

## *Research Materials* (資料)

# A simple method for measuring the acoustic startle response using a low-cost electromyography acquisition device

(聴覚性驚愕反応の簡易測定を試み)

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### **Abstract**

Acoustic startle response and its prepulse inhibition have been used as tools for elucidating auditory information processing of humans and animals and for screening some mental disorders such as schizophrenia. However, measuring these phenomena requires very expensive devices and a soundproof room. In addition, once the experimental system is established, the system is not easy to move to other experimental rooms. Thus, many laboratories have found it difficult to introduce the formal experimental system to measure the startle reflex. The present study aimed to propose a simple experimental method to measure acoustic startle response, and to assess the practicality of the device. The main components of the device were a commercially available and wearable electromyography (EMG) amplifier, a microcomputer board, closed headphones, a small audio mixing console, and a personal computer. This set of devices can be easily moved between rooms without rewiring and be set up on a standard school desk. Acoustic startle responses were successfully detected using this simple measuring system without a soundproof room. This method may facilitate the investigation of the effects of other sensory modalities (e.g., visual context) on auditory information processing, and provide a useful educational tool for undergraduate students in psychology courses.

**Key Word:** startle reflex, auditory information processing, prepulse inhibition, low-cost EMG amplifier, educational tool

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### **I . Introduction**

Startle response (SR) is a physical-mental reaction that arises in humans from unexpected strong external stimuli such as natural disasters and traffic accidents. SR consists of physical responses (e.g., a pale face and exaggerated heartbeat) and mental/psychological responses (e.g., psychomotor excitation and psychomotor suspension). SR is also observed in non-human animals such as rats, mice, and pigeons in a species-specific manner (i.e.,

SR to the acoustic stimuli in rats and mice and to the visual stimuli in pigeons) [1-4]. Exaggerated SRs disturb proper responses to stress stimuli (e.g., the fight-or-flight response). However, when a weak stimulus that cannot elicit an SR is presented shortly prior to the startle stimulus, the SR is largely suppressed. This phenomenon is called prepulse inhibition of the startle response (PPI) [5]. PPI is thought to regulate sensory input by filtering out irrelevant or distracting stimuli,

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to prevent sensory information overflow, and to allow for selective and efficient processing of relevant information [6]. Therefore, the use of SR and PPI together is a suitable experimental model of information processing including attention [7]. Furthermore, as a reduction of PPI of the auditory startle response (ASR) has been reported among patients of schizophrenia and other mental disorders [8, 9], the ASR and PPI have been used together as a screening method of schizophrenia and as therapeutics [10, 11].

In the experimental situation, participants sit individually on a chair with headphones in a soundproof room. Electrodes are placed below both eyes over the orbicularis oculi muscle and reference electrodes are placed behind the ears over the mastoid with adhesive conductive gel. A startle stimulus and prepulse are delivered through the headphones, and EMG activity is recorded using specialized startle reflex testing units for humans [6, 8, 9]. Although these systems are highly reliable for medical care, they are very expensive and cannot be easily moved after they are established in an experimental room. The ASR and PPI measure not only mental disorders but also anxiety and cognitive biases [12, 13]. Anxiety and cognitive biases are important research objectives in the fields of clinical and health psychology as well as medicine. Low cost devices to measure the ASR and PPI will be quite useful for both research and experimental practices for undergraduate students in psychology courses.

Recently, a small wearable device for EMG measurement was released (MyoWare; Switch Science, Tokyo, Japan; <https://www.sparkfun.com/products/13723>), and has been used to develop several bio-control systems (e.g., a motion-activated musical instrument [14] and a drowsiness detection system [15]). MyoWare is a ready-made EMG sensor and directory attached to one's body with adhesive electrodes. The signals are detected and calculated by an Arduino microcomputer board (Switch Science, Tokyo, Japan; <https://www.arduino.cc/>), and there are fabrication guides and

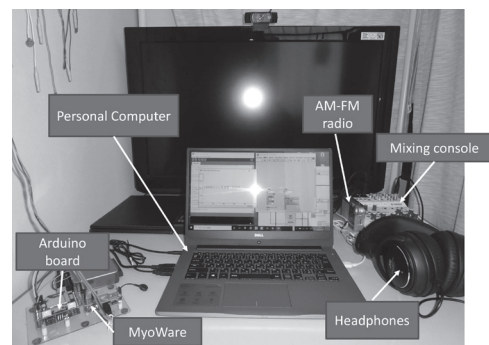
sample codes to measure EMG available on the web. Therefore, researchers and students can easily assemble EMG measuring systems using MyoWare and an Arduino board even with little experience with electronic works and programming.

The present study had two aims. One was to propose a simple ASR measuring method using MyoWare and an Arduino board, and to assess the practicality of the method to measure the ASR. The other aim was to investigate whether the ASR can be detected by EMG from a shrug using this method, since many students hesitated to attach electrodes to their faces because of uncomfortable skin preparation with alcohol.

