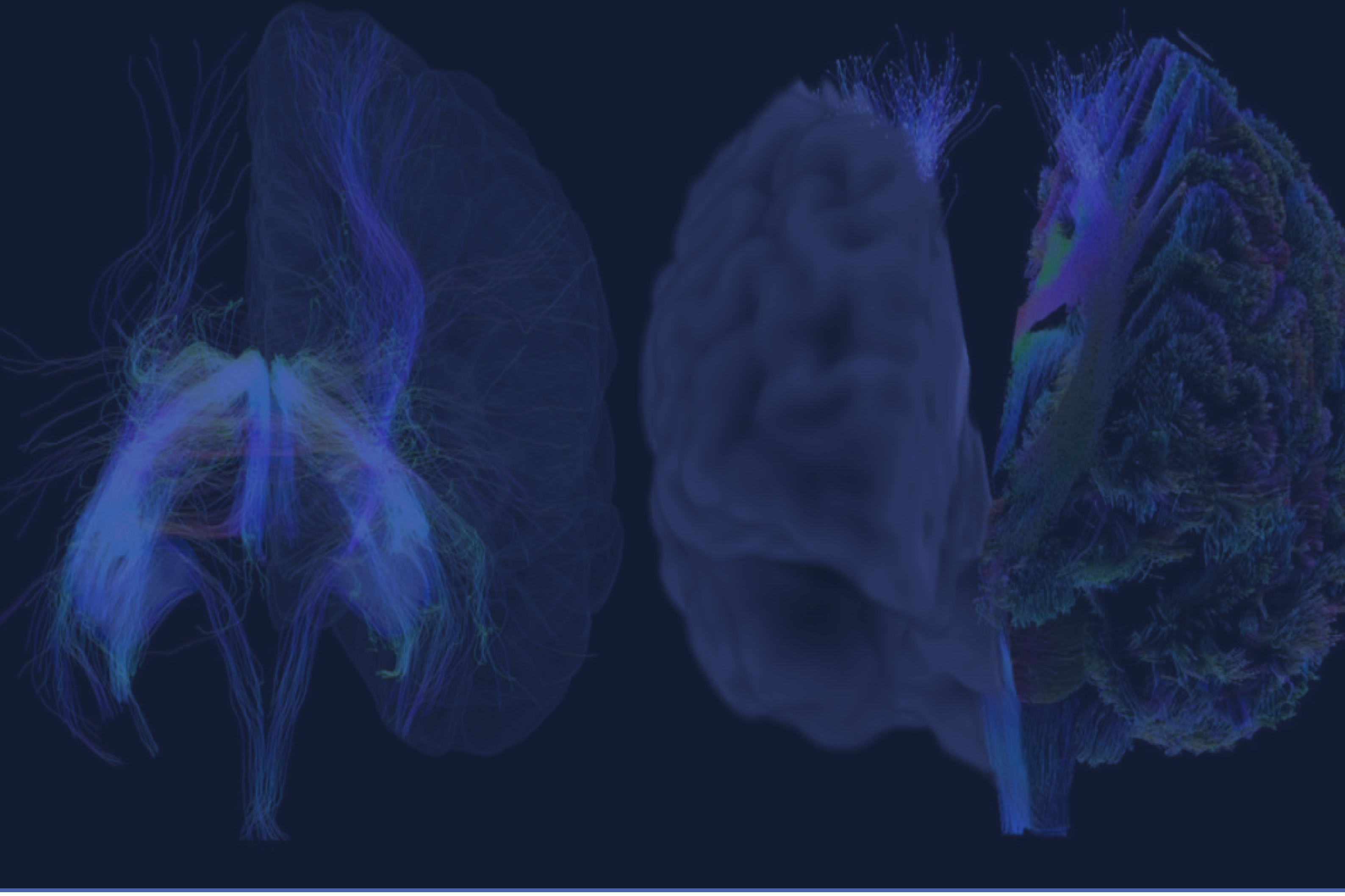

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Neuroscience Innovation Report

2018

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Introduction

In 1559, surgeons Ambroise Paré and Andreas Vesalius received permission from Queen Catherine to autopsy the brain of King Henri II of France, who had succumbed to an intracranial haemorrhage. While today this would be seen a normal investigative procedure, at the time it was a daring request. Dissections were usually performed only on criminals, who would be sentenced to the procedure as a posthumous punishment. It is unclear why Catherine gave in to Paré and Vesalius, since it was obvious that the cause of death was the lance injury he sustained in a jousting tournament. But when their predictions of the type of damage they'd find inside Henri's brain, and where they'd find it, proved to be true, it led to a turning point in the history of neuroscience – proof that a deeper understanding of the brain lay in science rather than superstition.

Today, neuroscience is continuing to innovate in our understanding of the structure of the brain. The data generated is so huge that many of these innovations are focused on creating ways to more efficiently catalogue and retrieve information from hundreds of thousands of brain scans made by researchers around the world. Platforms, such as the Human Connectome Project, and Open fMRI, have been established to share brain imaging data and analyse it collaboratively. Researchers like Julie Korenberg, at the University of Utah in Salt Lake City, are working on developing 3D coordinate systems to align various types of neuroimaging data to allow anyone to pick a point on one image and look at the same point at another resolution, a Google Earth of neuroimaging.

Another major driver of innovation in neuroscience is the development of brain-machine interfaces (BMIs). While much of the research in this area is focused on developing neuroprosthesis for restoring function after neurological disease or injury, a growing number of companies are developing BMIs for commercial uses. Tech start-up Emotiv has developed a cost-effective EEG headset, which could make this technology even more accessible. Similar headsets have already been used to develop technology for 3D printing a users' thoughts, to allow the less-physically-abled to control robots with their thoughts and even to translate the thoughts of dogs. Others, like Elon Musk, have even more ambitious goals for neuroscience – Musk's new company Neuralink is working to someday merge the human brain with artificial intelligence.

Neuroscience is changing rapidly, and with it our picture of the brain. Researchers and companies are working to apply innovative technologies to develop a complex, dynamic picture of the brain that shows how individual cells and neuronal circuits interact. As this picture is filled in, it will allow us to explore

Introduction

exactly how the brain enables the human body to record, process, utilize, store, and retrieve vast quantities of information, all at speeds faster than any computer. The innovations highlighted in the report could drastically change the way we treat disease, interact with computers, and even how we make decisions.

Neurohealth and the treatment of neurological diseases
Many innovations in neurohealth are being driven by a demand for effective treatments of neurological diseases and conditions ranging from Parkinson's and Alzheimer's to paralysis and autism. Although many of these innovations are still some way off from practical application, non-invasive techniques, such as virtual reality and augmented reality, are already being used to develop treatments for neurological illness. A VR gaming app called Sea Hero Quest, developed by Alzheimer's researchers and Deutsche Telekom, allows scientists to quickly gather data on subtle and detailed reactions, such as eye movements, forming a huge, crowdsourced database on human spatial navigation. VR is also being used by researchers at the University of Southern California to develop treatments for stroke victims. Their work is based on evidence that people in VR environments could identify so strongly with their avatar that they changed their behaviour to match that of the avatar. They found that giving stroke survivors with motor impairments a virtual avatar that moves properly helped to promote brain plasticity and recovery.

