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# The Power of Infant Statistical Learning and Correlated Cues on Visual Learning

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**Abstract**

The current study investigated whether infants are able to use correlated cues, cues that occur in conjunction with one another, to learn a visual pattern. Correlated cues are clues in the environment that help the individual detect patterns. During the learning phase of the experiment, 16-month-olds were exposed to a continuous sequence of colored shapes superimposed with faces. Each specific shape was superimposed with a distinct face. The shapes and faces act as correlated cues, which help the infant learn the pattern. During testing, infants saw the shapes without the superimposed faces. By removing the superimposed faces one of the cues infants used to recognize the pattern is taken away. On half the test trials infants saw sequences consistent with the shape pattern they viewed during learning. The other half of the trials contained sequences the infant had never seen before. Results indicate that infants look longer at the novel sequences. Although the infants were unable to demonstrate learning, the difference in looking time indicates infants were able to recognize the sequences were not exactly the same.

## Introduction

Infants have the ability to acquire language at an incredibly fast rate. Human language learners, including infants, are sensitive to structure in their environment (Lany & Saffran, 2013). Previous research indicates that infants use statistical learning in language development(Saffran, Aslin, & Newport, 1996). Statistical learning can be defined as the ability to learn about the surrounding environment by detecting patterns (Johnson & Jusczyk, 2003). Previous research indicates statistical learning may play a vital role in speech tasks such as word segmentation, dividing speech into meaningful units (Thiessen & Saffran, 2003).

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Although there is a general consensus that statistical learning plays a part in language development, there is disagreement about the extent of the role statistical learning plays in other domains, such as visual learning (Johnson & Jusczyk, 2003).

Several studies have reported findings suggesting infants use statistical aspects of speech to facilitate hearing. In order to determine infant statistical learning abilities, Saffran, Aslin, and Newport (1996) created a miniature language based on a set of rules, this is known as an artificial language. For example, the artificial language in this study contained no acoustic cues to word boundaries. The lack of pauses between words was meant to resemble a natural learning environment. The study investigated whether infants were able to identify the individual words in fluent speech.The artificial language was a continuous stream of speech consisting of four three-syllable nonsense words presented in a random order. After familiarization with the artificial language infants were presented with test trials consisting of the three-syllable nonsense words infants were exposed to in the familiarization phase orthree-syllable nonsense words that infants had not been exposed to. Saffran et al. (1996) found that infants listened longer to the novel nonsense words they had not been exposed to. This preference indicates that infants recognized the difference between the familiar and novel three-syllable words, which suggests that infants were using statistical learning.This study concluded that statistical learning could play an important role in language development.

Further research addressed whether statistical learning is a domain general learning mechanism. Saffran, Johnson, Aslin, and Newport (1999) studied whether statistical learning is used in other domains, implying infants should be able to track patterns and demonstrate learning in non-linguistic tasks. This study consisted of continuous streams of tones and shifted the focus from linguistic learning to auditory learning. Distinct tones were selected to replace each of the syllables used in the Saffran et al. (1996) study. For example, the syllable “bu” was altered to musical note D. The tones were than placed in a continuous stream, structured like the artificial language. 8-month-old infants were exposed to the tone stream. Test trials consisted of a three-tone sequence. Half the test trials consisted of familiar tone words, meaning the infant heard the entire three-tone sequence during the learning phase. The other half of test trials were composed of tone part words. The part words were created by joining the final syllable of a word to the first two syllables of another word. The listening times of tone part words was greater than the listening times of tone words.

The difference indicates that the infants were able to distinguish between the two sequences. This study suggests that infants were able to use statistical learning to separate tonal sequences. The application of statistical learning to tones demonstrates that statistical learning is used in non-linguistic tasks.

