CONDITIONS ASSOCIATED WITH GASTROINTESTINAL ACTIVITY[1]

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The general problem of the series of experiments here reported is to investigate the relation of gastrointestinal activity to certain external and internal factors, and in certain situations to the reports obtained from *S*s. The principal experimental variables are: (*a*) fullness or emptiness of the stomach, (*b*) rest, (*c*) visual stimulation, and (*d*) the presence of a balloon in the stomach.

Previous work on such subjects has been handicapped by the necessity of introducing something such as a balloon or a barium meal into the stomach or intestinal tract, something which may itself affect results. We have in these studies taken advantage of the electrical recording method described by Davis, Garafolo, and Gault (1957), a method which avoids inserting anything into the stomach. That such a method records gastrointestinal activity is obvious when it reveals the regular 3/min rhythm characteristic of the stomach, as seen in Figure 2. Alvarez (1948) has no doubt of the validity of the method, which he used as early as 1922. More information on the relation of electrical and mechanical records of activity will be provided by the data of several of the present experiments.

The electrodes used were silver disks 1 in. square which had been chlorided and on test showed little polarization. The skin was prepared by shaving, cleaning with alcohol, and rubbing with electrode jelly, which was then wiped off. The surface of the electrodes was given a light coating of electrode jelly containing NaCl, and the electrode was then taped to the desired location. The reference electrode, of the same type, was attached to the surface of the forearm in the same way.

To quantify recorded activity in several respects, a base line was drawn from the position of the pen at the beginning of each half-minute to its position at the end of that time. Our first measure, "amplitude," is the maximum departure of the recorded line from this base in each half-minute. Our second, "displacement," is the difference between the two ends of the base line, and our third, "frequency," is the number of times the record crosses the base line in the half-minute. The first two were reduced to microvolts by reference to a calibration taken at the end of each *S*'s run.

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EXPERIMENT I. ACTIVITY WITH AND WITHOUT FOOD

Method

The problem was to compare activity in the empty stomach with that found after eating a small amount of food. Eight volunteers were run at 8:00 A.M., when they had not eaten since the previous midnight. Six of these were students; three were accustomed to heavy breakfasts and the others to light or moderate ones. Records were taken before eating from each of the four abdominal quadrants, with the electrode near the center of each, in counterbalanced order. Each site was recorded for a total of 4 min. before eating and the whole sequence was repeated after eating. The food consisted of two cups of coffee or tea and a large sweet roll. Three of the *S*s were required to turn on the side as if eating before actually eating, and records were taken thereafter to determine the effects of such motion on the record. Food was then given and the recording completed.

Results

Each *S*'s mean for each of the three measures was computed for the two experimental conditions for each electrode location. The medians of these subject means are shown in Figure 1. Differences between conditions were tested by the Wilcoxon test for paired replicates. For our frequency measures there were no significant differences between conditions. Differences in amplitude are significant ($p < .05$) for all four locations, and when the four locations are averaged, every *S* shows an increase after eating. For displacement the increase is significant for the lead nearest the stomach and for the mean of all locations.

A sample record (Fig. 2) shows the effects indicated. It was chosen, however, because it is somewhat atypical in showing a pronounced 3/min rhythm before food in the upper right quadrant. Inspection of records shows, in general, no indication of large slow waves which might represent the so-called hunger

