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Critique of Shreesh Mysore's Attention Selection Experiments in Owls

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Shreesh Mysore, an assistant professor in the Department of Psychological & Brain Sciences at Johns Hopkins University (JHU), who has received National Eye Institute (NEI) grant #R01EY027718, purports to study the neural correlates of sensory selection and stimulus prioritization in humans by performing harmful and problematic brain experiments on barn owls. To this end, he holds barn owls captive in a JHU laboratory, where they are restrained for hours at a time, subjected to multiple invasive surgical procedures, bombarded with visual and auditory stimuli while being held in a head fixation device, and ultimately killed. He performs craniotomies on the owls in order to insert brain recording equipment and/or tubes to deliver drugs into the brain. His methods cause the owls permanent brain damage.

Mysore attempts and fails to justify subjecting owls to these extremely harmful procedures by claiming that data from these experiments can provide valuable information about sensory processing, attentional mechanisms, and attention deficit disorders in humans and that these data cannot be obtained through more humane methodology. However, as reviewed in detail below, critical species differences in sensory and attentional processes, the negative effects of captivity on normal brain function and behavior in birds, and the complexity of human attention and human attention disorders severely limit the usefulness of these experiments. ***Rather, these experiments are flawed in both design and execution and do not contribute to our understanding of sensory and attentional processing in humans. Additionally, there are more effective and relevant non-animal research tools available that can further our knowledge of attention mechanisms in humans.***

Sensory Selection Processes in Humans and Owls are Ecologically, Neurologically Distinct

There are critical differences in the sensory anatomy between owls and humans that make any inferences drawn about similarities in sensory responsivity across the two species likely inaccurate. Owls have very different sensory, sensory selection, and selective attention requirements and mechanisms, and they depend on distinctive sensory input. Unlike humans, barn owls are nocturnal predators with the capacity to detect prey and avoid predators in complete darkness using only auditory information. Their phenomenal auditory localization skills are in part due to a unique asymmetry of their outer ears and the ruff of sound reflective feathers that help direct sound to the ear openings,[1] features obviously not found in humans. Similarly, unlike humans, owls' visual systems, including a rod dominated retina, are designed to work under low light conditions, sacrificing spatial resolution for maximum light sensitivity.[2] Compared to other species, barn owls' eye movements are very restricted, and unlike humans and other mammals, they make head movements rather than eye movements when tracking prey.[3] In sum, owls have adapted specializations in sensory processing apparatus and mechanisms that are designed to meet their species specific needs and that differ significantly from sensory processing mechanisms in humans.

It is well established that stimulus selection in humans depends largely on critical top down and bottom up interactions between higher cortical areas, primary sensory cortices, and subcortical regions in the brain.[4,5,6,7,8,9,10] Humans engage higher cortical areas in order to attend selectively to stimuli based on reward expectations,[11,12] immediate or long term goals,[13,14] learned values of novel stimuli,[15] and learned predictiveness of stimuli[16] and for self regulation and performance monitoring.[17,18] The existence of similar cortically mediated "executive control" of sensory stimulus attention and selection in avian species is currently undocumented and is not being investigated or even considered in Mysore's experiments on owls. *The stimulus-selection processes and neuroanatomical regions he is attempting to assess involve only the subcortical optic tectum and inferior colliculus of the owls' brains and thus will add little value to our understanding of more complex cortically mediated human attention and stimulus-selection systems.*

Sensory Selection and Attention Cannot Be Accurately Measured in Owls in a Laboratory

It is well known that the general laboratory environment and routine experimental procedures cause acute and chronic stress in animals.[19] Additionally, studies of birds in captivity have documented marked changes in stress hormone production[20] and, subsequently, immune system dysfunction in response to the laboratory environment.[21,22,23] The effects of captivity and laboratory induced acute and chronic stress are not just ethically unacceptable; they also introduce serious disruptions to normal behavior and neurological structure and function in birds. For example, alterations in stress hormone levels are known to affect birds' cognitive abilities,[24] including spatial learning and memory.[25,26,27,28,29] Similarly, hyperinflammation, documented in captive birds, is a known mediator of brain function and cognition in humans and animals.[30,31,32,33] The impact of chronic and acute stress, elevated circulating stress hormones, and anxiety on goal directed attentional processes in animals is also well documented.[34,35,36,37,38,39]