## II. Materials and method

### *Overview of the device:*

Figure 1 shows the structure of the measuring device used in this study. The device consists of MyoWare, a microcomputer board (Arduino Uno, Switch Science, Tokyo, Japan), closed headphones (HA-RZ910, JVCKENWOOD, Kanagawa, Japan), a personal computer (PC), and cables. Background noise is supplied by a small AM-FM radio (RF-P155, Panasonic, Osaka, Japan) and auditory stimuli (i.e., the startle and prepulse stimuli) are supplied by the PC. The background noise and startle and prepulse stimuli were created using a mixing console (AG06, Yamaha, Shizuoka, Japan). The preparation of MyoWare was identical to that in a previous study [16], and data acquisition programs were created based on the sample codes



**Figure 1** Overview of the device setting

on the manufacturer's web page (<https://www.sparkfun.com/products/13723>). The EMG data were saved on a Secure Digital memory card (SD card) using an SD card shield for the Arduino board (<https://www.seeedstudio.com/SD-Card-Shield-V4-p-1381.html>).

### Operation verification test of the ASR:

Using above mentioned devices, the author and a laboratory student (female) served as the test participants and verified the operation of the device. The participants sat individually on ordinary office chairs. The participants were instructed to pay attention to a fixation point on the display in front of them. In the eye-blink condition, small electrodes (Biomedical Sensor pad: 24 mm x 1 mm, 4-mm connector; <https://www.sparkfun.com/products/12969>) were placed below the left eye over the orbicularis oculi muscle and a reference electrode was placed behind the right ear over the mastoid. In the shrug condition, small electrodes identical to those in the eye-blink condition were placed on the left shoulder over the trapezius and a reference electrode was placed on the back of the right side of the neck over the trapezius. Electrodes were placed after wiping and cleaning the skin with alcohol cotton swabs (Hakujiji, Tokyo, Japan).

The measurement verification tests were conducted in an experimental space partitioned by thick curtains in a non-soundproofed laboratory office. The background noise of the office was 45-55 dB, the luminance was approximately 300 lux at the center of the experimental space, the temperature was  $22 \pm 2^\circ\text{C}$ , and the humidity was  $40 \pm 5\%$ . The background noise (65 dB white noise) was presented through the headphones during experiments. After a three-minute acclimation period, thirty trials of ASR measurement were conducted. The ASR measurement trials were divided into two blocks. In the first block, the response to the startle stimulus (110 dB, 40-msec duration) was measured ten times. In the second block, the response to the startle stimulus preceded

by the prepulse stimulus (75 dB or 85 dB, 20-msec duration) was measured ten times for each lead time (time from prepulse stimulus onset to pulse stimulus onset; LT) condition (120 msec or 240 msec [8, 17]). Inter-trial intervals were semi-randomly assigned (20 to 35 sec, in 5 sec steps).

### Data analyses:

EMG was recorded at the rate of 1 kHz for 360 msec (Figure 2). The sampling schedule is shown in Figure 2. The peak EMG between 20 to 120 msec after the onset of the startle stimulus was quantified as the SR. The return values of MyoWare are 0 to 1023 in Arduino boards. The PPI ratio was calculated by the following formula:  $\text{PPI ratio} = \{(\text{the mean amplitude of startle only trials} - \text{the mean amplitude of prepulse-pulse trials}) / (\text{the mean amplitude of startle only trials alone}) * 100$  [18].

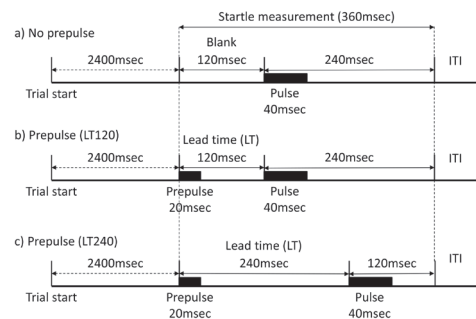
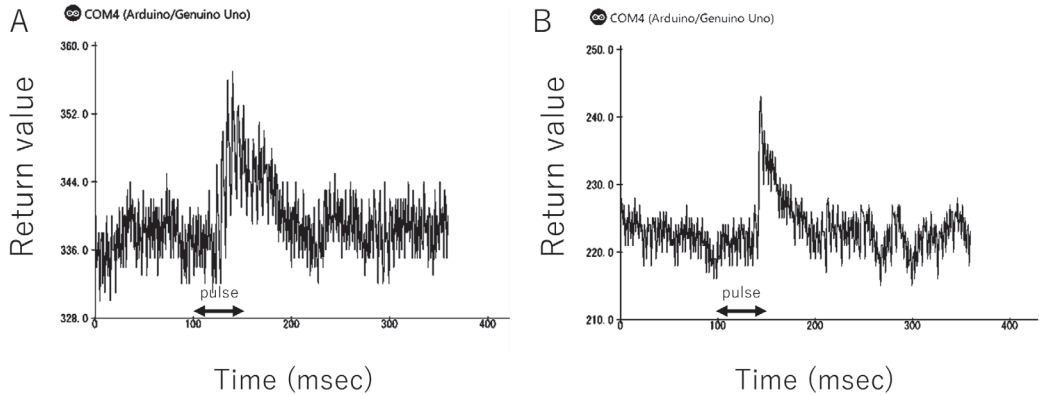