Advances are also taking place in behavioural neuroscience that could lead to treatments for autism spectrum disorders and related conditions. According to the CDC, as many as 1 in 68 children have been identified with autism spectrum disorder (ASD). An EU-funded project called Becoming Social is working to map the regions of the brain that are sensitive to social interactions, and how these regions develop as children grow. To accomplish this, the researchers have built 'virtual people' to engage in realistic social interactions. They are also using functional near-infrared spectroscopy (fNIRS) in an innovative way to measure issues such as trust-building during social interactions. By combining VR and brain scans, the team are bringing a new level of scientific rigour to social neuroscience, allowing theories that were previously hard to test to be subjected to controlled experiments.

At Carnegie Mellon University, robotics researchers have combined behavioural neuroscience with AI to develop a method that enables a computer to understand body poses and movements, including the pose of each individual's fingers. The method, which involves a two-story dome fitted with 500 video cameras, will make it possible for people to interact with computers in new and more natural ways, such as communicating with computers simply by pointing at things. Detecting the nuances of nonverbal communication will also allow robots to perceive what people around them are doing, what moods they

Introduction

are in and whether they can be interrupted. Ultimately, machines that can understand human behavior could be used to help people with autism and similar conditions.

Researchers are also using AI to aid in the creation of 'intelligent' neuroprosthetics for augmentation of brain function. Researchers at Britain's Newcastle University have developed AI devices that can solve problems, and have adapted these for use in prosthetics. Their work has already led to the development of a prosthetic limb which uses AI to decide which objects to grasp.

Consumer neuroscience

More controversially, neuroscience is also being used to influence the way we think, as companies like Nielsen apply ever-more sophisticated neuroscience-based tools to understand and influence consumer behaviour. Studies using fMRI have influenced marketing by suggesting, for example, that showing a higher price tag while people were tasting identical wines did actually make the wine taste better by changing the actual neural signature of the taste; and that the timing of when consumers see a price may entirely change the way they buy. This information is being put to use by companies such as DemandJump, which has recently developed an AI marketing platform which uses data on customer behaviour to help companies stay ahead of market changes.

Humans experience a range of subconscious emotions in response to products and experiences. Shoppers may get excited for certain brands and then overwhelmed by choices. Ad viewers can become frustrated, bored, and entertained all in a short space of time. Emotional analytics tools which use eye tracking, skin response, heart rate and facial expressions to measure a subject's emotional resonance are allowing marketers to broaden their understanding around nonconscious perceptions of a brand. This, in turn, allows them to make subtle changes that elicit the desired response from their audience. The next frontier in consumer neuroscience are wearable devices that allow more precise tracking of consumers emotions.

Consumer neuroscience companies such as Mindprober and IDG, are focusing on using wearable devices to collect more precise consumer neuro-data. Mindprober recently won an industry award for its process that enables the real-time collection and analysis of physiological and behavioural reactions of hundreds of people to media contents, like television ads or entertainment programs. They achieved this by having respondents wear specially-designed sensors to monitor perspiration and movement, and through developing an algorithm to analyse their global and second-by-second impact.

Introduction

To gain a more accurate picture of consumers' responses to specific stimuli, MIT Media Lab spinout mPath uses wearable stress sensors, analytics, and other technologies, to pinpoint the exact moment consumers feel subconscious responses. In doing so, the start-up has brought some interesting market research insights to major companies and organizations to help them refine their products and services. The companies' MOXO sensor wirelessly measures changes in skin conductance which reflect sympathetic nervous system activity and physiological arousal. To gain an accurate picture of consumers' responses to specific stimuli, mPath also developed a new approach to market research, called 'emototyping'. This process combines the stress sensors with eye-tracking glasses or cameras, to identify where a person looked at the exact moment of an emotional spike or dip.

Advances in neurobiohybrids and neuroceuticals
Neurobiohybrids – biomimetic systems where living tissue interacts with artificial systems – are an emerging field in neuroscience, and one which shows great promise in eventually restoring and enhancing organ function. A necessary first step in creating neurobiohybrids is the development of a brain-machine interface (BMI) or brain-computer interface (BCI) – a functional synergy between artificial neuronal networks or devices and the brain.

While implanted electrodes enable researchers to send messages to individual neurons, they can cause inflammation in the brain tissue, and scar tissue often forms around them over time. To get around this, a host of neuroprosthetics start-ups, such as Bryon Johnson's Kernel and Elon Musk's Neuralink, are aiming to develop injectiable neural implants made of mesh or other flexible structures. Sometimes referred to as neuroceuticals, it is hoped that these devices will be used in the future to treat a wide range of diseases, and to extend cognition. One of those farthest along is tech start-up Synchron, which is working on an implantable device called a stentrode that will allow paralyzed patients to achieve direct brain control of mobility-assistive devices. They have developed a small device which will pass through cerebral blood vessels to implant in the brain, where it will interpret electrical data emitted by neurons. The company is currently preparing for early-stage clinical trials.

The Harvard research group of Charles Lieber is taking a different approach. They have developed an electronic mesh that is injected via syringe into the brain, where it unfurls to make contact with neurons. The mesh can be precisely targeted to any brain region and forms a seamless and stable interface with neural tissue which lasts for many months. In the future, the mesh may be used to treat neurological and

Introduction

neurodegenerative diseases such as Parkinson's and Alzheimer's via deep-brain stimulation, as well as providing next-generation brain-computer interfaces.

Michel Maharbiz, co-director of the Center for Neural Engineering and Prostheses at Berkeley and UCSF, is taking neuroceuticals one step further with tiny, wireless electrodes he calls 'neural dust'. These could be scattered through the nervous system, where they act together to record signals. The team's current version of this tech is a device that measures 2.4 cubic millimeters, but they are working to scale it down to a more usable 50 cubic microns.

Innovative neuroscience technologies

At the center of many recent innovations in neuroscience is the development of new techniques for brain imaging and for handling the immense amounts of data generated. In Arthur Toga's lab at the University of Southern California, researchers are applying the techniques that brought Harry Potter to life in movies to magnetic resonance imaging (MRI) scans, turning massive amounts of data into images. These are then combined with virtual reality software to enable scientists to explore the brain in three dimensions, and even perform virtual dissections of the brain or trace neurons using handheld controllers.

Ever more creative methods are also being developed to speed up the creation of neuron models. Some researchers have turned to crowdsourcing. Dr. Zoran Popović, at the University of Washington, has created a video game called Mozak to crowdsource the creation of three-dimensional models of neurons. Players trace lines over images of neurons with a computer mouse, earning points and competing with other players. Using the game has allowed Popović's team to increase the number of neuronal reconstructions from 2.33 a week to 8.3 a week.

