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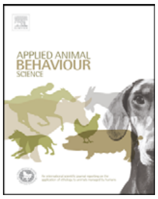

# Individual behavioural rhythmicity is linked to social motivation in Japanese quail

Laureline Formanek[a,*], Marie-Annick Richard-Yris[a], Cécile Arnould[b], Cécilia Houdelier[a], Sophie Lumineau[a]

[a] *UMR 6552, Ethologie animale et humaine, Université de Rennes 1 - CNRS, Campus de Beaulieu, Avenue du Général Leclerc, 35042 Rennes Cedex, France*
[b] *UMR 6175, Physiologie de la Reproduction et des Comportements, INRA - CNRS - Université de Tours - Haras Nationaux,*
*Centre INRA de Tours, 37380 Nouzilly, France*

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ABSTRACT

This experiment explored links between individual social traits and behavioural rhythms by comparing the feeding activity rhythms of HSR (high social reinstatement) Japanese quail that will cover long distances to reach conspecifics, to those of LSR (low social reinstatement) quail that will cover only short distances to reach conspecifics. We evaluated the functioning of their circadian and ultradian clocks under constant darkness (DD), and then under photoperiodic conditions (LD).

Our results revealed that, under DD conditions, the circadian periods of HSR quail were closer to 24 h than those of LSR quail. Under LD conditions, the daily rhythm of HSR quail was clearer than that of LSR quail. HSR quail synchronized faster and better to the environmental LD cycle than LSR quail. Our results also showed that, under DD conditions, more LSR than HSR quail expressed ultradian rhythmic phenotypes and that the ultradian rhythm of LSR quail was clearer than that of LSR quail. Under LD conditions, these differences between HSR and LSR quail showed the same tendencies. LSR quail seem to present a more functional ultradian system, and thus could possibly synchronise better on an ultradian environmental cue than HSR quail.

Our study demonstrated a link between individual rhythmicity and social traits at an intra-specific level. It revealed complex relationships between ultradian, circadian, and daily rhythms and level of social motivation in Japanese quail.

## 1. Introduction

Endogenous rhythmicity enhances the efficiency of organisms for many behavioural functions (Review: DeCoursey, 2004). In particular, the temporal adjustment of individual behaviour to the activity rhythms of social, sexual, or familial partners is fundamental for the cohesion of social groups, breeding pairs, or families.

Studies evaluated the impact of social life on individual behavioural rhythms. First, social stress (like conflicts) can modify behavioural rhythms of an individual (Meerlo et al., 1999; Bartolomucci et al., 2003). Second, an individual can be influenced by the rhythm of one or more social partners: mothers (Viswanathan and Chandrashekaran, 1985; Jilge, 1995) or other members of the social group (Marimuthu et al., 1981; Governale and Lee, 2001) can entrain the behavioural rhythmicity of an individual on their own rhythmicity. Last, social partners can modify the ontogeny of behavioural rhythms: the rhythmicity of an individual can depend on its previous experience with conspecifics

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* Corresponding author. Tel.: +33 0223236646; fax: +33 0223236927.
*E-mail address:* laureline.formanek@univ-rennes1.fr (L. Formanek).

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like its mothers (Formanek et al., 2009) or other members of its social group (Meshi and Bloch, 2007).

All these reports explored the influence of "others" on individual rhythmicity. Very few examined the effect of individual social characteristics on rhythmicity. Oosthuizen et al. (2003) reported a link between individual behavioural rhythmicity and the level of sociality. Singly housed African mole-rats from a solitary species (*Georychus capensis*) or from a social species (*Cryptomys hottentotus pretoriae*) present endogenous circadian activity rhythms in DD (dark–dark). However, social mole-rats are slower to adjust to new photoperiods, and have a lower rate of activity entrainment to LD (light-dark) cycles than do solitary mole-rats. The authors suggested that synchronization on environmental cycles could be of great importance for seasonally breeding solitary species because they must anticipate their breeding season in order to encounter sexual partners. This is not fundamental for aseasonal-breeding social species.

The evolution of any trait begins with mutations at genetic loci that control that trait. If these mutations produce favourable functional changes in overt behaviour, they can lead to adaptation. However, before natural selection can occur, a species must present heritable inter-individual variations. We hypothesized that a link between individual behavioural rhythmicity and social traits at an intra-specific level, similar to the link described by Oosthuizen et al. (2003) at an inter-specific level, could exist.

