Supplementary Information

S1. Individual pair-wise cross-correlation maps

Individual assessment of mean correlations in neuronal firing between pairs of recording sites demonstrate that modest changes in the spatial and temporal correlations due to visual stimulation did not result from averaging over many different patterns across individual sites. As observed previously for spontaneous activity in young animals[1], correlated activity under all stimulus conditions fell off as a function of distance from each recording site, with a secondary rise in correlations at intermediate separations. Although the level of correlations in visually evoked responses were typically higher than that in spontaneous activity at all ages, secondary peaks in each cross-correlation map were located at the same exact positions for all viewing conditions. The cross-correlation maps of dark spontaneous activity, and activity evoked by random noise and natural scenes, were virtually indistinguishable at P30-32 (r = mean ± SD: 0.98 ± 0.07 dark/movie, 0.97 ± 0.05 dark/noise), P44-45 (0.96 ± 0.07 dark/movie, 0.95 ± 0.05 dark/noise) and P83-90 (0.97 ± 0.07 dark/movie, 0.96 ± 0.05 dark/noise).

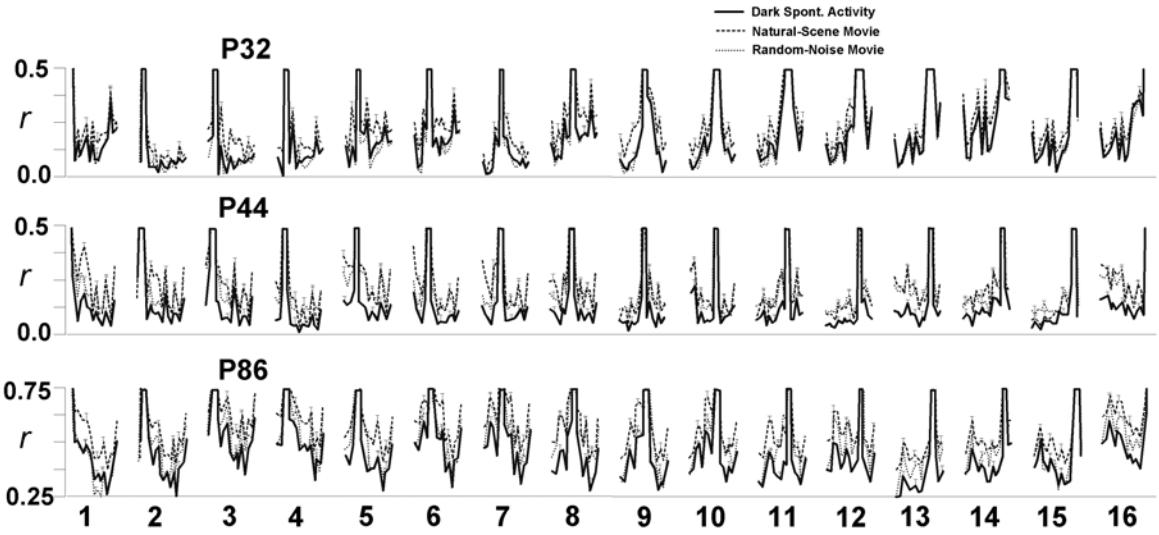

Fig. S1. Spatial cross-correlation maps computed for dark spontaneous activity, and evoked activity to random-noise and natural-scene movies in awake ferrets at various ages. For each map, the mean correlation between spike trains recorded at a given recording site and at each other site is plotted. Thus, these cross-correlation maps reveal spatial variations in the co-firing of neurons at all ages. Data obtained from a P32 (top), P44 (middle) and P86 ferret (bottom) are shown. Sixteen consecutive recording sites are labeled 1-16. Plots were truncated at 75% to convey the finer structure of the response profiles. Error bars represent SD.

