# Using Machine Learning to Decode and Reconstruct Visual Perception from Brain Scans

I received my PhD from the Utrecht University in computational neuroscience, after which I did a post-doctoral at the Center of Neuroscience at New York University. During this time, my focus was on understanding conscious visual perception.

I was amongst the first scientists to pioneer using machine learning to decode and even reconstruct human visual perception from brain scans (functional Magnetic Resonance Imaging). Specially, I trained classification and reconstruction ML algorithms on the distribution of neural activity in humans observing certain visual stimuli. This resulted in four main publications in a leading scientific journal.

## Ambiguous Depth Perception

Sometimes the brain has insufficient information to estimate certain visual aspects, like depth or motion. Together with my colleagues, we created a stimulus with conflicting depth cues: stereoscopic depth and perspective. By showing this stimulus to subjects while we recorded their brain activtity, and training a machine learning algorithm on the resulting activity, I was able to localize the where in thr brain our conscious perception of depth is localized.

Ambigious Motion Perception

Remember this dress? The one that some described as gold, and others as blue?

Well, have a look at this sphere of dots. Does it rotate clockwise or counter clockwise?

Show it to a few colleagues or friends. Do they see the same? It's very likely some of them will disagree with you. This is the motion equivalent of the dress. But it is actually more interesting. Because with a little practice, perhaps some blinking, you yourself can make it move the opposite direction of how you first perceived it. And back again. Since the thing you see doesn't actually change, but your conscious perception does, these stimuli are ideal for studying perception. As with the ambigious depth stimulus, by training a machine learning algorithm on the brain activity of a human subject watching such a stimulus you can look for where in the brain such conscious perception is localized. Any area of the brain that produces activity which a machine learning algorithm can use what a person is perceiving can thus be said to be at least correlated with conscious perception

Reconstructing Color Perception

The early applications of macine learning on brain activity were all classification. Is this patterns of activity A or B? But what if you could design an algorithm that is generative: it can literally recreate what somebody is perceiving. Imagine what you could do which such a algorithm! You could look inside somebody's mind! Well, that is exactly what I managed to do Specifcally, I used color perception, because it is a relatively simple type of visual input. Brain imaging is limited in what it can do, especially when I conducted these studies. While we scanned subjects brains, we showed them a few primary colors, plus a few that are not seen as primary. Then, I designed a novel machine learning algorithm and trained it on the activity produced by the primary colors so that a particular parttern of brain activbity would be rendered on screen as those same primary colors. After training, I applied it to the brain activity of non primary colors the algorithm has never seen (not been trained on). Lo and behold, the output, rendered to screen matched the non primary color!

Categorical Perception of Color

Have a Look at this color wheel. It varies continiously in hue and saturation (the vibrance of color). Yet, depending on where you are from, you automatically divide it into color categories. Probably you will see a division of areas of Green, Cyan, Blue, Magenta, Red, Orange, and Yellow. But, suprisingly, if you are Russian, you will perceive and extra category of blue. And certain amazonian tribespeople simply divide it into green, red, and unspecified or unnamed. Where does the brain go from a continiouslty representation to a categorical one? Or can a single brain area support bnoth representations and it switches depending on what you as an individual area asked to describe? Again, brain imaging and machine learning to the rescue. By showing humans a set of colors that are equally spaced on the color wheel, yet group into cluters while their brains are scanned we use a clustering algorithm to cluster the resulting brain activbity in diffferent areas. If the clustering algorithm performs poorly on a certain brain area, the representation is probably continious because there are no clusters to be found., if on the other hand they perform well and the clustering matches color categories, we have found a brain area that represents color in terms of categories. Interestingly, what I found is that some areas are strictly continious. Yet other areas can be both. If you are not paying attention to the colors but are instead doing some other task, the representation is continious. But as soon as you are asked to attend to the colors, the representation becomes categorical.