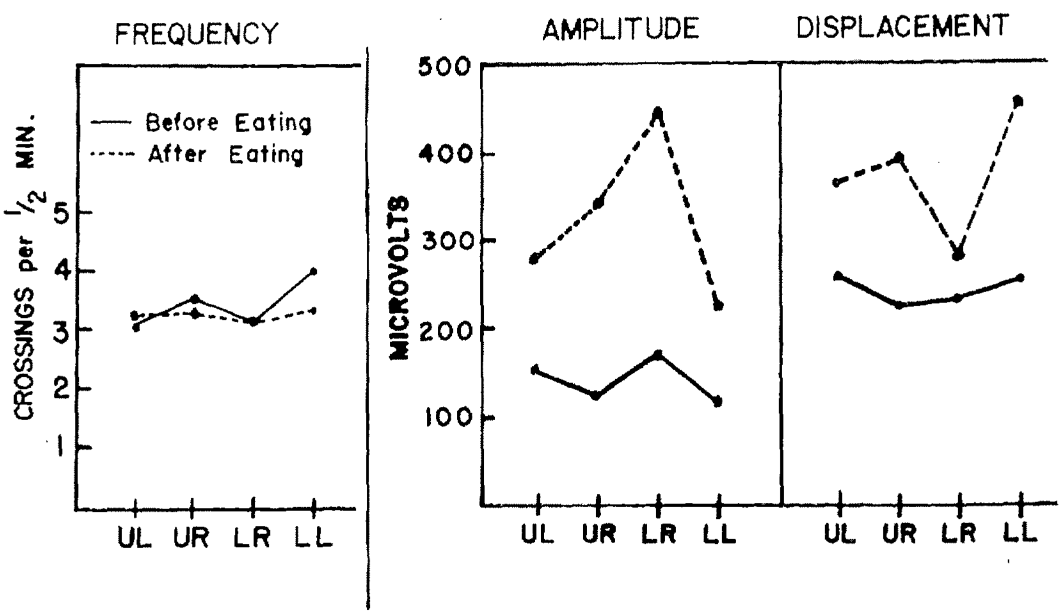

FIG. 1. Median reading (four locations) before and after eating.

contractions before eating. Such waves do appear in the records, along with an increase in the 3/min rhythm, after food had been taken.

The maneuver of having *S* lie on his side for a "sham eating" had a small and inconsistent effect on the records of the three *S*s so treated.

The results indicate, contrary to a common expectation, a condition of relative inactivity in the gastrointestinal tract in the morning when *S* has been without food overnight.

EXPERIMENT II. THE EFFECT OF REST AND STIMULATION UNDER VARIOUS DEPRIVATION CONDITIONS

In this experiment the problem was to determine the effect of rest in a quiet, darkened room and the subsequent administration of a strong visual stimulus when *S*s had eaten recently and when they had not.

Method

Sessions were scheduled at convenient times during the day, and *S* in each case was asked when he had last eaten. Six who were run in the morning had eaten no breakfast, 8 other morning *S*s had eaten breakfast, and 4 *S*s who had eaten lunch were run in the afternoon. Hence, there are three groups of *S*s classed according to the last meal consumed.

The *S* lay on his back on a cot and was informed of the experimental procedure. An electrode was attached to the middle of the upper left quadrant and a reference electrode to the right forearm with preparations made as in Experiment I. Illumination of the room was then reduced to the reading light of the instrument panel and a continuous recording made to the end of the

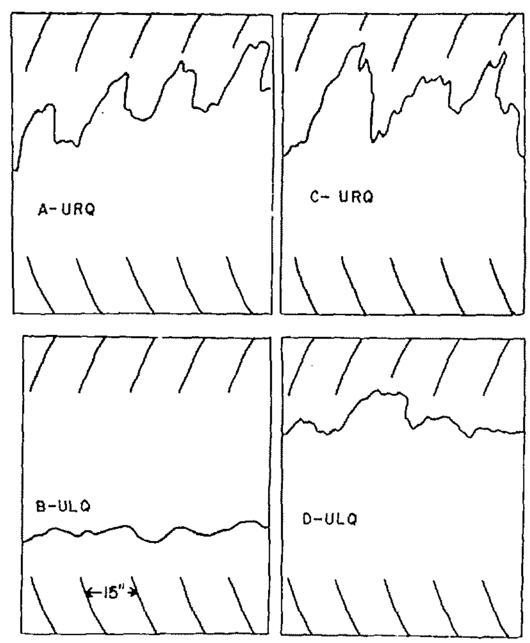

FIG. 2. Records before (*A* & *B*) and after eating (*C* & *D*) from two quadrants.

