Influence on the visual perception of the stochastic resonance

Masaaki Inoue[1] and Masaru Tanaka[1]
[1]Department Information and Computer Science, Faculty of Engineering
Saitama University
Shimo-okubo255, Saitama-shi, Saitama,338-8570 Japan
Tel. +81-48-858-3957, Fax.: +81-48-858-3716
E-mail: {inoue,mtanaka}@mi.ics.saitama-u.ac.jp

Abstract: In this paper, we report the influence on the visual perception of the stochastic resonance for Japanese, following Frank Moss and his group (1997) [1]. We confirm that the ability of recognition is improved by adding appropriately noise as same as that of non-Japanese.

1. Introduction

Generally, we make an effort to suppress any noises in order to obtain the necessary information effectively form noisy data. On the other hand, if the appropriate noise is added to the data, then signal to noise ratio (SN ratio) is, in some cases, improved. This phenomenon is called stochastic resonance (SR). SR is observed in the various fields from the earth scale to the cell level [2].

2. Stochastic resonance (SR)

The experiment by Moss and his group is derived from the simplest paradigm of SR: the threshold theory. As shown in Figure 1, the necessary components are a threshold, a signal, and additive noise. The system is assumed capable of transmitting single bits of information, each of which marks a threshold crossing, as shown by the pulse train.

Only the signal can't across the threshold (Figure 1 (a)). But adding the noise to the signal, the signal becomes to be able to across the threshold, and outputs rise (Figure 1 (b)). Needless to say, too much noise make output randomly (Figure 1 (c)).

In this way, in SR, information is emphasized by gained noise more than the case not to gain noise. However, information has been buried in the noise when too much noise occurs. It is the characteristic of SR that SN ratio of the system shows a curve like the mountain, improving to the appropriate noise strength and falls after that (Figure 2).

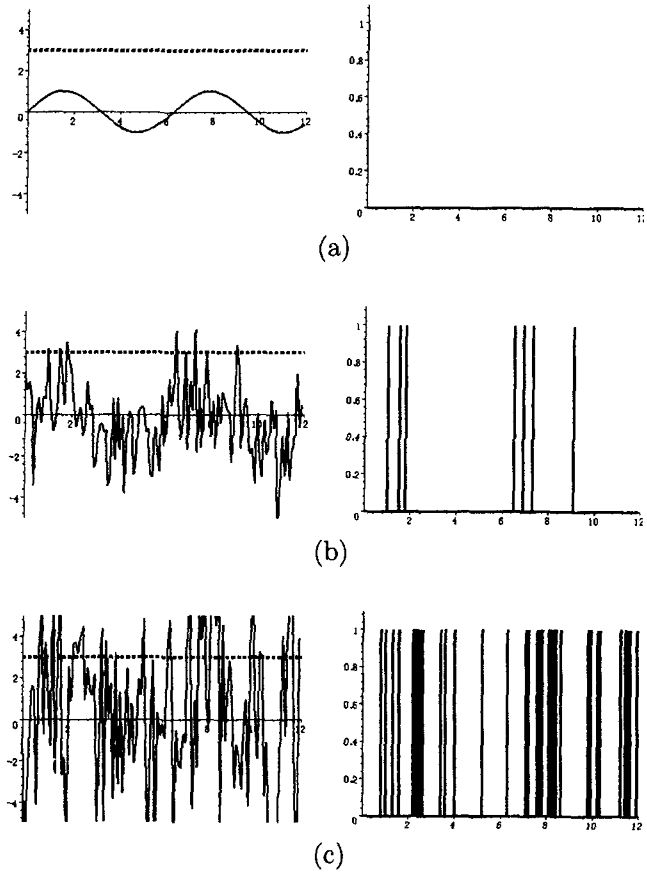

Figure 1. The threshold theory of SR : Left side is inputs Right side is outputs.

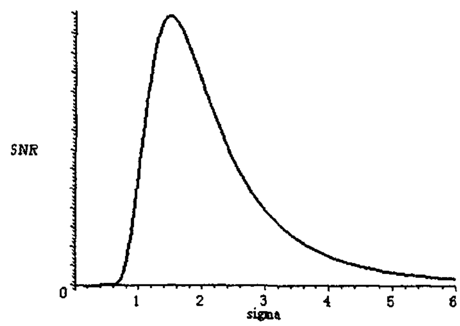

Figure 2. The example of SN ratio on SR

3. Experiment

Experiment does like bellow.

1. Gaussian noise with standard deviation σ is added to function $A\sin(1/x)$.
2. Then the value of this function is divided into two values 255 and 0 (the white and the black) with a threshold Δ .
3. The like band picture which have stripe pattern is made by changing the value of x.
4. We show the picture to subjects, changing the value of A.
5. We examine the value of A when subjects become not able to distinguish a stripe.

We call the value of this A perceptive threshold "A_{th}". And repeat it by several kinds of σ. Incidentally, we use fifty Japanese subjects. They are forty-seven males and three females. They are mainly between the ages of 18 and 20's with no visual impairments.

