

# Automatic Detection and Operant Reinforcement of Slow Potential Shifts

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SIEGEL, J. M., M. B. STERMAN AND S. ROSS. *Automatic detection and operant reinforcement of slow potential shifts*. *PHYSIOL. BEHAV.* 23(2) 411-413, 1979.—A technique for the automatic detection and operant reinforcement of slow potential (SP) changes is described. The SP shift detection device contains 3 inhibit channels to control sources of potential artifact including: vertical EOG, horizontal EOG and high voltage EEG transients. Two EEG SP shift detection circuits allow the simultaneous analysis of positive and negative shifts. The operation and potential uses of the device are discussed.

Slow potential shifts      Operant EEG conditioning

IT has been demonstrated that the magnitude of the averaged contingent negative variation, a slow potential (SP) shift occurring between warning and response signals in a reaction time experiment, can be altered by subjects "at will" [2]. Operant conditioning of SP shifts has also been reported in rat and monkey [3,5]. These experiments suggest that spontaneous SP shifts in humans might be operantly reinforced.

An automatic detection system could be used to operantly reinforce SP shifts and could also monitor changes in the characteristics of spontaneous shifts in response to different behavioral, pharmacological or physiological conditions. The present report describes a system with these capabilities.

## METHOD AND RESULTS

The primary requirement of any procedure for detecting SP shifts is control of artifactual sources of SP variability. This requires the use of electrodes with low drift characteristics and the monitoring of potential physiological and behavioral sources of artifact.

Beckman Biopotential Skin Electrodes (non-polarizable Ag-AgCl disks, type 650419) are used to record electroencephalogram (EEG) and electrooculogram (EOG). EEG electrodes are referred to a linked earlobe reference, a procedure which minimizes cephalic skin potential [1]. We have used EEG placements at 30% off Vertex (or midway between T3 and C3) to correspond to other studies in our laboratory. Standard placements are used to record vertical and horizontal EOG [4]. Electrode impedances are kept below 5,000 (ohms).

EOG signals are amplified with a Grass 6AIA plug-in with 0.8 sec time constant and 15 c/sec high frequency cut-off. Two separate EOG inhibit circuits are used (Fig. 1). Signals

are first passed through a 10 turn 100,000 fl potentiometer (Duncan electronics no. 3253) with precision dial and then fed into a high impedance (greater than  $10^9$  (ohms)) buffer amplifier. A coupling capacitor which provides 3 dB attenuation at 0.33 c/sec connects the buffer amplifier to a full wave rectifier and amplifier with voltage gain of 20. The rectifier allows detection of both positive and negative signals with a single comparator. The output of this circuit is then fed to the comparator. Signals exceeding criterion level, adjustable with the 10 turn potentiometer, activate a retriggerable timer (trip level 0.5 V) which can be repeatedly reset for 0.5 sec periods and which inactivates the EEG shift detection circuits. This arrangement prevents any reinforcements from occurring within 0.5 sec of an eye movement or blink. The inhibit circuits are manufactured by Neurofeedback Instruments, Inc., (NFI), 6901 Katherine Avenue, Van Nuys, CA 91405 (model FWC 40001).

Two polygraph channels are connected to the EEG electrodes. One is a conventional Grass 6A5D AC amplifier set to pass frequencies between 0.3 c/sec and 35 c/sec. The other is a 6AIA DC plug-in with 0.8 second time constant (down 3 dB at 0.6 c/sec, 6 dB at 0.35 c/sec) and 15 c/sec high frequency cutoff. The AC amplifier feeds into a third inhibit circuit. This can be set to trigger off high voltage transients such as epileptic spikes and muscle artifact. The circuit is the same as the EOG inhibit circuits except for the use of a coupling capacitor providing 3 dB attenuation at 0.66 c/sec.

The EEG signal from the DC plug-in provides the input for the SP detection circuits. It first passes through a 10 turn potentiometer and high impedance buffer amplifier and then into an active filter network that rolls off high frequencies (down 3 dB at 1 c/sec, 6 dB at 1.3 c/sec). The filtered signal is then sampled at a rate of 12 cps. Sample acquisition time is one msec. The difference between the previous sample value