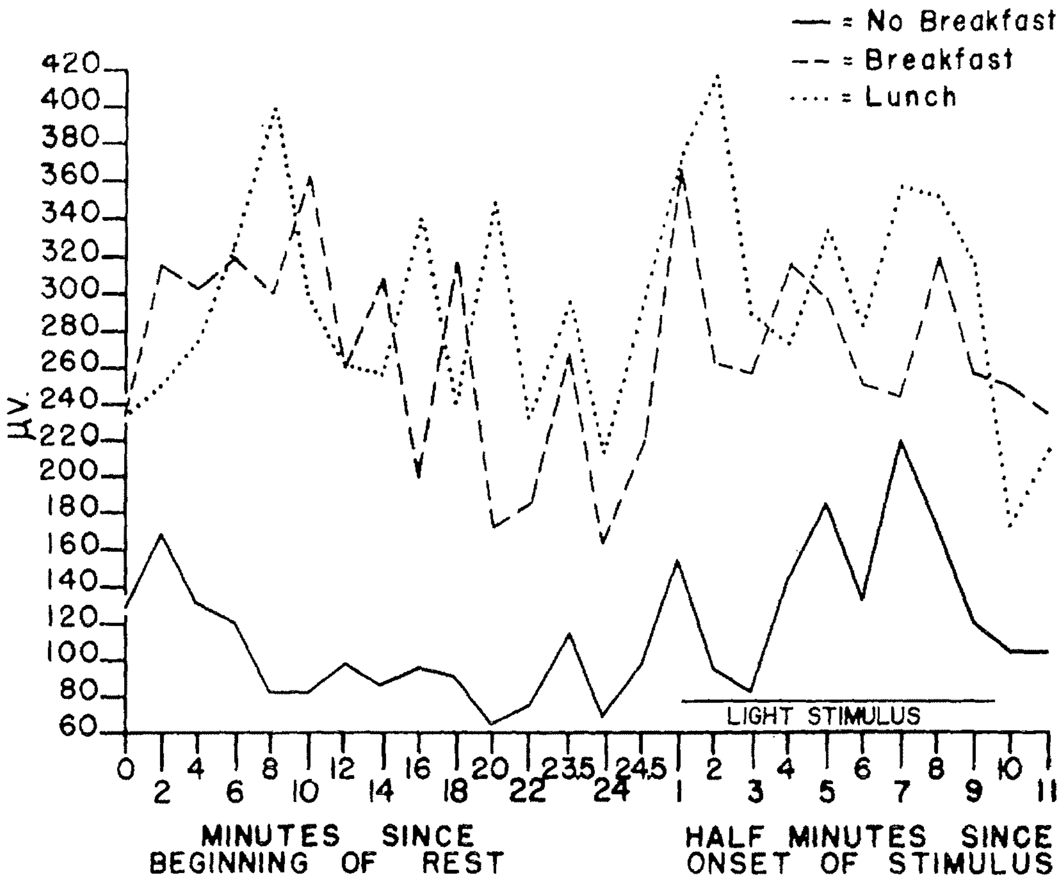

FIG. 3. Amplitude measure: Effect of rest on median amplitude.

experiment. For 25 min. no stimuli were delivered; then *E* turned on a 200-w. lamp in a reflector about 4 ft. above *S*'s face. Recording for $5\frac{1}{2}$ min. under these conditions terminated the sitting.

Measurements were made in the manner described on the first half-minute of each 2-min. period through the first 22 min. of rest, on the three half-minutes just before the stimulus, and on all the half-minutes thereafter.

Results

The frequency measure again showed no consistent trend. The results for the amplitude measure are shown in Figure 3 for the three groups. The displacement results produce a graph so similar to Figure 3 that it is not reproduced. The significance of the trend for all groups combined was ascertained by the Friedman test. Readings were ranked for each *S*, and the agreement of *S*s with each other was the object of the test. For amplitude the trend is significant at the .03 level and for displacement at the .01 level.

There are two phases evident in the graphs; a downward trend during the rest period and a rise following the stimulus. To isolate the downward trend for test, the mean of the first three measures for each *S* was compared with the mean of his last three in the rest period. In amplitude 15 of the 18 *S*s showed a decrease during rest, in displacement 17 of the 18 showed the decrease. Both these proportions are significant at the .01 level by the binomial test. For the post-stimulus rise, both the records and the graphs suggest a dual effect: a rise within a minute of stimulus onset, then some recession, followed by another rise about 4 min. after the onset. For the "immediate" effect we may compare the last reading before the stimulus with the first after its onset. In the amplitude measure, 13 show an increase following the stimulus, 4 do not change, and 1 shows a decrease. Discarding ties and applying the binomial test yields an increase significant at the level of .002. In displacement, 12 show an increase, 5 a decrease, and 1 no change. This is not significant by the binomial test, but is by the Wilcoxon test ($p < .02$). For the later effects of the stimulus the mean of Readings 7 and 8 were compared with the pre-stimulus level for each *S*. In amplitude, 14 *S*s show an increase, 2 a decrease, and 2 do not change ($p < .004$). For displacement the difference is not significant. In amplitude, then, there is either a maintenance of response or the production of another.

The nature of the response to the stimulus is shown in more detail in the original records such as the one presented in Figure 4. The first change after the beginning of the stimulus is typically a large, slow, wave with a latency of 4 to 5 sec., reaching its peak sometimes as late as 2 min. after the beginning of the stimulus. This type of wave was mentioned by Davis et al. (1957) and is described by Morton (1954) in records taken with an electrode on the inner surface of the stomach. After this response, or possibly along with it, there develops an increased 3/min. rhythm in the typical record. The first long transient response would tend to affect both our measures; the increase in amplitude of recurrent waves would affect principally our amplitude measure.

