

Behavioural synchronization from an ethological perspective: Overview of its adaptive value

Adaptive Behavior
2016, Vol. 24(3) 181–191
© The Author(s) 2016
Reprints and permissions:
sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/1059712316644966
adb.sagepub.com


Charlotte Duranton^{1,2} and Florence Gaunet¹

Abstract

Synchronized behaviours are found in various species, among all taxa of live beings. Being synchronized with other individuals is defined by doing the same thing, at the same time and at the same place as others. It is observed within intraspecific groups and dyads. We aim to provide a synthetic overview of what is behavioural synchronization and focus on the adaptive value of such a phenomenon among individuals. Then, as it is observed that some stable groups or dyads consist of individuals from different species, we finally propose to investigate the existence of interspecific behavioural synchronization.

Keywords

Adaptive mimicry, behavioural synchronization, dyadic synchrony, group synchrony, interspecific synchrony

I Introduction

1.1 Definitions

Being synchronized^{1,2} with other individuals is characterized by three components. Firstly, the temporal part of synchronization, called temporal synchrony, is defined as switching actions at the same time (Duranton & Gaunet, 2015; Dostálková & Špínka, 2007). The actions can be identical or different – the important feature is the timing. Secondly, the behavioural part of synchronization, called activity synchrony,^{3,4} behavioural matching or allelomimicry, is defined as exhibiting the same behaviour at the same time (Chartrand & Bargh, 1999; Chartrand & Lakin, 2013; Duranton & Gaunet, 2015; Gautrais, Michelena, Sibbald, Bon, & Deneubourg, 2007; Lakin, Jefferis, Cheng, & Chartrand, 2003). Thirdly, the local aspect of synchronization, called local synchrony, is defined as being at the same place at the same time (Bertram 1980; Duranton & Gaunet, 2015; King & Cowlishaw, 2009). These three components are often observed together and cited as the general phenomenon of behavioural synchronization in a broad sense, as suggested by Louwerse, Dale, Bard, and Jeniaux (2012). When considering non-conscious synchronization, the distinctions between the subconcepts are not always easy/possible to make (Ramseyer & Tschacher, 2006). Individuals do not choose to perform one or another type of synchrony; they mostly perform them together.

Indeed, these categories are not disjunctive and it is common to observe a mixture of two or all of them (Ramseyer & Tschacher, 2006). Thus, we decided to use behavioural synchronization for its broad meaning in the following parts, as proposed by Louwerse et al. (2012) and Ramseyer and Tschacher (2006).

1.2 Methodological issues

Behavioural synchronization is a very large field of research reaching physical, biological and psychological sciences. From this diversity come many studies with almost no consensus on methodological aspects, varying in the definitions, protocols and methods of data analysis.

Many authors mentioned synchronized behaviour(s) but did not present details and did not give quantitative information on the observations (Engel & Lamprecht, 1997).

Methods of collecting data can vary from scan sampling to focal sampling, with or without video

¹Laboratoire de Psychologie Cognitive, CNRS/Université Aix-Marseille, UMR 7290, 3 place Victor Hugo 13331 Marseille Cedex 01, France

²AVA Shelter, Ferme du Quesnoy, 76220 Cuy-Saint-Fiacre, France

Corresponding author:

Charlotte Duranton, Laboratoire de Psychologie Cognitive, CNRS/ Université Aix-Marseille, UMR 7290, 3 place Victor Hugo 13331 Marseille Cedex 01, France.
Email: charlotte.duranton@cegetel.net

recording, in natural or artificial settings. Behavioural synchronization can be divided into studies investigating the existence of synchronization in groups (i.e. animal association of more than two members), or in dyads (Engel & Lamprecht, 1997). Additionally, each category can be divided into studies on non-human or human animals. The authors of these different types of studies typically use different measures of synchronization.

