Smart Housing™ : A Home Cage Continuous Remote Health Monitoring System Utilizing Sensors, HD Video, and Automated Measurements

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Introduction

Vium Smart Housing™ contains an intelligent sensor and HD camera network that continuously records rodent activity in every home cage in a custom designed IVC rack. All hardware is positioned above the unmodified home cage, encapsulated in a secure slab, posing no risk to biosecurity; additional sensors aid in monitoring macro and microenvironmental parameters. Computer vision, data algorithms, and cloud computing generate continuous motion and breathing rate measurements. All video, observations, and automated measurements are accessible to staff and scientists through custom software on a secure web-based interface.

Vium Smart Housing™

Experiments were conducted in Vium's AAALAC-accredited Digital Vivarium™ in accordance with the NIH Guide for the Care and Use of Laboratory Animals and were approved by Vium's Institutional Animal Care and Use Committee.

Vium Smart Housing™: Cages are outfitted with sensors that stream data and environmental conditions 24/7 (Fig. 1). Multi-gas sensor modules report air change rates, temperature, and humidity at both supply and exhaust ports. Built-in white and IR lighting is provided at the cage level, providing consistent light levels across the vivarium. Illumination sensors report ambient light, providing a record of light cycle and light disruptions. Sanitizable in-cage scales (in development) record multiple mass measurements per day, and last a full cage change cycle. All hardware sits above every home cage on the IVC rack (Fig. 2).

Figure 1: Schematics showing Smart Housing™ layout.

Figure 2: Smart Housing rack system.

Research Suite™

Video and sensor data from Smart Housing is continuously streamed in real-time to the Vium Cloud, where it analyzed and made available for display in the online Research Suite™ (Fig. 3). Motion is displayed in relation to the light/dark cycle, presenting an accurate assessment of circadian rhythms. Remote observation of nighttime behaviors enables greater insights in the phenotyping of genetically modified rodents or disease models. Historical data from previous studies and groups can be accessed at any time through the Research Suite.

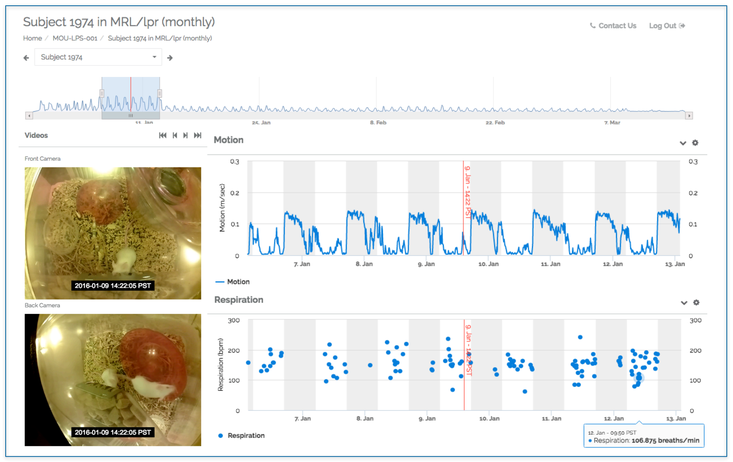

Figure 3: Fully auditable record of entire study, integrated access to all aspects of an experiment, Activity Level, Breathing Rate and other key metrics available in real-time.

Automated Metrics

Activity: Using computer vision analysis, HD video is converted into continuous high temporal resolution activity summaries (Fig. 4). The maximum speed of movements is extracted and aggregated by day for each animal.

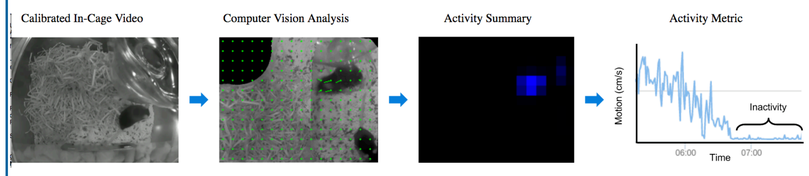

Figure 4: Data processing flow demonstrating how in-cage video of the animals is transformed into the activity metric.

Breathing Rate: Vium Breathing Rate™ (breaths per minute) is derived from continuous video streams of animals (Fig. 5). Computer vision algorithms search for regions of time when animals are stationary, and identify periodic motion that falls within a frequency band containing known rodent breathing rates. The peak root mean square (RMS) power is compared to a threshold to identify significant periodic motion.

