

Short communication

Sand rats see the light: Short photoperiod induces a depression-like response in a diurnal rodent

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Received 2 May 2006; received in revised form 1 June 2006; accepted 6 June 2006

Available online 10 July 2006

Abstract

The present study examined the effect of simulated change in day length on the behavior of a diurnal rodent, the fat sand rat (a species of gerbil). Animals were housed under a short photoperiod (5/19 light/dark cycle) for 3 weeks and compared with controls living under a 12/12 light/dark cycle. All sand rats then underwent the forced swim test for depression-like behavior, and the open-field test for overall activity. Sand rats exposed to the short photoperiod displayed a significantly earlier sinking in the swim test, but there was no difference between their open-field activity compared with controls. Taking these responses as indicative of depression-like behavior, we suggest that a short photoperiod may induce affective-like changes, and that the sand rat may thus offer an appropriate animal model to explore the effect of photoperiod on normal, and perhaps also abnormal, seasonal mood changes (e.g., SAD), which in humans is a prevalent disorder, with winter depression episodes and spring/summer remissions.

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Keywords: Animal model; Forced swim test; *Psammomys obesus*; Circadian rhythms; Photoperiod; Seasonal affective disorder (SAD)

The present study examines the possibility of using a diurnal rodent, the fat sand rat (*Psammomys obesus*), as an animal model for photoperiod-dependent affective-like changes. Numerous studies have dealt with seasonal acclimation in animals and the role of photoperiod in seasonal acclimation, focusing on physiological aspects. The length of the day, which is a reliable cue, allows animals to anticipate environmental changes and respond to them appropriately. Indeed, physiological parameters such as enzymatic activity, immune function, thermogenesis capacity, storage or mobilization of energy reserves and more, have to be adjusted well before the expected environmental changes actually take place. Furthermore, behavioral timing in feeding, reproduction, migration, etc., often precedes the external events [9]. Several studies have addressed seasonally induced changes in emotional and affective-like behavior in animals (for review see Ref. [28]). Indeed, past studies revealed that a short daylight induced anxiogenic and depressive effects in male but not in female hamsters [32]; that a long photoperiod regime may

produce an antidepressant effect in male rats [29]; that a single day of constant light can protect against the induction of behavioral despair in rats [40]. In the same vein, the present study is aimed at studying the effect of a shorter daylight period on sand rat behavior for its potential application to human affective disorder.

Emotional and affective seasonal changes are recognizable in humans. For example, seasonal affective disorder (SAD; [23,26]) is a depression-spectrum disorder with repeated winter episodes followed by spring/summer remissions, affecting 1–3% of adults in temperate climates, with higher prevalence in women and in areas with reduced light hours [22,23,26]. However, measuring emotional or mood changes in animals is challenging since these properties are not directly assessable. To date, the ‘Porsolt forced swim test’ (FST) is probably the most frequently used model to test for depression-like symptoms in rats and mice [32]. In this test, animals are forced to swim in a cylinder from which they cannot escape. After an initial period of vigorous activity, animals adopt an immobile posture, which is selectively sensitive to antidepressant treatments; immobility is consequently considered as a reflection of a state of depression [32]. Subsequent studies have found that behavior in the

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FST somewhat differs between rats and mice. Modifications to the FST are therefore required for different rodent species, although the test has still been demonstrated to be effective in other species/strains [33]. Here, we used the swim test to assess the effect of shorter daylight period on sand rat behavior, under the assumption that we would need to seek a behavior that might be indicative of affective-like changes in this species.

To assess the effect of shorter daylight period we used the diurnal fat sand rat (*P. obesus*)—a large burrow-dwelling gerbil (160 ± 30 g; 20 cm long + 20 cm tail) that inhabits wadi beds, saline and saline-marsh areas of loess plains in the deserts of North Africa, from Mauritania to Egypt, Sudan and Israel [25]. Sand rats are entirely diurnal, spending extended periods in foraging on and under shrubs in the high light levels of the deserts that they inhabit [12,16]. In addition, sand rats provide a practical modeling animal as they breed well in captivity and a familiar model animal in medical research [2,11,15,24].

