

*Citation:*

F. Roels, On after -sounds, in:  
KNAW, Proceedings, 18 I, 1915, Amsterdam, 1915, pp. 811-819

photographic registering apparatus, which he very kindly placed at our disposition, and for which we gladly express our sincere thanks to him once more here.

*Anorg. Chem. Laboratory of the University.*

*Amsterdam, Oct. 28, 1915.*

**Physiology.** — “*On after-sounds.*” By Dr. F. ROELS. (Communicated by Prof. Dr. H. ZWAARDEMAKER).

(Communicated in the meeting of October 30, 1915).

In daily life after-sounds are rarely perceptible to the ear of normal man and even then they are vague and comparatively feeble after violent detonations. We, therefore, had to apply rather potent stimuli and to screen our subjects from all disturbances above all from the ordinary street-noises.

The GALTON- and EDELMANN-whistles gave most satisfaction. The subject was placed in the camera silentia of the Physiological Laboratory at Utrecht; the head was fixed, the right ear at 2 cm. distance and right in front of the embouchure of the whistle. At every time an airstream of equal force was urged through the whistle by the experimenter outside the camera. In the first experiments the whistle was put into operation inside the camera by the experimenter, who also recorded the phenomena perceived by the subject. Although we used our utmost endeavour to do this as noiselessly as possible, it was detrimental to the production as well as to the observation of the phenomena. We, therefore, resolved to separate the experimenter from the subject. They spoke to each other by telephone, which enabled the experimenter to perform the time-measurements by means of a chronometer. The subject used the telephone only for these measurements; for the description of the nature of the phenomena he relied entirely upon his memory after the experiment. This procedure was not open to objection as the phenomena never took more time than  $1\frac{1}{2}$  minute.

Before entering upon our experiment proper a series of respectively 100 and 50 preliminary tests were performed with our two subjects, Prof. Dr. A. MICHOTTE from Louvain and Dr. BAKKER from Batavia. The total number of the subsequent conclusive tests amounted for M to 143 and for B to 129.

They are distributed among the various stimuli as follows:

	M.	B.		M.	B.		M.	B.		M.	B.
$e_2$	7	6	$cis_3$	8	6	$e_4$	8	6	$f_5$	10	12
$f_2$	8	6				$f_4$	12	6	$a_5^2$	8	12
$g_2$	8	6	$a_3$	12	7	$a_4$	20	22	$e_6$	8	16
$a_2$	8	6	$c_4$	7	6	$d_5$	17	12	$c_7$	2	

The order of the stimuli varied regularly. As a rule stimuli of the same pitch acted on the subject in 2 or 3 consecutive tests. From 6 to 12 experiments were made in succession.

$e_2$ . B. The after-sound immediately following the stimulus is short (1 sec.), feeble, and indistinct. Sometimes a short and slight sensation of strain is perceived directly after or simultaneously with the after-sound. Most often the subject announces a period of absolute or relative silence (total absence or considerable decrease of intensity of the murmurs usually perceived during a stay of some length in the camera silenta). This interval generally links itself to the after-sound. In half the cases it continues from 10—16 sec. Little by little the normal noises return intensified.

M. Directly after the stimulus an after-sound, being a typical murmur with pitch ( $\pm f_{is 4}$ ). The pitch disappears after a rather short time; the murmur continues and while being broken from time to time by feeble boundary tones, pulsations and the like, passes into the normal noises after 15 to 27 sec.

$f_2$ . B. The after-sound follows the stimulus instantaneously; it is a short ( $\pm 1$  sec.), feeble, shrill sound. It is closely followed by a period of absolute or relative silence (1—13½ sec.), which is gradually filled by reinforced normal noises. During the interval of silence the subject is generally conscious of a slight sensation of strain. Occasionally the reinforced noises are interrupted by a musical sound, of a pitch lying between that of the stimulus and that of the succeeding after-sound.

M. In 5 out of 10 cases a typical murmur with pitch, is yielded directly after the stimulus. The intensity of tone rapidly diminishes, so that at last only the murmur remains. The tone heard in the murmur, is higher than  $f_{is}$ , and afterwards recurs once or twice. In the other cases a tone is heard directly after the stimulus which, while lowering rapidly, sinks into the afore-said typical murmur.