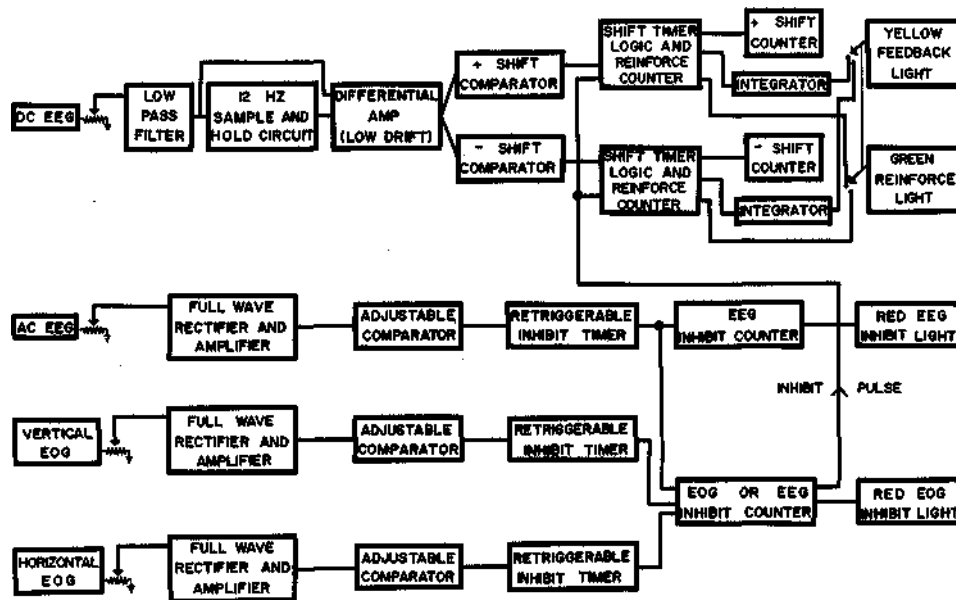


FIG. 1. Block diagram of the circuitry of the SP shift detection device. The subject's console contains the 4 indicator lights shown at the right of the diagram.

and the current value is increased by a differential amplifier (voltage gain of 220) and compared to the previous value by two comparators, one for positive and the other for negative shifts. If the sample exceeds the previous value by an adjustable criterion voltage, the positive shift timer is activated. If the sample is less than the previous value by the criterion voltage, the negative shift timer is activated. The timers run for 120 msec with each trigger and are retriggerable. This circuit was used because preliminary work showed that fixed voltage thresholds were unreliable for detecting SP shifts because of their sensitivity to small offsets in the DC baseline. It is available as a module from NFI, model D2654. The shift timer logic (NFI L1000) is a logic gate that activates the counter circuits and lamps when EEG or EOG inhibit circuits are off. It also sets minimum duration of uninterrupted shift for reward of 0.3, 0.4, 0.5, 0.6, or 0.8 sec by switch.

Test subjects, seated in a darkened room, are instructed to fixate their gaze on the center of a console containing a cluster of four indicator lights whose centers are 1 cm apart. The console is placed 2 meters away at eye level. It includes: (1) An EOG inhibit light. This red light is on whenever either EOG inhibit channel is activated. (2) An EEG inhibit light. This red light is on whenever the EEG transient inhibit circuit is on. Activation of any inhibit circuit prevents reinforcements for 0.5 sec after the final inhibit signal. (3) A yellow EEG "feedback" light. The brightness of this light increases in proportion to the length of time either the positive or negative EEG shift timer has been activated (depending on the experiment). This light is driven by an integrator with time constant of 0.2 sec (NFI ILD5000). (4) A green EEG "reinforcement" light. This light flashes once whenever either the positive or negative shift timers have been on for more than the minimum period set for reinforcement. Intervals ranging from 0.3 to 0.8 sec have been used. The flashing of this light is accompanied by a

chime. Lights are 7 mm in diameter and are manufactured by the Sloan Co., 7704 San Fernando Road, Sun Valley, CA 91352 (P175R-A-ATP-D, P175R-G-GTP-D and P175R-R-RTP-D).

The indicator lights are controlled by 2 switches. One switch (not shown in Fig. 1) disconnects the EEG reinforcement and feedback lights, leaving only the inhibit lights on. The subject can then be instructed to keep the inhibit lights off. In this condition it is possible to determine baseline SP shift levels. When the EEG feedback and reinforcement lights are connected, a second switch determines which polarity of shift (i.e., positive or negative) triggers them. The subject can then be instructed to keep these lights on, i.e., he is reinforced by the lights for producing EEG shifts in a specified direction. Any difference in the number of SP shifts occurring as a function of switch position can be attributed to information provided by the light, since no other circuitry is altered by the switch. The same is true for any difference between the condition where the EEG lights are disconnected (baseline condition) and the condition where they are on (reinforce condition).