The effects of chronic and acute stress on captive birds' sensory processing abilities confound any attempts to draw conclusions about typical selective attentional processing in owls. Additionally, owls held in a laboratory setting do not experience the natural visual, auditory, and spatial information of the natural world. Restrictions in space, alterations in lighting, and limited or experimentally controlled visual and auditory input will alter the organization of the neural networks that process this information. It is well established that artificially manipulating barn owls' visual and auditory experience affects the development and organization of the visual and auditory localization maps in the inferior colliculus as well as critical projections between the inferior colliculus, the optic tectum, and the isthmi pars tegmentum that Mysore is attempting to study.[40,41,42,43,44] Birds reared in captivity also exhibit reduced overall brain volume,[45] reduced brain volume in regions critical for processing spatial information,[46] and atypical hippocampal morphology and spatial processing abilities.[47,48,49]

In other words, the disruption of natural visual and auditory stimulation that occurs in owls held in Mysore's laboratory necessarily alters the underlying visual, auditory, and spatial information circuitry that he is trying to elucidate.

Birds in captivity are prone to neophobia and/or neophilia, reduced anti predatory behavior, and altered foraging and prey seeking behavior, which, in turn, alters the saliency, behavioral relevance, and behavioral and neurological response to both natural and artificial stimuli.[50,51,52,53] *Attempting to understand the species-typical sensory selection processes in owls housed or reared in an unnatural environment and exhibiting atypical behavior in response to sensory input that is no longer behaviorally relevant or salient is both unproductive and misleading.*

Mysore knows his experiments are hopelessly flawed. At a September 2, 2020, seminar at Albert Einstein College of Medicine, he admitted that experimenting on owls in a head fixed position could be misleading, stating:

> Almost all the work in attention so far has been done in head fixed animals, and there are lots of reasons that are emerging now, even more so than before, indicating that really, if possible, you should be doing things in freely behaving animals because the way they engage with the environment, the way locomotion, for instance, affects neuro responses, is quite significant, and it could change the way the brain is solving problems, and we might misinterpret what's happening or misunderstand if we do this in head fixed animals.[54]

Nevertheless, Mysore continues to use millions of taxpayer dollars to torment owls in his laboratory.

Attention Deficit/Hyperactivity Disorder Is a Complex, Uniquely Human Condition

Attention deficit/hyperactivity disorder (ADHD) is a complex, highly heritable, heterogeneous neurodevelopmental disorder with variable cognitive phenotypes, multiple genetic and environmental risk factors, and frequent psychiatric comorbidities. The age of onset, developmental course, and responsivity to pharmaceutical and/or behavioral treatments also vary across individuals with ADHD. *Attention deficit/hyperactivity disorder (ADHD) is a uniquely human condition, with environmental influences experienced only in humans. Its complex etiology and heterogeneity make it impossible to study in a nonhuman animal in a laboratory environment.*

Moreover, research with humans with ADHD suggests that it is the attentional processes mediated in higher cortical areas, including top down executive functions such as goal directed filtering and inhibition processes[55] and the fronto parietal network, that is dysfunctional in ADHD,[56,57,58] not the lower level thalamic sensory processing mechanisms being tested in Mysore's laboratory.

Human-Relevant Methods for Studying Stimulus Selection and Attentional Deficits

The use of animals, particularly in experiments that inflict considerable harm on them without any concurrent benefits, is wasteful and unethical. There are superior non-animal methods for studying attention that hold greater relevancy for human attention disorders.

I. Neuroimaging Techniques

Neuroimaging techniques including high resolution anatomical neuroimaging (MRI),[59] functional neuroimaging (fMRI),[60] single photon emission computed tomography (SPECT),[61] diffusion tensor imaging (DTI),[62] positron emission tomography (PET),[63] transcranial magnetic stimulation (TMS),[64] electroencephalography (EEG),[65] and magnetoencephalography (MEG)[66] are advancing our understanding of the neural underpinnings of visual, spatial, and auditory attention; stimulus selection; and disordered attentional processes in humans. It is data from these non animal research studies that have paved the way for the current pharmaceutical, behavioral, and TMS based treatments currently used to treat attention deficit disorder (ADD) and that will continue to pave the way for safe, more effective treatments in the future.

