.527, *p* < .05. Here again there was no significant main effect of label *F*(1, 44) = .038, *p* = .846. Separating the data by phase and block for the participants in the 180 degree transfer conditions, I found that for the first two blocks of transfer, there was an interaction between block and label type ($F(1, 44) = 11.595$, $p < .001$), (see figure 8). Thus, the results indicate an effect of label on transfer learning in one of the transfer conditions of the study, with labels facilitating faster learning after transfer for those participants who had to flexibly adjust their behavioral responses.

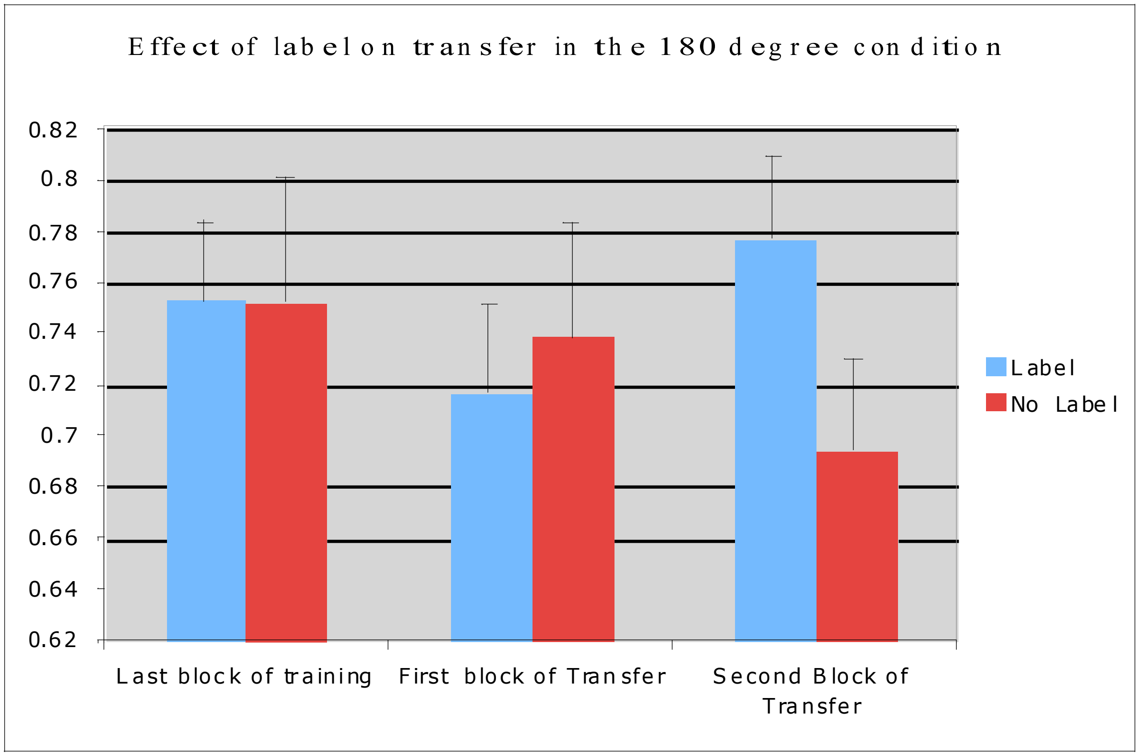

Figure 8: Accuracy averages for block for participants in the label and non-labeled conditions of the 180 degree transfer. Starting from equivalent positions at the end of training, those participants who learned the original categorization along with labels for the categories recovered from the transfer significantly faster.

Discussion

The purpose of the current investigation was to assess the effect of verbal labels on the ability to flexibly adjust categorization strategies when faced with changes in the environment. It was proposed that verbal labels, given previous findings supporting the notion that labels influence categorization, might have an effect on categorical flexibility, possibly by strengthening selective attention. However, no main effect of label on learning was found for either training or during transfer. While there was a significant effect of selective attention on relearning after transfer, the present investigation was unable to replicate previous studies that demonstrate the robust effect of verbal labels on category learning and maintenance.