Currently, most AI applications focus on specific tasks, such as speech recognition or identifying objects in an image. Building AI that can perform a host of general tasks, rather than one or two specific ones, is a long-held goal of machine learning. But expanding specialized algorithms to something more versatile remains a difficult problem, in part because a deeper understanding is needed of the neural basis of human traits like inquisitiveness, imagination, and memory. Chinese-based Emotibot have been working on applying a deep-learning approach to develop more emotionally intelligent chatbots.

Another approach to this problem is being advocated by Google researcher Geoffrey Hinton, who is a pioneer in the field of virtual neurons. He has been working on a new approach to AI, known as capsule

Introduction

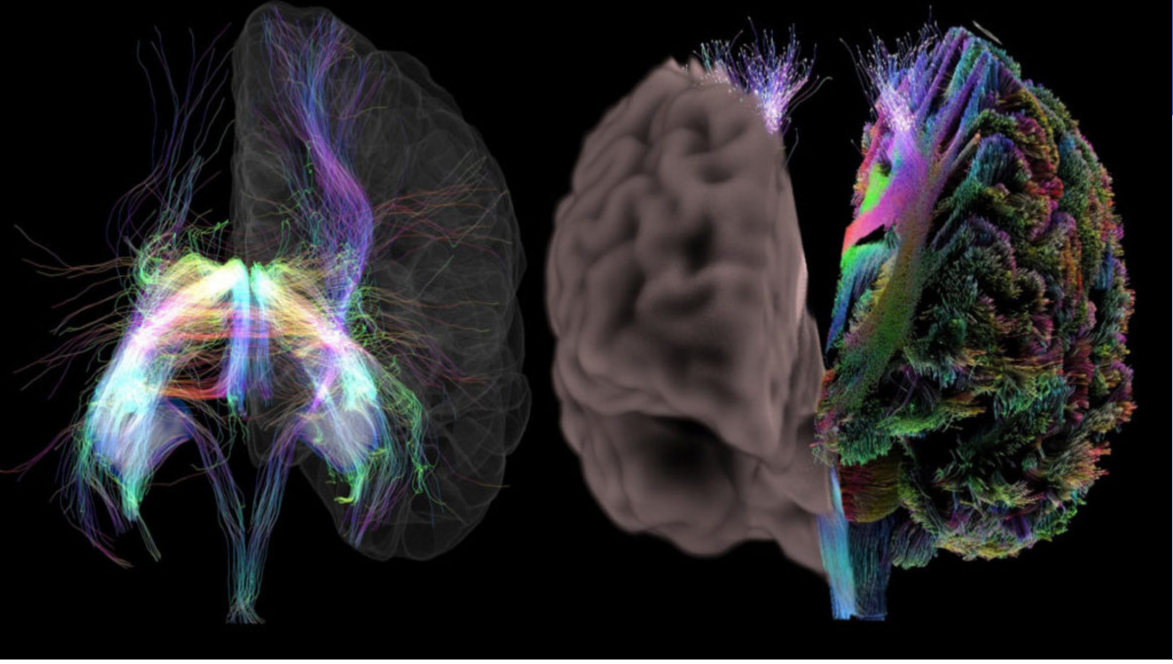
networks. These are small groups of virtual neurons which are designed to track different parts of an object and their relative positions in space. Hinton has demonstrated that capsule networks can allow software to generalize what it learns to new scenarios, for example understanding that an object is the same when seen from a different perspective. The system has the potential to allow AI to act more like the human brain.

Finally, neuroengineers are also increasingly exploring the use of more focused neural signal detectors, such as intracranial electrodes. A team at Stanford has developed an algorithm to translate signals from an intra-cortical brain-computer interface into point and click commands, which allowed people with paralysis to type at speeds approaching normal use. This is seen as a first step in developing a self-calibrating, fully implanted wireless BCI system which can be used without technical assistance.

From ideas about the structure of the brain put forward by two surgeons in the sixteenth century, the field of neuroscience has grown to encompass a host of new technologies. As the innovations featured in this report demonstrate, the developing ability to amass and analyse vast amount of neurological data is the key to unlocking the potential of our brains. Whether this is through improving health outcomes through neuroceuticals, improving brain-machine communication through neurobiohybrids, or developing better measurements of emotional intelligence, researchers are developing ever-more sophisticated tools for uncovering the secrets of the brain.

All of this may well present an advance in efficiency and health, but it can also present a moral dilemma. Already the ability to manipulate and influence behaviour has seen a pushback from those concerned about undue influence in areas such politics and education. With BMIs offering a future in which AI can anticipate our thoughts and actions, the future of neuroscience may also include a drive for a deeper understanding of the neurological basis of autonomy and identity. Despite the rapid pace of advancement in neuroscience, it is clear that there are still a great many questions to be answered.

SPRINGWISE EDITORIAL TEAM



At a Glance

WHAT
Techniques used on Harry Potter movies are being used to create detailed 3D images of the brain.

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Scientists use techniques from Hollywood to image brain in 3D

Techniques used on Harry Potter movies are being used to create detailed 3D images of the brain.

Neuroscientists studying the structure and function of the brain produce huge amounts of data. Just 1 cubic millimeter of human brain tissue contains around 50,000 neurons, with each neuron forming around 6,000 connections with their neighbors. Traditional imaging techniques require researchers to go through two-dimensional computer images of stained neurons, constantly altering the view to see what's behind a neuron's branches. This is painstaking and time-consuming work. In order to speed up this process and turn the mounds of data into useful images, researchers are tuning to an unlikely source – Hollywood.

Neuroscientists in the Laboratory of Neuroimaging at the University of Southern California in Los Angeles have developed a technique for creating 3D images of brain scans. The scientists first applied the same rendering techniques used to make the graphics for Harry Potter movies to magnetic resonance imaging (MRI) scans, to produce extremely detailed images of the brain. They then combined this visualization software with virtual reality software to create 3D images so detailed that they can be used for virtual dissections – allowing users to pull apart colored, segmented VR images of a brain like pieces of Lego.

According to Taylor Ard, a neuroscientist in Arthur Toga's lab, which is conducting the research, the technique will allow scientists to better understand the structure of the brain, saying, "The way that I learned it, we had to look at slices, and that's real hard. This is a way that allows you to understand 3D structure better." The team plans to release the program, called Neuro Imaging in Virtual Reality, online next year. We have already seen several innovations in creating 3D images for consumers, such as a scanner that can create high resolution 3D images without lasers, and a device that turns a phone into a 3D camera. Will this new technique allow researchers to better understand the structure of the brain?

At a Glance

WHAT
A computer scientist has developed a way to vastly improve the ability of AI to understand images.

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New technique vastly improves image recognition in AI

A computer scientist has developed a way to vastly improve the ability of AI to understand images.

Computer scientist Geoffrey Hinton was instrumental in developing image-recognition software used today for everything from transcribing speech to fighting online trolls. In two recent research papers, Hinton has developed a new approach to image recognition software that could help AI systems act more like humans. Hinton's system aims to remedy a weakness of exiting machine-learning systems, which is that these systems need a large number of example photos in order to reliably recognize even simple objects. This is because the software is limited in its ability to generalise what it learns from one image to another, such as understanding that an object is the same when seen from a new viewpoint. For example, teaching a computer to recognize a dog from any angle requires inputting photos of the dog from thousands of different angles.