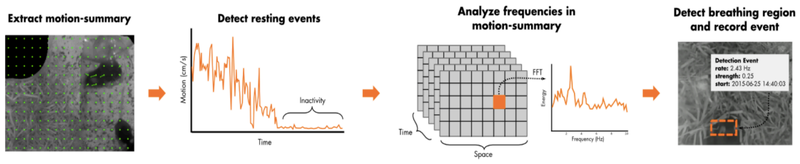

Figure 5: Breathing rate is generated from HD video using computer vision algorithms.

Research Examples

Acute Toxicity – Model of Liver Failure

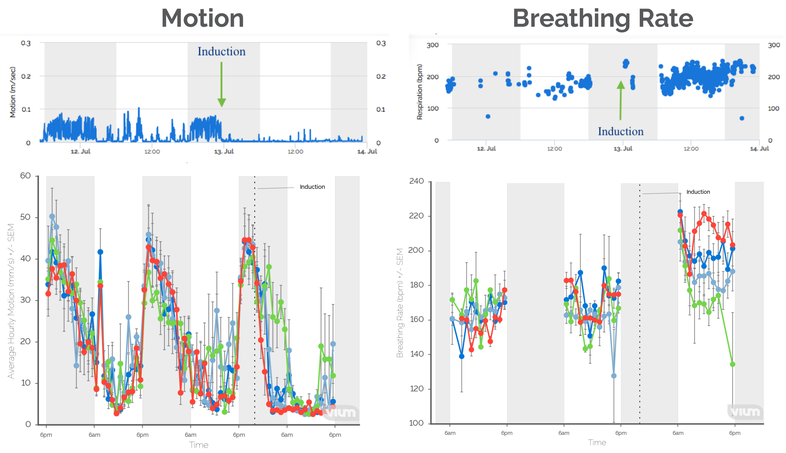

Figure 6: Acute liver injury was induced using a single IV dose of concanavalin A (ConA) given at 10pm. Onset of liver injury is associated with a drastic reduction in motion beginning within 1 hour post-induction and elevated breathing rate. Top panels show sample data from a single mouse dosed with 25 mg/kg ConA. Bottom panels show the average motion and breathing rates for mice dosed with PBS (green), 15 mg/kg (dark blue), 20 mg/kg (light blue) and 25 mg/kg (red) ConA. n = 5/group.

Chronic Disease – Systemic Lupus Erythematous (SLE)

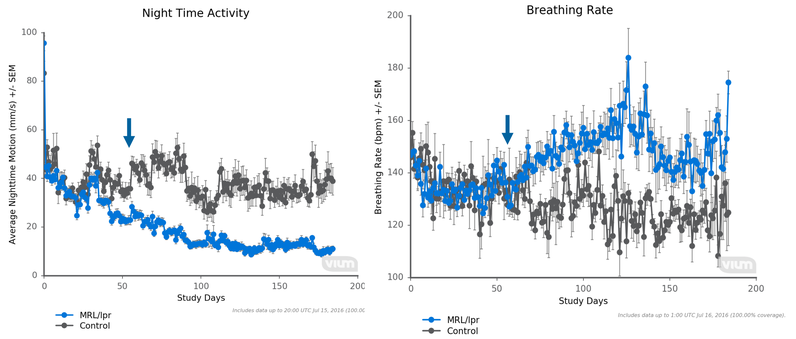

Figure 7: Night time motion significantly decreases and breathing rate significantly increases in MRL/MpJ-Fas^{lpr}/J (blue) compared to MRL/MpJ (control, grey) mice. Mice were 28 days old on Study Day 0. Arrows represent disease onset as measured by conventional proteinuria scores. N = 10 – 30/group.

Conclusion

The Vium platform captures a wide range of data—including physiology, behavior, environment, husbandry, and procedures. Sensors and software enable remote monitoring of health and behavior, and assessment of microenvironmental conditions. Researchers use our platform to:

- Continuously monitor animal activity in near- real time
- Conduct short-term studies to track acute effects of therapeutic interventions
- Compare baseline and post-therapeutic intervention motion and breathing rates
- Track motion and breathing rate over time to assess disease progression and acute conditions
- Monitor slow changes over long periods of time objectively and non-invasively

Motion and breathing rate measurements complement traditionally collected measurements such as body weight, body condition scores, clinical scores, and tumor or joint measurements. Future potential uses include automated endpoint detection, as well as remote clinical observations.