

THE PERFORMANCE OF GOATS IN TRIPLE CHOICE DELAYED RESPONSE TASKS

Stefan SOŁTYSIK and Basil A. BALDWIN

Institute of Psychoneurology, Pruszków, Poland
and

A. R. C. Institute of Animal Physiology, Babraham, Cambridge, England

Abstract. Goats have been successfully trained in types of triple choice delayed response situations. Their levels of performance indicated that they are able to solve delayed response tasks very successfully and can make correct choices in a post-delay response reward design after delays of 30 min, which is considerably longer than has been previously reported for dogs and cats. Goats do not readily approach and investigate novel stimuli and require a complex compound stimulus in the delayed response situation. They have been shown to be very useful experimental animals in the study of the mechanisms involved in recent memory.

INTRODUCTION

Goats have been used as experimental animals in a wide variety of behavioural and physiological studies. They are tame and patient creatures and make excellent subjects for studies requiring prolonged observations on individual animals. Goats possess a peculiar arrangement of their cephalic arterial system in which the entire brain anterior to the medullary region is supplied exclusively by blood from the common carotid arteries (Andersson and Jewell 1956, Baldwin 1965). This arrangement makes them particularly suitable for studies on cerebral ischaemia and it has proved possible to make a chronic preparation in which cerebral ischaemia, severe enough to render the EEG isoelectric, can be conveniently produced (Baldwin 1965, Baldwin and Sołtysik 1966). Goats have also proved very useful animals in experiments in which it is necessary to inject drugs (Baldwin and Sołtysik 1966, Baldwin et al. 1967) or electrolytes (Baldwin et al. 1967) directly into the common carotid arteries which are exteriorized as "carotid loops".

In addition to the above experiments they have proved to be good experimental animals in both classical (Liddel et al. 1934, Baldwin and Soltysik 1966) and operant (Baldwin et al. 1967) conditioning techniques. To this, certainly incomplete, list of the behavioural capabilities of goats under laboratory conditions, we should like to add another one: their ability to learn to solve "delayed response" tasks which are considered by Konorski (1967) to be a good test of recent memory.

In recent studies (Baldwin and Soltysik 1969*ab*) we considered the effects of a short period of electrical silence in the brain during the delay period in delayed response tasks. In this paper we shall describe in detail the procedures used to train goats in delayed response tasks and emphasize their peculiarities of behaviour in these situations compared with carnivores such as dogs and cats. We shall also provide evidence of the excellent performance of goats in these situations.

MATERIALS AND METHODS

Animals

The pilot experiments were conducted on Polish goats at the Institute of Psychoneurology, Pruszków, Poland, while the systematic observations were carried out in the A. R. C. Institute of Animal Physiology, Babraham, Cambridge, England on English Saanan or Welsh goats. Both females and castrated males were used. All of the goats used for the systematic observations were born on the Institute's farm and from their first hours of life were used to being handled by the animal attendants and were reared on artificial milk substitutes. This procedure ensured that the goats grew up well habituated if not actually "imprinted" to human beings. This procedure greatly facilitates the taming of adult animals even if they have subsequently been living outside on pasture. The animals used in this study were aged 1-3 years.

Living conditions and feeding

The goats lived in an animal house in individual pens. It is essential to keep goats separated once they have been implanted with cerebral electrodes as they tend to try to butt each other or alternately to lick and to chew the implants. The goats were fed with hay and standard high protein goat nuts. When the animals were not being tested the nuts were given once each day while during the delayed response training the nuts were only available as a reward for correct performance. Water

was always available ad libitum and mineral supplements were given to prevent deficiencies developing in animals always housed indoors. Goats are very social animals and it is essential in behavioural work if they are not to be upset that they are able to see and hear other goats when housed inside.