Two groups ($n = 8$ each) of male adult (~ 1 year old) sand rats, born in the breeding colony of the *I. Meier Segals Garden for Zoological Research* at Tel-Aviv University, were kept in large cages (80 cm \times 80 cm \times 50 cm, four animals per cage). Each group was housed in a different temperature-controlled room (30 °C). The test group was housed under a 5 h light and 19 h dark cycle and the control group under a 12 h light/12 h dark cycle. This lighting regime was set according to their winter/summer activity in nature, where during winter they are active outside their burrows for about 5 h daily around mid-day, while during summer their activity starts at the early hours of the morning and ends at the late afternoon, with a pause during the mid-day hours of extreme desert heat [6,14]. The sand rats were provided with an ad lib supply of special low-energy pellets (product 19560 by Koplock, Israel), *Atriplex* branches and water, and remained in these conditions for 3 weeks prior to onset of our experiments. The 3-week period was chosen as it is sufficient for physiological acclimation [18] and synchronization of circadian rhythms [1].

After the 3-week acclimation to a short light period (test group) and standard light period (control group), the animals underwent the swim test over two consecutive days that comprised a training day and a testing day, according to the standard procedures for rats [32]. In both groups testing started at 9 a.m. (1 h after lights-on) and terminated after 3–4 h, within the light/activity phase of the two groups. Animals were tested in alternating order of the two groups, with each animal individually placed in the water by the experimenter and left there to swim for 150 s. If a sand rat became entirely immersed in water (above the tip of snout) for at least 5 s, the experimenter rescued it, dried its fur with cloth, and placed it back into the home cage. The swim test was performed in a white, opaque plastic cylinder, 30 cm in diameter and 45 cm high. The cylinder was filled with water (21–23 °C) to a depth of 25 cm, preventing the sand rats from touching the floor or escaping. A video camera (Panasonic M9000) was mounted above the cylinder, recording behavior onto time-coded (25 frames/s) VHS videotapes which were then used to score behaviors.

On the training (first) swim test-day, performances of sand rats held under either photoperiod were not significantly different. However, the effect of light conditions became apparent

during the subsequent test-day, when sand rats that were housed under the 5 h light/19 h dark regime reached the 5 s full immersion criterion for rescue significantly faster than control animals (Fig. 1a) and displayed a shorter latency to first full immersion in water compared with controls (Fig. 1b). The shorter latency reflects different behavior of the two groups in the forced swim test: sand rats held under the 12/12 h light cycle swam longer distances and from time to time ceased swimming. When they started sinking, they immediately bobbed-up and started swimming again. In contrast, the sand rats held under the 5/19 h light–dark cycle swam vigorously as soon as they were introduced into the water. When sinking they did not bob-up and had to be rescued (Fig. 1).

On the third test-day (after the 2 days of swim test), each sand rat underwent a 10-min open-field test in a 1 m \times 1 m arena with 40 cm high walls. The open field [13] is the most widely used test in animal psychology [37]. In this test, an animal (usually a rodent) is introduced into a plain and illuminated arena [8] and its behavior is commonly regarded as a fundamental index of general behavior [37]. A video camera (Ikegami B/W ICD-47E) was mounted above the arena, recording behavior into the *Ethovision* videotracking system (Noldus, The Netherlands) that provided a variety of behavioral measures including distance traveled, locomotion time, speed and the distribution of locomotion among the different areas of the arena. All animals were then returned to the breeding and exhibition colonies at the research zoo.

Results in the open-field test revealed no difference between the two photoperiod groups in terms of the distance traveled (in 10 min: 56.0 ± 5.1 and 55.7 ± 4.8 m, respectively; in 5 min: 32.7 ± 2.8 and 33.5 ± 3.5 m, respectively), or the time spent in the center area of the arena (in 10 min: 99.7 ± 30.4 and 90.0 ± 17.7 s, respectively; in 5 min: 35.8 ± 3.8 and 48.6 ± 8.7 s, respectively). Therefore, although the two groups substantially differed in the swim test, the lack of difference in the open-field activity suggests no effect of the reduced photoperiod on short-term (10 or 5 min) generalized activity, while the lack of difference in the time spent in the center area of the field suggests no effects on anxiety-like behaviors [7].