Concerning data analysis, there are again disparities between studies. Several methods have been proposed to evaluate behavioural synchronization, ranging from behaviour microanalysis to global perception of synchrony. For studies on groups, the most common method is behavioural coding, which proposes the evaluation of behaviour using computer-based coding and trained raters (Delaherche et al., 2012; Schmidt, Morr, Fitzpatrick, & Richardson, 2012). Generally, a measure of synchrony is deduced from the co-variation of the coded behaviours. The codes can be either continuous (speed of a behaviour) or categorical (type of behaviour) (Delaherche et al., 2012). But coding these natural interactions is very challenging given the complexity of individuals' movement. This method is also a common one, used to code dyadic interactions of both non-human animals and humans. However, when it comes to dyadic human interactions, another coding method has been developed as an alternative to behavioural analysis. Bernieri (1988) proposed the judgment method. Raters judge short videos for e.g. simultaneous movement, tempo similarity, coordination and smoothness on a nine-point time scale (see Delaherche et al., 2012, and Schmidt et al., 2012, for reviews). Whereas untrained judges are consistent with one another and reliably judge the synchronization between partners, this method does not provide as detailed a measurement of the synchronized behaviour as the coding method does. Other methods, using mathematical or physical models are accurate, but not as common as the two previous mentioned (see Schmidt et al., 2012, for more details).

Finally, there are also issues when reporting the results of the analysis, with conclusions that are proposed without considering limitations of the methods. For instance, Engel and Lamprecht (1997) emphasized the fact that many studies reporting synchronization did not take into account the probability that partners were observed behaving synchronously by chance, especially when studying frequent behaviours in groups. Another example is when, considering groups in which a behaviour is frequently observed, many individuals can perform the behaviour at the same time because each individual has a high probability of doing it. Because the expected value from independent behaviour is already high, it will be very difficult to detect synchronized behaviour. Conversely, if the behaviour is not frequently observed in the group, there will be few

opportunities to observe synchronized scans. Thus a lack of synchronization may be a consequence of low power to reject the null hypothesis of independent scanning (Beauchamp, 2015).

1.3 Aim of the review

All the presented methodological issues have to be considered properly before jumping to conclusions. They highlight a gap between natural social interactions in non-human animals (at group vs. dyadic level) and natural or laboratory tasks used to evaluate human synchronization. To our knowledge, there is no existing paper reviewing such different studies at the same time (see Delaherche et al., 2012, for a review on dyadic human synchronization; Couzin, 2009, for a review on collective movement in animal groups; and Conradt & List, 2009, for an interdisciplinary review of conscious synchronization – not reviewed here, as we focused only on non-conscious synchronization). As behavioural synchronization is a multidisciplinary phenomenon and everyone interested in the topic should have access to such a review, we aimed to provide one. Behavioural synchronization is widespread among live beings and has various adaptive values. We will thus review them from an ethological perspective – enabling us to bridge the gap between all studies. We will present the advantages of synchronization at group then at dyadic levels. We will then open the reasoning by encouraging studies on interspecific synchronization, which is underrepresented in the behavioural synchronization research field.

2 Adaptive values of behavioural synchronization within groups

2.1 Decreasing the pressure of predation on offspring

One of the first causes of mortality in various species is predation on offspring (Gerlach & Vaughan, 1990; Linnell, Aanes, & Andersen, 1995; Longland & Jenkins, 1987). When the offspring are just produced/born, they are vulnerable and an easy target for predators. For example, predation is responsible for on average 67% of the juvenile ungulates' mortality, far ahead of starvation, accident and disease (Linnell et al., 1995). It is higher in some species, such as in pronghorns, in which 75% of the neonates' mortality is due to one single predator, the coyote (Linnell et al., 1995). In a study on porcupines, 90% of juvenile mortality was due to predation (Mabille & Berteaux, 2014). Canids also suffer from this phenomenon, with African wild dogs' first cause of pup mortality being predation by lions (van der Meer, Mpofu, Rasmussen, & Fritz, 2013). Some predators even specialized in juveniles, with jaguars who kill only cattle calves younger than 12 months for

58% of their diet (Rosas-Rosas, Bender, & Valdez, 2008).

One strategy to reduce this predation pressure is to synchronize the reproduction. Reproductive synchrony consists of individuals carrying out some part of the reproductive cycle at the same time as other group members, not explicable by environment constraints alone (Ims, 1990). Synchronizing the production of a large enough amount of offspring – large enough to satiate predators – at the same place and at the same time is one type of reproductive synchrony (Hernández-Matías, Jover, & Ruiz, 2003). By satisfying the satiation of the predators, it enables at least some offspring to survive compared with if they were all produced/born separately particularly when the genitors/parents cannot actively protect their offspring (Roy Nielsen, Parker, & Gates, 2008; Yasaka, Terazawa, Koyama, & Kon, 2003). For example, it has been observed in trees such as Japanese beech (*Fagus crenata*) in Hokkaido (Yasaka et al., 2003), or in 105 different coral species on the Great Barrier Reef (Babcock et al., 1986).