Delayed response training situation

The goats were trained in a laboratory situated about 50 m away from the goat house. The laboratory consisted of a wooden hut with an earth floor which was connected by a short corridor to a mobile recording laboratory in which an EEG machine and other instruments were placed (Fig. 1). The goats were brought from the animal house and entered the connecting corridor via a side door and were then restrained by means of a head harness between the two posts. In this situation the goat faced the interior of the delayed response (DR) room. While remaining in the corridor the goat could be connected to the recording apparatus in the mobile laboratory. The door between the DR room and the corridor could be closed by means of a thick canvas curtain and it was standard practice that, during the "delay" period, the goat was moved to the one corner of the corridor near to the mobile laboratory (Fig. 1, position 2) while the canvas curtain was kept drawn across the entrance to the DR room. Inside the DR room three remotely operated feeders were situated as shown in Fig. 1 near each of the three walls so that a triple-choice delayed response situation was created (see Fig. 1). Animals, when released from the leash, could step into the DR room and approach either the left, the right, or the middle feeder and in each case the distance from the door to the feeder was the same, namely 4.5 m. It was decided that a completed approach reaction had occurred if a goat went within 0.5 m of a feeder. Behind each feeder a set of visual and auditory stimuli (Fig. 2) was arranged and the whole stimulus complex could be operated by the experimenter from the connecting corridor.

Training and testing procedures

The delayed response procedure implies three consecutive phases within each trial: a stimulus display — a delay period — and finally a response in a choice situation in which the correct choice depends upon information supplied during the stimulus display. We shall describe our training situation in the same order beginning with the stimuli and ending with the response.

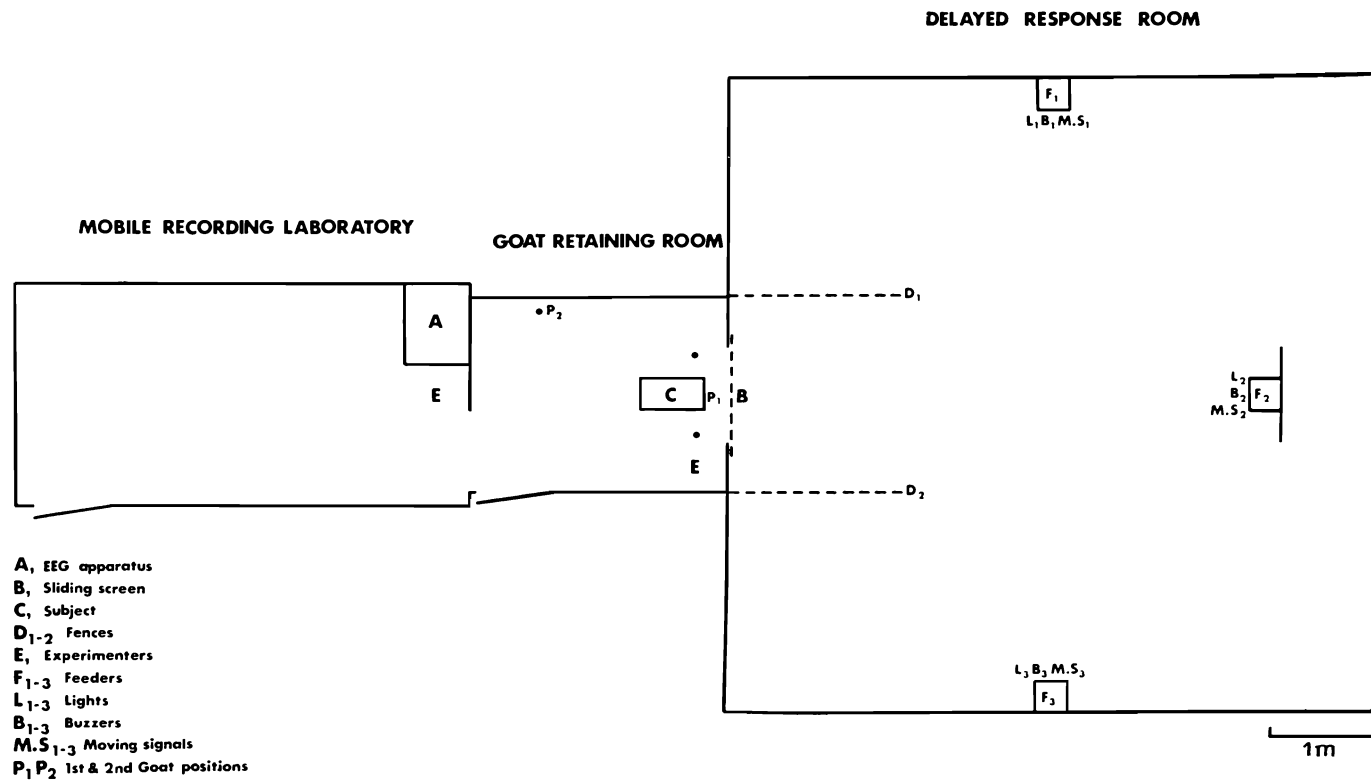


Fig. 1. The layout of the delayed response laboratory. (From Baldwin and Soltysik 1969b.)

