SEEING THINGS

Visual-Perception Research at the Pelli Lab

by Jordan Suchow

I have been enthralled by the human mind ever since my first exposure to robotics and machine learning in *Scientific American Frontiers*, a 1997 television series that presented hundreds of projects in which researchers had equipped robots with human sensory abilities. As the years went by, I maintained a strong interest in the behavioral sciences, and by the time I was in high school, I had also grown to love cognitive psychology and neural science.

In my sophomore year, I decided that I wanted to pursue research in one of these areas, so I sent e-mails to professors across the country asking them to recommend readings they thought were necessary for a solid background in cognitive psychology and neural science. I was amazed at the quick and excited responses I received.

The most exciting response came from Dr. Denis Pelli of the Department of Psychology and Center for Neural Science at New York University, who invited me to visit his lab. Little did I know at the time that I had found my home for the next two years, a lab where I would contribute to an understanding of our complex visual system.

Discovering Vision

The Pelli lab aims to uncover the mathematical underpinnings of object recognition, specifically seeking to answer the question, "How does our brain translate basic visual features such as color and edges between light and dark into the rich assortment of objects that we can recognize?"

The members of the Pelli lab, I learned, work independently on various projects throughout the week and meet once a week to discuss and analyze their past week's work. Those members bring to the lab a wide array of experience and include postdoctoral, doctoral, graduate, and college students. There are even a few high school students.

In February 2003, I entered my first meeting of Professor Pelli's lab knowing that I wanted to get my feet wet in research. I left knowing that there would be no wading; instead, this would be a headfirst dive into an utterly unfamiliar topic. I was thrilled.

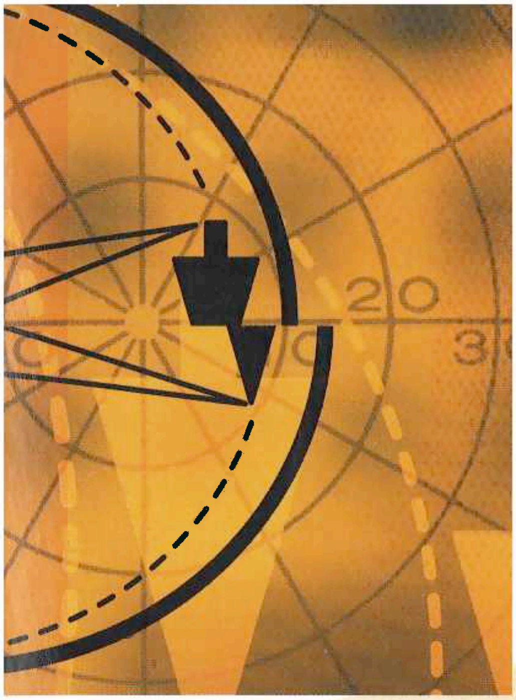
During that lab meeting, I learned about several fascinating projects. For example, a high school girl created an experiment to determine how the deaf read. While hearing people learn to read by equating symbols with sounds, people who are deaf do not have the benefit of using sound. So how do they read? A post-doc created an experiment to determine in which part of the brain letters are learned by training subjects to read foreign letters while undergoing an fMRI scan. These projects, a sample of the many I encountered over the coming months, inspired my interest in vision.

Learning to See

Vision has been the most extensively studied sense, and an enormous amount is now known about how the visual system works. The current model for object recognition is a bottom-up process: First, we detect features (colors, lines, edges), then we combine the parts to form the whole object (integration). Much as a chemist can build complex structures from a basic set of atoms, our visual system constructs the scenes we encounter using basic building blocks called features, which are thought to be simple curves, lines, and angles.

While scientists now have a firm grasp on feature detection and are beginning to understand feature integration, next to nothing is known about how we learn to recognize complete objects. After reading some of Professor Pelli's work on letter identification and learning, I proposed an experiment that would help illuminate how we learn to recognize objects.

Since feature detection is a fundamental part of recognizing an object, it follows that learning to identify the features of an object must be a necessary part of learning to identify an object. I wondered, "Must we relearn features and combinations of features each time they are presented in a new object?"



To answer this question, I designed a series of letter-learning experiments. I found Chinese characters particularly useful, as all of the thousands of complex characters are built upon 200 common radicals, specific combinations of brushstrokes (Figure 1). Presumably, characters that share radicals share some features. I decided to test the effect of prior knowledge on letter learning by comparing subjects' ability to learn one set of Chinese characters to their ability to learn a new but similar set of Chinese characters.

All observers in my experiments were trained to recognize Chinese characters through a computer-based letter-identification task, in which they were briefly (200ms) shown a hard-to-see character and then asked to match it with the corresponding character on an easy-to-see response screen. To make a character harder or easier to see, we would adjust its contrast.

After a number of these matching trials, a computer algorithm would calculate the lowest contrast at which that observer could correctly identify the entire set of characters at a certain percent correct (Figure 2). Over time, observers undergo a process of perceptual learning, defined as their ability to correctly identify a fainter and fainter set of characters at the same percent correct.

Interestingly, in this study, perceptual learning appeared to be unaffected by whether the observer had already learned a similar set of characters. Previous knowledge didn't help. Or did it? Maybe the Chinese characters I had chosen did not share enough features, or maybe the features they did share were not the same features the observers relied on for identification.

To address these concerns, I designed a second experiment in which observers first performed the identification task on the component brushstrokes and radicals of Chinese characters before learning characters consisting of those parts. This would now directly test the effect of prior knowledge of component parts on an observer's ability to perceive the entire object. To my surprise, and contrary to what I found in the first experiment, observers received a significant benefit from having already learned the component parts of a character. From this, I concluded that observers need not relearn component parts of new objects when those parts are presented in new contexts.

In all, the process of preparing and carrying out this research has been exciting and rewarding, especially as it has provided me with an invaluable glimpse of the science of visual perception. It is a field of great breadth, with room to explore topics such as reading, color perception, motion discrimination, and face recognition. It is also a field with tremendous applications to medicine, art, and our daily lives. It is amazing that, for a sense upon which we rely so heavily, there is so much we do not yet understand. Through this project, I was able to illuminate one aspect of how we see. I eagerly await my next project at the Pelli lab. ■

Character	Pinyin name	English meaning	Component radicals		Component brushstrokes
杪	MIAO	beard of grain; smallest part; a measure for seconds	木	少	丨 一 ㇏ ㇒ 丶 丶 ㇒ ㇀ ㇀ ㇓
牧	MU	to herd or tend	牛	攵	
环	HUAN	to encircle; ring or bracelet	王	不	
欣	XIN	to be happy	斤	欠	

Figure 1

Figure 2: English letters of decreasing contrast (L to R) with added "white" noise. How far can you read? The average among the Pelli lab's observers is seven letters.

(From left to right, the letters are Z, V, S, R, O, N, K, H, F, and C.)

Jordan Suchow is a senior at Irvington High School in New York. He was a semifinalist in this year's Intel STS for the project he completed at the Pelli lab. Jordan is an active member of his school's marching and concert bands, choral groups, Mock Trial team, and cross country and track teams, and is the president of the local chapter of United Synagogue Youth.