When the parents are able to actively protect their offspring against predators, synchronizing parental behaviour *per se* is another type of reproductive synchrony that provides advantages. In birds and mammals, adults synchronize their behaviours to protect their offspring by dissuading predators. In wild zebra finch, a high degree of synchronization of visits to the nest is proposed to decrease predation by reducing the activity around the nest (Mariette & Griffith, 2012). In pronghorns (*Antilocapra americana*), fawn born during the period of peak fawning survived longer than fawn born outside the period of peak (Gregg, Bray, Kilbride, & Dunbar, 2001). The authors proposed that fawn benefited from birth synchrony, as it enhances group defence by adults and create predator confusion. Birth synchrony is also found in wild and captive bats (*Phyllostomus hastatus*) (Porter & Wilkinson, 2001), or primates (e.g. Boinski, 1987).

2.2 Increasing the effectiveness of anti-predation strategies

When all individuals form a cohesive group, each individual benefits from better protection against predators than when alone (Conradt & Roper, 2000; Fernandez, Capurro, & Rebores, 2003). Being synchronized with other group members is thus essential for improving the individual probability of survival (Inman & Krebs, 1987; Hernández-Matías et al., 2003).

Firstly, this synchronization in groups leads to collective movements. They are well known in insects, schools of fishes, flocks of birds and groups of ungulates, primates, etc. (Conradt & List, 2009; Deneubourg & Goss, 1989). The tendency of individuals to move in the same direction as their neighbours creates adaptive

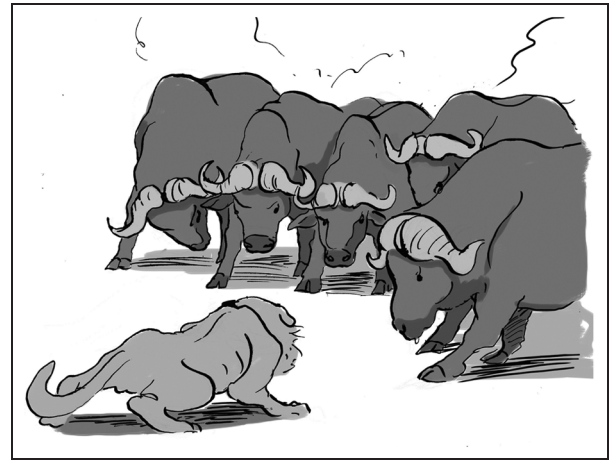


Figure 1. Cattle synchronizing their antipredator behaviour.

collective changes of direction to avoid threats and predators (Couzin, 2009; Dostálková & Špinka, 2010). Moreover, when all members of a group switch from one place to another place at the same time, it helps individuals to stay in close proximity (Bertram, 1980; Dostálková & Špinka 2010; King & Cowlshaw, 2009). This proximity promotes the so-called dilution effect: living in groups with great proximity reduces each individual's probability of being caught by a predator (Inman & Krebs, 1987; Roy Nielsen et al., 2008). The more individuals in the same place at the same time, the smaller the chance that any particular individual will be caught (Foster & Treherne, 1981; Inman & Krebs, 1987; Takahashi, Sato, & Nishikawa, 2004). For example, in ungulates such as cattle (*Bos taurus*) and horses (*Equus caballus*), behavioural synchronization helps to reduce predation risks (Šárová, Špinka, & Arias Panamá, 2007; Souris, Kaczensky, & Julliard, 2007).

Secondly, being synchronized increases the efficiency of individuals' active defence against predators. By doing the same action at the same time, prey are safer due to the number effect. For example, elephants (*Loxodonta africana*) and buffalos (*Bison bison*) form defensive circles against predators (Deneubourg & Goss, 1989; Figure 1). In birds, being synchronized allows an earlier detection of predators and a higher efficiency of mobbing on predators (Hernández-Matías et al., 2003). For example, yellow-rumped caciques are well known to synchronize their mobbing behaviours to protect their eggs from predators (Robinson, 1985). Chickens (*Gallus gallus*) show synchronization in perching behaviours, their usual anti-predator behaviour (Eklund & Jensen, 2011).