Hinton's idea for fixing this is to create capsules, small groups of crude virtual neurons, which are designed to track different parts of an object, such as the dog's nose, ears and tail, and their relative positions in space. The capsules can then be networked together to understand and recognise the dog from different views. One of Hinton's recent research papers demonstrated that his capsule networks can match the accuracy of the best existing software techniques on learning to recognize handwritten numbers. The second paper demonstrated that capsule networks can significantly improve on recognizing toys such as trucks and cars from different angles.

Although Hinton has demonstrated that capsule networks represent a significant improvement in image recognition, the technique remains to be proven on large image collections, and the speed of the system needs to be improved to make it faster than existing software. There have been a wide number of recent developments in AI, such as using AI to detect pre-cancerous growths and to provide detailed marketing analytics. Now, capsule networks may demonstrate a way to make AI operate more like the human brain. What new innovations might arise from AI that can work like the human brain?

At a Glance

WHAT
An AI-driven platform aims to predict exactly where and when brands place their marketing for the most impact.

WHO
DemandJump

WHERE
United States

CONTACT
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www.demandjump.com/company/contact

New AI marketing tool provides detailed analytics

An AI-driven platform aims to predict exactly where and when brands place their marketing for the most impact.

How much more impactful could your marketing be if you knew precisely what content to write and where to publish it to take advantage of up-to-the-minute trends? This is the question that Indianapolis-based DemandJump hopes to answer. The company has developed the first Artificial Intelligence Marketing (AIM) platform, dubbed TrafficCloud, which shows marketers exactly what to do next to maximize revenue growth, outmanoeuvre the competition, and stay ahead of market changes.

While most marketing tools collect historic data, such as page hits, designed to help companies with customer retention or cross-sell, TrafficCloud focuses on new customer acquisition. By using AI to collect data for every event and page view, the company is able to link customer activity across devices and present a much more detailed analysis of traffic between sources. The company's analytics can then pinpoint which sites have the greatest influence in a brand's competitive area, and which sites can help drive the highest number of customers to the brand. DemandJump claims that its proprietary algorithms, using machine learning, graph theory, algebraic topology, and natural language processing, can "map each client's entire digital ecosystem and then cull the data to reveal revenue growth opportunities brands didn't even know existed".

The marketing technology landscape has changed rapidly over the past several years. In 2011 there were just 150 companies offering marketing solutions, and today there are more than 5,000. These include an AI that matches brands with social media influencers and a system that produces real-time in-store data. This growth means that marketers must pay much closer attention to constantly shifting market dynamics in order to stay ahead of the competition. DemandJump currently has around 14 customers, but claims to have a number of major deals with multi-billion dollar companies pending, and is growing quickly. Will the type of AI marketing tool developed by DemandJump prove to be the way forward for marketing?

At a Glance

WHAT
Emotibot combines deep-learning AI, image and text-based recognition software to offer an open-source API for more emotionally aware chatbots.

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China

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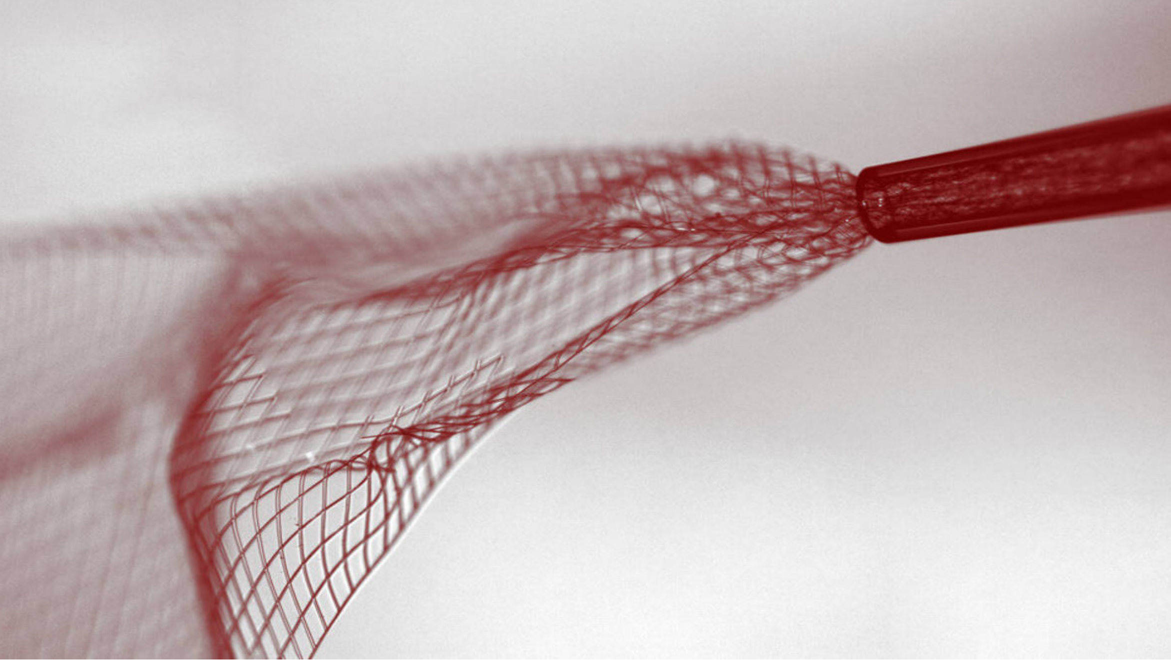
Adding emotional intelligence to AI

Emotibot combines deep-learning AI, image and text-based recognition software to offer an open-source API for more emotionally aware chatbots.

The use of AI chatbots is on the rise, whether it's helping users with recruitment, insomnia or acting as a hotel concierge, and now China-based Emotibot are enabling developers to offer more personable automated user experiences.

In collaboration with MIT Media Lab, Emotibot has been applying image recognition and a deep-learning approach to develop more emotionally intelligent chatbots. The API is able to pick up on 22 emotional patterns used in text conversation, 7 emotions from voice recognition and also 7 unique emotional states from facial expressions, so that if users have cameras and microphones activated on their personal devices, Emotibot will adapt it's responses and interactions based on how the user feels in real-time.
A feature called Emoti-eye will also enable the chatbot to recognize distinct types of clothing or objects also present through device cameras, which the API is capable of retaining a 'memory' of for subsequent interactions, with the chatbot constantly adapting via self-learning algorithms. The Emotibot API SaaS will be open source, allowing developers to fully customize user experience whatever the context.

Could emotionally intelligent chatbots be a feature in staff-less stores such as Amazon Go?



At a Glance

WHAT
A new system for recording the electrical signals of individual neurons could allow much better brain to computer interfaces.

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Mesh allows brain mapping of individual neurons

A new system for recording the electrical signals of individual neurons could allow much better brain to computer interfaces.