Additional research regarding statistical learning examines the application of statistical learning to visual input. Investigation of visual input is important to clarify statistical learning's domain generality. Either statistical learning is domain specific, meaning the statistical learning mechanism is only triggered when a specific type of input is detected. A different way to think about it may be that statistical learning isn't just assigned to one domain (like language) but that it is a general learning process that can take advantage of information in any form (language, tones, shapes, etc) Saffran et al. (1999). To investigate the question of domain generality researchers applied statistical learning to visual stimuli.

A study by Kirkham, Slemmer, and Johnson (2002) examined the domain generality of the statistical learning by investigating visual statistical learning. Participants included 2-, 5- and 8- month-old infants. Infants were habituated to a continuous stream of six different shapes; the shapes were presented one at a time. During the learning phase of the experiment shapes were presented in pairs where the first shape predicted the second shape. During the testing phase, infants viewed both familiar and novel sequences of shapes. The novel sequences consisted of the same six shapes presented in random orders. Infants in all three age groups showed a preference for the novel sequences. The difference in looking times for the familiar and novel sequences suggests that infants are using statistical learning to learn the visual pattern. The fact that participants can differentiate between the novel and familiar sequences demonstrates that the patterns are recognized and the statistical learning mechanism is being used. The application of statistical learning to visual stimuli supports the idea that statistical learning is a domain general mechanism.

To conduct further research on visual statistical learning and to investigate the role of correlated cues in an infants' learning environments, the Kirkham et al. experiment was modified. The present study investigates how infants respond to correlated cues.Correlated cues are two or more cues in the environment that help the infant recognize the pattern. In a child's learning environment there are multiple cues present.

In a natural environment nothing is ever in isolation, resulting in multiple cues available at any time. These cues in the environment can be used together in correlation to facilitate learning.

This experiment tested the ability of infants to use correlated statistical cues to detect the visual patterns.The current experiment differs from the Kirkham et al. in that infants were habituated to stimuli with two distinct cues. In this study the faces and the shapes served as correlated cues. Stimuli consisted of twelve distinct shapes and each shape was paired with a specific distinct face.For example, a diamond was always paired with a smiling face and a hexagon was always paired with a winking face that had its tongue sticking out. To test the importance of the presence of the correlated visual information, during testing, the face cue was removed and infants viewed shape sequences without the co-occurring faces. With one cue absent the experiment investigated whether infants can detect the pattern and differentiate between the familiar and novel sequences of shapes.Two different scenarios were possible. Firstly, infants may recognize the sequence despite only one cue being present. A difference in looking time between familiar and novel sequence of stimuli suggests that infants were able to detect the pattern. Alternatively, infants may show no significant time difference in how long they looked at the familiar and novel sequences. This would imply that taking away one of the two cues resulted in infants not being able to learn the pattern and differentiate between the familiar and unfamiliar sequences.

## Method

### Participants

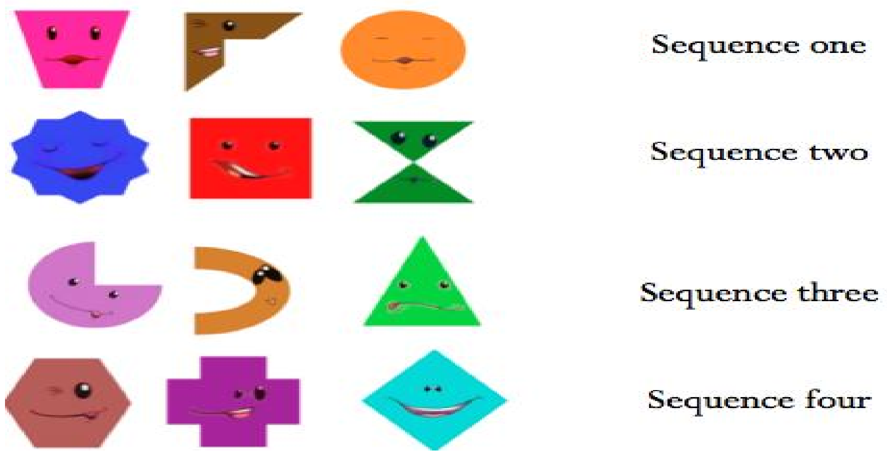
Participants were 22 infants ranging from 16 to 16.5 months of age (15 male, 7 female). The average age of the participants was 16.4 months. To obtain the 22 infants for the experiment 35 infants were tested. The 13 infants excluded were excluded for the following reasons: infants were distracted, fussy, or unable to complete the experiment.

