decreased ($P < .01$) with time on watch. The means for successive 10-minute intervals were 69, 65, 64 for the signal rate of ten per minute and 58, 55, 52, 50 for the signal rate of one per minute. The lowest signal rate (0.1 per minute) had only one signal per 10-minute interval for each subject and failed to provide a significant trend through the session. (iv) All three eye-movement rates showed significant decrements ($P < .001$) as sessions progressed. Means for successive 10-minute periods were 988, 957, 890, and 849.

In general, our data conform to traditional effects found for percentage of detections (*8*) and showed parallel eye-movement rates (*9*). The detection efficiency on the slow signal rate is an exception. However, this exception emphasizes the major difficulty with using a response which depends only on the occurrence of a signal. If signal rate is extremely low and few signals are presented, a very large $N$ must be used to obtain stable results, and a high degree of error variance must be tolerated in statistical analyses. In contrast, an observing-response measure can show moment-to-moment fluctuations in monitoring behavior even in the absence of signal presentation (Fig. 1). In addition, observing rates parallel detection rates, suggesting that the observing responses could reflect monitoring efficiency better since they are based on more data.

To evaluate the correspondence of eye-movement rates and percentage of detections, mean eye-movement rate and mean arc-sin percentage detections for each 10-minute period were then correlated. The Pearson $r$ for the two fast rates pooled was .98. The slow signal rate was analyzed separately. Its correlation of detection rate and eye-movement rate was low (.006). The eye-movement rate data and detection data of each individual for 10-minute periods were then correlated. Although a wide spread of values was found ($-$ .27 to $+$ .99), the majority of the correlations were high (median = .84). Those subjects who showed low correlations had slower and more erratic eye-movement rates and detection rates, or both (Fig. 2). Subjects with high correlations most often had higher and more uniform eye-movement rates (Fig. 1). It thus appears that, as signal rate decreases, response rates become more variable both within and between sessions; consequently, correlational analyses grow less stable and should be interpreted with caution. However, detection rate can be expected to be more susceptible to these inconsistencies since it is based on a much smaller amount of data than eye-movement rate is.

Individuals with higher overall eye-movement rates detected many more signals. Mackworth, Kaplan, and Metlay (*9*) found a similar result on a clock-watching vigilance task. Their interpretation is that speed of shifting of fixation is an index of "alertness."

Subjects sometimes fixate a signal without seeing it, as Baker (*5*) found for a clock-monitoring task, and Mackworth, Kaplan, and Metlay (*9*) found for both a one- or two-clock monitoring task. The same result was confirmed in our study. But, in addition, it was found that rate of looking without reporting was sensitive both to signal rate and time on watch. The slower the signal rate and the longer the time on watch, the greater the tendency to fixate a signal without reporting it. Thus "looking without seeing" seems to follow the same course as detections and eye movements and seems to be controlled by the same variables. This effect might be a function of other more subtle components of the act of observing.

In conclusion, our results support Holland's (*2*) suggestion that detection data in vigilance experiments reflect observing responses, be they contrived, like key-pressing to illuminate the display, or more natural, like eye movements.

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## Temporal Relation Between Long-Lasting Aftercontractions and Action Potentials in Cat Papillary Muscles

Abstract. *Sotalol, an adrenergic-blocking and antiarrhythmic agent, increases markedly and simultaneously the duration of both action potentials and contractions in papillary muscles. The active tension is manifested as a main twitch contraction followed by a maintained low level of residual tension (aftercontraction) which persists until the terminal phase of rapid repolarization. The strength of the aftercontraction is augmented when the extracellular concentration of calcium is increased.*