Group differences in level of activity were tested by comparing records of *S*s who had eaten during the day with those who had not, by the Mann-Whitney test applied to the mean readings before the stimulus and to the mean of readings after it. For amplitude the two p values are less than .01 and .02, respectively, and for displacement less than .01 and .05. Indeed, in the amplitude measure before the stimulus the two groups do not overlap at all. The increase in activity following the stimulus is not, however, different in the groups, so far as our data can show.

As in Experiment 1, *S*s with empty stomachs were found to have low activity, with little sign of the classic "hunger contractions" during a resting state. They do, however, as do people with recent meals, respond to an external stimulus with increased activity. The decline of activity during the rest period may be taken as recovery from the effects of prior stimulation.

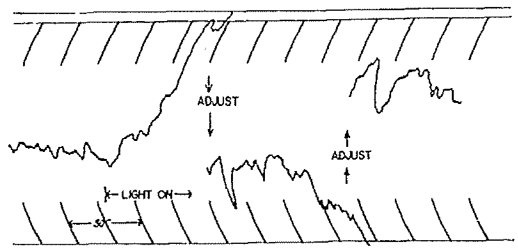

FIG. 4. Effect of visual stimulus on electrogastrogram.

EXPERIMENT III. EFFECT OF A STOMACH BALLOON ON GASTRIC ACTIVITY

In view of the unexpected results on the activity of the empty stomach it is desirable to examine the effects of a stomach balloon upon the stomach. Such effects have, in fact, been suspected before. Alvarez remarked, "Contractions seen by the users of balloons should not be spoken of as contractions of an empty stomach." Code has done careful work to minimize the possible effects of a balloon, but observes that one cannot be certain that the effect has been eliminated. Gianturco found that activity in the empty stomach of the dog was almost nonexistent when he used a method which did not involve a balloon. Martin and Morton, recording from the interior of the stomach, reported an increase in electrical waves with the introduction of a balloon. On the general question of "hunger contractions" Alvarez commented, "I have never been able to satisfy myself as to the nature of the difference, if there is one, between hunger contractions and the normal waves of the lower half of the stomach." Wolf and Wolff, in their fistula patient, found little or no correlation between stomach contractions and reports of hunger. Carlson, on the other hand, using the balloon technique, reported on the basis of recordings from 50 *S*s that the empty stomach shows bursts of strong contractions with a rhythm of about 30 sec. and that when such a contraction occurs, "the subject invariably signals that he feels hunger."

Method

In our experiment the main problem was to compare the electrical signs of activity before the insertion of a balloon with those present while the balloon was in place. By recording from the balloon and electrically at the same time, we also obtained some information on the relation of the two measures. Following the procedure of Cannon and Washburn, records were taken between 2 and 5 P.M. on *S*s who had eaten no lunch. All but one of the *S*s were student volunteers, and all but one male. One or more electrodes were attached to *S*'s abdomen just to the left of the navel or about an inch higher than that. During preliminary recording a selection was made of which position gave the most active record (though this was difficult to judge) and subsequent recording was from it. The reference electrode, as before, was on the right forearm. There were 15 records taken on 11 different *S*s, 2 of whom served more than once.

Electrical recording was carried out for approximately 10 min. before the balloon was inserted. Then *S* sat up and attempted to swallow the balloon. One *S* (not counted) failed to get it down, and most had some difficulty doing so. The balloon was inflated to the customary low pressure,[2] and dual recording was begun. When the mechanical record failed to show the normal respiration waves, the position or inflation of the balloon was adjusted to produce them if possible. The balloon was also adjusted in an attempt to locate the expected stomach contractions if they did not appear in a reasonable time. The *S* was provided with a signal key which he was instructed to press whenever he felt a pang, cramp, or pain in his abdomen. The dual recording lasted approximately 30 min. with some time additional for balloon adjustments. In 3 cases showing no "hunger contractions" questions about food were introduced at intervals of 3 to 4 min. in the latter half of the session.

Results

In addition to the changes of balloon position produced by *E*, it was evident that there were "spontaneous" shifts produced by stomach activity, for the character of the record would change occasionally. One troublesome change was evidently a folding-over of the balloon, which blocked the tube opening. The reverse, a spontaneous opening, also occurred.