We have recently seen the development of number of potential treatments for neurological conditions, such as virtual reality used to help treat Alzheimer's patients and a device that helps stroke victims regain mobility by sending electrical signals to their brain. One key to developing effective new treatments for neurological conditions such as Parkinson's and Alzheimer's is finding a way to better understand what is happening in the brain. To do this, it is necessary to monitor and map the activity of neurons in the brain. Up to now, the most accurate devices for taking these types of measurements have been intracranial probes, which are surgically implanted in or near the brain. Now, a team of nanoscientists at Harvard have developed an electronic mesh, around the width of a human hair, which is flexible enough to be stuffed into the needle of a syringe and injected into the brain. Once injected, the mesh unfurls to make contact with the brain, where it can then record the activity of individual neurons.

The new device starts off as a tiny, flat sheet about the size of a postage stamp. It is made of metal electrodes and silicone wires that are each only billionths of a meter thick. A variety of sensors can incorporated into the mesh, which is suspended in liquid and drawn up into a syringe. It can then be precisely injected to any region of the brain, without causing damage. After injection, the mesh returns to its original shape and can network wirelessly with neurons in the brain, recording signals and stimulating activity in targeted areas of the brain without risk of damage that can occur from other types of probes. The mesh can also be injected into other areas, such as the eyes.

The lab conducting the research, the Lieber Group, has also demonstrated that similar types of electronic mesh probes can be injected into synthetic materials as well, such as cavities inside silicone rubber blocks. These could then be used to monitor the stability and strength of buildings and other structures using corrosion and pressure sensors. Team leader Charles Leiber points out that many conventional probes fail over time due to damage to the brain they are implanted it, while the mesh does not cause any damage or immune response. Could this type of implant lead to improved treatments for neurological diseases? What other uses might it have?

At a Glance

WHAT
A new platform and biometric sensor allows the collection of more scientifically accurate consumer neuroscience data.

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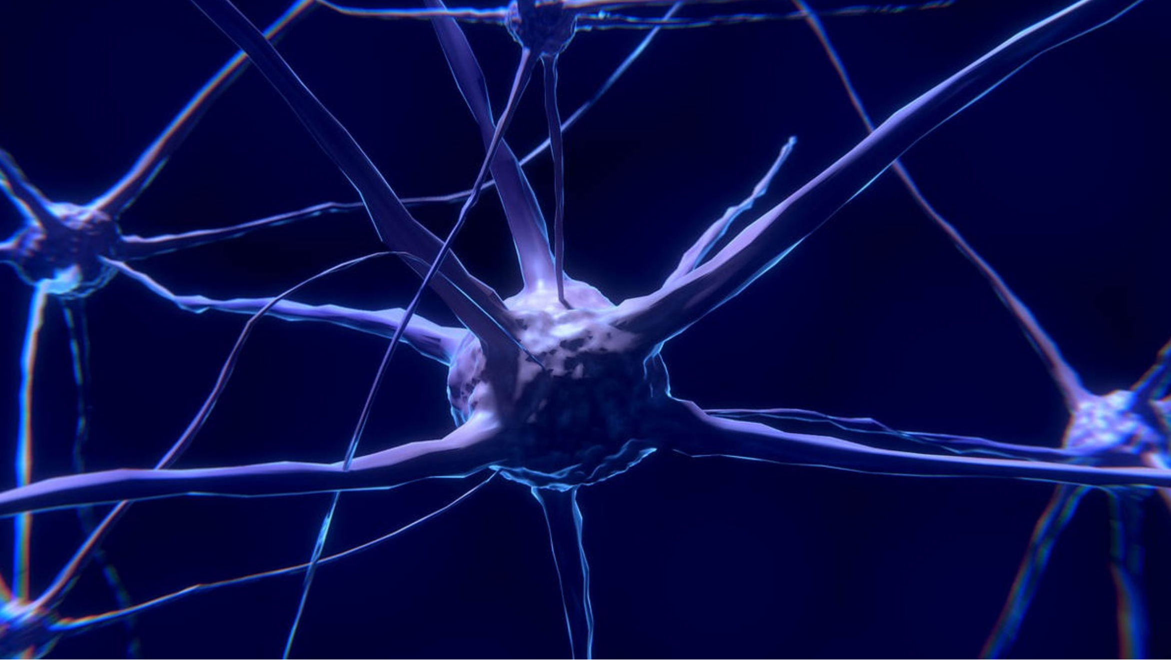
New platform allows more accurate consumer data collection

A new platform and biometric sensor allows the collection of more scientifically accurate consumer neuroscience data.

There have been a number of innovations that try to use neuroscience to help gauge the opinions and feelings of consumers. These have included ways of allowing communities to participate in marketing and having customers chose the price they want to pay. However, the nascent field of consumer neuroscience has suffered from two major limitations - a lack of credibility, stemming from abuse and the use of voodoo science, and a reliance on traditional, focus-group based methods for gathering data. The use of focus groups means that it can be costly and time-consuming to collect data in real time. Now, Portuguese consumer neuroscience start-up MindProber has developed a platform to allow panel-based automated media testing, free from pseudoscience.

At the heart of MindProber's system is James One – a newly devised biometric sensor, named after William James, the author of the groundbreaking nineteenth-century psychology work entitled, "What is an Emotion?". James One is designed to unobtrusively and remotely capture high-quality heart and electrodermal indexes from panel members, recording their reactions to different media content. MindProber distributes the sensor to hundreds of panel members and then captures their biometric and declarative reactions while they watch media content. The device records data on a second-by-second basis, and can be used in real time to collect the physiological and behavioural reactions of hundreds of people to content such as television ads or entertainment programs, as well as analyse their global and second-by-second impact.

MindProber has also created a fully automated, DIY platform that allows users to set up and launch studies on their own, as well as monitor study progression and explore results. The platform allows users to design and run customised studies with hundreds of participants in just a few days. MindProber's app manages the interaction between panelists and platform, from distributing invitations for studies to survey deployment and compensation information. By creating a science-based platform for collecting and analysing data, MindProber has made it easier for companies to test their content in a more precise and valid manner. The company recently won an award for innovation given jointly by the Market Research Society and the Association for Survey Computing. How could more accurate data on consumer neuroscience help companies to grow their business?



At a Glance

WHAT
A new game allows ordinary people to conduct scientific research while competing with others.

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Crowdsourcing neuroscience research with a game

A new game allows ordinary people to conduct scientific research while competing with others.

We have seen a number of unusual innovation in neuroscience, such as a device that helps owners understand what their dogs are thinking and a system that allows people to 3D print their thoughts. Ultimately, more useful innovations in neuroscience will depend on a better understanding of the connections between the 80-90 billion neurons in the human brain. Although existing technology enables the creation of images of individual neurons, it requires human input in order to trace and classify the different shapes of each nerve cell. This is because human eyes are much better than computers at distinguishing the delicate and highly branched structures of the neurons, and at inferring detailed structures from faint and often incomplete data.