In one condition, however, there was a significant interaction of label and accuracy for the first half of the relearning phase, the first two blocks after transfer. In contrast with the predictions of the author, who proposed that labels would be detrimental to transfers when the participants were required to switch attention from one stimulus dimension to another, labels play a facilitative role in the relearning of categorization when the boundaries of the categories do not change, but the non-perceptual conceptual associations (whether the aliens were friendly or dangerous) and the related behavioral responses (approach or retreat) do. In facilitating relearning in the transfer in the 180 degree condition,labels allowed those participants who learned the original category-response matches with the help of verbal category names to recover faster from the initial cost of transfer than those participants in the same transfer condition who did not learn the categories with labels. While no main effect of label was found in the current study, previous research that did find this effect proposed that when verbal labels become attached to the categories which they are used to express, the categories become more abstract, with the label acting as a place-holder for the category (Lupyan & Thompson-Schill, 2011). It's possible that this abstraction occurred here as well, although not shown in a main effect, the labels may have had enough of an effect in abstracting away from irrelevant information that the mental representation in this condition became more easily adjusted to the changing task demands. When the structure of the categories do not change, such as when the relevant dimension continues to be relevant, but only the associated non-perceptual features and the following behavioral responses change, these labels continue to act as more easily computed symbolic abstractions of the categories for which they stand. It then becomes possible for the participants in the 180 degree transfer condition to switch from '*Gowachi'* and '*Caleba'* to '*not Gowachi'* and '*not Caleba'* through the logical transformation of negation.

The visibility of this effect of label on transfer flexibility seems to be made possible by the low cost of transfer when the transfer does not involve modulation of selective attention. The cost of transfer, however, was much larger for those who had to relearn their categorization strategies based on a previously unimportant dimension. That is, those participants who learned during training to categorize based on frequency of the lines of the eyes and discovered on the planet that the aliens were either friendly or unfriendly based on the orientation demonstrated reduced ability to flexibly adjust to this new categorization strategy. While selective attention is an important process in the development of accurate categorization (Goldstone, 1998), it also reduces the degree of flexibility present in categorization cognitive processes. Changes that did not involve restructuring the categories, such as learning to respond to the categories of previously 'friendly' aliens as 'dangerous' and vice versa without a change in the diagnostic dimensions, did not appear as a strong impediment to flexibly adjusting to the conditions at transfer, as demonstrated by those individuals in the 180 degree transfer condition. Indeed, the first block of transfer showed a small gain in accuracy, rather than the steep decline witnessed in the 90 degree transfer condition.

Not only was this type of transfer more difficult for participants than relearning friendly/unfriendly distinctions while maintaining attention on orientation, as with those in the 180 degree transfer condition, they also had a slower rate of learning than those approaching the same category learning task for the first time (see figure 7). At transfer, these participants must not only learn to pay more attention to the previously ignored dimension, they must also inhibit attention to the previously diagnostic features (Goldstone & Steyvers, 2001). This is demonstrated by the comparison of the four blocks of training for the identification condition with the four blocks of transfer for those participants whose transfer included a change in the diagnostic dimension; despite having had 144 trials more experience than those approaching the task for the first time they should a reduced learning trajectory. This is a clear indication of the cost that comes with increased attention to one, historically predictive, dimension combined with decreased attention to all other dimensions. By matching the same categorization strategy across training, taken as a control, and transfer, we demonstrate that the positive effect of dimensional differentiation, through which those in the 90 degree transfer condition should have learned to separate the dimension of orientation from frequency (Goldstone & Steyvers, 2001), is not large enough to make the performance of those participants who transferred across dimensions on par with those coming to the same task without any previous experience with the stimuli set, and therefore undifferentiated dimensions. This is, participants who learned to categorize aliens using the frequency of lines in their gabor patch eyes did not find it easier to recategorize the same aliens using orientation of the lines instead, compared to those individuals approaching the task of learning to categorize based on orientation for the first.

This role of selective attention in reducing flexibility was not, however, modulated by the presence of verbal labels corresponding to the categories being learned. While participants did learn the correct categories over the course of training, across all conditions this learning trajectory was not modulated by the presence or lack of label as feedback on individual trials. Similarly, transfer-learning trajectories were not significantly affected for those participants whose initial training included verbal labels, for better or for worse. Previous research has also demonstrated that speakers of a particular language may change their categorization structures.