As balloon records were not secured during two sittings, we have 13 simultaneous recordings. In eight of these there are some waves which answer the description of the classic hunger contraction, perhaps better called "Cannon-Carlson waves." As Carlson reported, these tend to occur in bursts and during a given burst to increase in frequency. In records which do not show such contractions, there are small fluctuations in the base line, of similar period, which may be of the same nature but are not usually counted as hunger contractions.

[2] Grace Wertenberger, of the Department of Physiology, formerly a student of Carlson, kindly assisted with the balloon recording in this experiment.

TABLE 1
Comparison of Amplitude Reading in Rest and Balloon Periods

Measure	1st Rest	1st Balloon	Last Balloon	Last Rest
Median (μv.)	147	369	241	194
No. of Records	15	15	15	13
No. of *S*s	11	11	11	10
Records showing increase over first rest		14	11	9

To compare the electrical records with and without the balloon, measurements were made in the same way as described for Experiment I. For each *S* the mean amplitude was computed for each 2½-min. period. Table 1 gives the medians of all *S*s for 2½-min. intervals at the end of the rest period, at the beginning and end of the balloon period, and in the final rest period, and associated data. The increase from the rest level to the first balloon period is found in all 11 individuals and is, of course, significant. (Multiple readings for the same individual were averaged.) By the end of the balloon period the median has declined; it is still higher than the rest level by an amount about equal to the difference between an empty and full stomach in Experiment II. The difference is just short of significance at the .05 level by the Wilcoxon test. The activity level is, however, not falling at this point: 9 of the 11 *S*s, a significant proportion ($p < .01$, Wilcoxon test), show a rise during the last 5 min. *In no case is the last reading the minimum* of the balloon period. After the balloon is removed, the median does fall, though in the period tested significance of change is not established. Nor is the figure significantly different from the level at the end of the initial rest period. In short, there is increased activity at the beginning of the balloon period. This declines somewhat, but appears to be increasing again at the end of the balloon period.

There were very few reports of pangs, cramps, etc. except from one person (*S* 9). This one signaled 38 reports in 20 min. One gave 5 reports in 20 min. One gave 5 reports in one session, another (*S* 10), 3, distributed over 3 sessions, and 5 others gave 2 per session. In the records of *S* 9 there were a good number of mechanical and electrical waves, but so far as we can see, the reports bear no relation to them. For *S* 10, the senior author, there is a good, though not perfect, coincidence of reports with mechanical and electrical waves. Another *S* reported a period of several minutes of pain at the beginning of the session, a period showing considerable activity in both types of record. The scattered reports of other *S*s can be matched with balloon or electrical waves or both about half the time. The great majority of recorded waves were unreported.

The correspondence of mechanical and electrical records is sometimes obvious. But the relation is not always so clear. For a general assessment of it, we divided the balloon records into half-minutes corresponding to the half-minutes of the electrical records. These were thereupon classified into two groups: half-minutes showing evidence of increasing balloon pressure and those not showing it. The corresponding amplitude readings from the electrical records were then averaged for the two groups of half-minute intervals for each *S*. The median amplitude for the active periods (balloon criterion) was 207 and for the inactive 151 μv. A difference of this sort was found in every *S* and every record. To carry the analysis further, *S*s were divided into two equal groups according to size of balloon-recorded contraction. (This division happened to be rather clear cut.) Means for the four subclasses are given in Table 2. Both within and between *S*s the electrical measurement agrees with the mechanical. ($p < .05$ between *S*s for the active period by the Mann-Whitney test.)

Experiment III may be summarized: the introduction of a balloon produces an increase in the electrical activity recorded; *S*s' reports of pangs or cramps rarely correspond to recorded contractions; and mechanical and electrical records agree in trend for average readings and sometimes in considerable detail for individual records.

TABLE 2

Relation of Microvolts of Amplitude to Mechanically Recorded Activity

*S*s with:	Condition Shown by Mechanical Record		
	Active Period	Non active Period	Diff.
Large balloon waves	297	188	109
Small balloon waves	212	162	50

EXPERIMENT IV. FURTHER COMPARISON OF MECHANICAL AND ELECTRICAL RECORDS

This experiment was carried out principally to explore further the relation of the two types of recording, and incidentally to verify the results of Experiment III. A problem which calls for explanation is why in some *S*s there was a clear second-by-second correspondence of electrical and mechanical records, whereas in others the relation appears only on a 30-sec. by 30-sec. basis. It may be supposed that position of the recording electrodes in relation to the balloon or to the stomach is a determining factor. Certain tests indicate that an abdominal electrode records from a rather narrow area. In exploratory experiments an electrode moved only an inch would sometimes pick up quite a different rhythm, such as the small 7–8/min common in the intestine (Code, Wilkinson, & Sauer, 1954) instead of the 3/min which is common in the stomach.

