Hallucination Machine: Simulating Altered Perceptual Phenomenology with a Deep-Dream Virtual Reality platform

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Abstract

Simulating phenomenological aspects of altered states of consciousness provides an important experimental tool for consciousness science and psychiatry. Here we describe the Hallucination Machine, which comprises a novel combination of two powerful technologies: deep convolutional neural networks (DCNNs) and panoramic videos of natural scenes, viewed immersively through a head-mounted display. The Hallucination Machine enables the simulation of visual hallucinatory experiences in a biologically plausible and ecologically valid way. We show that the system induces visual phenomenology qualitatively similar to classical psychedelics. The Hallucination Machine offers a valuable new technique for simulating altered phenomenology without directly altering the underlying neurophysiology.

Introduction

Although the synthetic approach to biological and cognitive systems is a core methodology in Artificial Life, it has not yet been fully applied to experiential aspects of mind, such as conscious phenomenology (Froese, Suzuki, Ogai, & Ikegami, 2012). Here, we extend the synthetic approach to understand human conscious phenomenology by combining two powerful technologies: deep convolutional neural networks (DCNNs) and panoramic videos of natural scenes, viewed immersively through a head-mounted display.

There is a long history of studying altered states of consciousness in order to better understand phenomenological properties of conscious perception (Oxman et al., 1988). Altered states are defined as a qualitative alteration in the overall pattern of mental functioning, such that the experiencer feels their consciousness is radically different from "normal". In recent years, there has been a resurgence in research investigating altered states induced by psychedelic drugs (Carhart-Harris et al., 2012). These studies attempt to understand the neural underpinnings that cause altered conscious experience. However, psychedelic compounds have many systemic physiological effects, not all of which are likely relevant to the generation of altered perceptual phenomenology. It is difficult, using pharmacological manipulations alone, to distinguish the primary causes of altered phenomenology from the secondary effects of other more general aspects of neurophysiology and basic sensory processing. Understanding the specific nature of altered phenomenology in the psychedelic state therefore stands as an important experimental challenge. Here, we address this challenge by combining virtual reality and machine learning to isolate and simulate one specific aspect of psychedelic phenomenology: visual hallucinations.

In machine learning, DCNNs developed for machine vision have now achieved human-level performances on some object recognition and detection tasks (LeCun, Bengio, & Hinton, 2015). Studies comparing the internal representational structure of trained DCNNs with primate and human brains performing similar object recognition tasks, have revealed surprising similarities in the representational spaces between these two distinct systems (Kriegeskorte, 2015), even though DCNNs were not explicitly designed to model the visual system. Recently, a novel visualization algorithm called Deep Dream was developed to visualize the internal representation of DNNs (Mordvintsev, Olah, & Tyka, 2015). Deep Dream works by clamping the activity of nodes at a user-defined layer in the DCNN and then inverting the information flow, so that an input image is changed until the network settles into a stable state. What is striking about this process is that the resulting images often have a marked 'hallucinatory' quality, bearing intuitive similarities to a wide range of psychedelic visual hallucinations reported in the literature (Shanon, 2002) (see Figure 1).

We thus set out to investigate the phenomenological aspects of biologically realistic visual hallucinations by simulating visual hallucinatory aspects of the psychedelic state using Deep Dream. To enhance the immersive experiential qualities of these hallucinations, we utilised virtual reality (VR), calling this combination of techniques the Hallucination Machine (Suzuki, et al., 2017).

Implementation

The Hallucination Machine was created by applying the Deep Dream algorithm to each frame of a pre-recorded panoramic video presented using a head-mounted display. Participants could freely explore the virtual environment by moving their head, experiencing highly immersive dynamic hallucination-like visual scenes (See the detail of the implementation in our paper (Suzuki et al., 2017)). Our software for creating the Deep Dream video can be found on GitHub (https://github.com/ksk-S/DeepDreamVideoOpticalFlow).

Figure 1: The original and deep-dreamed images.

Evaluation

We compared subjective experiences evoked by the Hallucination Machine with those elicited by both (unaltered) control videos (within subjects) and by pharmacologically induced psychedelic states (across studies) using the Altered State of Consciousness (ASC) questionnaire (adpated from Muthukumaraswamy et al., 2013). See the details of our experiment in our paper (Suzuki et al., 2017).

Comparisons between control and Hallucination Machine with natural scenes revealed significant differences in perceptual and imagination dimensions ('patterns', 'imagery', 'strange', 'vivid', and 'space') as well as the overall intensity and emotional arousal of the experience. Notably, these specific dimensions were also reported as being increased after pharmacological administration of psilocybin. We therefore showed that the Hallucination Machine gave rise to subjective visual experiences that displayed marked similarities across multiple dimensions to actual psychedelic states.

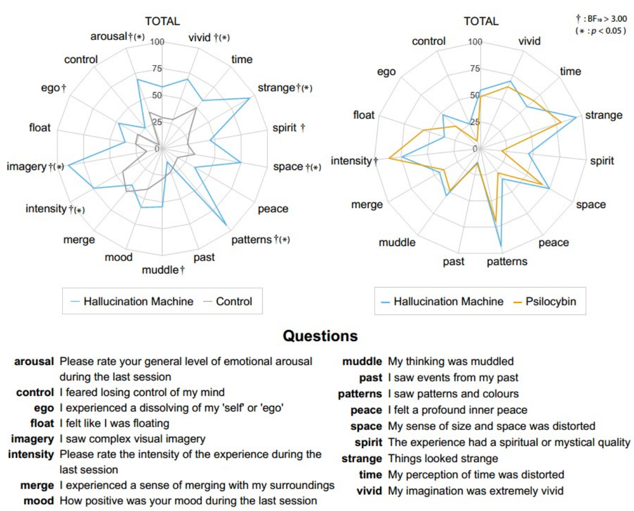

Figure 2: Subjective ratings, as measured by the ASC questionnaire (Muthukumaraswamy et al., 2013) following Hallucination Machine and Control videos (Left) and Hallucination Machine and Psilocybin (Right).

Conclusions

We developed a method for simulating altered visual phenomenology similar to the visual hallucinations reported during the psychedelic state. In contrast to the previous work, which focused primarily on simulating geometric hallucinations (e.g. Froese, Woodward, & Ikegami, 2013), our setup enables the generation of more figurative hallucinations, thanks to the hierarchical nature of DCNNs. We found that the subjective experiences induced by the Hallucination Machine differed significantly from control videos, while bearing phenomenological similarities to the psychedelic state following administration of psilocybin. The immersive nature of our paradigm, the close correspondence in representational levels between layers of DCNNs and the primate visual hierarchy along with the informal similarities between DCNNs and biological visual systems, together suggest that the Hallucination Machine is capable of simulating biologically plausible and ecologically valid visual hallucinations. We conclude that the Hallucination Machine provides a powerful new tool to complement the resurgence of research into altered states of consciousness.

Acknowledgements. This work has been supported by the Dr. Mortimer and Theresa Sackler Foundation, which supports the Sackler Centre for Consciousness Science.

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