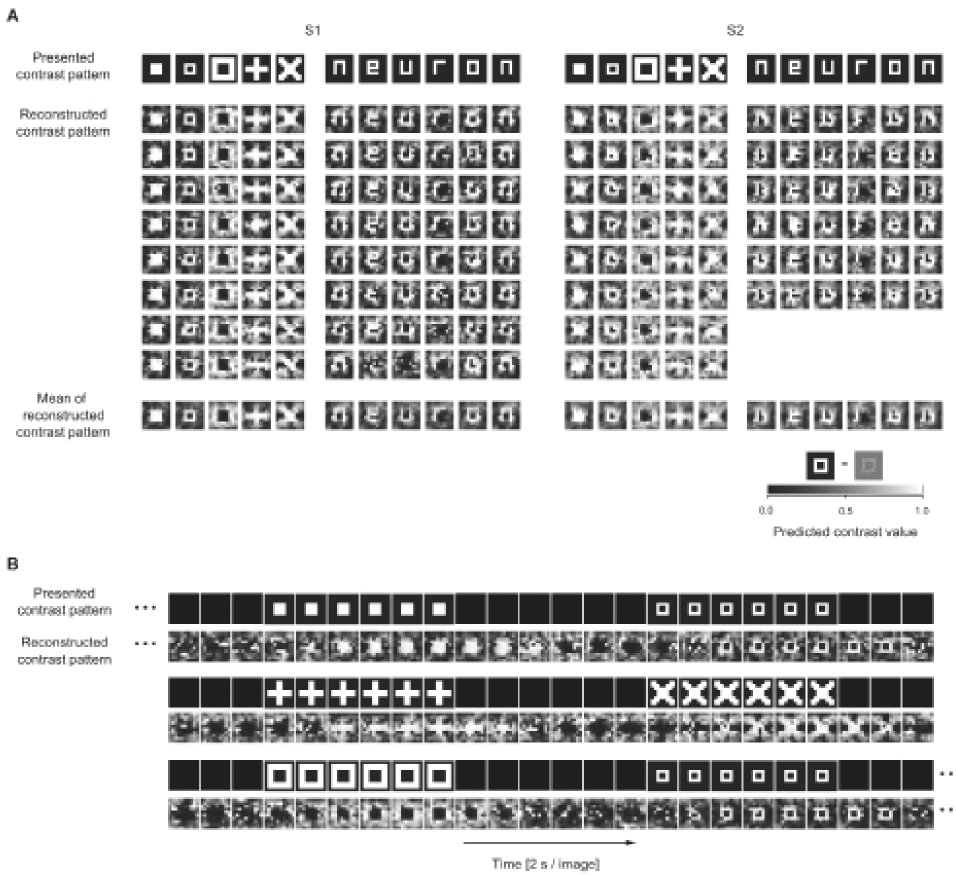


Figure 1: Software trained to recognize the activity of two human patients' brains while viewing black and white patterns was able to decode and reconstruct novel black and white patterns presented to the patients (in this case the letters that spell out neuron, the title of the journal that published this work) (a). The results from multiple trials are averaged for clarity. Also, the acitvity of the visual cortex demonstrated time-dependency according to the presentation of visual stimuli (b).

A wake-up call for dream research

By Colleen Carlston

How often have you woken up with a vivid sensation of something that just happened in a dream only to have that dream fade away minutes later? The phenomenon of dreaming is still poorly understood although theories abound as to why the brain generates its own stimulation in this way. Is it a time when we problem-solve or work out emotional angst? Is it important to memory or skill consolidation? One thing that scientist have long known is that the dream state is associated with rapid eye movements (REM) and more intense dreams are associated with more rapid eye movements. However, some classes of anti-depressant drugs completely eliminate REM in patients with few if any ill effects (1). Another fact that further complicates this story is that the most intense period of REMs is during the month before birth (1). What exactly would these fetuses, who presumably have little in the way of experience in the world, be dreaming about? Given these complications, what exactly is the purpose of sleep and dreaming?

Recent research from the ATR Computational Neuroscience Laboratory in Kyoto, Japan may soon help us answer this question, or at least get a better look at it. The Kamitami group was able to project a novel image of what a patient was perceiving based on brain activity alone (2). They accomplished this by analyzing blood flow using functional magnetic resonance imaging (fMRI) in the visual cortex of the human brain. Previously, similar techniques had been used at UC Berkeley in a matching task in which fMRIs were taken as a patient viewed different scenes, and the computer

credit: (2)

could accurately match any scene that was viewed a second time to its initial viewing (3). However, it has yet to be determined if this can only work when a patient is awake and actively taking in visual input or if it might be applied towards imagined scenes or dreams. The Japanese team predicts that this system could yield insight into the process of dreaming, perhaps even allowing us to record our dreams and play them back later while we are conscious.