Procedures for investigating excitation-contraction coupling in cardiac muscle are still rather limited. We now describe a pharmacological method by which electrical and mechanical events may be varied. Sotalol [(±)-4-(2-isopropylamine-1-hydroxyethyl)methanesulfonanilide HCl], or MJ 1999, is a competitive blocking agent at the adrenergic receptors of the heart ($\beta$-receptors) (*1*) and has antiarrhythmic properties (*2*). It also enhances the strength of contraction of cat papillary muscles; this positive inotropic effect occurs even in the presence of (±)propranolol and is, therefore, considered nonadrenergic (*3*). In approximately $10^{-4}M$ sotalol, the increase in developed twitch tension is greatest. Once this maximum tension is attained, the terminal phase of relaxation is slowed and becomes longer with continued exposure to the drug. A small amount of active tension (which we shall call an aftercontraction) persists after each contraction, and may last as long as 5 seconds (*3*). We have found that if a driving stimulus is delivered during such an aftercontraction it does not elicit a twitch, even when the voltage is increased to as much as 20 times the previous threshold. This increase in refractory period suggests that the drug may cause an increase in the duration of the action potential. To test this possibility we have examined

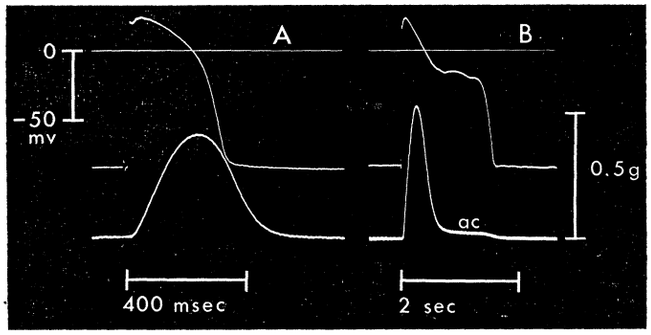


Fig. 1. Papillary muscle 3.0 mm long and 0.4 mm thick from an 850-g kitten. Upper trace, action potential; lower trace, isometric contraction. (A) Control before sotalol; (B) 30 minutes after the addition of sotalol ($6 \times 10^{-4}$ mole/liter) to the bathing solution. Notice the fivefold compression in time scale in B. The duration of the twitch plus aftercontraction (*ac*) and of the action potential is about five times longer than that of the control. Peak tension was larger after sotalol.

the changes in the transmembrane potential accompanying these aftercontractions.

Thin papillary muscles from the right ventricles of kitten hearts were mounted in a bath through which an oxygenated physiological salt solution (*4*) flowed at 32.0° to 32.5°C. The glass capillary electrodes for intracellular recording were suspended from fine, flexible chlorided silver wires. The muscles were stimulated with threshold square pulses 5 msec long at 5-second intervals throughout the experiment. The tension developed in isometric contractions was recorded at the muscle length optimum for maximum developed tension. Both mechanical and electrical events were displayed on a double-beam (Tektronix 502) oscilloscope and recorded on film.

Control action potentials were recorded from about ten cells in each muscle. The total duration of the action potential was about 60 percent of the total duration of the contraction. The times from onset of depolarization to 50 and 90 percent repolarization were chosen as an arbitrary index of the duration of the action potential. The time to 50 percent repolarization was 349.2 ± 43.2 msec [(mean and standard deviation (S.D.) of 49 cells from five muscles)]. The time to 90 percent polarization was 401.3 ± 46.4 msec. Control resting membrane potentials averaged 80.5 ± 4.82 mv.

The muscles were then perfused with solutions containing various concentrations of sotalol. The main effect of sotalol on the electrical activity of cardiac cells in concentrations between $2 \times 10^{-6}$ and $6 \times 10^{-4}$ mole/liter was an increase in the duration of the action potential. This effect grew more pronounced the greater the concentration within this range. After the tissues had been exposed to $6 \times 10^{-4}M$ sotalol for 1 to 2 hours, the time from onset of depolarization to 50 percent repolarization was 973.3 ± 334.0 msec (mean and S.D. of 30 cells from five muscles). The time to 90 percent repolarization averaged 1209.4 ± 290.0 msec. There was no significant change in resting membrane potential in the presence of $6 \times 10^{-4}M$ sotalol.