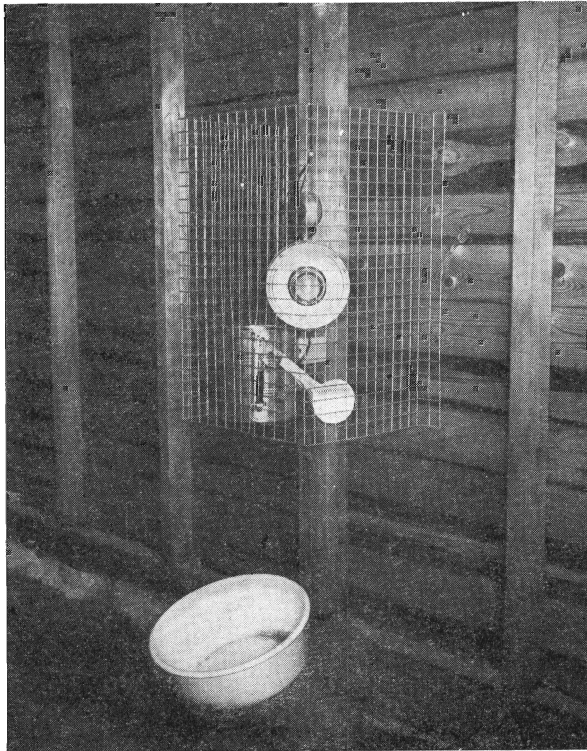


Fig. 2. The apparatus used to deliver food and present the compound stimulus. The buzzer is at the top, above the flashing light. The moving signal arm is in front of the food dispenser. The wire screen was used to prevent the apparatus being damaged by the goats.

Stimuli

At the beginning of the experiments on goats, only a flashing light bulb and a buzzer were installed because such stimuli are satisfactory for dogs and cats and never fail to elicit an orientating response. However, it soon became apparent that much stronger stimuli were necessary for goats and the following additional devices were used (Fig. 2).

1. A signal arm, of the type at one time used on British cars to signal changes in direction, which moved up and down in synchrony with the flashes of light and the noise from the buzzer.

2. The white plastic feeding bowl (Fig. 2) connected to a fine nylon fishing line which led across the ceiling of the DR room to a control panel in the corridor. This arrangement enabled the experimenter to move the feeding bowls by pulling on the end of the line. This procedure

presented the goat with a relatively large white moving object directly associated with the food reward.

3. During the training of the goats it was found a useful procedure to deliver remotely some goat nuts or some inedible object such as a metal chain into the bowl during the stimulus display; this could be regarded as a complex visuo-auditory stimulus which was also directly associated with the food reward.

4. Another procedure which proved very effective in the early stages of training was for an experimenter to enter the DR room during the stimulus display and approach by the shortest route the selected feeder and if necessary touch and shake the bowl to rattle the previously delivered nuts. At the end of this procedure the experimenter could return to the goat retaining room again by the shortest route.

In procedures 3 and 4 it was necessary to reload the feeder magazine with goat nuts during the delay period and after doing so the experimenter would also approach the other feeders in order to avoid leaving any olfactory cues for the goats to follow. During the experiments we never observed any of the goats behaving as though they were using their sense of smell to ascertain which feeder to go to. However, as wild goats are known to have a keen sense of smell these precautions seemed to be justified.

5. The most elaborate stimulus complex was created by releasing the goat at the end of the display of stimuli listed under 1, 2, 3 and 4 and letting it approach the feeder. Once the animal had approached the feeder several types of procedure were possible and are listed below.

a) The goat was immediately led back to the goat retaining room and the delay period began.

b) The goat was allowed to investigate the inedible objects such as metal chains which fell from the feeder into the bowl.

c) If the feeder dropped nuts into the bowl the animal would be allowed to commence eating them but the feeding was interrupted before the goat had eaten all the nuts.

d) The animal might be allowed to eat all the nuts and only then be led back to the goat retaining room.

e) The approaches to the feeder and feeding might be repeated twice or more.

All these variations of the delayed response could be classified according to the presence or absence of the approaching response and a reward during the display phase. The classifications are listed below.