In its turn the latter gets lost again in the ordinary entotic noises.

$g_2$ . B. Very likely the after-sound comes close upon the stimulus. It is short ( $\pm 1\frac{1}{4}$  sec.) and very high. Less often than in the case of  $f_4$  it is followed directly by an interval of absolute or relative silence, as mostly a feeble musical tone is heard whose pitch lies between that of the after-sound and the stimulus and whose duration varies from 2— $3\frac{1}{2}$  sec.

Whenever the musical tone is not heard, the normal noises, which, while intensifying gradually, follow the after-sound directly or are heard after a space of absolute or relative silence, possess a certain pitch. Eventually the space of silence lasts 5—9,5 sec.

M. In three cases a tone is heard instantly after the whistle is blown. It is rather higher than  $f_{s_4}$ , gradually grows less intense, to be replaced after 4—7 seconds by a typical murmur. In the other cases the tone and the typical murmur occur simultaneously. Its pitch (invariably  $\pm f_{s_4}$ ) gets lost after 6—8 sec., when the pure murmur continues to flow (as is ever the case) into the normal noises; sometimes a strain is felt.

$a_2$ . B. The after-sound is short ( $\pm 1\frac{1}{3}$  sec.), feeble, and high-pitched. Only twice a vague sensation of strain is announced. Close upon the after-sound follows a "dark" space (period of absolute or relative silence of 10.5—11 sec.). At times it is succeeded by a feeble musical tone by the side of which the normal noises are generated and reinforced so as to supersede the tone, whose pitch lies between that of the after-sound and the stimulus. Every now and then a high bird's note interferes with these noises.

M. In every experiment the subject notices immediately after the stimulus a murmur, with markedly varying pitch and intensity, the former fluctuating between  $d_6$  and  $a_2$ . The pitch gradually disappears, so that only the typical murmur is left. Occasionally a great strain, which sometimes causes pain.

$c_{is_3}$  B. Short ( $\pm 1$  sec.) and feeble after-sound, followed in 5 out of 6 cases by a "dark" space, which lasts from 13 to 16 seconds. Little by little the normal noises recur with growing intensity.

M. Immediately after the stimulus in all cases a murmur, evidently of a definite pitch; it most often belongs to the 6<sup>th</sup> octave. The intensity of the tone decreases by degrees, so that at last only a typical murmur remains, in which, however, a pitch is still plainly discernible. At times the quality of this murmur is modified, both the intensity and the richness being diminished; the pitch also is gradually lowered.

$a_3$  B. The after-sound is short ( $\pm 1.1$  sec.), feeble and high. Some-

times it is followed by a feeble musical tone ( $3\frac{1}{2}$ —4 sec.). Then a period of absolute or relative silence sets in. In almost all cases this "dark" interval commences immediately when the after-sound has ceased; it takes  $19\frac{1}{2}$ — $20\frac{1}{2}$  sec. Then the normal noises recur, gradually intensified. Feeble bird's notes of distinctly varying pitch often mingle with the noises at more or less regular intervals. Sometimes a strongly marked sensation of strain occurs in the gap of absolute or comparative silence.

M. A murmur with pitch in almost all cases directly after the production of the stimulus. The pitch is about  $1\frac{1}{2}$  octave higher than  $fs_4$ . At times only a tone is heard, succeeded by a murmur after 14—17 sec.

The pitch of the tone is modified in a few cases: being rather low at first, it rises up to  $\pm d_6$ . The intensity of tone and murmur gradually lessens. The pulsations heard anterior to the production of the stimulus recur during the experiment with augmented intensity and with a decided pitch. Only once or twice the subject makes mention of a sensation of strain.

$c_4$  B. The after-sound is short ( $\pm 1,1$  sec.), feeble, and shrill. In 4 out of 6 cases it passes into a very feeble tone of different pitch (lower than the after-sound, higher than the stimulus), lasting from 4— $7\frac{1}{2}$  sec. A gap of absolute or relative silence immediately links itself to it. The gap covers 14 to 25 seconds, whereas only 13—15 seconds are taken by the "dark" interval that follows the after-sound. Ultimately the normal noises return gradually with augmented intensity, intermitted by several high and feeble musical tones. In one case only a slight sensation of strain.

