Research objectives of ERC Advanced Grant project: "ORIENT"

Abstract of the ERC proposal: Rapid object identification is crucial for survival of all organisms, but poses daunting challenges if many stimuli compete for attention, and multiple sensory and motor systems are involved in the processing, programming and generating of an eye- head gaze-orienting response to a selected goal. How do normal and sensory-impaired brains decide which signals to integrate ("goal"), or suppress ("distracter")? Audio-visual (AV) integration only helps for spatially and temporally aligned stimuli. However, sensory inputs differ markedly in their reliability, reference frames, and processing delays, yielding considerable spatial-temporal uncertainty to the brain. Vision and audition utilize coordinates that misalign whenever eyes and head move. Meanwhile, their sensory acuities vary across space and time in essentially different ways. As a result, assessing AV alignment poses major computational problems, which so far have only been studied for the simplest stimulus-response conditions.
Our ground-breaking approaches will tackle these problems on different levels, by applying dynamic eye-head coordination paradigms in complex environments, while systematically manipulating visual-vestibular-auditory context and uncertainty. I parametrically vary AV goal/distracter statistics, stimulus motion, and active vs. passive-evoked body movements. We perform advanced psychophysics to healthy subjects, and to patients with well-defined sensory disorders. We probe sensorimotor strategies of normal and impaired systems, by quantifying their acquisition of priors about the (changing) environment, and use of feedback about active or passive-induced self-motion of eyes and head.
We challenge current eye-head control models by incorporating top-down adaptive processes and eye-head motor feedback in realistic cortical-midbrain networks. Our modeling will be critically tested on an autonomously learning humanoid robot, equipped with binocular foveal vision and human-like audition.

Brief scientific background. Vision and audition inform the brain about the identity and location of objects in the environment, and the vestibular system provides information about the head orientation and movement in space. Often, objects emit both auditory and visual signals, and it may be crucial for an organism's survival to decide in a split second whether and which perceived sensory events, all competing for attention, emanated from the same object in space and time, or from different sources, and whether and how these objects move with respect to the environment, and with respect to the observer. Often, sensory signals are ambiguous, leaving the problem of segregating target from background fundamentally impossible (i.e., mathematically '*ill-posed*'). This is e.g. the case in acoustic scenes, for which infinitely many combinations of sound sources can yield the *same* superimposed sound wave at the ears.

Whereas the healthy brain seems to effortlessly solve these daunting problems, modern computer algorithms and engineered systems, like robots, are still far behind, despite their phenomenal computational speed. However, when perception is hampered, due to (partial) sensory loss, or neural damage caused by accident, stroke, or neurocognitive disorder (Parkinson's Disease), sensorimotor, memory, and target selection behaviors can become abnormal, causing loss of the quality of life to those affected and to their social environment.

It is widely acknowledged that *multisensory integration* could greatly enhance identification, selection, disambiguation, and gaze-orienting performance in unfamiliar, complex environments, but through what mechanisms the central nervous system decides which signals to integrate, and which to ignore, is unclear.

- ***In our experiments we will study, model and mimic dynamic gaze-orienting at its full complexity in health, disease and in sensorimotor dysfunction.***
- ***We will reveal how the brain embeds optimal audio-visual-vestibular integration by accurate dynamic motor feedback, and by acquired prior evidence to improve gaze accuracy, speed, and precision in naturalistic worlds.***
- ***We will show how these integrative mechanisms are selectively affected in different disorders. system that is equipped with foveate eyes, human-like pinnae, and controlled by our novel models.***

This ERC project will tackle the research problem of multisensory integration in several inter-connected subprojects, which are divided into specific research tasks.

The two PhD students and 1 postdoc for this project will work on complementary research questions: the first project will concentrate on human psychophysics (behavioral experiments), the second project will focus on the development of advanced neurocomputational models.

1) **PhD 1 and Postdoc 1: Challenging human psychophysics:** Multisensory-evoked eye~, or eye-head orienting in cluttered environments, with or without induced passive self-motion through a unique 2-axis vestibular and audiovisual stimulator, and/or audio-visual stimulus motion. We will also perform spatial-temporal neuro-imaging with *fNIRS-EEG* during these challenging tasks. We compare healthy control subjects with patients suffering from sensory impairments (auditory, visual, vestibular), or neurodegenerative Parkinson's disease.

   Educational background of the candidates:

   (bio)physics, (medical, or neuro-)biology, cognitive neuroscience (psychophysics), or equivalent.

   If you are interested in this position, please refer to **ERC-693400-PhD1 or** to **ERC-693400-PD1**

2) **PhD 2: Advanced neurocomputational modeling** of (near-optimal) Bayesian and causal inference, sensory sparse-encoding algorithms, and optimal 3D gaze control, incorporating top-down (feedback; adaptive priors; attentive filtering) and bottom-up (3D kinematics; sensory encoding) mechanisms, acting within populations of neurons.

   Educational background of the candidate:

   (bio)physics, neuro-informatics, computational neuroscience, or equivalent.

   If you are interested in this position, please refer to **ERC-693400-PhD2**

Each PhD appointment will be 1.0 fte, for 48 months; after 12 months there will be a formal evaluation.

Interested candidates should apply to Prof. dr. AJ van Opstal,
preferably by E-mail: j.vanopstal@donders.ru.nl
In your application, please include:

i) A letter of motivation
ii) Your CV
iii) A brief (max. 1A4) summary of your master thesis work, or most recent research activities.
iv) At least two letters of recommendation from former supervisors (with contact info).

For more information on this project, please contact prof. dr. AJ van Opstal (E-mail above).

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