1. A post-delay response and reward design. In this situation only teloreceptive directional stimuli, however complex, were presented during the display period and the goat was not allowed to approach the

feeder to obtain reward prior to the end of the delay period. All the various procedures listed under 1, 2, 3 and 4 belong to this category of teloreceptive directional stimuli.

II. A pre-delay response design. This covers the procedures listed under 5a and 5b.

III. A pre-delay response reward design. This covers the procedures listed under 5c and 5d. When the approach to the feeder and reward is repeated we refer to it as the double pre-delay response reward design.

A delay period

When the canvas screen covered the door to the DR room the delay period began, and its duration could vary from a few seconds to many hours.

The duration is not the only important aspect of the delay period. Equally important is what the animal is doing during the delay period. In contrast with many studies on delayed responses such as those of Ławicka et al. (1966) using dogs, our goats were never allowed to look into the DR room during the delay. This restriction was imposed not only to prevent the animals remembering by adopting a particular posture directed towards the signalled feeder, but also for practical reason connected with the nature of our subsequent experiments. In most experiments concerned with the physiological mechanisms of memory some kind of interfering procedure has to be applied during the delay period and thus continuous observation of the DR room is not possible.

Post-delay behaviour

At the end of the delay period the goat was again restrained facing the door of the DR room (Fig. 1, P_1), the canvas screen was drawn aside and the animal released after a few seconds. As the goat entered the DR room, for the first 2 m it had to go straight forward between the two fences D_1 and D_2 in Fig. 1. This was necessary during training to prevent animals tending to run to the first feeder they noticed after the canvas screen was drawn back, to ensure that the animal had time to make a choice the goat was not released from the restraining leash for a few seconds after the screen was withdrawn; in this way the goats had a chance to look around the DR room before entering it.

Despite the above precautions, some of the goats during their training still had a tendency to rush "blindly" into the DR room and to prevent this several wooden rods were placed transversely between the two fences about 20–30 cm above the ground. This practice ensured that the goats had to step carefully over the rods and when they had ceased to

try to rush into the room the rods could be dispensed with. It was apparent that goats which entered the DR room slowly, sometimes even stopping and hesitating before making their choice, made fewer errors than goats which went quickly towards the feeders. After several weeks experience in the DR situation it was typical for the goats to enter the DR room slowly and quietly to walk to the feeder of their choice; if for any reason they were unable to make a choice, they would often stop at the end of the fences and refuse to enter the DR room rather than make a chance response. Sometimes a goat would develop a preference, either positive or negative, towards one of the feeders but this could usually be eliminated by corrective training procedures.

RESULTS

At the start of their training the animals were brought to the DR room and allowed to explore it thoroughly. Goats are cautious animals and will not enter a room which is strange to them without some hesitation. When the goats were used to the DR room they were fed from each of the plastic feeding bowls (Fig. 2). Initially, goat nuts were thrown into the bowls but later they were delivered from the dispensing mechanism. The goats soon learned to run over to the appropriate feeder as soon as the nuts were dispensed and at this stage the compound stimulus was introduced and operated for several seconds before releasing the nuts. When the goats tended to approach the feeder during the compound signals in anticipation of the delivery of the nuts, the animals were restrained at the entrance to the DR room while the signals were presented. Training then proceeded in the double pre-delay response reward design.

During the training period several peculiar features were noticed about the way in which the goats reacted to the compound stimulus. It was apparent that they had very little tendency to approach and investigate novel stimuli but instead tended to react apprehensively. Later in the training of the animals it was found that the "targetting response" (Konorski 1968) to the compound stimuli was sometimes almost absent and often the experimenter would not know whether the goat had paid attention to the stimuli until it had been released and had made a correct choice.

The results presented are intended to illustrate the level of performance which can be obtained using highly trained goats in various types of delayed response tests. It should be emphasized that the results do not necessarily reveal the limits that these animals could achieve in such situations. The details of the particular procedures used in the tests

described are outlined below together with the results obtained. The goats were trained firstly in the double pre-delay response reward design, then in the pre-delay response design and finally in the post-delay response reward design.

1. Double pre-delay response reward design

The results obtained from five goats using delay periods of 10 min, 1 hr and 24 hr are presented in Table I. The results were tested for statistical significance using the Binomial test.