Thirdly, synchronization can also lead group members to have greater efficiency in their vigilance against predators (Beauchamp, 2015). Animal vigilance has been widely studied in prey species, and consists of scanning the environment in order to detect the presence of a potential predator (Beauchamp, 2015; Pays

et al., 2007b). Synchronization of vigilance produces periods in which many group members are vigilant at the same time and periods in which only few/no group members are vigilant at the same time. What is essential to keep in mind to understand how synchronization of vigilance is adaptive is that direct detection of predators ensures a more rapid escape (Beauchamp, 2015). Additionally, if predators target laggards, group members gain vigilance at the same time as other group members (Beauchamp, 2015; Sirot & Touzalin, 2009). Conversely, if no group members are vigilant and are foraging or sleeping together, they reduce the chance of being targeted by a predator thanks to the dilution effect (Beauchamp, 2015). For example, in grey kangaroos (*Macropus giganteus*), individuals are synchronized in their switch from feeding to vigilance behaviours and vice versa, producing waves of vigilance and waves of foraging. In gulls (*Larus* spp.) sleeping individuals in a resting flock rose and fell periodically, as would be predicted for synchronized periods of high and low vigilance (Beauchamp, 2011). The same effect was also found in various mammals, for instance in Defassa waterbucks (*Kobus ellipsiprymnus*) (Pays et al., 2007b), red-necked pademelons (*Thylogale thetis*) (Pays, Dubot, Jarman, Loisel, & Goldizen, 2008), degus (*Octodon degus*) (Ebensperger, Hurtado, & Ramos-Jiliberto, 2006) and merino sheep (*Ovis orientalis aries*) (Michelena & Deneubourg, 2011). It was also found in birds, for instance in red-crowned cranes (*Grus japonensis*) (Ge, Beauchamp, & Li, 2011), common eider (*Somateria mollissima*) (Oäst & Tierala, 2011) and starlings (*Sturnus vulgaris*) (Fernández-Juricic, Smith, & Kacelnik, 2005). Further research on the mechanism underlying synchronization of vigilance and the factors predicting its level is needed.

2.3 Increasing social cohesion

Being synchronized with other group members is essential for group living and it is crucial/a prerequisite for social cohesion (Bertram 1980; Engel & Lamprecht, 1997; King & Cowlshaw, 2009; Gautrais et al., 2007; Pays, Jarman, Loisel, & Gerard, 2007a). In fact, the more disharmony and asynchrony there is between the activities of group members, the more likely the group is to split up (Conradt & Roper 2005; Engel & Lamprecht 1997; Focardi & Pecchiol 2005; Gautrais et al., 2007). When considering the link between social cohesion and synchronization, it is important to focus on behavioural states rather than specific activities, i.e. to focus on temporal synchrony. Social cohesion relies on individuals being active and inactive at the same time, whatever the activities (Gautrais et al., 2007). In ruminants, group members alternate between periods of activity (e.g. grazing, walking) and inactivity (e.g. resting or rumination) and they do so in synchronization (Rook & Penning 1991a; Coté, Schaefer, &

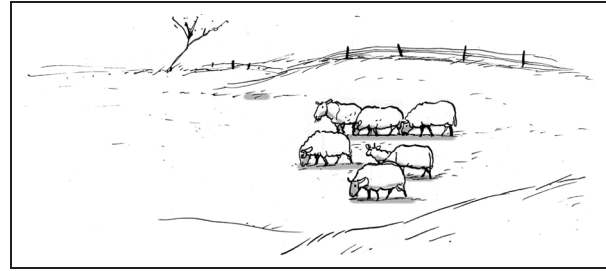


Figure 2. Sheep grazing together are synchronized in both spatial and temporal manner.

Messier, 1997; Michelena et al., 2006). For example, members of groups of sheep (*Ovis aries*) synchronize their switching between being inactive and being active (Gautrais et al., 2007; Rook and Penning, 1991) (Figure 2). Pastured cattle (*Bos Taurus*) exhibit postural synchrony, i.e. individuals change their posture (e.g. from lying to standing or the reverse) synchronously with other group members (Stoye, Porter, & Stamp Dawkins, 2012). In fallow deer (*Dama dama*), due to the social affinities hypothesis (males and females differing in their behaviour and motivation; Bon, 1992; Michelena et al., 2004) and to the activity budget hypothesis (males and females differing in the time they need for different activities; Conradt, 1998; Neuhaus & Ruckstuhl, 2004; Ruckstuhl, 1998), social cohesion between males and females appears to be correlated with a higher degree of activity synchrony in unisex groups compare to mix-sex groups (Villerette, Helder, Angibault, Cargnelutti, & Gerard, 2006).