Table 1 shows the value of parameters used by my experiment. Figure 3 is the one shown picture to subjects.

Table 1. The value of parameters

A	$25, 50, 75, 100, 125, 150, 175$
x	$0.24 \sim 0.02$ (at intervals of 0.002)
σ	$40, 60, 80, 120, 160, 200, 240, 280, 320, 360$
Δ	250

Figure 3. The example of shown picture

Figure 3 is being the example of the picture which is shown when being $\sigma = 80$ and $\Delta = 250$, $A = 175$, 150 , 125 , 100 , 75 , 50 , 25 (bottom to top). The value of x is from 0.24 to 0.02.

4. Result

Equation (1) was derived from the formula that shows SN ratio of the threshold principle of SR like Figure 1 [2].

The calculation neglects correlations between crossing events and thus assumes a signal amplitude, much smaller than the noise. An additional approximation assumes that the frequency of the signal is much smaller than the mean threshold crossing rate. The power spectrum of the spike train (of identical pulses) is then a delta function at the signal frequency riding on a white noise background. The signal-to-noise power ratio is the ratio of the strength of the delta function's power to the noise power in a 1 Hz bandwidth. B is the amplitude of input signal. Δ_0 is the threshold. f_0 is the noise bandwidth. σ is the standard deviation of noise. S is input's powor. N is noise's power.

$$(S/N)_{out} = \frac{2 f_0 \Delta_0^2 B^2}{\sigma^4 \sqrt{3}} \exp\left[-\frac{\Delta_0^2}{2\sigma^2}\right] \qquad (1)$$

We examine the value of perceptive threshold A_{th}, and repeat it by several kinds of σ. Therefore, it is important that show the relation between Ath and σ. So, we get the equation of the relation between A_{th} and σ, transforming equation (1).

Equation (2) is the equation which transformed equation 1 as $\Delta_0^2 = 2\Delta^2$, $B = A_{th}$, $Nf_0 = \sigma^2$, $(\sqrt{3}S)^{\frac{1}{2}}/2\Delta = K$.

$$A_{th} = K\sigma \exp\left[\frac{\Delta^2}{2\sigma^2}\right] \qquad (2)$$

This equation was fit to the data using K as the only adjustable parameter. The value of K means subject's ability to take out necessary information from noisy data.

Equation (3) is the equation which differentiated equation (2) in σ. From equation (3), in case of $\sigma = \Delta$, A_{th} becomes a polar value. In other words, it becomes that information is most strengthened by the noise when $\sigma = \Delta$.

$$\frac{dA_{th}}{d\sigma} = K\frac{\sigma^2 - \Delta^2}{\sigma^2} \exp\left[\frac{\Delta^2}{2\sigma^2}\right] \qquad (3)$$

Figure 4 shows the value of standard deviation σ of the noise versus the value of A_{th} at one of subjects. The error bars are the standard deviation of the value of A_{th} that repeated 10 times at each noise level. The broken line is equation (2) with $K = 0.294$, and for $\Delta = 77$ determined by least squares fit.

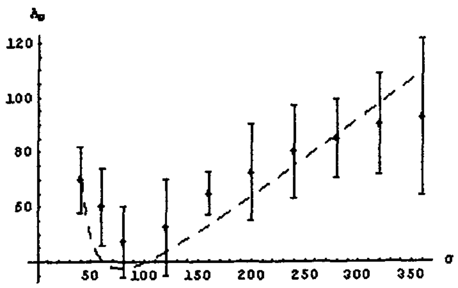

Figure 4. The value of standard deviation σ of the noise versus the value of A_{th} at one subject

From Figure 4 and equation (3), when standard deviation σ is around 77, it finds that the value of A_{th} becomes small. In other words, it is possible to think that information is strengthened by the noise around here. .

Figure 5 shows the value of standard deviation σ of the noise versus the value of A_{th} at all of subjects. The error bars are the standard deviation of the value of A_{th} at each noise level. The broken line is equation (2) with $K = 0.225$, and for $\Delta = 71$ determined by least squares fit.

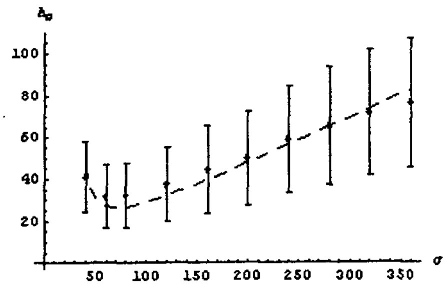

Figure 5. The value of standard deviation σ of the noise versus the value of A_{th} at all subjects

It isn't as conspicuous as the Figure 4 but the value of A_{th} becomes smaller in the time gained degree noise than when σ is small. Information is strengthened which gained moderate noise. Also, From Figure 4 and Figure 5, fitting of equation (2) is very well.

Figure 6 shows the value of standard deviation σ of the noise versus the value of A_{th} at some of subjects. K and Δ are determined by least squares fit of equation (2). From Figure 6, the values of Δ are similar value for each subject. Individual difference of Δ is small. The best strength of the noise intensify information is same for each subject.