TABLE I
Double pre-delay response reward design

Goat number	Correct responses		
	Total trials		
	10 min delay	1 hr delay	24 hr delay
28	$\frac{11}{12} p < 0.0001$	$\frac{10}{15} p < 0.01$	$\frac{5}{15} p < 0.59$
29	$\frac{12}{12} p < 0.0001$	$\frac{10}{15} p < 0.01$	$\frac{11}{15} p < 0.01$
31	$\frac{11}{12} p < 0.0001$	$\frac{9}{15} p < 0.05$	$\frac{7}{15} p < 0.20$
34	$\frac{10}{12} p < 0.001$	$\frac{11}{15} p < 0.01$	$\frac{9}{15} p < 0.05$
36	$\frac{12}{12} p < 0.0001$	$\frac{7}{15} p < 0.20$	$\frac{6}{15} p < 0.37$
Total scores for all goats	$\frac{54}{60}$	$\frac{47}{75}$	$\frac{38}{75}$

10 min delay period. The 10 min delay tests were carried out as follows. The goat was restrained at the entrance to the delayed response room at position 1 (Fig. 1) and the canvas screen which prevented the goat looking into the DR room was drawn back. The first part of the compound stimulus, presented from one of the feeders, consisted of moving the feeding bowl slowly up and down by means of the nylon line. When the goat was looking at the feeder the buzzer, the flashing light and the moving signal arm presented the remainder of the compound stimulus for 8 to 10 sec. The choice of which feeder to use was decided in a random fashion but with the provision that all three feeders were

used an equal number of times during the series of trials and that one of the feeders was used twice in succession during the series in order to obviate the remote possibility that the goats might learn never to approach the same feeder on successive trials. A few seconds after the end of the compound stimulus the goat was released and if it went within 50 cm of the correct feeder, without first going to one of the other feeders, it was rewarded with goat nuts delivered remotely by the experimenter. If the goat went first to one of the other feeders no reward was given. When the goat had returned from the feeder it was restrained in position 2 (Fig. 1) and the canvas screen drawn to prevent it looking into the DR room. One of the experimenters then entered the DR room and refilled the food dispenser taking care to avoid leaving olfactory cues by visiting all the feeders, a procedure which took 30–45 sec. When the experimenter returned after filling the food dispenser the canvas screen was drawn back and the goat released without a signal being given. If it went to the correct feeder it was rewarded with a delivery of nuts into the bowl and after eating them it returned and was restrained in position 2 and the canvas screen drawn across the entrance to the DR room. The 10 min delay period then began. At the end of the 10 min delay period, during which the goat did not maintain any particular posture, it was moved to position 1 (Fig. 1), the canvas screen was drawn back and the goat released to make its choice. The feeder had been refilled during the 10 min delay period taking care as before to avoid olfactory or auditory cues. If the goat went straight to the correct feeder it was rewarded with nuts.

As can be seen from Table I all the goats performed very well in this situation.

1 hr delay. In these tests the stimuli and first part of the trials were as described above, the essential difference being that the goats after spending 2 min in position 2 were returned to their pens for the 1 hr delay period before being allowed to choose which feeder to approach. Two tests were given each day, one in the early morning and the other in the late afternoon.

As can be seen from Table I all the five goats were able to perform the delayed response task but their scores were relatively lower than their performance after only 10 min delay.

24 hr delay. The tests were run as follows: on the first day the stimulus was given and the goat made its two initial responses and was then restrained in position 2 (Fig. 1) for 2 min after which it returned to its pen for 24 hr. On the second day the goat was tested for retention of the response. On the third day the next stimulus was given and the two initial responses occurred and so on.

The result obtained are shown in Table I from which it can be seen that two of the goats performed significantly above the chance level ($p < 0.01$ and $p < 0.05$) with this delay period. It is obvious also that all the goats tended to score above one-third success level which would be expected on purely random choices.

2. Pre-delay response design

10 min delay period. The goat was initially restrained in position 1 (Fig. 1) and the same compound stimulus as before was given. A few seconds after the end of the stimulus the goat was released and if it went directly to the signalled feeder a "reward", in the form of a short metal chain, was delivered into the feeding bowl. The goat then returned to the starting place and was restrained in position 2 for the 10 min delay period before being released from position 1. During the delay period one of the experimenters filled the feeder with nuts, taking care to avoid olfactory cues. Two trials were given each day, one in the morning and the other in the afternoon.