In the presence of $2 \times 10^{-4}$ to $6 \times 10^{-4}M$ sotalol the plateau of the action potential acquired two characteristic features. First, the duration of this part of the action potential became as long or longer than the duration of the twitch contraction. Second, during this sustained plateau the membrane potential tended to oscillate (Figs. 1 and 2) between −25 mv and about 0 mv. During this part of the action potential, some active tension persisted (the aftercontraction). After the period of oscillation of the membrane potential, rapid repolarization began and simultaneously the remaining active tension declined. The membrane potential and the twitch reached their resting values at essentially the same time (Figs. 1 and 2).

At large concentrations ($10^{-3}$ mole/liter) of sotalol, there is a reduction in the duration of the action potential and aftercontraction. This suggests that there is an optimum concentration of sotalol for production of the longest aftercontractions and action potentials. Usually the greatest increase in the duration of the action potentials and contractions occurred after high concentrations of sotalol were washed out. Since this maximum prolongation is more often seen during washout of the drug than with the drug in the bathing solution, there seems to be a time factor as well as a concentration factor influencing the production of the phenomenon. The effect of sotalol on the duration of the electrical and mechanical activity was slowly and completely reversible, provided the concentration did not exceed $6 \times 10^{-4}$ mole/liter.

The equality of the total duration of the electrical and mechanical events in the presence of various concentrations of sotalol suggests that the aftercontraction is a result of the prolonged depolarization. Because it is believed that during depolarization an influx of calcium occurs in cardiac muscle (*5*), we tested whether the tension of the aftercontractions was related to the concentration of calcium in the external solution. If calcium flows into the myocardial cell for a time equal to the long-lasting depolarization and if the tension of the aftercontraction is related to this calcium influx, then one would anticipate an increase in the tension with increased calcium in the external solution. This prediction proved correct. In six papillary muscles doubling the calcium concentration from 4.5 to 9.0 meq/liter increased the tension of the

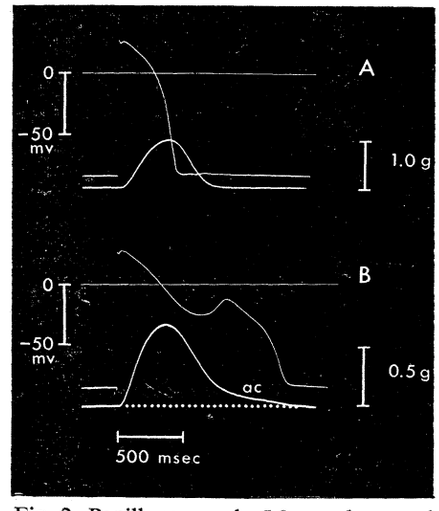


Fig. 2. Papillary muscle 5.0 mm long and 0.3 mm thick from a 1.4-kg cat. Upper trace, action potential; lower trace, isometric contraction. (A) Control before sotalol; (B) 97 minutes after the drug was washed out (the tissue had previously been exposed to $2 \times 10^{-3}M$ sotalol for 50 minutes). The oscillation in the plateau appeared in this muscle only after sotalol was washed out; *ac*, aftercontraction. Resting tension is indicated by dotted line.

aftercontraction induced by sotalol from 75.8 ± 14.9 mg (mean ± standard error to 264.5 ± 32.8 mg. According to Niedergerke (*5*) frog ventricular strips, depolarized with high concentrations of external potassium, contract more strongly the higher the concentration of extracellular calcium, and calcium exchange is directly related to contracture tension. Similarly, in the presence of sotalol the striking increase in tension of the aftercontractions caused by doubling external calcium supports the hypothesis that during a prolonged depolarization an influx of calcium may contribute to the production of active tension.