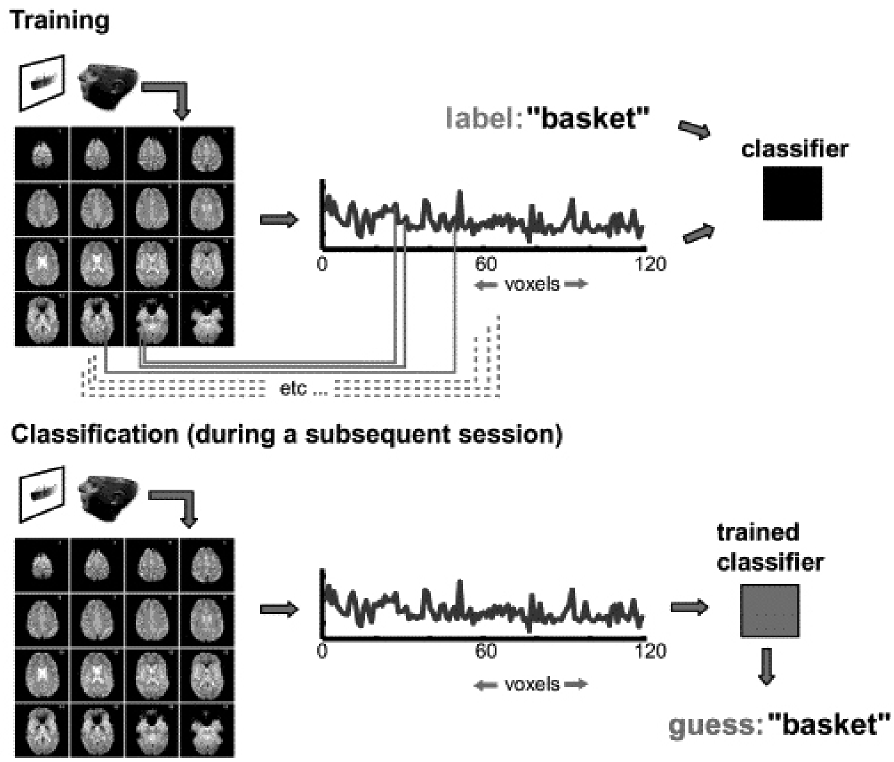
How does the technology work?

Blood flow in the brain is generally considered a good measure of activity in that part of the brain. This can be gauged using fMRI. The ATR group applied this technique to the visual cortex in two adult males who were selected for their limited head moments and normal, uncorrected vision (2). The scientists divided up the visual field perceived by the subjects into several regions and monitored corresponding areas in the visual cortex. This approach relies heavily on the retinotopic organization of the visual cortex – that is to say, a patch of the retina will correspond directly to a patch of the visual cortex and that adjacent areas in one remain adjacent in the other (4). Thus activity in the primary visual cortex represents a map of activity in the retina, and the image being viewed can be inferred from the fMRI of the visual cortex (5).

Contrast detection is one of the most important perceptual attributes in viewing a scene. Therefore they compared the activity of each small block of the cortex to the regions adjacent to it as an estimate of contrast in the image. Scientists trained software to detect contrast within a scene by training it on more than 440 black and white images (6). A statistical learning algorithm was employed that determined the proper weight to assign differential activity in the visual cortex when recreating a trained image (7). Then when new black and white images were viewed these boundaries could be detected and a rough estimate of the image projected onto a 10 X 10 pixel display. One issue with displaying readouts of brain activity is that this data is often noisy, meaning that there is always some baseline of brain activity not necessarily associated with a particular image. To resolve this issue the researchers averaged the results from multiple fMRIs of the brain to get the clearest image possible.

"If recorded dreams are anywhere near as bizarre as the snippets that surface to consciousness, it is unlikely that anyone could specifically extract a particular secret. More likely, they would just end up eavesdropping in on that same old anxiety dream where you show up at a final exam in your pajamas."

One way to think of visual processing is that the brain is mining an image for the most relevant information that it will use to inform the organism's actions. Processing of visual images occurs on multiple levels in different places in the brain; as information is passed from one level of processing to another, different types of information about a scene are extracted and processed. Interesting to note is that these researchers found that their techniques worked best in the primary visual cortex (V1) (2). By this point the image has already made its way through the initial stages of processing in the retinofugal projection and the lateral geniculate nucleus. The information that arrives to the primary visual cortex has been streamed according to which eye it came from, and also to an extent it has been broken up into a stream that perceives color, another that interprets motion, and a third that detects edges. It was this third category



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▲ **Figure 2:** Previous research using fMRI had shown it was possible to train a computer to select the image viewed by a patient from a set of pre-trained images. However this new research expands the technology's capacity to interpret unfamiliar images.

credit: (9)