Method

Accordingly, in Experiment IV, simultaneous electrical records were taken from three locations: upper left, halfway between navel and ribs; upper right, also halfway between navel and ribs; and lower, immediately below the navel. For most *S*s of this group the reference electrode was placed on the right calf rather than on the forearm, since it was noted that this disposition reduces the electrocardiogram recorded. The three recorders used were of the servo type which include photoelectric choppers and had a range of 0 to 1 mv. Each was equipped with the control and calibration circuits described by Davis et al. A filter condenser was added to the input of each to protect from stray 60-cycle voltage, which is disturbing to them. These instruments have the advantage of recording on rectangular coordinates. An improvement was likewise made in the balloon recording technique. (A balloon about 3 in. long was used.) A special manometer had its long arm made of half-inch copper tubing coated with paraffin on the inside, which prevented wetting and also served as a dielectric. The manometer fluid was weak saline. One side of an electric circuit was connected to the saline and the other to the outside of the copper tubing, and recording was accomplished on the basis of changes in capacity between the saline and the copper tubing as the fluid moves up and down. The capacity

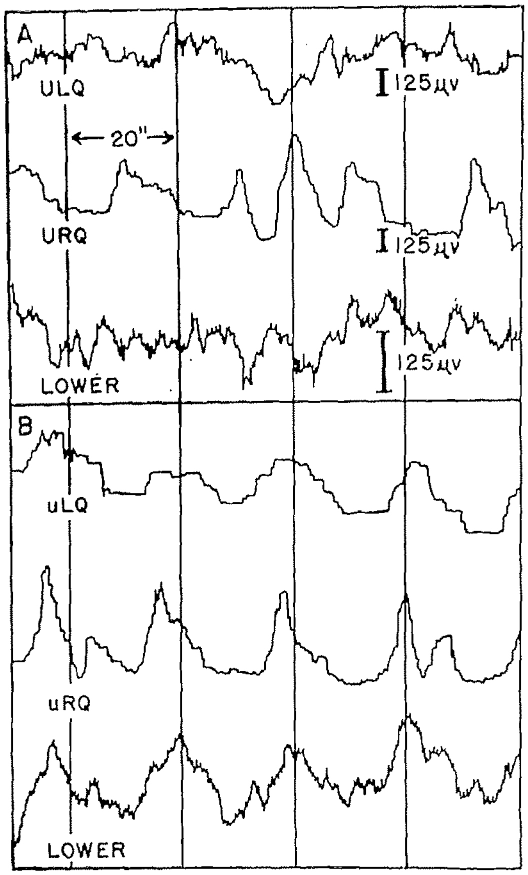

FIG. 5. Comparison of electrical records in three locations.

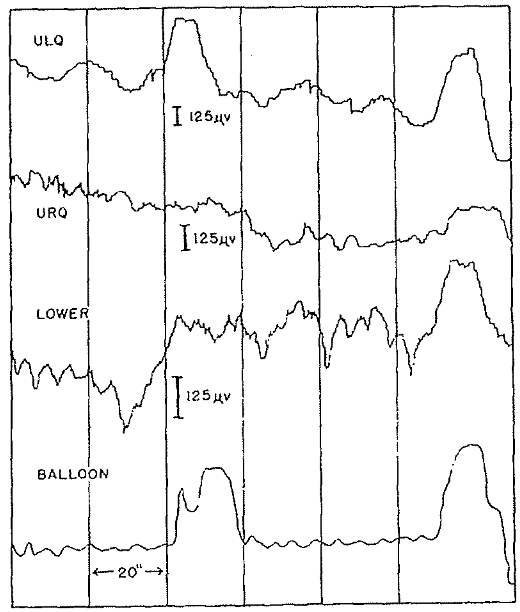

FIG. 6. Comparison of mechanical and electrical records of Cannon-Carlson contractions.

changes were detected by the sort of instrument described as a plethysmograph by Davis, Siddons, and Stout. The output of this was connected through a gain control to another servorecorder (0–50 mv. in range). This instrument is linear, and has extremely high sensitivity. By changing gain, and compensating for shifts in level of pressure, the operator is able to record much that would be lost with the traditional float and smoked-drum technique, and of course, can take a record of any desired length.

The *S*s were 13 volunteers who were at least 5 hr. without food. Half were run in the morning without breakfast. Electrical records were made for 10 min. of rest, then the balloon was swallowed and inflated to 100 mm. of water, and recording continued with all channels. After 20 min., a 1-min. burst of high-intensity noise was delivered, and recording continued at least 5 min. thereafter.

