Supplementary Material I

Entropy Calculation

Shannon entropy (Shannon 1948), a generalisation of the thermodynamic entropy, measures the uncertainty (or variability) that can be attributed to a random variable. While the Shannon entropy can be calculated using the standard "plugin" estimator (main text, Eqn. 1), with a limited number of samples, the resulting quantity tends to be downwardly biased. A number of approaches have been taken to reduce this bias (Panzeri & Treves 1996; Strong et al 1998; Paninski 2003)). We have found that a recently described approach to overcoming this bias, the Nemenman-Shafee-Bialek (NSB) estimator proposed by Nemenman et al. (2002), performs extremely well over a wide (although not exhaustive) range of conditions. This approach involves constructing a Bayesian prior so as to generate an almost uniform distribution of entropies, correcting for the sample size dependent bias at its source. We have previously reviewed the basic ideas of the NSB estimator (Montani 2007a) and have also shown that it is more effective than several other commonly used methods for bias correction, under data conditions which are broadly similar to those faced in the current work (Montani 2007b).

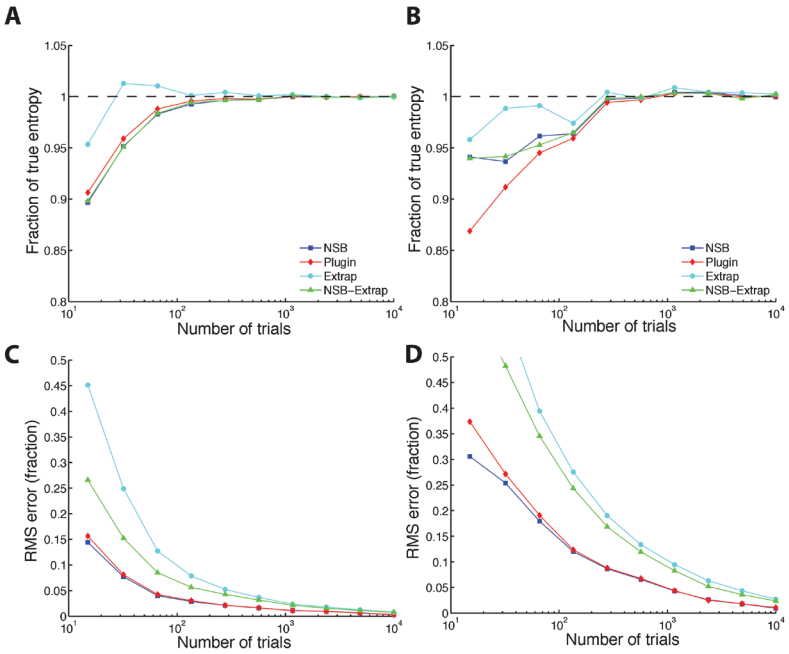


Figure S1. A comparison of the sampling performance of a number of entropy estimators, for surrogate data derived from the results presented in the main text. ***A***,***C*** Surrogate data generated with probabilities as measured in the 22nd epoch of the V5 experiment. ***B***,***D*** Surrogate data generated for 50% probability of a phosphene report on any trial. Panels ***A***,***B*** show the fraction by which the estimated entropy can be expected to be (on average) downwardly biased due to limited sampling. Panels ***C***,***D*** on the other hand, show the root mean square (RMS) error of the distribution of estimated entropies from the true value, which is a better measure of the utility of an estimator.

To definitively ascertain which entropy estimation procedure was most applicable to the phosphene detection dataset, we generated surrogate data for two cases: (i) where the probability of observing a phosphene was that measured, averaged over all subjects, in the 22nd epoch of the V5 dataset (0.21), i.e. the point of maximum entropy change in the V5 condition (Figure S1A and S1C); (ii) where the probability of phosphene reporting was 50%, i.e. the "baseline" condition (Figure S1B and S1D). Surrogate data was generated under the assumption of binomial statistics. Taking the entropy value computed for 10,000 trials as the "true" value, we computed the entropy for limited-trial subsets of this dataset (averaging over subsets). Figure S1 shows that, for both surrogate datasets, while extrapolation procedures for estimating entropy result in the lowest bias, they pay too great a penalty in terms of variance. What we really desire from an entropy estimator is to be as close to the true value as possible, as often as possible, and this is better captured by the root mean square (RMS) error of the estimator. The NSB entropy estimator provides a lower RMS error estimate, and thus is the preferred estimator in this instance. It is also apparent from Figure S1 that the RMS error of the NSB entropy estimate is under 5% in both conditions, and thus we can be confident in any conclusions made as a result.

Supplementary Material II

Additional subject data

Only 4 subjects volunteered for both experiments. We thus assessed subject responses for the second experiment (EVC responses) divided into two groups; those who participated in the first V5 experiment and those who did not. Table S1 shows individual responses (viz. probability of reporting a phosphene) for the V1 experiment for the four subjects who also participated in the V5 experiment and Table S2 show EVC responses for the eight subjects who did not take part in the V5 experiment. Simple qualitative observation suggests a similar spectrum of responses in both groups in terms of increase or decrease in phosphene reports with vestibular activation in comparison to baseline. For comparison we show the subject responses similarly divided for V5 (Table S3 and S4).