M. Frequently, directly after the production of the stimulus a murmur with pitch ( $\pm c_6, d_6$ ; duration 24—31 sec.) In a few cases a pure tone is heard, which only somewhat later makes way for the typical murmur, which in its turn passes into the normal noises, broken now and again by pulsations and feeble cricket-chirps.

$e_4$  B. The duration of the after-sound, mostly forcible and very high, averages 2 sec. Directly after it a constantly feeble, musical tone with a pitch, intermediate between that of the after-sound and the stimulus. Sometimes the after-sound coalesces with the musical tone so gradually that it seems to sound musical at the outset. The tone continues from 1 to 18 seconds and is succeeded by a gap of absolute or relative silence lasting from 3 to 34 sec. Finally the normal noises slowly return with augmenting intensity. Only once a sensation of strain is recorded.

M. Almost always directly after the emission of the stimulus a

murmur with pitch ( $\pm c_5$ ). Both tone and murmur soon get weaker and weaker; when they have disappeared the normal noises are heard.

$f_4$  B. The after-sound is very forcible and high; its time averages  $1\frac{3}{4}$  sec. It always makes way for a musical sound of a pitch lying between that of after-sound and stimulus. Its intensity lessens gradually, so that finally (in 3 cases after 4, 7 and  $20\frac{1}{2}$  min.) an absolute or relative silence ensues. This interval lasts about 6 sec., after which not the normal noises are perceived, but again a musical sound whose length varies from 7 to 18 sec. and with which the gradually reinforced normal noises coalesce, while being interrupted every now and then by feeble bird's notes. Ultimately the musical tone flows together with the normal noises.

M. Only rarely does the subject observe a murmur with pitch directly after the emission of the stimulus. While maintaining its pitch ( $\pm c_5$ ) till the end it gets gradually fainter and finally makes way for the normal noises. Oftenest, however, the subject observes instantly after the stimulus a powerful, highpitched tone (6th Octave) of fairly long duration (7—9 sec.), fading away slowly. In the end the normal noises return.

$a_4$  B. The after-sound heard directly after the stimulus, is high and powerful; its duration averages  $\pm 1\frac{1}{4}$  sec. In well nigh all cases it is succeeded by a musical sound of a pitch lying between that of the after-sound and the stimulus and of a duration varying from 2 to 4 sec. This sound makes way for a period of absolute or relative silence, which is gradually filled by intensified normal noises.

M. In 17 out of 20 cases a tone is heard instantly after the stimulus is emitted. It gradually swells up to a maximum, reached after 2 or 3 seconds. Then the tone dies out very slowly. Its pitch is about that of the stimulus. Its length is considerable (21—63 sec.) When lasting very long there is sometimes a breach of continuity; it is plainly audible, though it is, of course, comparatively feeble. When discontinuous it sounds like a succession of pulsations of the same periodicity with those observed by the subject when not experimented upon. In the end there is a recurrence of the ordinary entotic noises.

In 3 cases the subject is for about 20—58 sec. conscious of a powerful, typical blowing noise immediately after the stimulus issues from the whistle. It is discontinuous at rather regular intervals and makes way for the normal noises, in which it may be distinguished a few times.

$d_5$  B. The after-sound is very high and powerful; its time averages

$\pm 1\frac{4}{8}$  sec. The subject often announces a regularly recurring intense strain, which vanishes by slow degrees. In 11 out of 12 cases the after-sound is succeeded by a pause of absolute or relative silence. In about half the cases it lasts 13—17 sec. when it is filled by the gradually intensifying murmur. In the remaining cases this pause is much shorter (8—10 sec.) and is filled not by the normal noises, but by a second after-sound, a continuous tone lasting  $\pm 7$ —10 sec. and fading before the gradually intensifying normal noises. In only one case does the second after-sound follow the first immediately. Its pitch is lower than that of the first.