For example, Hespos & Spelke (2004), while not using labels, did find that English speakers were able to become attuned to the distinction between tight fitting and loose fitting placement events, a distinction not lexicalized in English. The inability of the current data to replicate previous findings on the influence of verbal labels in category learning draws into question the extent to which the Label Feedback Hypothesis can be extended into categorization.

Previous studies that have demonstrated a positive influence of verbal labels have focused mostly on shape-based categories, including the study upon which the present study is based (e.g. Lupyan et al, 2007; Lupyan & Thompson-Schill, 2011). Very early in language learning, English-speaking children develop a bias towards categorizing labeled object categories based on shape (Yoshida & Smith, 2005; Colunga & Smith, 2005). This word-learning bias allows for accurate extension of the category to include appropriate exemplars. It's possible that, as shape-based categories are based on dimensions that are historically predictive for English language speakers, the effect of labels during this type of categorization would be stronger than for other types of learning. This is supported by findings from Brojde, Proter, & Colunga (2011), who, while similarly being unable to replicate a positive effect of label on category learning, demonstrated that verbal labels hinder category learning defined by either texture or brightness. They argue that the advantage of label comes about only when the relevant dimension aligns with the relevant dimensions in previous similar tasks, which in the case of our English-speaking participants would be shape versus features such as orientation and frequency of line. It is possible that since English speakers' experience with the use of object category labels has rendered shape as the most relevant and salient dimension for categorization, the use of labels must be aligned with this dimension in order for it to be facilitative. However, in support to the notion that labels play a role in creating more abstract representations, Brodje et al (2011) did show that when categorization could be based on two features, shape and color, those who learned the categories without labels were more likely to describe their categorization strategy as involving both dimensions, while those in the label condition were more likely to report that they focused only on one of the two dimensions. Again it is shown that even without a main effect of label on category learning, the information stored in the mental representations of the categories appears to be modulated by the presence of label.

A similar reduction in the positive effect of verbal labels on categorization was found in studies that compare rule-based with information-integration category type structures. Information-integration type categories are those whose in which accuracy requires the integration of two or more stimulus dimensions, for example category X would be those stimuli high in value along dimension A while also low in value in dimension B and category Y would be the reverse, making any verbal description of a rule difficult or impossible (Ashby et al, 1998). A study by Maddox and colleagues (2008) demonstrated verbal labels actually hinder the learning of information-integration type categories. For learning these categories, performance is best with minimal ‘yes/no’ feedback.

However, the types of categories learned in the present experiment are differentiated through easily verbalized rules, and do not require the integration of multiple stimulus dimensions. For rule-based category learning, Maddox et al (2008) did demonstrate a positive effect of labels, making use of stimuli very similar to gabor patches (differing on orientation and length rather than orientation and band width). Thus, it seems more likely that rather than being solely applicable to shape-based perceptual categories, the relationship between label and categorization is present, but simply not as strongly for some types of categories than for others.

This positive effect was found over the first 200 trials of training, equivalent to the length of training for the present endeavor, which did not find any such positive effect.

The relationship between verbal labels, and language in general, and categorization continues to be elusive for psychologists and linguists alike. Since Lakoff (1987), scientists have made use of linguistic categories to understand domain general categorical cognition. Yet the relationship between our cognitive categories and the words we use to denote them is still under contention (see Levinson, 1997 for review). The Label Feedback Hypothesis could be seen as a bridge, uniting theories that consider semantic structure and conceptual structure to be one and the same as those theories that consider them to be distinct. The previous findings of the effect of label were online, meaning that label played a role when used for a specific task, and the influence of label continued to play a role after feedback was removed (Lupyan et al, 2007). The role of the label could than be considered tantamount to Slobin's (1996) 'thinking for speaking'; categories brought online through representation by label are modulated by the relationship between labels and highly correlated discrete environmental cues, allowing the speaker to use verbal labels as cues to categories compared to other types of information (Lupyan, 2008). This is supported by research on the effect of labels for color terms on color discrimination, where research has demonstrated that having separate category labels facilitates color discrimination (Winawer et al, 2007).