Table S1. Vertigo effect on EVC phosphenes in subjects who participated in V5 experiment

Subject	Baseline	Vertigo	Effect
YB	0.49	0.51	Neutral
YN	0.51	0.31	Decrease
CM	0.56	0.63	Increase
LD	0.50	0.55	Increase

Table S2. Vertigo effect on EVC phosphenes in subjects not participating in V5 experiment

Subject	Baseline	Vertigo	Effect
KS	0.54	0.53	Neutral
MT	0.49	0.41	Decrease
AP	0.53	0.63	Increase
YW	0.59	0.74	Increase
MB	0.54	0.54	Neutral
JD	0.55	0.63	Increase
BS	0.51	0.69	Increase
MD	0.50	0.58	Increase

Table S3. Vertigo effect on V5 phosphenes in subjects participating in EVC experiment

Subject	Baseline	Vertigo	Effect
YB	0.50	0.51	Neutral
YN	0.41	0.33	Decrease
CM	0.55	0.45	Decrease
LD	0.51	0.61	Increase

Table S4. Vertigo effect on V5 phosphenes in subjects not participating in EVC experiment

Subject	Baseline	Vertigo	Effect
NK	0.54	0.33	Decrease
RE	0.56	0.40	Decrease
CA	0.56	0.59	Increase
JG	0.53	0.36	Decrease
AB	0.58	0.39	Decrease
PL	0.48	0.45	Decrease
AD	0.49	0.60	Increase
VA	0.51	0.29	Decrease

Supplementary Material III

The effect of auditory vection on V5/MT phosphene reports

Background

Probst et al., (1986; ref. in main manuscript) reported that during self-motion, perceived visual motion threshold is increased. One potential confound for our results could thus be the possibility that during vertigo, the ability to perceive any moving stimulus is impaired. Hence, if this is correct then the observed differential effect of vertigo on perception on V5/MT phosphenes versus EVC cortex could simply be due to the fact that V5/MT phosphenes move whilst EVC phosphenes are static.

To assess whether any engendered sense of self-motion would reduce reports of V5/MT phosphenes, we employed the phenomenon of auditory circularvection (Dichgans and Brandt, 1978; supp refs). Circularvection is the sensation of self-motion rotation reliably engendered by whole field optokinetic motion. Auditory vection (for review see Väljamäe, 2009; supp refs) is less easily obtained than visual vection but about 50% of individuals are susceptible to this illusion of self-motion which can be elicited by rotating a sound source around the subject in the dark. In this experiment we specifically tested the hypothesis that phosphene reports would be suppressed during auditory vection-induced self motion sensation (given the results of Experiment 1) versus no self-motion.

Methods

Subjects were first screened for the presence of reliable V5/MT phosphenes (see Methods main manuscript). Subjects were then screened for the presence of illusory self-motion from a moving sound source ('auditory vection'). Subject sat on a motorised rotating chair (Contraves DC motor) surrounded by a whole-field optokinetic drum (of diameter 152.4 cm) which could also be rotated independently from the chair. A buzzer which emitted a continuous 116Hz sound was fixed to the external aspect of the drum to provide a focal sound source for subjects. To improve the robustness of perceived auditory vection, subjects were primed by whole-body 0.2Hz sinusoidal oscillation in the chair (the possibility of real self-motion is important in generating the illusion) in the light for 2 minutes whilst the buzzer remained on and fixed in space. The chair was then kept stationary and with the light still on, the curtain (and attached buzzer) rotated at 90^0/s in one direction, and then the next, for two minutes at a time (this whole-field optokinetic stimulation invariably induced circularvection; i.e. visually induced illusory self-motion). At the end of each two minute optokinetic epoch the light was switched off whilst the curtain (and attached buzzer) maintained continuous angular rotation. Subjects were then asked whether they had any sensation of self-motion derived from the relative motion of the sound. If this was a stable sensation (>2mins in the dark) they were asked to rate the degree of vection in the dark as a percentage of the sensation of self-motion with that engendered in the light.

Following screening, phosphene thresholds (see Methods in main manuscript for thresholding protocol) were obtained in the dark for V5/MT in one hemisphere for subjects susceptible to auditory vection. Subjects were then required to report whether they perceived a phosphene or not, at threshold TMS intensity, under three conditions in the dark: (i) silence (ii) sound but no vection (buzzer on, but not moving) (iii) auditory vection (buzzer on and moving around subject). The order of the 3 conditions was randomised and balanced between subjects. For every condition, there were 20 TMS pulses with an inter-stimulus interval of 6s. The three conditions with V5/MT phosphene reports were repeated to allow for ipsilateral and contralateral sound rotation and equal numbers between conditions (i.e. there were 40 responses per condition per TMS location/subject). Following a short break but remaining dark adapted, we then repeated the experiment (including the thresholding process) with V5/MT phosphenes obtained from the opposite hemisphere (resulting in 80 responses per condition per subject). Subjects were asked to compare the size and intensity of phosphenes during the different conditions using a 1-5 scale. The specific contrast that we were interested in was that between the static and moving sound condition. Hence subjects were asked to rate phosphene size and intensity at 3/5 for the static sound condition and then to give a relative rating for their phosphene size and intensity for the moving sound condition.