M. Close upon the issue of the stimulus a rapid tone, gradually growing less intense, lying somewhere about  $a_4$ . In well-nigh every case it is succeeded by a vigorous blowing noise, which lasts from 65—93 sec; the maximum of intensity is reached after  $2\frac{1}{2}$ —3 sec.; then it fades away extremely slowly and regularly. Sometimes it recurs once or twice. In synchronism with this blowing noise pulsations are audible, weak as compared with the force of the blowing noise (pitch  $\pm a_4$ ).

$f_5$ . B. The average duration of the after-sound, appearing at the emission of the stimulus, is 2 sec. It is high (cricket-chirp), vigorous, often extremely so. It is constantly succeeded by a period of absolute or relative silence, (5—16 sec.); in this pause a strong sensation of strain is often perceived. In some cases a second after-sound is heard after the first, lower but of longer duration (3—7 sec.). In the majority of cases the pause is filled by gradually intensifying normal noises broken by a few bird's notes.

M. In some cases directly after the emission of the stimulus a high-pitched tone, followed immediately by a typical, continuous blowing noise (duration 69—87 sec.). Mostly this noise is heard close upon the stimulus. It is very powerful, sometimes with pitch especially at the beginning. At times it is interrupted by the ordinary pulsations. Finally the normal murmur returns.

$a_5$ . B. The after-sound is comparatively long ( $\pm 3$  sec.), powerful and high-pitched (cricket-chirp) and seems to follow the stimulus immediately. In most cases it is succeeded by a period of absolute or relative silence (3—12 $\frac{1}{2}$  sec.). In one third of the cases, however, the normal noises recur, either to continue with growing intensity, or to make way for a second after-sound, most often a musical sound lower and feebler than the first.

This after-sound covers about 4—13 sec. Ultimately it is also replaced by the gradually intensifying normal noises.

M. Only in one of the 10 cases does the subject announce a short

## Subject B.

	Duration of the first after-sound	Intensity of the first after-sound	Sensation of strain	Period of absolute or relative silence	2 <sup>nd</sup> after-sound	Blowing noise.
$e_2$ (6)	1	feeble	rarely, short and slight	10—16 after 1 <sup>st</sup> after-sound		
$f_2$ (6)	1	feeble	most often, not very great	6—13.5 after 1 <sup>st</sup> after-sound		
$g_2$ (6)	1.25	feeble		5—9.5 after 1 <sup>st</sup> after-sound	2—3.5 mostly after 1 <sup>st</sup> after-sound	
$a_2$ (6)	1.3	feeble	rarely, slight	10.5—11 after 1 <sup>st</sup> after-sound	Short, after the period of silence	
$as_3$ (6)	1	feeble		13—16 after 1 <sup>st</sup> after-sound		
$a_3$ (7)	1.1	feeble	distinct, rather slight	19.5—20.5 In 6 cases after the 1 <sup>st</sup> after-sound. In one case after the musical tone following the after-sound.	3.5—4 occasionally, feeble, directly after the first after-sound	
$c_4$ (6)	1.1	feeble	rarely, rather slight	13—15 In 4 cases after the musical tone. 14—25 In 2 cases after the 1 <sup>st</sup> after-sound	4—7.5 In 4 cases directly after the 1 <sup>st</sup> after-sound	
$e_4$ (6)	2	mostly intense	rarely	3—34 after the musical tone following the after-sound	1—18 always after the 1 <sup>st</sup> after-sound	
$f_4$ (6)	1.75	intense	most often, sometimes very intense	6 after the musical tone	4—20.5 always after the 1 <sup>st</sup> after-sound	
$a_4$ (22)	1.25	intense	sometimes	6 almost always after the musical tone	18 always after the 1 <sup>st</sup> after-sound	
$d_5$ (12)	1.8	intense	regularly	almost always after the 1 <sup>st</sup> after-sound; in 6 cases: 8—10; in 5 cases: 5—16	7—10 in five cases after the period of silence	
$f_5$ (12)	2	often very intense	regularly, often very great	after the 1 <sup>st</sup> after-sound	3—7 in 3 cases after the period of silence	
$a_5$ (12)	3	intense	rarely, slight	3—12.5 mostly after 1 <sup>st</sup> after-sound	4—13 in 2 cases after the period of silence	
$e_6$ (16)	2.6	intense	none	2—10 after the first hiss		3—7 During or after the 1 <sup>st</sup> after-sound 15—40 Intermittent blow. sound.



