

Rethinking visual impairment

Dr Lotfi Merabet is dedicating his career to the study of blindness and visual impairment. Here, he talks about his work so far, and what he has learned from collaborating internationally



Firstly, what inspired you to study the human visual system, and particularly how the brain adapts to the loss of sight?

This is related to my personal interest in photography and the visual arts. As a graduate student I studied the neurophysiology of the visual system in animal models and then pursued an optometry degree so as to merge this knowledge with clinical practice. In parallel, I am fascinated by how blind individuals adapt to the loss of sight and how compensatory behaviours are intimately related to changes occurring at the level of the brain. Such changes, which we refer to in neuroscience as plasticity, represent a great opportunity for studying brain development and how the brain is able to adapt.

How has your training in multiple areas of neuroscience, optometry and public health

informed your research?

I view work in all of these fields as integrated and part of a continuum. First, there needs to be sensitivity to unmet clinical and educational demands in the blind community. Solutions and strategies should be evidence-based and supported by data-driven research. Additionally, these solutions should be translated into policies and upheld through legislative efforts. Effective rehabilitative solutions for the blind need to incorporate all of these considerations.

What do you hope to achieve through your studies on eye care for patients with intellectual disabilities and visual impairment?

Our goal is to leverage current technology for the purposes of developing assistive approaches for individuals with disabilities in

order to remain functionally, intellectually and socially integrated within society. We apply an evidence and scientific-based approach to assess usability and accessibility, and to answer the question of why certain strategies work while others do not. Technology progresses very rapidly and many individuals with disabilities feel they are being left behind. The goal is to allow individuals with disabilities to use technology as a facilitator and enabler rather than thinking of it as a barrier. As part of the development process, effective assistive technology must incorporate the end-user, regardless of whether their disability is physical or intellectual. Further, approaches must be grounded in evidence-based and scientific



BLIND PERSON WALKING WITH A CANE



CLOSE UP OF HANDS READING BRAILLE

work rather than the assumption of what an individual needs, wants, or can and cannot do. Finally, technology can be a strong source of motivation which is crucial for maintaining drive and interest to help individuals achieve the goals they seek.

To shed further light on your humanitarian interests, what insights did you gain from spending time as a clinical volunteer in Ghana for a non-profit eye care organisation?

My experiences have helped to galvanise my awareness of the sheer magnitude of the need for healthcare worldwide. Many of the issues in the developing world do not match the priorities of more developed nations and therefore go unresolved. There is clearly a need for low-cost solutions directed at treating eye-related diseases as well as for education and rehabilitation problems for the blind. This reality also illustrates the need for legislation and policy in order to institute transformative change. This experience was a strong motivation and further inspired me to pursue my degree in public health.

Similarly, how has your affiliation with areas such as South America and Europe benefited your research and teaching interests?

I believe international collaborations are excellent for promoting creativity and productive dialogue. Furthermore, as resources are often limited, international collaborations can allow for leverage to facilitate progress in a synergistic manner. Often, what can be limiting and/or challenging in one country is easier to accomplish elsewhere, allowing for the scaling-up of studies, implementation and field testing. Working with developing countries with a greater limitation of resources has created tremendous sensitivity and awareness of the importance of creativity and dedication. Many times we have observed strong social commitment and responsibility, as well as the ability of individuals to achieve significant progress with substantially fewer resources at their disposal.

Could you discuss some of the major challenges associated with your work?

The scientific and rehabilitative communities alike tend to treat blindness as a uniform condition. However, it is clear that there is tremendous variability in terms of aetiology, pattern of progression, onset and degree of visual impairment. Future work should concentrate on understanding the effects of these variables in terms of brain plasticity and, in turn, inform us of how to develop better case-specific education and rehabilitation strategies.