Altogether, the present data demonstrate that reduced light availability to a diurnal rodent, the sand rat, results in two behavioral changes in the FST: (1) shorter latency to the first event of sinking; (2) shorter time to reach a 5-s long full immersion (rescue criterion). These behavioral effects are probably specific and unrelated to a general hypoactivity or changes in anxiety levels, since the same individual sand rats were not affected in the amount or distribution of activity in a 10-min open-field session.

The measures used in the present study to evaluate behavioral change in the swim test differ from the standard measures in rats or mice, which are those of immobility time, and swimming or struggle time within a session [32]. However, the swim test has been previously modified for different species, and even in its standard form the initial application developed for rats had to be modified for mice [33], and scoring of different behaviors was demonstrated to be beneficial for screening the effects of different drugs [3]. Since the sand rats did not show floating behavior but switched from swimming to sinking, we scored this transition as a criterion of “despair”, equivalent to the immobil-

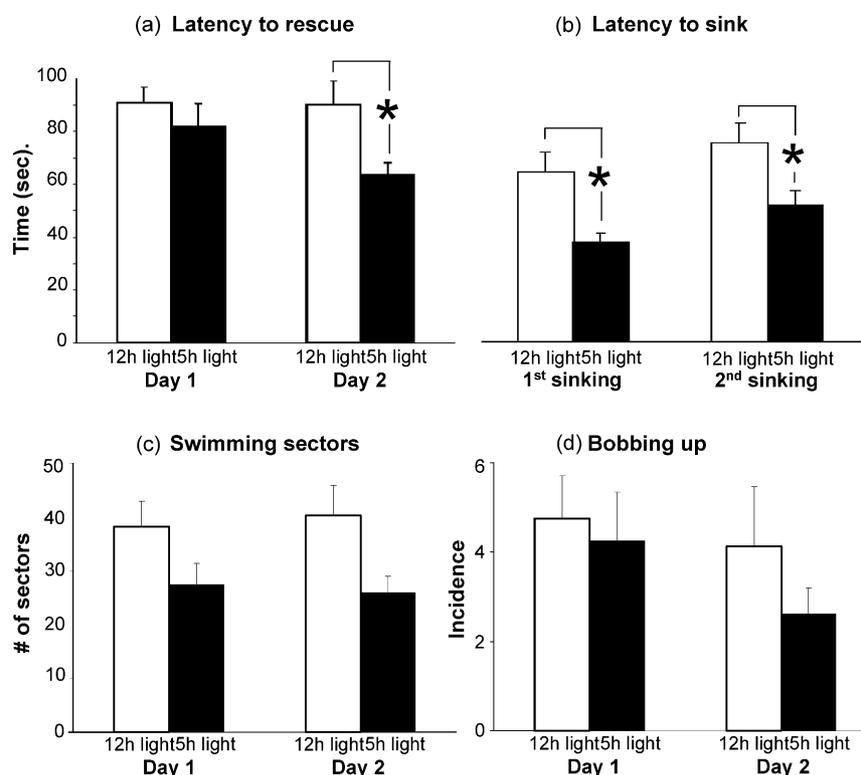


Fig. 1. Behavior during the FST for both training and testing days as scored during slow-motion playback of the video recordings. Controls are depicted by clear bars and test animals by dark bars. All values describe mean \pm S.E.M. (a) We measured the elapsed time (s) from the beginning of the test until each event in which the sand rat was entirely immersed in water. Timing and number of immersions were scored until the time when the sand rat did not raise its head above water for more than 5 s, and was rescued (test session terminated). A two-way ANOVA with repeated measure revealed a significant effect of the test-day ($F_1 = 8.87$, $p < 0.01$) but not of daylight condition alone ($F_1 = 3.79$, $p = 0.07$). The interaction of test-day \times daylight was significant ($F_{1,14} = 7.31$, $p = 0.017$). Post hoc Tukey HSD test revealed that the only significant difference ($p = 0.0003$) was in day 2 between test and control groups. (b) The elapsed time (s \pm S.E.M.) in day 2 to first and second sinking in sand rats kept under a short daylight period (dark bars) compared with controls that were kept under a long light period. These immersions were shorter than the 5-s rescue criterion, typically taking the form of a brief full immersion of the entire trunk and head with the water covering momentarily the tip of snout. The sand rats then bobbed-up to resume a vigorous swim. The duration to first and second sinking was significantly shorter under short daylight (two-tailed paired *Student t-test*; $t_{10} = 1.81$; $p = 0.007$ and $t_{12} = 1.78$; $p = 0.017$, respectively). (c) Swimming distance during the FST for both training and testing days as scored during slow-motion playback of the video recordings. We measured the number of sectors (1 sector = 1 quarter of the swimming apparatus) traversed by each sand rats. A two-way ANOVA with repeated measure revealed a significant effect of only the daylight condition ($F_1 = 9.6$, $p = 0.007$). The effect of test-day and the interaction of test-day \times daylight was not significant. Indeed, as shown in the figure, swimming distance was greater in both days 1 and 2 of the control compared with the test group. This may, however, reflect the shorter latency to sink in the test group. (d) Incidence of bobbing-up after sinking in the control and test sand rats. A two-way ANOVA with repeated measure revealed no significant effect of daylight condition, of test-day, or of the interaction of test-day \times daylight.