Figure 2 Sampling schedule of ASR and PPI

### III. Results

When the MyoWare was directly attached to the eyelid and shoulder, outputs were so varied that the SR could not be detected. Therefore, the following results were obtained from modified measurements in which the MyoWare was attached with screws to a plastic plate, together with the Arduino board, then fixed onto the desk with adhesion tape (Figure 1).

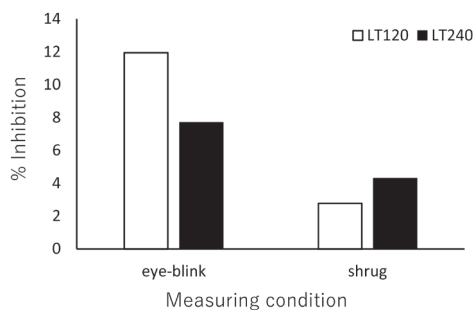
Figure 3 shows a graph of the MyoWare outputs drawn using Serial Plotter of Arduino IDE. The output amplitude sharply increased immediately



**Figure 3** Detected wave forms of ASR in the startle only trials (return value: analog input to Arduino board from MyoWare  
A: the eye-blink condition; B: the shrug condition)

after the startle stimulus in both the eye-blink (Figure 3A) and the shrug conditions (Figure 3B). These results showed that SRs can be detected using the proposed methods. Although wave forms obtained from the eye-blink condition were far less stable than those from the shrug condition, the SR was detected in increasing samples.

The SR amplitude in the prepulse-pulse trials was lower than that of the startle only trials in both the eye-blink and the shrug conditions when the prepulse was 85 db. As the calculated PPI indices were positive (2.78-11.94, Figure 4), the PPI can also be detected by this method. However, the effect of lead-time length was not observed in the present study.



**Figure 4** PPI in both eye-blink and shrug conditions (LT: lead time (msec), prepulse: 85dB)

#### IV. Discussion

In the present study, a simple measurement method using a low-cost EMG sensor (MyoWare) and a microcomputer board (Arduino Uno) detected the ASR and PPI in a non-soundproofed laboratory office. A disadvantage of this was that the data obtained by the proposed method were far less accurate compared to those measured using specialized startle reflex testing units for humans. However, the results of the present study indicate that this method will provide a useful tool for researching auditory information processing and attention and for education in psychology courses without comprehensive experimental facilities.

Problems often arise when performing research experiments and/or experimental practices with undergraduate students. Regarding EMG measurement, many students and/or participants hesitate to have electrodes attached to their faces because skin preparation using alcohol causes discomfort for many participants. Thus, whether the ASR can be detected using EMG from other body parts (e.g., the shoulder via a shrug) was examined, since skin preparation and attaching electrodes on the back of the neck is far easier than around the eyes; the ASR was indeed detected using EMG from a shrug, as well as from an eye-blink response. These results show that the

proposed ASR measuring method is practical for research experiments and experimental practices with students. In the present study, EMG wave forms from the shrug were relatively clearer than those from the eye-blink. As the environmental stimuli in the laboratory office may cause frequent spontaneous eye-blink responses, the measurement of the baseline EMG was unstable and the ASR was unclear. These results suggest that EMG from the shrug may be more suitable for detecting the ASR than EMG from the eye-blink when using simple measurements within the context of ordinary laboratories and/or classrooms.

The method proposed in the present study is quite simple and has many limitations. These include a small number of verification trials (only two participants including the author), low accuracy and reproducibility of the data, instability of baseline measurements, and a low signal-to-noise ratio. However, it has the advantage of assessing the responses of participants within many environments with low restraint conditions. Therefore, it would be fruitful to improve the accuracy of the measurement without sacrificing the simplicity of the method by both modification of the hardware and improvement of the software for analyses. Another low-cost EMG sensor that used a free software oscilloscope to analyze EMG has been proposed and applied within a clinical setting [19]. There is a free programming software entitled "Processing" (<https://processing.org/>) that cooperates with Arduino and can make charts of data from Arduino. Utilization of free software will progress the simple measurement of EMG in both research and clinical treatment settings.

## V. Conclusion

In the present study, the ASR and the PPI could be detected using a simple system consisting of a ready-made EMG sensor (MyoWare) and a microcomputer board (Arduino Uno) in both eye-blink and shrug conditions. The proposed system will provide not only a mobile research tool for measuring auditory information processing and

attention but also a new educational instrument for undergraduate students in psychology courses. It would be fruitful to improve the accuracy of the measurement without sacrificing the simplicity of the method.

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