3 Adaptive values of behavioural synchronization within pairs of conspecifics

3.1 Evidence in non-human animals

Synchronization of activities is not only present in large groups of individuals, it also occurs between only two interacting individuals. Animals in pairs benefit from behaving in a synchronous manner. For example in red-necked pademelons, pairs of individuals increase the efficiency of anti-predation strategies by synchronizing bouts of vigilance and foraging (Pays et al., 2008). In emperor penguins (*Aptenodytes forsteri*), synchronization between pairmates increases huddle efficiency by saving more energy and securing the partnership (Ancel, Beaulieu, Le Maho, & Gilbert, 2009). In wild bottlenose dolphins (*Tursiops aduncus*), a high level of pair-swimming synchronization is linked to high affiliation between the individuals (Sakai, Morisaka, Kogi, Hishii, & Kohshima, 2010; Figure 3). In migratory birds such as the black-tailed godwit (*Limosa limosa islandica*), synchrony of the arrival of pairs is observed and it is thought to help maintaining pair bonds between the birds (Gunnarsson, Gill, Sigurbjörnsson, &

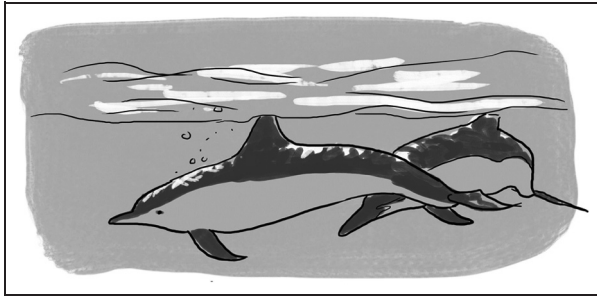


Figure 3. Synchronized swimming between two dolphins.

Sutherland, 2004). In play contexts, orang-utans mimic their partner's facial expressions in an involuntary and rapid manner (Ross and Menzler, 2008), participating in maintaining affiliative bonds between the partners. In bird species with long-lasting pair bonds, nest-visiting synchrony between the pair is often observed (Mariette & Griffith, 2012). For example in zebra finches, the pair forages and visits the nest at the same moment for 78% of the times (Mariette & Griffith, 2012). It has various adaptive values, such as decreasing the cost of food searching, reducing predation risk (by reducing time of activity around the nest) and maintaining pair bonds between the individuals (Mariette & Griffith, 2012).

3.2 Evidence in humans

3.2.1 Definitions for synchronization in human literature. Dyadic human interactions have been intensively studied. Interpersonal coordination corresponds to the degree to which the behaviours of two interacting individuals are synchronized in both timing and form (Lakin et al., 2003). For example, pair movement synchrony can be classified as having 'no synchrony', 'intermediate synchrony', 'strong synchrony' and 'complete synchrony' (for details, see Polansky & Wittemyer, 2011). When focusing on the timing, interactional synchrony or rhythmic synchrony refers to the rhythm of an interaction and how smooth it is (Chartrand & Bargh, 1999; Lakin et al., 2003). When focusing on the form, behavioural matching refers to the tendency to mimic the behaviours between interacting partners by adopting similar postures or showing similar bodily configurations (Chartrand & Bargh, 1999; Lakin et al., 2003). Different types of behavioural matching are distinguished. Emotional mimicry (or emotional contagion) is the contagion of display of emotions by others. Facial mimicry is the tendency to mimic the facial expressions of others. Behavioural mimicry is the adoption of the mannerisms, postures and gestures of the partner. Finally, verbal mimicry is the matching of speech characteristics and patterns of the interaction partner (Chartrand & van Baaren, 2009).