Two of the *S*s had swallowed balloons and other devices many times previously. In addition, four *S*s chosen because they would insert the balloon easily were given an additional series of four subsequent recording sessions.

Results

Electrical records from the three locations do have a different character as may be seen in Figure 5*A*, *B*. In 5*A* (no balloon) the record from the upper right quadrant shows a three-per-minute rhythm not evident in the other two records. This is interrupted at the third wave by a diphasic (or triphasic) transient (middle of figure), which is reflected in some degree in the other two records. Figure 5*B* shows the condition in the same *S* 10 min. after the insertion of a balloon. Here the 3/min rhythm appears in all three leads, though each has its peculiarities of wave form, phase, and amplitude. In other portions of the same record such a rhythm then appears in two leads only. It is evident that the three abdominal leads are not recording waves from the same source, but that the three sources may develop correlated activity for the three leads.

There are certain notable differences in the character of the electrical and balloon records. As may be seen in Figure 6, there may be relatively less representation of respiration in the electrical records than in the mechanical. Quite often it is not detectable in the electrical records. On the other hand the 3/min rhythm is much more prominent in the electrical records than in balloon records taken with our technique. As the Cannon-Carlson waves recorded from the balloon are of special interest, we examined a number in some detail. Figure 6, showing two successive waves, illustrates certain common features of the electrical-mechanical relationship. An electrical wave corresponding to the mechanical appears in one or more of the leads; this is often diphasic, positive (downward in the figure) followed by negative. The crest of the mechanical wave tends to be associated with the negative phase. For the larger (second) of the mechanical waves there is representation in all three leads. For the smaller, the typical wave is not apparent in the URQ lead. On the descending part of the mechanical wave, however, there is a fall in the URQ which may offset the continued high level in the lower lead. In other words the sum of the recorded voltages would give the best resemblance to the mechanical wave.

The interpretation seems to be that the electrodes record from a highly restricted area, whereas the balloon, at least one of the size we used, shows a kind of net effect over a large area. This difference may explain the more pronounced 3/min waves found in the electrical records. These waves, known to be propagated down the stomach walls, would likely be out of phase in different localities, and offset each other so far as the balloon is concerned.

On this view a Cannon-Carlson wave would be poorly represented in an electrical record if the area close to the electrode did not participate much in the contraction. In the data there are cases of mechanical waves whose electrical components are not obvious to inspection. On the other hand one would expect unsynchronized waves in different localities to be poorly represented in the mechanical record. The 3/min waves are instances of this sort. For such reasons we may find a good or poor momentary correspondence detween the two kinds of record, though a general agreement between them.

Medians for the amplitude measure of electrical activity are given in Table 3 for the 2½-min. period just before insertion of the balloon and for various similar periods while the balloon was in place. The data include first and last runs on the four *S*s with five trials each and two trials on each of the two *S*s with previous experience. All trials for each *S* were averaged to make one set of figures for each. In measuring records any waves which might be of respiratory origin were smoothed out before readings were taken. The trends are like those of Table 1. The increase immediately following the insertion of the balloon is significant for each of the locations by the sign test ($p < .05$). After the initial high level, the medians suggest that activity in all locations recedes to about the rest level, then rises again in the last 5 min., as it did in Experiment III. The decrease from the first to third reading in the balloon period is significant for each location (by two-tailed sign test, $p < .05$). The increase in the last 5 min. is not significant by the Wilcoxon test, but confirms the trend found in Experiment III. Further confirming the long-term effects is the experience of one volunteer who kept a balloon (inflated to something more than our usual pressure) in place overnight. He woke in the morning with such violent spasms that the balloon had to be removed before a recording could be made.

TABLE 3
Median Amplitude (μv.) Before and During Balloon Period

Position	Before Insertion	Minutes after Insertion			
	Last Period	0–2½	7½–10	15–17½	17½–20
ULQ	98	129	124	110	121
URQ	88	132	100	100	116
Lower	88	173	124	103	96

A special group of 5 *S*s, all experienced in balloon experiments, was used to test the effect of a balloon over moderately long periods. Records were made on these *S*s, who were at least 5 hr. without food, during a 20-min. rest period and during a 20-min. balloon period immediately following. The *S*s were then allowed a period of 30 to 40 min. of free activity with the balloon in place and inflated. (One *S*, however, remained on the bed and studied a book.) Then another 20-min.