The game-changers

The rehabilitation and education of individuals living with blindness and visual impairment are both pressing medical and social issues. Unique work at **Harvard Medical School** is seeking to address them



BLIND PARTICIPANT PLAYS A VIDEO GAME WHILE AN INVESTIGATOR (LEFT) OBSERVES

THE HUMAN BRAIN was once thought to be a static, unchanging organ whose functions and mechanisms remained constant throughout an individual's lifespan. Whilst it is now acknowledged that this is far from the case, neuroplasticity – the extent to which the brain is capable of change – is still poorly understood. There is growing evidence that, particularly in instances of sensory deprivation, the brain may be capable of adaptation through rewiring certain pathways to perform functions usually associated with other areas. This opens up fascinating possibilities for research, uncovering greater potential for the rehabilitation of individuals with physical or intellectual disabilities.

Dr Lotfi Merabet, Director of the Laboratory for Visual Neuroplasticity and Assistant Professor at the Massachusetts Eye and Ear Infirmary at Harvard Medical School, USA, is conducting valuable research in the area of neuroplasticity in individuals without sight. With the help of his colleagues, both within the US and abroad, Merabet is employing novel techniques in the hope that they can aid the development of assistive technology and rehabilitation strategies grounded in neuroscientific research, and thus improve the quality of life for the blind and visually impaired.

GAME-BASED APPROACH

Merabet and his team are particularly interested in the potential application of non-visual virtual environments (VE) and video game-based strategies to teach blind individuals new cognitive and motor skills. He explains:

“We use virtual environments as a means for blind individuals to interact with non-visual information in a meaningful and ecologically valid manner”. Through the use of audio and/or tactile based interfaces, a blind individual is able to acquire and interact with sensory information leading to the generation of appropriate mental constructs and representations that can be manipulated for the purposes of learning, skill development and decision making.

Using this system, an individual can respond to iconic spatialised sound – such as the sound of a door being opened in the left stereo channel of their headphones indicating a door on their left – to explore a virtual environment and create a mental map of its layout. “Acquired information,” elaborates Merabet, “is based on dynamically updated verbal descriptions detailing the user's current location, orientation, heading, and the identity of objects and obstacles in their path.” The user is able to use this to create an accurate mental representation known as a spatial cognitive map, which correlates to a real-life building on which the virtual environment was based. In the study, individuals have subsequently been able to successfully navigate the real-life equivalents by rehearsing in a digital version. Merabet likens this to an aircraft pilot who is able to learn to fly a plane correctly by first practising in a flight simulator.

A further benefit to this type of learning is an increase in motivation and encouragement for the individual taking part. The basic task itself – learning the layout of an unfamiliar building – is not particularly stimulating, but by developing a game-based metaphor where a person has

INTELLIGENCE

LABORATORY FOR VISUAL NEUROPLASTICITY

OBJECTIVES

To understand the neuroplasticity associated with vision loss and to develop methods to modulate brain function and optimise behavioural and functional outcomes using novel rehabilitative strategies, non-invasive brain stimulation and functional neuroimaging. The findings are likely to impact both the rehabilitation and education of the blind and visually impaired. Furthermore, these underlying neuroplastic mechanisms may serve as a basis to enhance the development of novel rehabilitation approaches grounded in neuroscience.

KEY COLLABORATORS

USA: Schepens Eye Research Institute • Massachusetts Institute of Technology • Boston University School of Medicine Center for Biomedical Imaging • Carroll Center for the Blind • Spaulding Rehabilitation Hospital • Boston Children's Hospital

Chile: University of Chile

Italy: University of Milan

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CONTACT

Dr Lotfi Merabet, OD PhD MPH
Assistant Professor of Ophthalmology, Harvard Medical School.