3.2.2 Benefits of synchronization in human dyads. Synchronization between interacting partners



Figure 4. Synchronization in human promotes liking and social bonds.

has been widely studied in humans. Partners synchronize their behaviours in numerous daily situations: sitting side by side in rocking chairs (Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007), walking together (van Ulzen, Lamoth, Daffertshofer, Semin, & Beek, 2008) or simply chatting together (Richardson, Dale, & Shockley, 2008). Synchronization is evolutionary adaptive for humans, as it contributes to communication between individuals by signalling convergence of inner states (Guéguen, Jacob, & Martin, 2009). During talks, it has been shown that the listener rhythmically synchronizes his/her flow of movements with the pace of the speech and movements of the speaker, making the interaction smoother (Kendon, 1970). Even neonates are sensitive to the rhythm of speech – not only of their mother, but also of all adults – and they move in synchronization with it (Condon & Sander, 1974). The authors proposed that this is an adaptive phenomenon to prepare motor organization for future language acquisition, essential for communication between individuals.

Moreover, synchronization also helps fostering relationships/social bonds between individuals (Chartrand & Bargh, 1999; Emanuel, 2012; Guéguen et al., 2009; Lakin et al., 2003; McIntosh, 2006). For neonates, behavioural synchronization consisting in exchanging gaze with their mothers allows to create and to maintain a strong attachment relationship between the two, essential for the infant's development (Isabella, Belsky, & von Eye, 1989). In adults, it has been found that individuals reported to like more someone who synchronized with them (even if non-aware of it), compared with others (Chartrand & Bargh, 1999). When two individuals present synchronized behaviours, they reported interactions to be smoother (Sanchez-Burks, Bartel, & Blount, 2000; Figure 4).

As a consequence, being behaviourally synchronized with someone leads to prosocial behaviour (Emanuel, 2012; Guéguen et al., 2009). For example, in restaurants, waitresses who synchronized their verbal attitude with the customers (by repeating/using the same words)

received bigger tips compared with when the waitresses did not mimic the customers (van Baaren, Holland, Steenaert, & van Knippenberg, 2003; Jacob & Guéguen, 2013). In another study, two interacting partners (the experimenter and the subject) had to comment on advertisements. The experimenter behaved in a synchronous manner with half of the subjects and not with the others. Then the experimenter pretended incidentally to drop pens. The subjects were more likely to help the experimenter to pick the pens up when they had been mimicked than if not (van Baaren, Holland, Kawakami, & van Knippenberg, 2004). The fact that synchronization enhances prosociality is found in other daily situations such as donating money for charity purpose or helping an unfamiliar colleague (Ashton-James, van Baaren, Chartrand, Decety, & Karremans, 2007; Guéguen et al., 2009; van Baaren et al., 2004). Even when the costs are important (helping someone to reach a train station by a 15-minute walk), people who are mimicked agreed to help more often than when they are not (Muller, Maaskant, van Baaren, & Dijksterhuis, 2012).

4 Discussion and further research: behavioural synchronization during interspecific interactions?

Interspecific stable groups, or mixed-species groups, are defined as groups composed of two or more species that travel and forage together (Arbeláez-Cortés, Rodríguez-Correa, & Restrepo-Chica, 2011; Stensland, Angerbjörn, & Berggren, 2003). Interspecific groups are observed in a wide range of taxa and can concern closely related species or species from different orders. Stable interspecific groups are observed in bird flocks, which can be small or large, composed of few or many species (see Terborgh, 1990, for a review and Sridhar, Beauchamp, & Shanker, 2009, for an overview of costs and benefits of mixed-species flocking). Interspecific groups are also observed among mammals, in diverse habitats, e.g. groups of various species of tamarins (Garber, 1988; Peres, 1993), groups of various species of dolphins (Quérouil et al., 2008), groups of common impalas (*Aepyceros melampus*) and bigger prey species (Pays, Ekor, & Fritz, 2014), groups of zebra and other prey species (Schmitt, Stears, Wilmers, & Shrader, 2014) (see Stensland et al., 2003, for a review on mixed-species groups in mammals). Even if less studied, interspecific groups are also observed in insects (e.g. Errard and Lenoir, 1995) and fishes (e.g. Semeniuk & Dill, 2006). Two main non-mutually exclusive hypotheses have been proposed to explain the benefits for animals to form mixed-species flocks. First, an increase in foraging efficiency and secondly, an increase in anti-predator strategy efficiency (Arbeláez-Cortés et al.,



Figure 5. Interspecific stable group: grey langurs and dogs, India. Credits: Cyril Ruoso, France.

2011; Diamond, 1981; Stensland et al., 2003; Terborgh, 1990).