Tracing and classifying the neuronal structure is slow work and requires specialised training, but a game designed by computer scientists at the University of Washington Center for Game Science and the Allen Institute for Brain Science allows ordinary citizen-scientists to compete to produce complete, three-dimensional reconstructions of neurons from imaging data. The game, called Mozak, shows players a magnified volumetric image of a neuron, and asks the player to trace or draw its visible branches. New players get real-time feedback from expert neuroscientists, which allows them to quickly acquire world-class expertise. Mozak also requires general consensus among multiple players about a neuron's shape, which allows the game to provide neuroscientists with validated, gold-standard reconstructions.

Mozak players — around 200 a day — have been able to reconstruct neurons 3.6 times faster than previous methods. The players also outperform computers at the complicated task of tracing the shapes of neurons, producing reconstructions that are between 70 to 90 percent complete, compared to just 10 to 20 percent for the best computer-generated reconstructions. Such accurate and fast mapping will help researchers to better understand how neuronal structure relates to brain function. In what other fields might a crowdsourced game enable citizen-scientists to speed up research?

At a Glance

WHAT
Startup's stress sensor tracks users' unconscious responses to products and experiences.

WHO
mPath

WHERE
United States

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www.buildempathy.com
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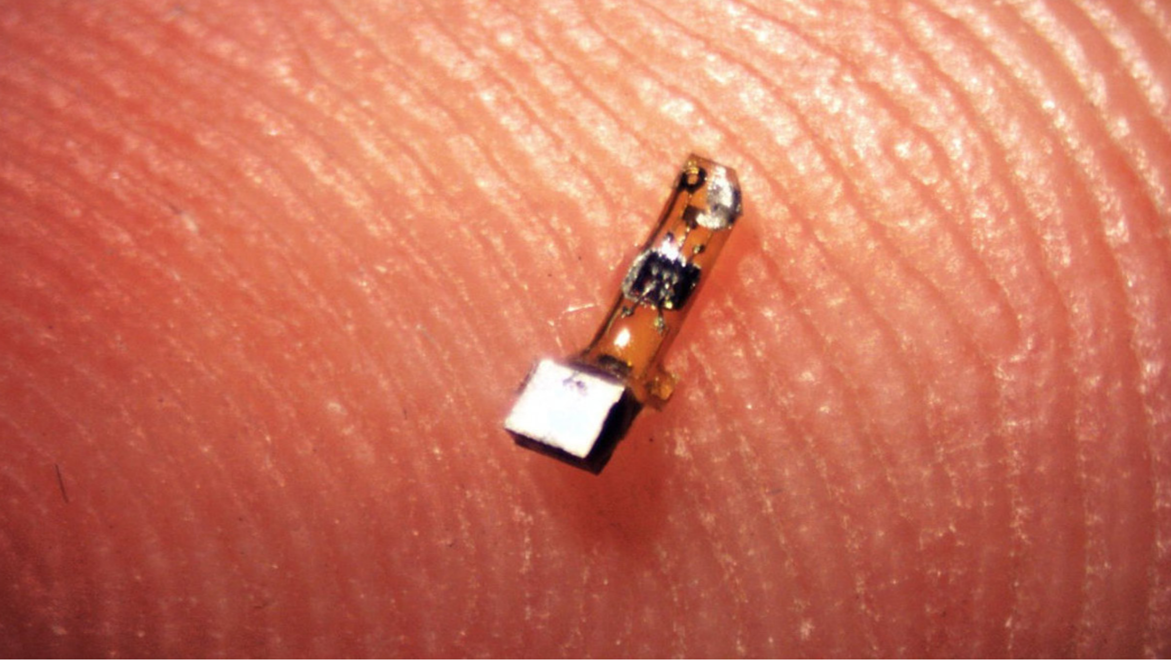
Wearable device detects consumer emotions

Startup's stress sensor tracks users' unconscious responses to products and experiences.

Much of consumer neurological testing focuses on gauging consumers' responses to what they see and hear. But consumer responses are not black and white, like or dislike. In fact, people experience a wide range of emotions in response to products and experiences. Shoppers may become initially excited by certain brands, but then become overwhelmed by choices and lose interest; viewers may become frustrated, bored and entertained in the course of watching a single video. Now, MIT Media Lab spinout mPath has developed a way to measure the exact moment when consumers feel these subconscious responses. Their work allows companies and organisations to better refine their products and services to match consumer expectations.

To collect data, the startup created the MOXO sensor - a wearable that looks like a bulky smartwatch. The sensor wirelessly measures changes in skin conductance (small electrical changes across the skin), which reflect different types of activity in the wearers' nervous system. Spikes in conductance can signal stress or frustration, while dips may indicate disinterest or boredom. To gain a more accurate picture of consumers' responses to specific stimuli, mPath combines the MOXO with eye-tracking glasses or cameras, to identify where a person was looking at the exact moment of an emotional spike or dip. The resulting approach, dubbed 'emototyping', creates a more in-depth, precise emotional profile of consumers than previous forms of market research. It is especially useful when studying children, as it can be difficult for children to describe what they feel.

In addition to retail studies, the system has been used to help engage new audiences in classical music, and to track peoples' fear levels throughout different parts of a haunted house. The company is also working with the Boys and Girls Clubs of America to develop methods to encourage reading by better understanding when children feel overwhelmed by reading. In the future, Hedman sees the MOXO as a potentially useful tool to help therapists understand what children with autism are feeling, and to allow educationalists to design curriculum and classroom experiences that are more engaging. The MOXO and mPath join other consumer neuroscience innovations such as an AI marketing tool that provides detailed analytics and a cooking app that helps convince kids to eat more healthily. What other uses could the MOXO have for helping children and retail companies?



At a Glance

WHAT
Engineers have developed a brain-machine interface device that is small enough to attach to small groups of neurons.

WHO
University of California at Berkeley

WHERE
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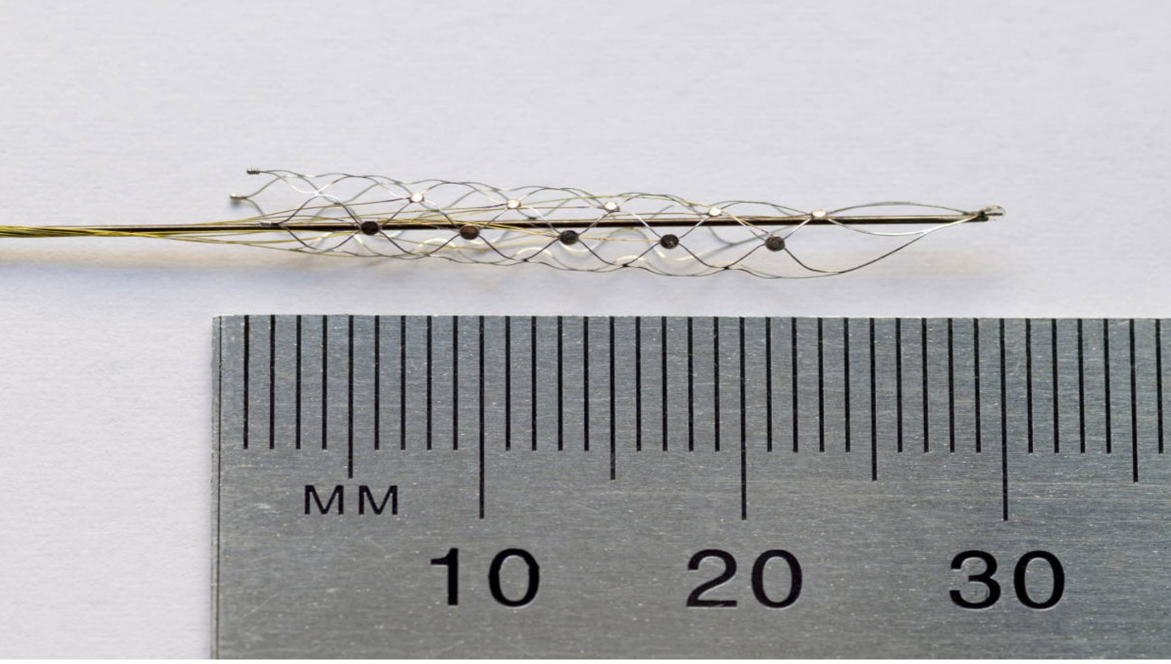
Researchers develop dust-sized BMI