TABLE 4
Medians for Combined Locations for Practiced Subjects (μv.)

Before Insertion	Minutes after Insertion			
Last Period	0–2½	7½–10	15–17½	17½–20
100	168	166	149	137

recording was made, the balloon removed, and a final 20-min. rest record obtained. Alternate half-minutes were measured for amplitude. For both locations (URQ and below the navel) the first and last rest periods are nearly identical with each other. The last balloon period is nearly identical with the first, differences being + 1 and − 7 μv., and both are, in both locations, substantially above the rest level. There is no evidence of general adaptation to the balloon over this period of time.

In Experiment IV as in Experiment II the noise stimulus frequently produced a very large slow wave with latency of about 10 sec. This was in no instance paralleled by a similar wave in the balloon record. Since the wave sometimes appears only on one electrode, it must however be abdominal, and not something occurring at the common reference electrode. The noise stimulus apparently increased the amount of activity in the same way as did the visual stimulus, but since analysis of the noise effect is being carried out on a more extensive set of data, it will not be discussed here.

Table 4 gives the results for the practiced *S*s. The increments during the balloon period are still present in all *S*s, the change in the median being greater than it is in Table 3. The four *S*s on whom comparable first records exist show a higher level of activity during the balloon period on the last trial than they did on their first. None showed less over-all effect of the balloon, and 11 showed more effect at the end of the period on the last trial than they did on the first. This increase of balloon effect, though not quite significant by the *t* test, argues against a general adaptation to the presence of the balloon. The medians do not show evidence of a minimum followed by a rise: the majority of the individual records do show a minimum before the end of the sitting, however.

DISCUSSION

On the matter of technique, the electrical record is evidently such that a stomach contraction, either a periodic wave or a Cannon-Carlson contraction, will be revealed by it. If an electrode is near the site of the activity, the relation will be a close one; if it is farther away, the reflection in the electrode will be rather slight. Electrodes such as we have used evidently show chiefly what is going on within a few centimeters of their location. A broader picture could presumably be obtained by connecting several abdominal electrodes into the same recording channel.

In a fasting state, voluntary or imposed, *S*s have a low level of activity as compared with those who have eaten a meal within the previous several hours. In both conditions a rest period of 25 min. lowers activity significantly. Eating a small amount of food increases the activity of the abdominal region very considerably over that of the fasting-resting state. The very low activity of the fasting-resting state casts doubt on the existence of the Cannon-Carlson contractions in a state of food deprivation. In a few *S*s there are conspicuous waves of the 3/min rhythm generally supposed to be smaller than the Cannon-Carlson contractions (Carlson). Were these latter actually present one would expect to see them.

An increase in activity can be produced by at least two conditions. An external stimulus such as a strong light will often produce an initial wave which is not correlated with gastric movement and heightens and shortens waves for some minutes thereafter. The relatively high activity at the beginning of a rest period can be explained as an example of this effect. The insertion of a balloon into the empty stomach also produces a notable increase in activity. There is evidence, not quite so conclusive, that the continued presence of the balloon in the stomach produces another increase of activity in the stomach, beginning about 15 min. after insertion. The effect of a balloon shows no signs of diminishing with long retention or practice. It seems reasonable that the stomach should respond thus to a balloon as it does to the swallowing of food and its presence in the stomach. Since the Cannon-Carlson account of hunger is based upon data recorded from balloons, it seems the authors may have been misled by artifacts of the method, as some have suspected.

With our *S*s we were quite unable to confirm the widely accepted correlation of Cannon-Carlson waves and reported "hunger pangs." Reports of these were very few, even in the presence of such contractions, and generally had little relation to them. Wolf & Wolff similarly found poor correspondence in their fistula case, and concluded that the waves are mistakenly called "hunger contractions."

SUMMARY

A series of experiments investigated the effects of food, rest, visual stimulation, and a gastric balloon on activity recorded from the abdomen by external electrodes and compared this electrical activity with that recorded from a gastric balloon.

The correspondence between the electrical and mechanical records is sometimes only general and sometimes quite exact. These recordings are evidently specific to locality.

Under resting conditions the recorded activity of the stomach, whether empty or not, declines but is at its lowest when the stomach is empty. The Cannon-Carlson "hunger contractions" are evidently rather rare in such conditions. Activity can be induced by a strong visual stimulus. Introducing a balloon into the stomach increases the electrical activity of the stomach. This increase, it is suspected, is a principal factor in producing the Cannon-Carlson waves.

In contrast to some previous results our *S*s were rarely successful in reporting these waves even when they were present.

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