

News from the field

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SENSORY NOISE

This must be Laplace

Neri, P. (2013) The statistical distribution of noisy transmission in human sensors. *Journal of Neural Engineering*, 10(1). doi:10.1088/1741-2560/10/1/016014.

Organisms do not always respond in the same way to the same stimuli. Typically, this stochastic nature of psychophysical responses is modelled as a Gaussian process. This is more a matter of convenience than anything else. Gaussian statistics are relatively easy to work with, and in most cases it is only the variance of internal noise that matters, not the shape of its distribution. On the other hand, there is growing interest in models of behavior on individual trials, and likelihood-based fits of these models do require more a more precise characterization of the statistics of sensory noise.

Neri (2013) proves the noise that limits masked pattern detection has excess kurtosis. You might say its distribution is peaky. To appreciate Neri's proof, it helps if you first understand that most psychometric functions are completely uninformative regarding the distribution of internal noise. When deciding how to respond in a psychophysical experiment, observers evaluate sensory evidence on an internal scale (some call it the decision axis), which need not be a linear transformation of the signal intensity over which psychometric functions are typically drawn. Neri used the aforementioned analysis of individual trials to infer the transformation from stimulus space to the decision axis. At first, he used the most straightforward task he could think of: detecting a pattern of fixed contrast masked by random graylevels (the latter were sampled from a Gaussian distribution). For this task, decisions were consistent with observers simply choosing which of two temporal intervals best matched something like the target pattern. That is, their behavior was that of a linear filter with added noise. Psychometric functions over the output of that filter were decidedly non-

Gaussian. Instead, they were better fit by the more heavy-tailed Laplacian distribution.

Neri was not convinced. His Gaussian distribution of graylevels ensured poor sampling of those heavy tails. So Neri repeated his experiment using random masks that were selected to better sample psychometric functions over the decision axis. The results of this experiment were an even better fit by the Laplacian distribution. Next, Neri tried a task guaranteed to produce non-linear decision behavior: he randomly inverted the signal's contrast. It made no difference. Results remained consistent with the same amount of Laplacian noise being added to the output of what was now a non-linear detection mechanism. Neri even tried spatial intervals instead of temporal intervals. All together, something like half a million trials kept repeating the same story: internal noise distributions must be Laplace. Naive adherence to Gauss' formula is no longer acceptable.—J.A.S.

SYNESTHESIA

The Fisher-Price effect

Witthoft, N., & Winawer, J. (2013). Learning, memory, and synesthesia. *Psychological Science*, 24(3), 258–265.

Synesthesia is a topic of fascination for scientists and the lay public alike: it even has its own rock song (Peter Himmelman, "Synesthesia", Synesthesia, Island Records, 1989). The term refers to the phenomenon where a stimulus evokes a consistent sensation which is not obviously derivable from the stimulus. While there are many types of synesthesia, probably the most widespread is color-grapheme synesthesia, in which achromatic letters or numbers reliably evoke particular colors. The particular associations are idiosyncratic, but there are regularities; the letter "R" is likely to be red, for example, and "Y" yellow (Rich, Bradshaw, & Mattingley, 2005). Some of these regularities may reflect underlying regularities in the way our sensory systems are structured; on this view, synesthetes are people for whom typically implicit connections become explicit (Ramachandran & Hubbard, 2001).

However, anecdotal evidence suggests that some of these associations may be learned in childhood. A few case studies have described synesthetes whose color-grapheme pairings reflected childhood toys or refrigerator magnets (Hancock, 2006; Witthoft & Winawer, 2006), though a large-scale study did not support this hypothesis (Rich et al., 2005). In this paper, Witthoft and Winawer (2013) go beyond the case study: they have found a group of nearly a dozen synesthetes whose color-grapheme pairings differ from the usual pattern. For these subjects, for example, “R” tends to be purple, and “Y” red. Intriguingly, these mappings match a set of magnetic letter toys sold by Fisher-Price between 1972 and 1989, and all but one of the synesthetes in the study remembers having this set as a child; several still have them. The authors estimate that the odds of finding 11 subjects whose mappings match such a set is astronomically low.