S2. Monitoring of eye-movements

The eye movements of animals were not controlled in our recordings, which may have reduced the correspondence between evoked neural responses and the input statistics in three different ways: 1) the animal may have kept its eyes closed for a significant period of time, 2) the animal may have looked off the screen during stimulus presentation, and 3) frequent saccadic eye movements itself may have increased the variability of neural responses to visual stimulation[2]. To test these possibilities, experiments under identical conditions were performed in a separate set of animals while eye movements were monitored during random-noise and natural-scene presentation (P88-90, n=2; P44-45, n=2; P30-32, n=1). During stimulus presentation, animals at different ages exhibited different patterns of eye movements which included 1) maintained eye position at relatively fixed locations, 2) rapid saccadic eye-movements, or 3) slow eye-position drifts. During natural-scene and random-noise presentation, animals at P83-90 made 2.03 ± 0.63 and 1.05 ± 0.31 rapid eye-movements per second, respectively, whereas animals at P44-45 made only 1.13 ± 0.29 and 1.15 ± 0.33 eye-movements and at P30-32, only 0.53 ± 0.15 and 0.51 ± 0.21 eye movements, respectively. The largest recorded azimuth and elevation eye deflections occurred at P83-90, ± 46º and ± 22º from rest, respectively, but the majority of the saccades were much smaller (mean ± SD: 11.5 ± 6.3º, and 3.3 ± 1.2º for horizontal and vertical saccades, respectively). Since the display screen filled ± 65º by ± 50º (azimuth vs. elevation), and the receptive fields of all recorded sites were within the central 20-30º, receptive fields stayed within the screen at all times (Fig. S2b). The use of a video based eye-tracking system also allowed us to monitor whether the animal's eyes' were open or shut. Trials where the animal closed its eye during a stimulus trial for a period longer than just a transient blink were discarded. To assess whether eye-movements induced artifacts in the neural recordings, portions of binned spike traces that occurred during saccadic eye-movements were excluded and "uncontaminated" temporal and spatial correlation functions were recomputed (Fig. S2a, c). These new correlation functions were then compared to correlation functions computed using the full spike traces. Correlation functions computed under these two conditions were not significantly different ($p > 0.05$, coefficient of regression), and fully replicated the results of the main experiment. Thus, eye movements, or lack of visual stimulation, cannot explain the relatively small modulation of spontaneous activity by the visual input.

Method

To monitor eye movements, a non-invasive video-based ISCAN dark pupil-to-corneal reflection tracking system (ETL-200) was used. Eye position relative to the head was recorded in real time while animals viewed dynamic natural-scene images or random-noise movies. A low-level infrared light source was illuminated into the left eye and a high-speed video camera (120 Hz), fitted with an infrared filter, continuously obtained clear, in-focus images of the eye. Eye video images were displayed onto a black and white video monitor (512x512 pixel resolution). The eye tracking processor, operating at a sample rate of 60 Hz, calculated the pupil and corneal reflection positions with 12-bit resolution. Signals encoding horizontal and vertical eye position were collected simultaneously, in real time, with recordings of neural activity. The eye position signals were differentiated offline to produce eye movement velocity profiles. A saccade was

defined as displacements with velocities greater than 17º/sec. Calibration of eye position signal was performed in lightly anesthetized animals when the eye was in a relaxed position, looking straight ahead. This position was taken to be the point-of-regard at 0º in visual space, directly in front of the nose. Receptive fields were then mapped to obtain their positions relative to the point-of-regard. This information was used to determine receptive field positions during recordings in the awake animal.