In Japanese quail (*Coturnix coturnix japonica*), reports revealed inter-individual variations in the degree of social motivation (Mills and Faure, 1991), defined as the internal impulse driving an isolated animal to establish contact with, to move towards, and to remain close to conspecifics (Le Masne, 1996). Genetic selection based on the social reinstatement (SR) tendency of young quail (estimated by the distance that they will cover to reach conspecifics) leads to two divergent lines: a high social reinstatement tendency (HSR) line and a low social reinstatement tendency (LSR) line (Mills and Faure, 1991). SR is associated with other social characteristics that, when they are all considered together, reflect the social motivation of an animal (Launay et al., 1991; Mills et al., 1993; François et al., 1999; Formanek et al., 2008a).

Almost all research investigating links between social life and rhythmicity focus on circadian rhythms. The functions of circadian rhythmicity is relatively well known (DeCoursey, 2004), whereas this is not the case for ultradian rhythmicity. One of the problems is the great difficulty to demonstrate the existence of ultradian rhythms because they are particularly sensitive to masking effects due to experimental conditions (Lavie, 1989). Aschoff and Gerkema (1985) suggested that ultradian rhythms could possibly contribute to inter-individual social synchronization. Therefore, we thought it was indispensable to examine circadian as well as ultradian rhythmicity as these two levels of organisation could be important during social life.

The experiment presented here investigated links between social motivation and behavioural rhythmicity by comparing the feeding activity rhythms of HSR quail to that of LSR quail, first under constant conditions, to examine the free-running functioning of endogenous clocks, then under photoperiodic conditions, to evaluate the synchronization of the endogenous clocks to an external zeitgeber.

## 2. Materials and methods

### 2.1. Subjects and housing

Our subjects were 80 Japanese quail, *Coturnix coturnix japonica*, issued from the F38 generation of two lines genetically selected, either for high (HSR; $n_{\mathrm{HSR}} = 40$, 18 males and 22 females) or low (LSR; $n_{\mathrm{LSR}} = 40$, 22 males and 18 females) levels of social reinstatement behaviour (Mills and Faure, 1991). They were produced by a French experimental research unit (UE PEAT, INRA Nouzilly, France). Quail had been selected on the basis of their behaviour in a treadmill while facing conspecifics in a target box, as described by Mills and Faure (1990). Quail having covered long distances on the treadmill carpet were considered to have a high level of social motivation (HSR). On the contrary, quail having covered only short distances were considered to have a low level of social motivation (LSR).

Between 1 day and 3 weeks old, quail were housed in single-line groups in two rooms (225 cm long × 185 cm wide × 280 cm high) with wood shavings on the floor. Ambient temperature was 20 ± 1 °C, except under the warming bulbs (35 ± 2 °C) placed in the rooms for thermoregulation. The non-stimulant photoperiod was LD 10:14 h. During the scotophase a very low intensity light (less than 2 lux) was left in the room so that the chicks could find the warming bulb, food and water easily. When they were 3 weeks old, quail were caged (22 cm long × 20 cm wide × 15 cm high) individually in six soundproof rooms (11–12 birds per room), with food and water containers. Ambient temperature was 20 ± 1 °C. Water and food (dindonneau/pintadeau/faisandeau 458, 1st age for chicks and 2nd age for adults, VEGAM, Vern-sur-Seiche, France) were always available *ad libitum* during experiments.

### 2.2. Experimental protocol

First, two behavioural tests (one in social isolation and one in the presence of conspecifics) verified the divergence of social motivation between lines of our 80 subjects (40 HSR and 40 LSR quail), when they were still juveniles (9–12 days old). No subject presented characteristics of the opposite line. We could record only 68 of the 80 quail because of technical limitations (i.e., number of places in the soundproof rooms). Thus, when they were 3 weeks old, 68 quail (17 HSR males, 17 HSR females, 17 LSR males and 17 LSR females) were randomly chosen and transferred to the soundproof rooms and their feeding activity was recorded.

#### 2.2.1. Behavioural tests

*2.2.1.1. Test in social isolation = open-field test.* This test consisted in transferring a quail from its familiar rearing place to a new environment (Launay, 1993). Quail were placed individually in the middle of a wire-netting cylinder