Lupyan and colleagues (2007) summarized from their finding that the Label Feedback Hypothesis might provide evidence in support of cross-linguistic differences leading to differences in conceptual thought. In the present study, however, the lack of influence on verbal labels in changing flexible adjustment of categorization, both across responses and across diagnostic dimensions argues against this. Verbal labels did not hinder the participants from relearning categories. Thus, differences in language do not lead to an increased inability to rapidly adapt to categorical boundaries that were previously inexpressible in a particular language.

Potential Sources of Error

The above analysis considers the boundaries of the positive effect of verbal labels on categorization. It is possible that this effect does not exist, or at least not strongly, beyond typical, shape-based perceptual categories (Brojde et al, 2011). However, there may also be issues in the present experimental design that should be investigated, considering the unexpected lack of replication. It remains unlikely that the procedure itself could have caused the failure to replicate, as these were based entirely on the Lupyan, Rakison, & McClelland (2007) and Goldstone & Steyvers (2001) studies, including the use of the astronaut explorer story line. Possible confounds arise most clearly in the stimuli used for the present experiment which differed from those in the Lupyan study.

As visible in figure 6 in the results section, those participants in the two 90 degree transfer conditions, whose categorizations during training were based on the dimension of frequency learned much quicker than those in the other 4 conditions, who learned to discriminate based on orientation. This could be explained two ways; either frequency is simply more categorical than orientation and so participants will learn these types of categories more easily, or the array of values along the orientation dimension were too compressed and therefore perceptually distinguishing between them too difficult. While all participants did learn, it's possible either a ceiling effect for the frequency condition or the high level of difficulty for the two orientation dimensions made the effect of label more elusive. In future work, the stimuli will be normed prior to their use in the experiment in order to identify such confounds.

Future Directions

Whether or not the influence of verbal labels is simply weak or does not extend to all types of perceptual categories, it still remains the case that previous studies have found significant increases in the learning and robustness of labeled categories compared to those not given names. The use of the gabor patches was chosen specifically to avoid shape-bias present in English-speakers, as it would have influenced transfer either towards or away from this historically predictive dimension, but it is possible that making use of shape-bias would allow for the effect of verbal label to be studied. These stimuli do have precedence in the literature, as previous research within perceptual categorization research paradigms has been successful with the use of gabor patches (e.g. Maddox et al 2008). However, without first replicating this effect, the question as to the role of verbal labels in flexible categorization remains weakened, for if there is no primary effect of label during learning, there is less likely to be a following effect of label on relearning. For this, it may be necessary to make use of shape-based stimuli sets. Once the main effect of verbal labels on category learning has been replicated, it then becomes possible to secondarily consider the role this effect plays in the ability to flexibly adjust one's categorization strategies.

Future work could also develop a deeper understanding of the role of verbal labels in increasing flexibility when selective attention is not modified. The positive effect of label found for those who relearned their responses to categories, without changing their categories' structures, was an unexpected result and one that could be explored.

Conclusion

Despite a replication of the effect of selective attention across stimuli dimensions, the previous finding of the positive effect of labels as feedback for category learning as not replicated. The failure to replicate a positive effect of label on category learning raises questions as to the strength and extendibility of the label feedback hypothesis. Given the issues raised in the current study raised above, it appears that not all types of category learning benefit from the presence of verbal labels (see also Brojde et al, 2011). Similarly, there is no evidence that labels modulate selective attention in a way that would either help or hinder flexibly adjusting one's categorization strategies. There was however, an effect in a single transfer condition that demonstrates that labels may aide in recovery from transfer when the type of transfer does not involve a change in selective attention. In the 180 degree transfer condition, while labels did not have a positive effect on learning during training, labels did interact with accuracy immediately after transfer, allowing those who learned with labels to recover faster. Future endeavors could continue to develop an understanding of the relationship between concepts, categories, and the words we use to invoke them.