Engineers have developed a brain-machine interface device that is small enough to attach to small groups of neurons.

Up to now, researchers working to develop more sensitive brain-machine interfaces have relied on electroencephalogram (EEG) readers and devices implanted in or near the brain through surgery. We have recently seen some of these devices, such as a device that helps improve concentration and another that can provide greater autonomy to the less-physically-abled. Now, engineers at the University of California at Berkeley have built a dust-sized, wireless sensor that can be sprinkled throughout the body and brain, and used to monitor and stimulate very small groups of neurons. Eventually, similar devices could be used to monitor internal organs in real time or to stimulate individual nerves to treat disorders such as epilepsy.

While most implanted sensors break down after a year or two, the motes are built from a thin film which could last in the body for up to a decade. For a power source, the neural dust uses ultrasound which, unlike radio waves, can penetrate nearly anywhere in the body. The sensors contain a piezoelectric crystal that converts ultrasound vibrations from outside the body into electricity to power a tiny, on-board transistor that is in contact with a nerve or muscle fibre. According to engineer Michel Maharbiz, one of the projects leads, "Having access to in-body telemetry has never been possible because there has been no way to put something super tiny super deep. But now I can take a speck of nothing and park it next to a nerve or organ, your GI tract or a muscle, and read out the data."

The team is now working on shrinking the sensors from a 1 mm cube (about the size of a grain of sand) down to a cube just 50 microns on a side (around half the width of a human hair). At that size, the motes could be capable of attaching to individual nerves. They also plan to develop ways to focus the sounds waves on individual motes and to expand the motes' ability to detect non-electrical signals, such as oxygen or hormone levels. In the future, the team envisions the neural dust being used to control robots and computers using thought, to stimulate nerves to treat diseases like epilepsy and Parkinson's, by doctor's to take very precise measurements, and even used to stimulate nerves to tell users to stop smoking. Will we all one day have neural dust sprinkled throughout our body to help us connect our brains with computers and stay healthy?



At a Glance

WHAT
A neural interface that could restore mobility to paralysed patients is ready for human trials.

WHO
Synchron

WHERE
Australia / United States

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www.synchronmed.com
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A device that could help the paralysed walk again

A neural interface that could restore mobility to paralysed patients is ready for human trials.

In 2011, University of Melbourne neurologist Dr Thomas Oxley was travelling in New York when he was invited to have a chat with the military neurologist directing the prosthetic limb program for DARPA, the research unit of the U.S. Department of Defense. While there, Oxley suggested that it might be possible to allow paraplegics and quadriplegics to move by directing an exoskeleton with their thoughts – without the need for complex and invasive brain surgery. Impressed, DARPA gave Oxley a grant to pursue his idea. The DARPA funding was eventually extended with additional grants from the Australian National Health and Medical Research Council and a group made up of more than 39 senior researchers from engineering, science and medicine departments at the University of Melbourne succeeded in creating the device, called the stentrode.

There have been many recent innovations which use headsets to create a link between computers and the brain, such as a device which can aid concentration or a helmet that can help users to become calmer. The stentrode is also a neural interface, but one which is designed to sit inside a blood vessel next to the brain's motor cortex. It is inserted into a blood vessel in the brain using a catheter, and resembles a small net-like 'basket' wired with electrodes. These electrodes sit on the wall of the blood vessel, next to the brain tissue, and record brainwave activity. This is then coded into software that is used to move a robotic exoskeleton attached to the arms or legs. Users visualise movements, and the signals are transferred to the exoskeleton, which moves the users' limbs.

Oxley and chief engineer Dr Nick Opie, co-founded a company to translate their research into reality. After recently raising USD 10 million, the Palo Alto and Melbourne-based company, Synchron, is ready to begin human trials. A select group of paralysed patients will be chosen for the trial, where they will be implanted with the stentrode. If the trial succeeds, the technology could become commercially available in as little as six years. What other uses could there be for a device that allows people to move robots with their mind?

At a Glance

WHAT
Researchers are working on a way to use virtual reality to retrain the brain and muscles of stroke victims to aid in recovery.

WHO
Neural Plasticity and Neurorehabilitation Laboratory

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VR could trick stroke victims to aid recovery

Researchers are working on a way to use virtual reality to retrain the brain and muscles of stroke victims to aid in recovery.

We have seen how virtual reality can be used for allowing collaborative design and controlling robots remotely. Now, researchers believe that VR may be able to help stroke victims regain lost motor function. Research conducted by University of Barcelona professor Mel Slater and Stanford professor Jeremy Bailenson has demonstrated that virtual experiences can lead to changes in perceptions of oneself and others. For example, having an avatar of a child in a virtual reality environment can encourage people to exhibit more childlike behaviour in the 'real world'. Inspired by this work, researchers at the University of Southern California are now examining how virtual reality could promote brain plasticity and recovery.

Sook-Lei Liew, who is director of the Neural Plasticity and Neurorehabilitation Laboratory, has been working on a study called Rehabilitation Environment using the Integration of Neuromuscular-based Virtual Enhancements for Neural Training. Liew's team used an electroencephalography (EEG)-based brain-computer interface to help those with neuromuscular weakness in their arms control an avatar in VR. If EEG signals corresponding to an attempt to move an arm are detected, the avatar's arm is moved in the VR environment. The team hopes that the resulting visual feedback through a VR headset could help strengthen neural pathways from the damaged motor cortex to the impaired arm, leading to real improvements in mobility.

The research group recently finished testing the prototype with 22 healthy older adults, who provided data on what the brain and muscle signals look like when they move. They are now starting to test with stroke patients in a controlled lab setting. While the possibilities for using VR in health care are promising, there are many unanswered questions on the best ways to use it. As Liew points out, "A lot of the work that we're trying to do is to test assumptions, because there's a lot of excitement about VR, but there's not that much that's scientifically known." Will we see virtual reality used in a wide variety of medical treatments in the future?