### Stimuli

Learning phase stimuli consisted of twelve shapes. Each of the twelve shapes was superimposed with a distinct face, as shown in Figure 1.

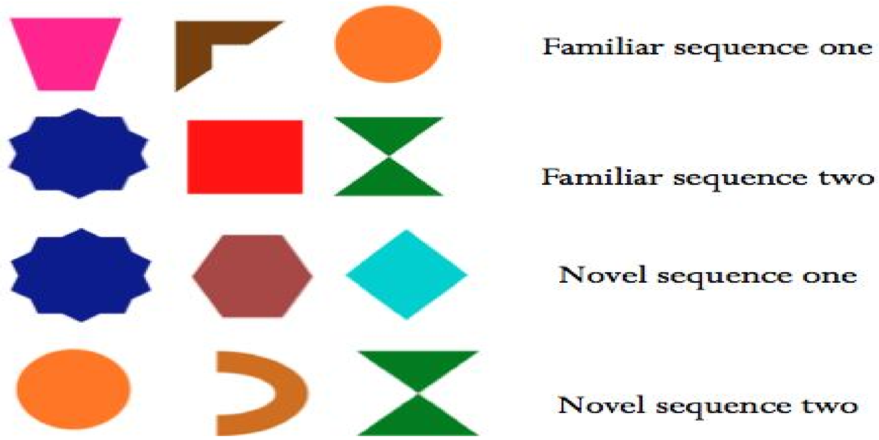
Each shape appeared and loomed on the screen one at a time in a continuous stream. The observer was unaware of the stimuli sequence the infant viewed. During the learning phase the shapers were organized into triplets with perfect transitional probability. Transitional probability is a set of cues used to identify the phrase structure of a language (Morgan and Newport, 1981).For example, transitional probabilities allow us to group syllables into words and form breaks in between words(Saffran et al.,1996). Within triplets, the shapes occurred in a consistent order. For example, one triplet consisted of a circle with a slice cut out, followed by a backwards “c” shape and the triplet concluded with a triangle (see Figure 1, Sequence 3). This is the statistical pattern the infants had available to detect. The triplets were organized in a pseudo-random order so that no triplet occurred twice in succession.

**Figure 1:Learning Phase Item Shape Sequences**




Testing phase stimuli were presented as triplets of shapes. The stimuli in the testing phase consisted of shapes without the superimposed faces. Removing the faces from the shapes is equivalent to taking away one of the two correlated cues the infants had during the learning phase. The testing phase stimuli appeared on the screen one at a time in a continuous stream. Test trials were continuous sequences, with the sequences being either familiar or novel (Figure 2). Familiar sequences were the original four sequences infants were exposed to in the learning phase. Novel sequences consisted of the same twelve shapes, however shapes were no longer presented in the sequences. Novel sequences were randomized so there were no longer consistent patterns.