Director, The Laboratory for Visual Neuroplasticity

Massachusetts Eye and Ear Infirmary
20 Staniford Street
Boston, Massachusetts
02114, USA

T +1 617 573 4130
F +1 617 573 4178
E lotfi_merabet@meei.harvard.edu

www.scholar.harvard.edu/merabetlab

www.masseyeandear.org

DR LOTFI MERABET is a clinician-neuroscientist interested in how the brain adapts to the loss of sight. He completed his doctorate in Neuroscience at the University of Montreal, Canada, and his clinical doctorate in Optometry at the New England College of Optometry, USA. He then continued his postdoctoral training at Harvard Medical School, Boston University, and the MGH Martinos Center for Biomedical Imaging and completed his Master's in Public Health (Harvard). In 2010, he joined the faculty of the Massachusetts Eye and Ear Infirmary as a clinical researcher.

to find jewels and dodge monsters, Merabet's project succeeds in incentivising the learning process. Certainly, when compared to traditional systematic or rote-based approaches to learning, the system has seen an improvement in both the speed and facility of learning as well as the high level of knowledge gained. Merabet is optimistic that the applications for learning through gaming are potentially far-reaching, encompassing mathematics, science and language development. "In order to develop these software and interfaces, we work closely with teachers of the visually impaired; orientation and mobility specialists; and blind end-users," he summarises. "Incorporating their input and feedback early on in the process is essential to developing effective and accessible design strategies."

According to Merabet, initial results have been very promising and demonstrate that interacting with non-visual VE leads to the development of spatial navigation skills in the blind, as he elucidates: "These skills can be transferred to real-world settings. Further, interacting and learning with VE using a game-based self-exploration strategy leads to enhanced skills related to problem solving and decision making".

NEURO-IMAGING

Alongside this work, Merabet's lab has also used non-invasive brain scanning technology – functional magnetic resonance imaging – to monitor neuroactivity in blind individuals, and they have met with some startling results: "We have found that a good deal of the non-visual compensatory behaviours observed in the blind implicate areas of the brain normally associated with visual processing". In particular, the occipital visual cortex, which is linked to visual functions, appears to be involved in the processing of non-visual sensory information. Indeed, a similar phenomenon has been noted in cases of non-auditory compensation, with the brains of deaf individuals showing that areas associated with hearing participate in tasks such as tactile, language and visual processing. This begins to shed some light on the process of neuroplasticity, demonstrating concretely that the brain is capable of adapting, to some extent, using facets normally associated with processing information by the sense that was lost or that failed to develop.

INDEPENDENCE AND SOCIAL INTEGRATION

Whilst Merabet is hopeful that current technological advancements will continue to help close the accessibility gap, making the lives of blind individuals easier, he maintains that there is much work still to be done. Mobile telephones, for example, often come with integrated voiceover functions, and GPS systems have facilitated pedestrian travel for the blind. Yet, Merabet is wary that the developers of new technologies may not take the needs of all potential customers into account. "If the accessibility gap is not to widen again," he warns, "assistive technology needs to be continuously updated in order to keep pace with the latest advances."

Merabet also sees Braille literacy as a crucial issue in maintaining a high standard of living for individuals without sight: "Opportunities for the blind population to secure education and employment are closely tied to Braille literacy, yet current trends suggest that literacy is on the decline". He believes that in order to arrest the decline in the ability to read Braille, a multifaceted approach is required, which is able to harness the power of novel accessible technologies such as refreshable displays for presenting Braille text and tactile graphics. Coupled with this, he champions legislative action to make Braille education and literacy a priority, along with new modes of teaching, especially in instances of late-blindness in adults.

"Advances in modern science and medicine have helped tremendously in increasing life expectancy and survival from what were once considered untreatable conditions," Merabet summarises, "but we need to remain committed to individuals living with disabilities such as visual impairment." He considers there will always be a premium on the development of better strategies, education and rehabilitation for these individuals, arguing that a sincere and focused belief must be maintained in the potential for blind and visually impaired people to contribute to society and lead fulfilled and productive lives. Ultimately, he sees technological advancement and the development of new tools as central to changing not just the lives of those affected by blindness, but attitudes towards them.

STUDY PARTICIPANT LYING IN AN fMRI SCANNER