At a Glance

WHAT
Biomedical engineers at Newcastle University created a prosthetic limb that uses AI to respond to the environment, adjusting its grip and movements as needed.

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Smart prosthetic limb that sees makes motion more natural

Biomedical engineers at Newcastle University created a prosthetic limb that uses AI to respond to the environment, adjusting its grip and movements as needed.

Already being introduced to patients at Newcastle's Freeman Hospital, the bionic hand with vision capabilities uses artificial intelligence (AI) rather than electrical signals from muscles to control its movements. While prostheses have greatly improved over time through material developments, the methods for controlling them have not greatly advanced. The new prosthesis designed by Newcastle University engineers has been taught to recognize objects using neural networks.

By learning which objects require which type of grasp - depending on size, orientation and shape - the smart limb can immediately make a decision as to which is needed. The camera fitted to the top of the prosthesis views an object, and then the AI system determines which grasp is needed and tells the hand to move accordingly. The entire process takes only milliseconds, which is ten times faster than the current method, which requires the user to concentrate on the object and work the muscles connected to the limb to achieve the desired action.

Other projects working to improve prostheses include a solar powered skin that could return the sensation of touch to amputees, and a connected wristband that provides amputees with the fine motor movements needed to work on a computer. How else could smart cities incorporate these ideas and new technologies to help make public services more accessible?

At a Glance

WHAT
A team of researchers has developed a brain-computer interface that allows users to type at nearly normal rates.

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Device allows people to type with their mind

A team of researchers has developed a brain-computer interface that allows users to type at nearly normal rates.

A newly-developed brain-computer (BCI) interface allows people with severe limb weakness to type, using their minds, at speeds approaching normal. The participants each had an electrode array around the size of a baby aspirin implanted in their brains. The array recorded signals from the motor cortex, the region of the brain controlling muscle movement. Following the surgery, the participants were encouraged to visualise the arm, hand and finger movements involved in typing. The resulting neural signals were then translated by algorithms into point and click commands that were used to guide a cursor on an onscreen keyboard.

Similar techniques using headsets have already allowed users to control movies with their thoughts and to track stress levels. Participants in the study were able to outperform the results of any previous BCI, and without the use of any word prediction software. One participant was able to type 39 correct characters per minute, equivalent to about eight words per minute. Researcher Krishna Shenoy, professor of electrical engineering at Stanford, where the study took place, said, “This study reports the highest speed and accuracy, by a factor of three, over what’s been shown before … we’re approaching the speed at which you can type text on your cellphone.”

Previous studies used intracranial BCIs that were positioned at the brain’s surface beneath the skull. However, the BCI used in the Stanford study consisted of a tiny silicon chip, around one-sixth of an inch square, out of which protrude 100 electrodes that each penetrate around 1.7m mm into the brain, tapping into the electrical activity of individual nerve cells in the motor cortex. This allowed for greater precision. The team also noted that the point-and-click approach pioneered at Stanford could be applied to a variety of computing devices, including smartphones and tablets. This could substantially improve the ability to communicate and the quality of life for people with paralysis. Shenoy believes that they may be less than ten years away from a self-calibrating, fully implanted wireless BCI system, which can be used without caregiver assistance, to restore some function to those with severe neuromuscular impairment. Will the development of intracranial BCIs be able to restore communication, mobility and independence for people with neurologic disease or injury?

At a Glance

WHAT
UK researchers are using VR and brain scans to identify parts of the brain associated with social cues.

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Virtual reality may help those with autism

UK researchers are using VR and brain scans to identify parts of the brain associated with social cues.

According to the U.S. Centers for Disease Control and Prevention, as many as 1 in 68 children have been identified with autism spectrum disorder (ASD). Since people with autism struggle to read social cues, such as facial expressions, being able to understand the neurological basis for this may eventually lead to new diagnosis and treatment for the condition. Now, a project funded by the EU Commission, called Becoming Social, is working to map the regions of the brain that are sensitive to social interactions, and how these regions develop as children grow.

The brain networks responsible for our social intuition are still largely a mystery. Exactly when they develop, or even where in the brain they lie is still unknown. It is also not yet clear whether these skills are learned, or if they are present from birth. In order to try and answer some of these questions, Dr Kami Koldewyn, a psychologist at Bangor University, is using functional MRI brain scans to try and identify which neural networks are active when volunteers observe people interacting. However, studying the way the brain processes non-verbal cues during social interactions can be a challenge because researchers need to completely control one side of a conversation to ensure that the test is accurate. To accomplish this, the team turned to researchers at University College London, who are using VR to create realistic social interactions. According to UCL researcher Dr Alexandra Georgescu, 'We have built virtual people using a commercial VR system combined with our own code that allows us to control our virtual characters. It offers quite a realistic experience of social conversations and allows us to study things like turn-taking and mimicry.'

We have previously seen VR used to help prevent motion sickness and to control robots. Now, by combining VR and brain scans, researchers are able to bring a new level of scientific rigour to social neuroscience, and allow theories that were previously hard to test to be subjected to controlled experiments. Understanding the link between brain development and social ability could open the door to helping those with autism to develop real-world social skills through training exercises. In addition, this research may have commercial applications, by creating AI which can interact more naturally with humans. What other ways might exist for using VR and AI to help those with autism?

At a Glance

WHAT
Researchers have developed software that helps computers understand human body movements and poses.

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New method allows computers to understand human movements

Researchers have developed software that helps computers understand human body movements and poses.

We have already seen artificial intelligence software that can make critical decisions and direct drones to prevent poaching. At Carnegie Mellon University (CMU), robotics researchers have now developed a method that enables a computer to understand the body poses and movements of multiple people at the same time, including the positions of individual fingers. Yaser Sheikh, associate professor of robotics, has pointed out that this technique allows computers to track the nuances of human non-verbal communication and could open up new ways for people and machines to interact with each other.

Tracking multiple people in real time, particularly in social situations where one or more people may be in physical contact, presented a number of challenges. For body parts, such as arms, legs, faces, Sheikh and his team first identified all the body parts in each scene, and then associated those parts with particular individuals. Fingers, however, represented an even greater challenge. Since people use their hands to hold objects and make gestures, cameras have a hard time seeing all the parts of a hand at once. To get around this, researchers used CMU's multi-camera Panoptic Studio, which is a two-story dome fitted with 500 video cameras. The studio is capable of providing 500 views of a person's hand from a single shot, as well as automatically annotating the hand positions.

Using the photos, the team were able to build a dataset and software that could detect the pose of a group of people using just a single camera and a laptop computer. To encourage more research in this area, the team have made their data and computer code available to other research and commercial groups. Shiekh says that possible applications include allowing people to communicate with computers by pointing; enabling self-driving software to 'learn' when a pedestrian is about to step into the street by monitoring body language; and enabling new approaches to behavioural diagnosis and rehabilitation for conditions such as autism, dyslexia and depression. What other uses could there be for software that can read and understand human movements and poses?

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