According to the authors, the bottom line is that some synesthetic experiences can be learned, and thus learning and memory should become more important in the study of synesthesia. Of course, synesthesia is a heterogenous phenomenon (Rich & Mattingley, 2002), and most color-grapheme synesthetes probably did not acquire their pairings from the Fisher-Price School Days Play Desk. The differences, neurally or genetically, between those who learned their associations from specific external objects and those who did not will probably prove instructive.

On a personal note, while I wouldn’t meet the criteria for a synesthete, I strongly associate the digit “8” with the color green. It turns out that the magnetic “8” from the Fisher-Price play sets reported in this paper is green.—T.H.

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VISUAL WORKING MEMORY

To OBE or not to OBE?

Shen, M., Tang, N., Wu, F., Shui, R., & Gao, Z. (2013). Robust object-based encoding in visual working memory. *Journal of Vision* 13(2):1, 1–11

Our conscious experience of visual scenes is composed of structured, multi-feature objects rather than independent features. It is not surprising, therefore, that the leading candidate for the basic unit of visual processing is an integrated object rather than an individual feature. Indeed such object-based approaches dominant the current views of both visual attention and visual working memory. When regarding the latter, the common belief is that the fundamental unit stored in visual working memory is an integrated object rather than a separate feature. Thus, when an object is encoded into memory all its features are equally encoded, regardless of their task-relevance.

However, not all of the empirical evidence is in line with this object-based encoding (OBE) approach. For instance, a strong OBE view predicts that memory for different features of the same object will be highly correlated, and if one feature is remembered, the other features will also be remembered. Yet, Fougny and Alvarez (2011) analyzed memory errors made by participants that had to report two features (color and orientation) of the same object and found that the reports of color and orientation were largely independent: often, when one feature was remembered, the other was forgotten.

In attempts to resolve this discrepancy, Shen and colleagues raise three factors that may explain differences between studies that support the OBE approach and those that do not. The first factor is exposure duration. Supporting studies often employed relatively short exposure duration of the to-be-remembered stimuli (up to about 500 ms), while some of the opposing studies have used longer durations. According to Shen et al., longer durations may allow the involvement of control processes that prevent storing the object’s irrelevant features. The second factor is related to the fact that OBE studies often employ a change detection task, in which the participants have to detect a change in one of the object’s feature—the relevant feature—and ignore changes occurring in another feature—the irrelevant feature. The ‘irrelevant-change distracting effect’ refers to changes in the irrelevant feature that affect performance (e.g., lead to slower response time). This effect is taken as evidence for OBE as it implies failure to ignore the irrelevant feature. However, Shen et al. note that irrelevant changes typically occur on 50 % of the trials, which may be critical for the emergence of irrelevant-change distracting effect. They theorize it might be harder to ignore irrelevant changes when they are not rare. Finally, Shen et al. also suggest that the

fact that the memory load in OBE studies was low may play a significant role, as low memory load may leave free resources for the encoding of irrelevant information.

To test whether these three factors are indeed critical, Shen et al. performed three experiments in which these factors were systematically manipulated. The task in the experiments was a change detection task. The participants saw two visual displays composed of several objects and had to indicate whether one of the objects changed its color in the second display, while ignoring any change in the objects' shape. The magnitude of the irrelevant-change distracting effect was compared when the exposure duration of the first display was short (100 ms) vs. long (1,000 ms); when the irrelevant change was relatively frequent (50 %) vs. rare (20 % or 16 %); and when memory load was low (only the change detection task had to be performed) vs. high (an additional verbal rehearsal task had to be performed).

Interestingly, an irrelevant-change distracting effect was found regardless of exposure duration, the frequency of irrelevant change, or memory load. This led Shen et al. to conclude that OBE is in fact robust and does not depend on these three factors. Of course, because the task in all three experiments required change detection, and the marker of obligatory encoding of irrelevant features also involved a change, it remains to be seen whether such strong evidence of OBE depends on task demands.—Y.Y.