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Appendix A

Post-Study Questionnaire

After finishing the experiment, subjects were asked to briefly answer the following questions:

1. Did you use any strategies when learning the categories?

2. How did you determine which aliens to approach? Which aliens to escape? What was the difference?

3. Did your strategies change when you got the planet? Did the aliens? If yes, how so?

4. *Labeled conditions:* Did you find the alien's names useful when you got to the planet? *Non-labeled conditions:* Did you find it useful to name, or describe the different aliens as you were learning?

5. What was going on in the experiment, or what was the experiment about?

Appendix B

Code for the Creation of Stimuli

The following script was implemented using the program MatLab. The code saves a jpeg of the desired gabor patch. The image is designed to be varied along the dimensions of frequency, or how thick the individual light and dark lines are, orientation, and color. The portions in italics are notes for the user. This code was implemented individually for each of the 36 gabor patches, whose dimensional values can be found in the following appendix.

```
%define sf as desired frequency in cycles/pixel, e.g.:
sf = .09;
%define so as desired orientation in radians (from horizontal), e.g.:
so = 0;
%define fname as desired file name for output, e.g.:
fname = 'gabor.jpg';

colorA = [250 250 250]; colorB = [
0 0 0 ]; midColor=(colorA +
colorB)/2; increment =
abs(colorA+colorB)/2;

size = 200; %height and width in pixels of final image
halfSize = size/2;

[x,y]=meshgrid(-halfSize:halfSize,-halfSize:halfSize);
m = exp(-(x/50).^2-(y/50).^2).*sin((sin(so)*x+cos(so)*y)*2*pi*sf);
m = m.*(abs(m)>0.01);
colorArray = zeros(size+1, size+1, 3);
for i = 1:3
  colorArray(:,:,4-i) = (midColor(i) + increment(i)*m);
end

imwrite(uint8(colorArray),fname,'jpg','Quality',100); %create jpeg file
```

Appendix C

Stimuli Values

36 unique gabor patches were created for the stimuli set, varying along the dimensions of frequency and orientation, while remaining constant in color. Orientation is measured in radians, frequency in pixels per cycle. Color was held constant equally distant from pure red and pure blue. The values for each individual gabor patch can be found in the following table.

Picture name	Orientation	Frequency	Color
o1f1cC	20	0.075	[250 0 250]
o2f1cC	30	0.075	[250 0 250]
o3f1cC	40	0.075	[250 0 250]

o4f1cC	50	0.075	[250 0 250]
o5f1cC	60	0.075	[250 0 250]
o6f1cC	70	0.075	[250 0 250]
o1f2cC	20	0.09	[250 0 250]
o2f2cC	30	0.09	[250 0 250]
o3f2cC	40	0.09	[250 0 250]
o4f2cC	50	0.09	[250 0 250]
o5f2cC	60	0.09	[250 0 250]
o6f2cC	70	0.09	[250 0 250]
o1f3cC	20	0.105	[250 0 250]
o2f3cC	30	0.105	[250 0 250]
o3f3cC	40	0.105	[250 0 250]
o4f3cC	50	0.105	[250 0 250]
o5f3cC	60	0.105	[250 0 250]
o6f3cC	70	0.105	[250 0 250]
o1f4cC	20	0.135	[250 0 250]
o2f4cC	30	0.135	[250 0 250]
o3f4cC	40	0.135	[250 0 250]
o4f4cC	50	0.135	[250 0 250]
o5f4cC	60	0.135	[250 0 250]
o6f4cC	70	0.135	[250 0 250]
o1f5cC	20	0.15	[250 0 250]
o2f5cC	30	0.15	[250 0 250]
o3f5cC	40	0.15	[250 0 250]
o4f5cC	50	0.15	[250 0 250]
o5f5cC	60	0.15	[250 0 250]
o6f5cC	70	0.15	[250 0 250]
o1f6cC	20	0.165	[250 0 250]
o2f6cC	30	0.165	[250 0 250]
o3f6cC	40	0.165	[250 0 250]
o4f6cC	50	0.165	[250 0 250]
o5f6cC	60	0.165	[250 0 250]
o6f6cC	70	0.165	[250 0 250]

Appendix D

Stimuli Set

The 36 gabor patches used as alien eyes.