Several research groups are also successfully combining the use of the tools described below to develop a comprehensive understanding of the complex interplay of structural, neurochemical, and electrophysiological mechanisms in typical and atypical human attention networks.[67,68,69,70,71,72,73,74,75,76]

a. fMRI/MRI/DTI

High resolution fMRI has allowed researchers to study the neural networks involved in a variety of attentional mechanisms in humans performing species relevant attention mediated tasks,[77] including those requiring sustained attention[78,79,80,81] attention shifting[82,83,84,85] selective attention[86,87] and distraction laden target selection[88,89] across and within stimulus modalities. These studies have also successfully deciphered the roles of the superior and inferior colliculi and lateral geniculate nucleus during visual, spatial, and auditory attentional processing in humans[90,91,92,93,94,95,96] and their interactions with cortical regions during that processing.[97,98,99,100]

Structural imaging tools, including high resolution MRI and DTI, have been used to identify neurological abnormalities associated with ADD[101,102,103,104] and fMRI has also been used to identify atypical activity within brain regions during impaired attentional processing in individuals with ADD.[105,106,107,108,109,110] These neuroimaging methods have been used to identify biomarkers for more accurate diagnosis of ADD[111,112] as well as to clarify the genetic[113,114,115,116] and environmental[117,118,119] contributors to ADD. These tools also allow researchers to study the variability in symptoms[120,121,122] and the impact of different treatments[123,124,125] in this population at the neurological level.

b. TMS

TMS in humans, which can be used to modulate neural activity in a target brain region, can now simulate the chemical lesion and induced activation and deactivation studies once performed on animals. This tool has been used extensively to detail the various roles of individual neural regions in the attentional networks in humans[126,127,128,129,130,131,132,133] and to systematically identify the functional and dysfunctional components of attentional networks in individuals with ADD.[134] Importantly, these investigations have led to the use of repeated TMS (rTMS) in healthy individuals and individuals with ADD as a successful method for improving attentional control.[135,136,137]

c. MEG/EEG

The ability to measure and localize electrophysiological responses in humans using EEG and MEG has provided researchers with an in depth understanding of the time course of different neural contributions to attentional processes as well as the multi mechanistic nature of human attention.[138,139,140,141] These tools identified specific atypicalities in the ADD brain during a multitude of attention related tasks that can be used for better diagnosis and potentially for the development of new treatments.[142,143,144,145]

d. PET/SPECT

PET and SPECT imaging allows researchers to determine the dopaminergic, serotonergic, nicotinergic, GABAergic, and noradrenergic systems in typical and atypical neurological functions. These methods have been used to pinpoint both the neuroanatomical and neurochemical contributors to attentional processes in humans.[146,147,148] Additionally, these tools have been used to successfully identify the neural correlates of individual variation within the ADD population.[149,150,151] PET and SPECT have been used to determine the dopaminergic,[152,153,154,155] noradrenergic,[156,157] GABAergic,[158] and serotonergic[159,160] dysregulation associated with ADD and to study the effects of pharmaceutical treatment on these systems in individuals with ADD.[161,162]

II. Computational Models of Attention

Computational and mathematical models have been instrumental in furthering our understanding of visual attention. There are numerous models that assist in clarifying and investigating theories of visual attention using human relevant tasks and situations. These computational models fall into two broad categories: those that investigate bottom up visual attention, which is driven by visual input and saliency and occurs rapidly, and those that model top down attention, which is task oriented, based on subjective experience, and goal oriented.[163] Studies using computational modeling have successfully described how information from tasks such as making a sandwich guides eye movements[164] and how distractions while driving can affect eye movements,[165] as well as other human relevant tasks and functions. Population receptive field (pRF) computational models have successfully mapped how clinical conditions such as autism and Alzheimer's can affect attentional networks and plasticity in the visual cortex.[166] These tools have also been invaluable in elucidating the complex interactions between cortical and subcortical interactions during auditory and visual stimulus selection in humans[167168169170] and in modeling aberrant information processing in ADD.[171,172,173]

These Experiments May Have Violated Maryland State Law

Not only are the owl experiments at JHU indefensibly cruel and scientifically invalid, according to state records that we have uncovered, they're also apparently illegal, and we note that JHU chose not to dispute this point in an October 7, 2020, *Baltimore Sun* article.[174]

Because Mysore keeps barn owls in his laboratory, he is required by Maryland law to obtain an annual scientific collection permit from the Maryland Department of Natural Resources (DNR) to possess protected birds for educational or scientific purposes.[175,176] However, public records that PETA received from the DNR show that Mysore does not appear to have acquired the necessary permits for the period of January 1, 2015, to December 31, 2018. If corroborated, this means that Mysore may have violated Maryland law and his agreement with the National Eye Institute, from which he has received more than $1.5 million.

Conclusions

Bombarding sensory deprived, acutely and chronically stressed owls housed in an unnatural environment with computerized visual and auditory sensory input will not reliably contribute information of real value to our understanding of the complexity of typical human attention and its disorders. Moreover, there are more effective non animal research tools available that other researchers are already effectively using to assess stimulus selection, attentional processing, and attention deficits in humans. Mysore's invasive experiments on owls are uninformative with regard to human health, cruel, and in his own words misleading, and they should no longer receive taxpayer funding.

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