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ATTENTION AND DYSLEXIA

Bring on the demonic rabbits

Franceschini, S., Gori, S., Ruffino, M., Viola, S., Molteni, M., & Facoetti, A. (2013). Action video games make dyslexic children read better. *Current Biology*, *23*(6), 462–466. doi: [10.1016/j.cub.2013.01.044](https://doi.org/10.1016/j.cub.2013.01.044)

Let us suppose that you have a child who is having a hard time learning to read. Indeed, the child has a diagnosis of dyslexia, a learning disability marked by problems with acquiring literacy despite normal intelligence. How should you feel if that child, rather than doing his reading drills, plans to spend the afternoon honing his skills on “Rayman Raving Rabbids”, a videogame in which (in the words of the Amazon description) “the world of *Rayman*” is threatened by a devastating invasion of demonic *raving rabbids*.” Apparently, the rabbids “enslave him, forcing Rayman to participate in a series of gladiator-like trials. In order to win

his freedom, Rayman must entertain and outwit these crazed, out-of-control bunnies.”? According to Franceschini et al., writing in *Current Biology*, you might want to permit or even encourage this behavior because reading skills improved in a group of children who received action videogame training (with this specific game).

People who routinely read this journal may not be totally surprised by this finding. In 2003, Green and Bavelier reported that training in a first-person shooter, action videogame (AVG) led to changes on a range of attentional tasks that suggested increased speed and capacity. This has produced a decade of research and controversy. We may not all agree on the efficacy of AVG training but it is no longer a surprise to see research suggesting that AVGs might be educational and not merely entertaining. The present study is fairly small. Twenty children, ages 7–13 were split into two groups. Seven-year olds aren't going to play Medal of Honor or some other violent first-person shooter; hence, “Rayman Raving Rabbids”. The game is composed of a set of sub-games that can be divided into action and non-action games (NAVG). After 9 sessions of 80 min over a couple of weeks, the AVG group improved on a variety of reading tasks. For example, reading inefficiency (speed/accuracy) went down significantly for the AVG group but was unchanged for the NAVG group.

The logic of the study was that reading makes strong demands on visual attention and AVG training might improve attention. Indeed, the AVG group did show improvement on attention tasks unrelated to reading. Again, the NAVG group did not. As further support for the attention hypothesis, the AVG group did not show any change in phonological skills. Those skills are part of the task of reading but may be orthogonal to the attentional demands of the task. The authors are not arguing that dyslexia is an attentional disorder. They are simply suggesting that if attention is important in learning to read and if AVG training improves attentional function, then it is reasonable to imagine that AVG training could help a vulnerable child to cope with dyslexia, whatever its underlying cause.

This paper will stimulate other work as we continue to work out if, when, and why AVGs really work as training. It may well stimulate someone to develop games specific for dyslexics (such games may already exist.) As this industry of therapeutic gaming evolves, we will also need to figure out what makes one game addictive fun while another is merely ‘Good For You’. If AVG training is like exercise, it will need to be ongoing. We will need to understand what makes one game fun for an extended period of time while another is an obsession this week and a bore the next. Finally, many of us may need to get over the idea that, if it is

fun, it can't be good for you. Bring on the "crazed, out-of-control bunnies".—J.M.W.

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MUSIC PERCEPTION

How happy is this tune?

Temperley, D., & Tan, D. (2013). Emotional connotations of diatonic modes. *Music Perception: An Interdisciplinary Journal* (30)3, 237–257.

I have long been fascinated by the question of how it is that modal music achieves the remarkable emotional qualities that it does. The qualities of "happiness" and "sadness" that characterize music in the major and minor modes belong (at least in my experience) to the music, not to the listener (although beautiful music can certainly make one happy). Normally, we use words like "happy" and "sad" to describe the state of conscious beings that care about the outcomes of the situations in which they find themselves. How can a piece of music BE happy? How is it that these words seem to apply so naturally to abstract sequences of sounds? I have always had the feeling that a full understanding of these effects might have important philosophical ramifications.