The tension of the sotalol-induced aftercontraction is only a small fraction of the main twitch tension (5 to 18 percent at 4.5 meq of calcium per liter). Kavaler, who succeeded in extending the duration of the contraction of ventricular strips by holding the plateau of the action potential at a positive potential (+ 15 mv) with an applied current, observed long-lasting contractures which developed about 80 percent of the active tension of the main twitch (*6*). The reason for this discrepancy may be that the electrically sustained plateau potential is positive, whereas the plateau produced by sotalol is slightly negative.

The change in the time course of myocardial electrical activity produced by sotalol may have a bearing on the antiarrhythmic properties of this drug (*2*). Sotalol prevents the ventricular fibrillation produced by coronary ligation or poisoning with ouabain (*2*). Other antiarrhythmic agents such as the β-adrenergic blocking agents pronethalol and propranolol do not prolong the cardiac action potential. These drugs have local anesthetic activity, and probably act by reducing depolarizing ($Na^+$) current (*7*). Sotalol, on the other hand, is not a local anesthetic agent (*8*). The QT interval is increased about 50 percent in animals when sotalol is present in concentrations sufficient to exert antifibrillatory activity (*2*). The concentration of sotalol for antifibrillatory action is estimated to be of the same order as the concentration that prolongs the action potential in vitro. Our studies indicate that in concentrations from $6 \times 10^{-6}$ to $6 \times 10^{-4}$ mole/liter, this drug does not decrease the rate of depolarization and hence does not interfere with the inward depolarizing current. Consequently, it appears that the antifibrillatory activity of sotalol, unlike that of other presently known antiarrhythmic agents, is attributable to the marked prolongation of the ventricular action potential.

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## Visual Evoked Response Correlates of Unconscious Mental Processes

Abstract. *Average evoked responses and accompanying free associations elicited by subthreshold visual stimuli were studied to determine if a differential discrimination between two stimuli would be reflected in either or both of these responses. The results indicate that the effects of subliminal perception are encoded in the average evoked response and also influence the content of free associations.*

Bevan (*1*), in reviewing a number of studies which sought to investigate the influence of subliminal stimuli upon cognitive processes, concluded in favor of subliminal perception. Shevrin and colleagues (*2*) have shown that subliminal visual stimuli influence associations and imagery and also elicit verbal behavior which depends upon clanglike rather than conceptual relationships; this is in parallel with thinking as noted in clinical psychopathology (*2*).

Modifications in electrical activity of the brain—average evoked potentials—have been reported to be associated with complex psychological processes such as attention (*3*). Libet *et al.* (*4*) found electrocortical responses to somatosensory stimuli below the level of conscious awareness even when attention was directed to the stimuli. Schwartz and Shagass (*5*), by contrast, reported that electrocortical response and consciousness are coordinate and suggested that subliminal effects can be explained as attentional phenomena not reflected in the average evoked response. Pribram *et al.* (*6*), recording average evoked responses from the striate cortex of the monkey, found that these responses discriminate between a circle and vertical stripes flashed at 0.001 second.

Here we ask the following. (i) Will these responses discriminate between two subliminal stimuli matched essentially for size, color, general configuration, and brightness, but differing in specific content and complexity of internal contours (Fig. 1)? (ii) Will verbal free associations to subliminal stimuli which produce average evoked response discrimination suggest a complex symbolic process rather than a primitive sensing of difference?

Stimuli were presented in a two-field, Dodge-type tachistoscope. Luminance of blank and stimulus fields was 3.0 mlam. The room luminance was 0.9 mlam. Average evoked responses were recorded by Grass model III-D 8 channel electroencephalograph, Sanborn model 2007 channel tape recorder, Enhancetron model 1024, and Mosely model 7000 X-Y plotter. Bipolar recordings were made between frontal, vertex, and left occipital (2 cm above inion) placements; the left ear was grounded. Thirteen male college students of ages 20 to 22 served as subjects. Electroencephalogram (EEG) and free-association data were obtained in one 3-hour session.

Pilot investigations established that subjects did not perceive the stimuli presented at durations of 0.001 second