## Subject M.

	1st After-sound	Pitch of the after-sound	Duration of the after-sound (sec.)
$e_2$ (7)	In 6 cases murmur with pitch In 1 case: tone	slightly lower than $fs_4$	tone: 2 murmur: 15-21
$f_2$ (8)	In 5 cases murmur with pitch In 3 cases: tone	slightly higher than $fs_4$	
$g_2$ (8)	In 2 cases murmur with pitch In 6 cases: tone	slightly higher than $fs_4$	tone: 4-7 (6-8) murmur: 17-26
$a_2$ (8)	Murmur with pitch	between $d_6$ and $fs_4$	
$cis_3$ (8)	" " "	between $d_6$ and $fs_4$	
$a_3$ (12)	In 11 cases murmur with pitch In 1 case: tone	$\pm 1\frac{1}{2}$ octave higher than $fs_4$	tone: 14-17
$c_4$ (7)	In 4 cases murmur with pitch In 3 cases: tone	$\pm c_5, d_5$	tone: 24-31
$e_4$ (8)	In 6 cases murmur with pitch In 2 cases: tone	higher than $c_5$	
$f_4$ (12)	Nearly always tone	$\pm$ 6th octave	tone: 7-9
$a_4$ (20)	In 17 cases: tone In 3 cases: blowing sound	mostly $\pm c_5$	tone: 21-63 (not continuous)
$d_5$ (17)	Nearly always blowing sound		Blowing sound: 65-93
$f_5$ (10)	" " " "		" " : 69-87
$a_5$ (8)	Always " "		" " : 46-71 (not continuous)
$e_6$ (8)	" " "	higher than $c_5$	Blowing sound: 13-35
$c_7$ (2)	Typical murmur No blowing sound		

tone directly after the stimulus. In the other cases a vigorous blowing noise is observed, sometimes (especially at the commencement) of a certain pitch (a boundary tone). Mostly the blowing noise continues very vigorously, but not unintermittently, as in 5 of the 10 experiments it ceases altogether only after 46-71 sec. In three experiments the noise disappears after 15 or 15,5 sec. In its final stage other phenomena are also discernible, such as pulsations etc.

$e_6$ . B. Immediately after the stimulus the after-sound, which is powerful and high-pitched (cricket-chirp) (duration  $2\frac{3}{5}$  sec.).—

A highly, powerful blowing noise in conjunction with the after-sound and continuing when this has ceased. With one exception (15.5 sec.) it continues for 3—7 sec., to be succeeded by a gap of absolute or relative silence (2—10 sec.). Subsequently a second discontinuous blowing noise is distinguished, slightly differing in character from the first. The intervals are characterized by a slowly increasing murmur. The second blowing noise disappears entirely only after 15—40 sec. In the end the normal noises return while intensifying gradually.

M. Immediately when the stimulus is emitted a blowing noise is plainly audible, which especially in its initial phase, assumes a certain pitch (higher than  $c_5$ ). The intensity of the noise lessens rapidly; after 2 or 3 sec. the subject has to concentrate his attention considerably to follow it; in 7 cases it is inaudible after 13—15 sec. Sometimes it is not continuous; the moment of its first disappearance occurs after 4—23 sec. Usually it is superseded by the normal noises.

$c_7$ . M. Directly after the stimulus a typical murmur, heard also before the experiment but less vigorously.

In the foregoing tables we give the principal data regarding the character and the duration of the phenomena as apprehended by our subjects when acted upon by the stimuli applied.

### CONCLUSIONS.

1. Invariably a constant after-sound, differing individually has been observed close upon the stimulus. With the lower stimuli it consists chiefly in a murmur of a certain pitch, while the latter prevails before the discant. At one stage after the discant the after-sound changes into a typical blowing noise.

The most forcible after-sound is yielded by the high discant. Its duration varies from 2 to 30 sec. As for the pitch of the after-sound, it is constantly higher than that of the stimulus. The lowest stimuli as a rule yield the lowest after-sound; the highest are produced by the highest stimuli.

2. An interval of 2—30 sec. is most often filled by a second after-sound, lower than the first, mostly of longer duration and much less distinguishable from the normal entotic noises.