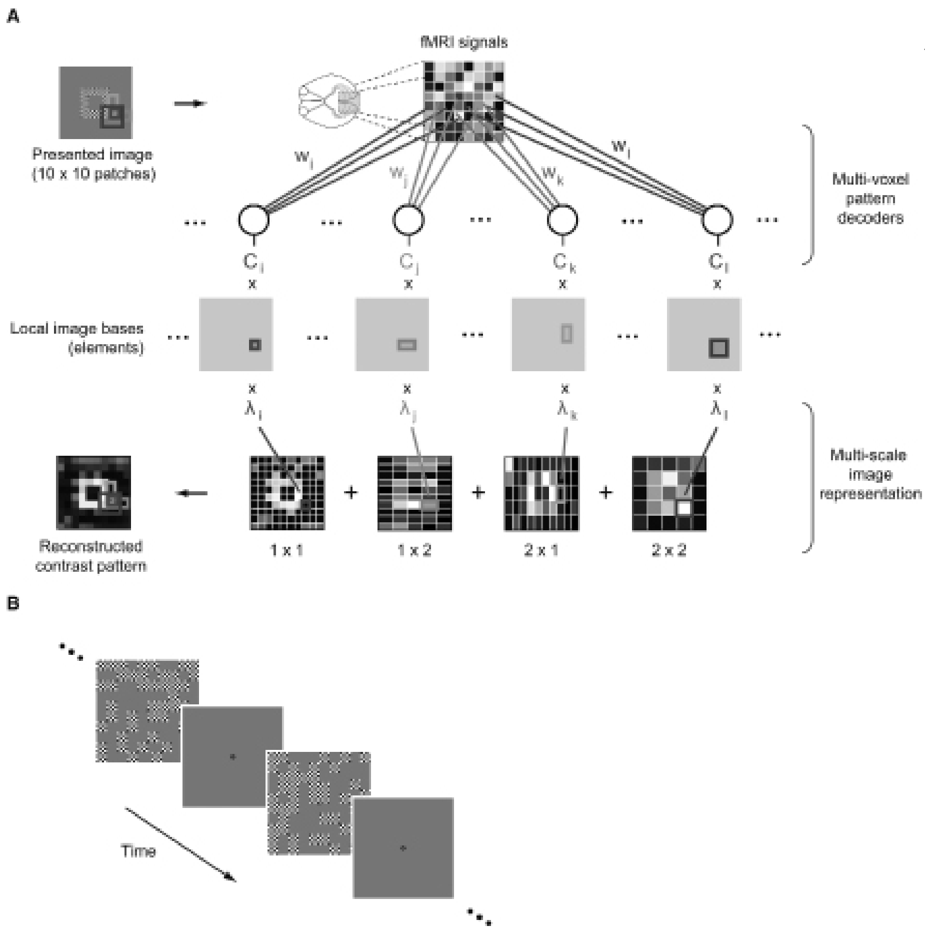

Figure 3: The decoding proess for the computer to interpret the fMRI signals relies on contrasting the strength of firing with adjacent blocks of the visual cortex (a). Understanding the differences in temporal firing also allow the activity of an area when an image is on to be compared to that same region's activity when the image is off (b).

credit: (2)

that the researchers in this study were most interested in. By taping into this information in the striate visual cortex V1, the researchers were able to recreate fairly accurate visual images of what a subject perceived.

Further along the visual processing pathway, in the extrastriate visual cortical areas V2, V3, V4, and V5, the recreated images began to appear blurrier (2). One possible explanation for this is that additional information was being extracted at these levels so that the neuronal representation of the image in areas more distant from the retina becomes less recognizable as the original image. However, in other studies fMRI information from the extrastriate visual cortical areas such as V5 has been used to decode motion direction (8) and for detecting categories of objects (9).

Implications

With the advent of a new technology, concerns tend to arise concerning potential misapplications. Indeed, on the surface it does seem that this technology could be employed to monitor people's dreams and perhaps extract information from them unwillingly. However, fMRI machines are not like wire taps that could be hidden in someone's bedroom and you would almost certainly realize when you were placed in one. Also, if recorded dreams are anywhere near as bizarre as the snippets that surface to consciousness, it is unlikely that anyone could specifically extract a particular secret. More likely, they would just end up eavesdropping in on that same old anxiety dream where you show up at a final exam in your pajamas. Certainly this might prove somewhat embarassing, but would hardly be useful for espionage.

It is important to remember the many concrete benefits that could be provided by developing this technology. This research isn't just for the fun of looking in on what we might be seeing when we are dreaming; there are potentially serious applications as well. The decoding approach may prove useful in developing neuro-prosthetics or brain-machine interfaces that are more flexible at predicting a patient's intentions (10).

In fact, it has yet to be determined if this technology could be applied to dreams at all. In this study visual images provided sensory stimulation to the subjects, and it would be interesting to see what would happen without the sensory input. For example, Kamitani wonders what would happen with shapes that a subject is imagining rather than actually seeing (11), or to extrapolate, in situations such as dreaming or hallucinating. This technology could provide a powerful tool for doctors and therapists—if it can be used to help recreate situations such as dreaming or hallucination, it might allow them to see more precisely what it is their patients are seeing, and help them better understand the patient's condition. For everyone else, who knows if replaying dreams would reveal any additional meanings that were not already evident when they were originally dreamt. H

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