Two four digit LED displays (IEE Atlas Co., Vay Nuys, CA, model 1750) on the subject monitoring unit keep track of number of positive rewards, and number of negative rewards (NFI model 4777A). Five additional counters accumulate positive shift time, negative shift time, EEG inhibit time, EOG inhibit time and total run time. These counters each contain a time base that converts switch closure time into pulses at a rate of 1/second. These pulses activate the LED display circuits. The time base and counters are available as a unit from NFI (TBIS-5). Both rewards and EEG shift times are accumulated even if the EEG shift and reinforce lights on the console are off. The functioning of this device can also be monitored polygraphically. Figure 2A contains a typical record. Computer averaging can be used to confirm the absence of EOG artifact (Fig. 2B).

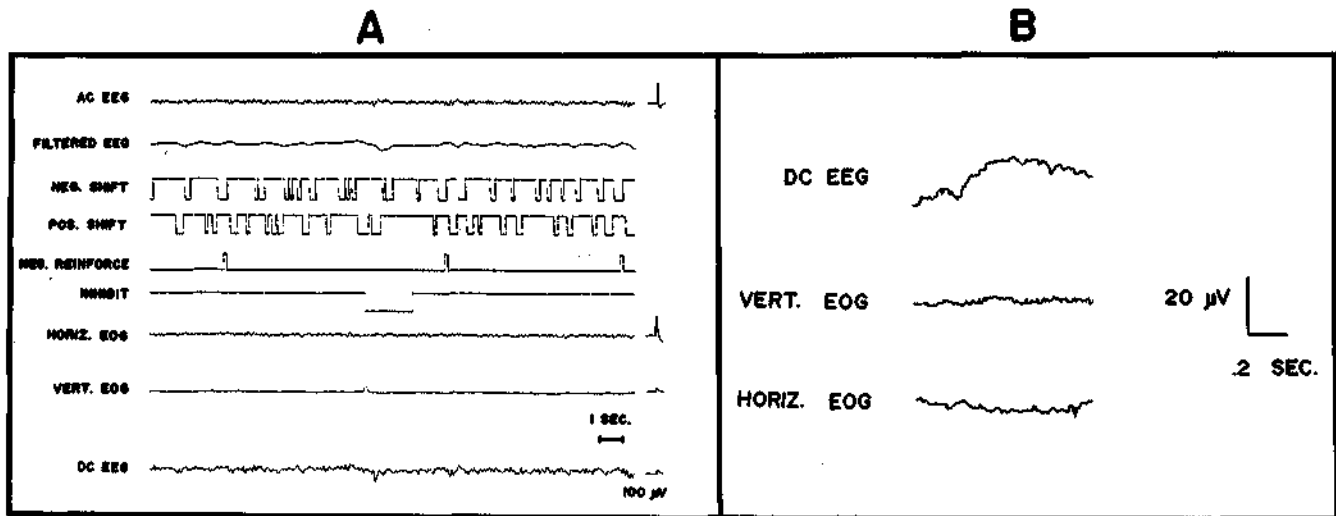


FIG. 2A. Polygraph record showing operation of SP shift detection device. Channel 2 in this record is the filtered DC EEG signal used by the EEG SP shift detector circuits. Downward deflections in channels 3 and 4 indicate the detection of negative and positive shifts, respectively. Channel 5 indicates the occurrence of a reinforcement for negative shifts (an identical pulse channel indicates the occurrence of positive shifts). In this example the device was set to deliver reinforcements for negative shifts whose duration exceeded .4 sec. These pulses can be used to trigger computer averages of EEG and EOG in the pre- and post-reinforcement periods. FIG. 2B. Averaged record of EEG and EOG changes prior to reinforcement. Average is based on 30 consecutive reinforcements for negative EEG shifts. Data were played backwards through an Ortec signal averager. The reinforce pulse was used as the trigger. Time flows from right to left. Note the absence of EOG activity during the EEG shift. Cal. pulse applies to all 3 traces.

#### DISCUSSION

The device described here allows extensive on line analysis of slow potential data. It can be used to reinforce SP changes in humans and could be adapted to control reinforcement dispensers in animals. There are several patterns of response that a subject might evolve in order to receive reinforcements for SP shifts. One pattern would involve a criterion SP shift, with a subsequent return to baseline or an increase in the variability of EEG baseline shifts. Another would be to produce continuing shifts in baseline in the direction of the reinforced polarity resulting in a staircase type of function. An intermediate response might involve shifts showing an incomplete return to baseline. The ratio of

positive to negative shifts can be used to decide which of these patterns is occurring. Further research using these techniques may shed light on the correlates of spontaneous and conditioned SP changes.

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