**Figure 2: Test Item Shape Sequences**




Procedure

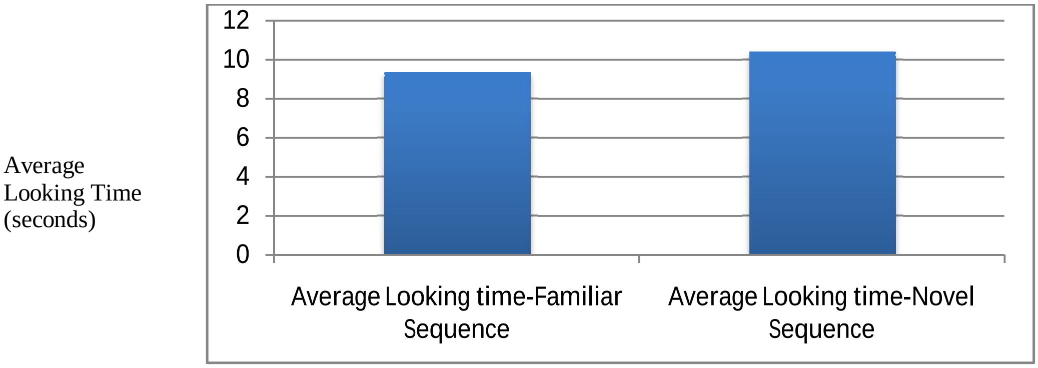
Infants were tested individually and sat on a parents lap. Testing was completed in a sound-attenuated booth. Stimuli appeared on a television screen and a video camera was used to record where the infant was looking.The experiment was run on the Habit program (Cohen, Atkinson, and Chaput, 2004). The experiment consisted of two phases. The first phase of the experiment was the learning phase. During the learning phase stimuli were presented in a continuous stream. The learning phase continued until the infant habituated (see habituation criteria below). Infants underwent a minimum of four habituation trials and a maximum of twenty-one habituation trials. The program advanced to the next habituation trial when an infant looks away for longer than one second. In between habituation trials an attention getter was played to direct the infants attention back to the screen. The attention getter was a multicolored pinwheel accompanied by music.

Habituation was reached when the looking time for three consecutive habituation trials had diminished by more than half from the looking time of the initialthree habituation trials. After habituating, the infant proceeded to the testing phase of the experiment. The testing phase consisted of eight trials. Infants saw a continuous stream of shapes. Half of the test trials contained familiar sequences while the remaining half contained novel sequences. Looking time for each test trial was measured. Total looking time at the four familiar sequence trials was compared to total looking time of the four novel trials.

## Results

A two-tailed paired samples t-test revealed that there was no significant difference between looking time to familiar and novel test items, $t(22) = -1.38$, $p = 0.17$. The average looking time for novel sequences was 10.44 seconds. The average looking time for familiar sequences was 9.39 seconds (see Figure 3). The difference between novel and familiar sequences was 1.05 seconds. Twelve of the twenty-two participants looked longer at the novel sequences of stimuli.

**Figure 3: Average Looking Time of Familiar and Novel Sequences**




## Discussion

The infants looked longer at the novel sequences of stimuli.Although there was a difference in looking time, the difference was not statistically significant.Results suggest infants are not able to demonstrate learning when one cue is removed. One possible explanation for these results is that this is a very difficult task. Visual sequences are not common in the natural learning environment. The reason the experiment used a sequential visual task is because a lot of auditory statistical learning studies use sequential tasks. To investigate the idea of domain generality the task was designed to be as similar to auditory learning tasks as possible.

Another possible explanation for these results is that both cues were present during learning. If infants relied on both, having only one cue presentis not sufficient to demonstrate learning. By removing the faces during the testing phase of the experiment the infants have less information and fewer clues to recall the pattern.

Infants do not necessarily pay attention to all the cues in their environment equally. Perhaps infants focused more on the face cue, therefore removing the face cue may have prevented infants from being able to recognize the pattern. To test the possibility that the face cue was more important in allowing infants to recall the pattern, a second condition will be run. The face only condition removes the shapes during the testing phase, leaving only the face cue for infants to use to differentiate the pattern. A study done by Shina, Balas and Ostrovsky (2007), explains that human infants can distinguish faces from non-faces as early as a few weeks after birth.Faces are important for children to recognize in everyday life and can help infants identify threats. A study conducted by LoBue and DeLoache (2009) revealed that 8- to 14-month old infants responded more rapidly to angry than happy human faces.Perhaps the face cue in this experiment plays more of a role in an infant’s ability to recognize the pattern.

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