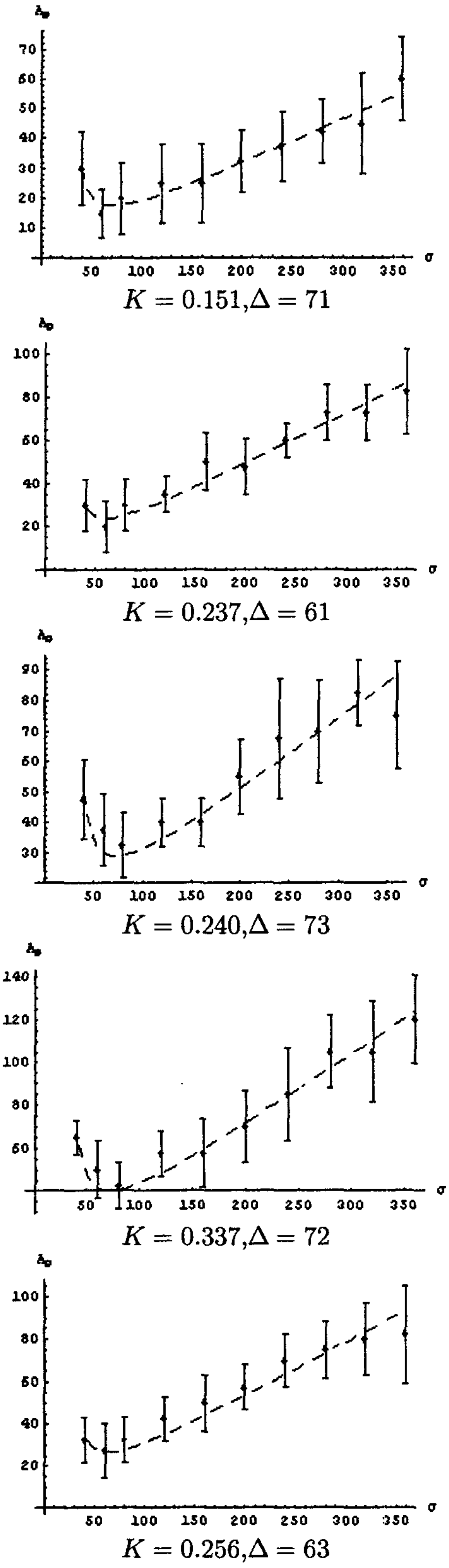

Figure 6. The value of standard deviation σ of the noise versus the value of A_{th} at some subjects

Figure 7 and Figure 8 are histgram of the value of K and Δ. The horizontal axis meen K and Δ, the vertical axis meen frequency.

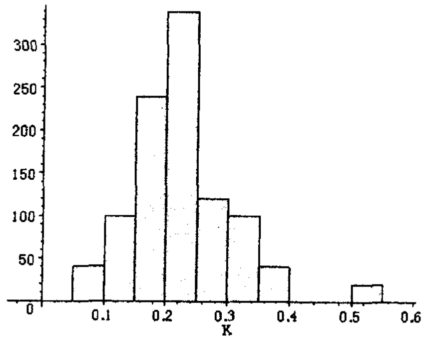

Figure 7. The histogram of K

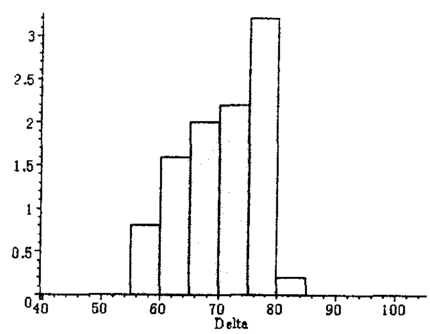

Figure 8. The histogram of Δ

Average of K is 0.226, standard deviation of K is 0.082. Average of Δ is 70, standard deviation of Δ is 6. K is widely distributed. Individual difference of Δ is small.

5. Conclusion

From our experiments, such as suggested by Moss and his group, it is confirmed that the recognition is improved by adding the appropriate noise to source signal in the case of Japanese.

Individual difference of Δ is small. The best strength of the noise intensify information is same for each subject, if other conditions are same.

Moreover, we think that we can know the characteristic of the vision against the noise by comparing the value of K of the each person. The characteristic is mainly strength of the ability to get some information that exists in the noise by comparing the value of K of the each person. We think that this becomes the help to find both of the person who reacts sharply to the information in the noise, and the person whose visual ability has some faults.

References

[1] Enrico Simonotto, Charles Seife, Mark Roberts, Jennifer Twitty, and Frank Moss, "Visual Perception of Stochastic Resonance", *PHYSICAL REVIEW LETTERS*, Vol. 78, no. 6, pp.1186-1189, 10 February 1997.

[2] Frank Moss, David Pierson, and David O'Gorman, "Stochastic Resonance: Tutorial and Update", *International Journal of Bifurcation and Chaos*, Vol. 4, No. 6, pp.1383-1397, 1994.