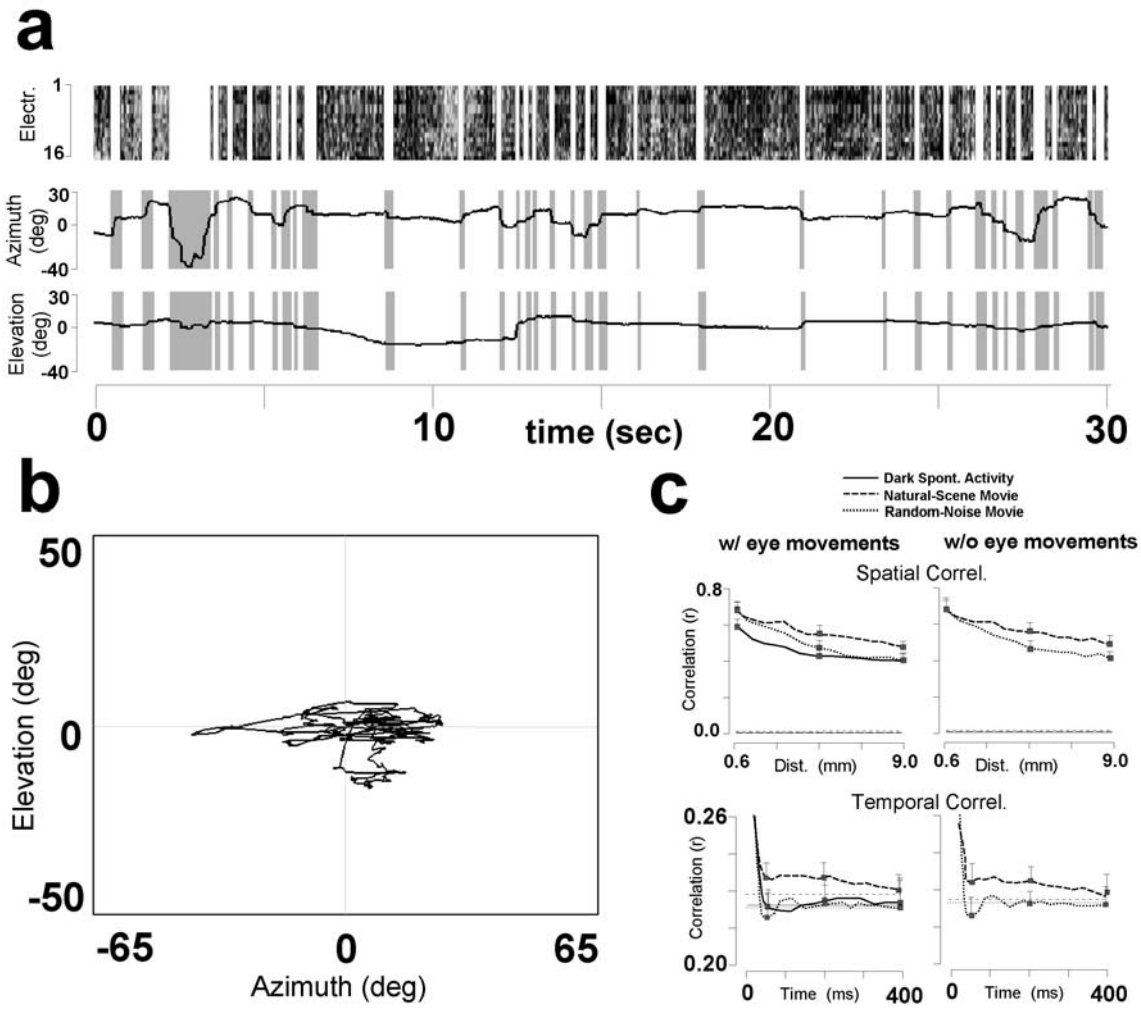

Fig. S2. The effects of eye movement on neural activity in awake free viewing P83-90 ferrets. (a) Removing neural activity during eye movement from a recorded trial. (Top Row) A 30-sec section of recording from one trial for 16 electrodes during natural-scene stimulation. Greyscale encodes spike firing rate (bright pixels represent high activity levels), and large whited-out regions mark recording periods which were excluded from analysis due to eye movement. (Middle and Bottom Rows) Real time horizontal and vertical eye movements during stimulus presentation, recorded simultaneously with the neural activity shown in the top row. Gray areas identify periods of saccadic eye movement, during which neural activity was excluded. Most of the eye movements are in the horizontal direction. (b) Eye scan pattern within the field of stimulation during 100

sec of free viewing. Line trace represents saccades and fixations during the recording, which were confined to the central 30° of the stimulus screen. (c) Comparison of spatial and temporal correlation functions computed with and without eye movements. Because the eye tracking system could not accurately monitor eye movements in complete darkness, due to pupils that were dilated beyond the exposed eye surface, analysis of dark spontaneous activity without eye movements were not performed. Both spatial and temporal correlation functions computed after excluding spikes during periods of eye movements are not significantly different from the corresponding functions computed with the inclusion of those spikes. Error bars represent SEM.

S3. Recordings of neural activity under light anesthesia

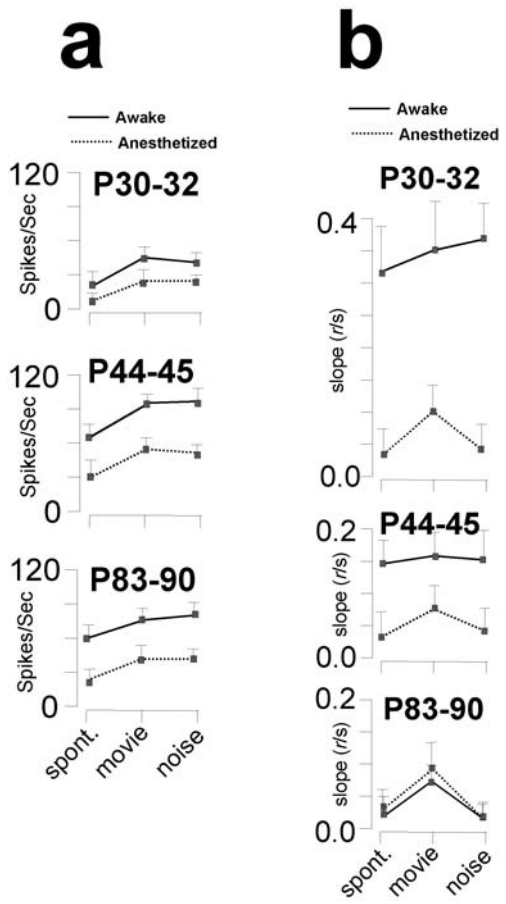

Fig. S3. Changes in neural activity due to anesthesia. (a) Spike firing rates decrease as a result of light anesthesia. At each age group, neural activity is significantly reduced in the anesthetized animal compared to the awake condition, but visual stimulation reliably increases neural firing. Error bars represent SEM. (b) Quantitative comparison of changes in temporal correlations due to anesthesia. At P30-32 and P44-45, the slope of the regression functions fitted to the tails of the temporal correlation functions changed significantly in all three conditions.

References

1. Chiu, C. & Weliky, M. Spontaneous activity in developing ferret visual cortex in vivo. *Journal of Neuroscience* **21**, 8906-8914 (2001).

2. Gur, M., Beylin, A. & Snodderly, D. M. Response variability of neurons in primary visual cortex (V1) of alert monkeys. *Journal of Neuroscience* **17**, 2914-2920 (1997).