In order for music to manifest emotional qualities such as happiness and sadness, it must have a "tonic center"—a single note of the scale that predominates in conferring structure to the melody. For reasons that are themselves deeply mysterious, we naturally tend to hear music with a tonic center as "needing to return to" that note in order to achieve final stability. As the melody departs from the tonic, it visits a (typically restricted) set of other notes. The intervals that separate these other notes from the tonic determine the mode of the melody and are largely responsible for determining its emotional quality. (Warning: I'm about to go off the metaphysical deep end.) These other notes thus represent the "horizon of possibilities" for the melody. It is difficult (for me at least) to resist the idea that the emotional quality that emerges from the melody reflects some overall evaluative assessment of this horizon of possibilities, an assessment that we hear as having been made by the melody itself in the light of its "need to continue" in order to return to the tonic. I recognize that this last sentence is so conceptually tangled as to be almost meaningless. This reflects fairly accurately the state of my brain when I think about this problem.

Anyway, Temperley and Tan (2013) have performed an experiment that sheds important light on these issues. Most previous research related to this question has focused on the major and minor modes that predominate in western music. This study, however, investigated the happiness and sadness characterizing six of the seven different modes that can be derived by taking different white keys of the piano as the tonic of the scale. (The Locrian mode was excluded because, "it is virtually impossible to compose a melody that 'sounds' Locrian—for example a melody that uses the five flat key signature but that has a tonic of C." (p. 244).) On a given trial the listener heard two versions of the same melody cast into different musical modes (by varying the key signature while keeping the tonic fixed). The listener's task was to judge which of the two versions of the melody sounded happier. It should be noted that the listeners in this experiment were not musically trained. Nonetheless, the results were beautifully systematic when considered with reference to a structure familiar to composers called "the circle of fifths."

The circle of fifths is the cyclic sequence C, G, D, A, E, B, F#, C#, G#, D#, A#, F, C... that visits all 12 tones of the chromatic scale by jumping in each successive step 7 semitones up in the scale (this interval is called a "fifth" because this corresponds to the fifth note of each of the major and minor diatonic scales). The circle of fifths is important in music theory for reasons that it would take too long to explain here. Each of the six musical modes compared in this study comprised a sequence of seven successive notes from the circle of fifths. We can summarize the results as follows: With one caveat, the farther to the left the tonic was in the circle of fifths relative to the other notes in the mode, the happier the mode sounded. The one interesting exception to this rule is that the Lydian mode (which has the tonic all the way to the left) sounded significantly less happy than the Lonian mode (the major scale of western music) which has its tonic all the way to the left except for including the note a fifth below the tonic (e.g., the F in the C major scale). Although this finding does not break open the problem, it certainly gives us a rich new view of the relevant terrain.—C.C.

VISUAL PERCEPTION

Visual sampling and oscillations

Blais, C., Arguin, M., & Gosselin, F. (in press). Human visual processing oscillates: Evidence from a classification image technique. *Cognition*.

How information is extracted during visual processing is a fundamental issue in vision, and in perceptual science in general. For instance, the wagon wheel illusion could be interpreted as the result of a discrete sampling of information. Indeed, there are different signs in the literature, like reaction time distributions, visual thresholds and temporal processing, indicating the possible involvement of a periodical mechanism. In their two-experiment investigation, Blais, Arguin and Gosselin used a classification image technique to study the properties of what is assumed to be a discrete sampling of information. They controlled the signal-to-noise ratio of faces (stimulus visibility) through time. In other words, on some moments, visual information was available and on other moments, no information was

available. Their investigation was designed to address two critical issues: how discrete sampling synchronizes with the environment, and at what frequency discrete sampling operates. The study showed that the frequency and phase with which the visibility of a stimulus is varied actually influences performance.

This finding is consistent with the idea that there are oscillations in the time course of information utilization. More specifically, the authors demonstrated (1) that the information sampling function of participants was synchronized with the beginning of the trial (the onset of the stimulus), and (2) that this information sampling mechanism probably operates at a rate of about 10 to 15 Hz since it is at this frequency range that performance is better.—S.G.