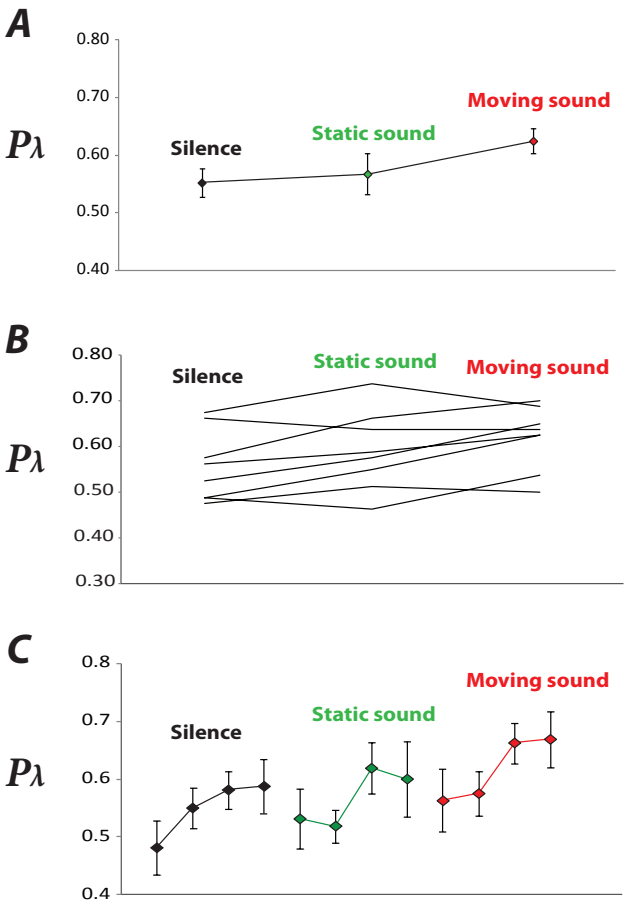
Results

Sixteen subjects (average age 29yrs, 6 female) were screened. One subject did not have reliable V5/MT phosphenes and seven were not susceptible to auditory vection. The remaining eight volunteers (average age; 29 years; range 26-35; 1 female) with reliable phosphenes and robust and sustained auditory vection were tested. Subjects with stable auditory vection gave a subjective estimate of the intensity of sense of self-rotation in the dark compared to visual vection an average rating of 44% (range 35-60%).

Figure S2 shows the probability of reporting a phosphene (Pλ) for the three conditions for all subjects combined (S2A), individually (S2B) and the combined responses when the data was binned and averaged responses obtained for every 5 stimuli (S2C).

Overall there was a no significant effect with a trend for increased phosphene reports during the moving sound condition compared to static sound using either parametric (paired t-test of individuals' average 'scores' obtained by binning the data for every 5 responses: $t = 1.8$; $df = 7$; $P = 0.1$) or non-parametric statistics (binomial statistics; $P = 0.07$; $n = 720$). Regarding the perceived size and intensity of phosphenes during auditory vection; we tested subjects's mean ratings against a value of 3 using a 1-sample t-test (subjects were required to give a rating of 3/5 for the static sound condition). There was no significant effect of the moving sound condition (compared to the static sound condition = rating 3/5) for either size or intensity (Size: mean 3.125; $t=0.99$, $P=0.35$, $df=7$; Intensity: mean 3.188; $t=1.16$, $P=0.29$, $df=7$).

Figure S2. The probability for reporting a phosphene (***Pλ***) during three conditions: silence, static sound ('no vection') and moving sound ('vection'). ***A***, Response for all subjects combined. ***B***, Individual responses. ***C***, Time course of response for each of the three conditions obtained by binning data for every 5 responses; note that the order of the 3 conditions was balanced.



Discussion

The additional data shown in Figure S2 argue against the idea that any sensory input resulting in a sensation of self-motion reduces the reports of V5/MT phosphenes (which are moving percepts). Thus these data taken together with that from Experiment 1 suggest that it is vestibular activation that results in a reduction in phosphene reports at area V5/MT and not a sensation per se of self-motion.

Even without our additional data shown in Figure S2, it could be argued however that a phosphene is not a stimulus but the perceptual result of an electrical impulse in a region of visual cortex. Indeed microstimulation in single V5/MT locations in primates have established "conclusively that activity in directionally specific circuits of the monkey's visual cortex underlies judgments of motion direction ....." (taken from Parker and Newsome regarding V5/MT; Ann Rev Neursci 1998; Supp refs)". Thus, this logic suggests that V5/MT phosphenes move and EVC phosphenes are static because this reflects the different types of visual signals encoded in these two cortical regions. One explanation for the failure to perceive a V5/MT phosphene for a given TMS impulse (when previously it was) is that an insufficient volume of underlying V5/MT cortical tissue was stimulated to generate a phosphene percept. This latter interpretation evokes the explanation of a change in local (V5/MT) cortical excitability.

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