ity scored in laboratory rats, which unlike sand rats are good swimmers.

We suggest that the response of fat sand rats to a short photoperiod offers a plausible model of seasonal mood disorder. To date, the study of the pathophysiology underlying such disorders has been mostly linked with light therapy [29], circadian rhythms [4,20,39] and retinal mechanisms [38]. However, no consistent evidence supports the circadian hypothesis or reduced retinal light sensitivity [20], and other hypotheses have emphasized monoamine neurotransmitters [31] evolutionary and genetic factors [5,20]. A number of theories also attempt to explore the similarities and differences with major depression [21]. From a biological perspective, seasonal affective disorder (SAD) may also be viewed as an extreme form of seasonal acclimation, once biologically advantageous. The occurrence and severity of SAD tend to correlate positively with latitude [38], hence it is more salient in areas of the world where climate changes

are severe enough to cause annual variation in energy availability [5]. Indeed, the physiological hallmarks of SAD (reduced energy, hypersomnia, increased appetite, carbohydrate craving, and weight gain) are similar to seasonal acclimation in mammals from similar environments [17–19,34]. A random sample of New York City residents indicated seasonal changes in all the physiological hallmark (not including depression) symptoms of SAD (although less pronounced; [36]). It has thus been suggested that SAD-induced changes in humans evolved to enable seasonal energy savings, as in other mammals, with SAD being an exaggerated form of this strategy [30].

In all, the present hypothesis is that the sensitivity of the diurnal fat sand rat to a short photoperiod, as found here, may be based on a biobehavioral mechanism that could have a biologically adaptive value on the one hand, but may also account for the type of changes that are involved in seasonal affective disorders. It has not escaped our mind that in order to make

a causal link between the proposed plausible model and seasonal mood disorder, it is mandatory also to demonstrate a reversal of the behavioral response by means of an effective therapy: for example, bright-light therapy, which is utilized in SAD patients [10,21], or antidepressant treatment [27,35]. Application of these treatments to fat sand rats under a short photoperiod may corroborate the potential of the present finding in studying seasonally induced mood disorders.

Acknowledgements

We are grateful to Chen Shemesh and Pazit Zadicario for their help in testing and behavioral analysis, to Barak Levy and the zookeepers of the *I. Meier Segals Gardens for Zoological Research* in Tel-Aviv University for providing us with the sand rats, and to Naomi Paz for editing this manuscript. The study was carried out under the regulations and approval of TAU institutional committee for animal experimentation (permit # L-05-056). The study was supported by The Charles E. Smith National Institute for Psychobiology in Israel award to NKS.

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