TABLE II
Pre-delay response design

Goat number	Correct responses	
	Total trials	
	10 min delay	1 hr delay
28	$\frac{11}{12} p < 0.0001$	$\frac{5}{15} p < 0.5$
29	$\frac{11}{12} p < 0.0001$	$\frac{7}{15} p < 0.20$
31	$\frac{11}{12} p < 0.001$	$\frac{6}{15} p < 0.4$
34	$\frac{9}{12} p < 0.01$	$\frac{7}{15} p < 0.20$
36		$\frac{8}{15} p < 0.08$
Total score for all goats	$\frac{42}{48}$	$\frac{33}{75}$

The results obtained are displayed in Table II and it can be seen that all four of the goats performed the task successfully.

1 hr delay period. After the initial response, the goat was restrained for 2 min in position 2 and was then returned to its pen for the rest of

the 1 hr delay period before being released from position 1. Two trials were carried out each day one in the early morning and the other in the late afternoon.

The results are shown in Table II and it can be seen that none of the five goats tested performed at a statistically significant level, although as is apparent from the total scores they performed well above the one-third level expected from pure chance.

3. Post-delay response reward design

10 min delay period. The goat was restrained in position 1 and the compound stimulus presented for about 10–15 sec, the goat was then restrained in position 2 for the 10 min delay period. At the end of the delay the goat was released from position 1.

TABLE III
Post-delay response reward design

Goat number	Correct responses	
	Total trials	
	10 min delay	30 min delay
28	$\frac{13}{15} p < 0.0001$	$\frac{22}{30} p < 0.0001$
30	$\frac{14}{15} p < 0.0001$	$\frac{21}{30} p < 0.0001$
34	$\frac{13}{15} p < 0.0001$	$\frac{26}{30} p < 0.0001$
Total score for all goats	$\frac{40}{45}$	$\frac{69}{90}$

The results obtained from three goats are illustrated in Table III and it can be seen that all the goats performed very successfully.

30 min delay period. In these tests which were carried out as described above except that the delay period was 30 min. The results are shown in Table III and it can be seen that the three goats were very successful in these tests.

DISCUSSION

The delayed response problem, which was introduced by Hunter (1913) over 50 years ago, continues to be an extremely valuable technique in a wide range of behavioural and neurophysiological experiments. With various procedural modifications, delayed response tests have been used

with many animal species including rats (Cowles 1940), cats and dogs (Ławicka 1959) and monkeys (Jacobson 1936).

The results obtained in our experiments, using goats, clearly indicate that these animals perform very successfully in delayed response problems. They also showed that it was not necessary for the goats to be able to look into the DR room during the delay and that they did not preserve any postural orientation during the delay. Successful performance in delayed response situations by preserving particular body orientations has been termed "pseudo-delayed response" by Ławicka (1959). The results obtained in the post-delay response reward design are of particular interest as successful performance with delay periods of 30 min does not appear to have been previously reported for dogs or cats. The maximum reported delay periods for dogs and cats in triple choice situations used by Ławicka (1959) are 12 to 18 min and 6 min respectively although it is obvious that the length of delay period which can be achieved is greatly influenced by the length of the training period. In our experiments the goats became very tame and relaxed and it was obvious that animals in this condition were more likely to display their true capabilities in the delayed response problem. The goats were not distracted by anxiety and the trials could almost be regarded as an elaborate method of providing the animals with a highly preferred food.

In a recent series of experiments (Baldwin and Soltysik 1969*ab*) we have examined the effects of producing a short period of electrical silence in the brain during the delay period in delayed response tests. It was found that this procedure did not impair the performance of the goats and we concluded that the memory trace was held in a chemical form rather than by means of reverberating neuronal circuits. In view of the impairments in delayed response performance which follows prefrontal ablations in monkeys (Jacobson 1936) and dogs and cats (Ławicka and Konorski 1959, 1961) it would seem worthwhile to examine the effects of similar lesions in goats. The relatively long delays after which goats are still able to make correct choices would also make them a very useful experimental animal for the study of interferences which might involve recovery periods lasting many minutes in the case of the post-delay response reward design or even hours in the case of the double pre-delay response reward design. In conclusion, the goat seems likely to be a useful experimental animal for those numerous types of behavioural experiments for which delayed response problems are the appropriate test.

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Stefan SOLTYSIK, Department of Physiology of the Nervous System, Institute of Psychoneurology, Partyzantów 65, Pruszków, Poland.

Basil A. BALDWIN, Agricultural Research Council, Institute of Animal Physiology, Babraham, Cambridge, England,