Despite the great interest that scientists have shown in the observation of mixed-species groups, the existence of behavioural synchronization at the interspecific level has been little studied. At group level, Goodale, Ratnayake, and Kotagama (2014) observed simultaneous responses to alarm call in mixed-species bird flocks. Farine, Aplin, Garroway, Mann, and Sheldon (2014) observed highly synchronized feeding behaviour in mixed-species flocks, even across members of the different species. However, there is no evidence so far of synchronization of vigilance between the different species of mixed-species groups. In dyads, to our knowledge, only one study has investigated the existence of interspecific behavioural synchronization. Paukner, Anderson, Borelli, Visalberghi, and Ferrari (2005) showed that capuchin monkeys (*Cebus capucinus*) were sensitive to the fact that humans were synchronizing their ball-handling behaviours with them. The monkeys looked longer at the imitator and interacted more with him than with the person who did not synchronize (Paukner et al., 2005). The authors concluded that synchronization could occur and could play a role in interspecific interactions, at least between humans and non-human primates.

Does interspecific synchronization at dyadic level also exist between primates and non-primates? Stable groups or dyads involving primates and non-primate species are not very common but have been empirically observed. For example, at group level, we can give the case of a stable group of grey langurs and dogs found in India (*Daily Mail*, 2013; Figure 5), or groups of Pyrenean mountain dogs and sheep in France (*The Times*, 2011). At dyadic level, many videos can be found, for example of Surya, an orang-utan, and her favourite play partner Roscoe, a hunting dog (*National Geographic*, 2013). Even if these observations have not been made in a scientific way, they cannot be ignored.

In this line, one situation in which individuals from different species form a stable group/dyad and interact on a daily basis at dyadic level does exist and is easily observable by scientists: dogs and humans living in the same house. All individuals interact regularly by playing, sleeping together or just staying in the same room. However, to our knowledge, synchronization between individuals in this situation has not yet been studied. These interspecific stable groups and dyads, their interactions, the existence of synchronization and its potential advantages deserve to be studied. The interspecies human–dog dyad would thus be an interesting biological model that is underrepresented in research so far. Studying such a dyad and the synchronization between the two interacting partners has the potential to uncover new theoretical issues on shared cognitive processes between different species. We thus recommend further studies in that direction, as it could provide essential background to better understand interspecific synchronization, its implications and mechanisms. If dogs synchronize with humans (and conversely), new knowledge about the evolution of social skills may be discovered.

Acknowledgements

The authors gratefully acknowledge Marion Montaigne for her drawings and Cyril Ruoso for his picture. We thank Prescott Breeden and Dr. Thierry Bedossa for their helpful suggestions. We are grateful to the anonymous reviewers whose suggestions helped improving this manuscript.

Declaration of conflicting interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the association Aide aux Vieux Animaux, the Centre National de la Recherche Scientifique, the Université Aix-Marseille and the Association Nationale de la Recherche et de la Technologie (France).

Notes

- Mechanisms and factors modulating behavioural synchronization are not reviewed here.
- We choose to focus our review on non-conscious synchronization. Conscious synchronization is a different field of study leading to complex phenomena such as cooperation.
- Activity synchrony is different from cooperation since the latter is defined as when one individual performs a behaviour that provides a direct benefit to another individual (the recipient) and which is selected for because of *this* beneficial effects (West, Griffin, & Gardner, 2007). During activity synchrony, there is neither necessarily a benefit for a recipient nor a common goal.
- Activity synchrony can result from response/social facilitation. For many authors, social facilitation and response facilitation are similar social learning processes, but there is still no consensus. A commonly admitted definition of response/social facilitation is: a learning process that occurs when the presence of a conspecific performing an act (often resulting in reward) temporarily increases the probability that an observing animal will perform the same act (Hoppitt & Laland, 2008). But Hoppitt and Laland (2008) also mentioned a definition made by Zajonc, not linked with learning process, but considering social facilitation as an increase in arousal: ‘social facilitation occurs when the mere presence of a demonstrator affects the observer’s behaviour’. In addition, in canine literature, James and Gilbert (1955) proposed that ‘social facilitation may be based on learning or it may be a response relatively independent of learning’, and Kubinyi, Pongrácz, and Miklósi (2009) classified synchronization as a non-learning-based processes that they called social influence. Thus the authors of the present review chose not to mention the potential mechanisms underlying activity synchrony and the link with response/social facilitation, as this review is centred on the behavioural outcome of synchronization and its ecological value.

References

- Ancel, A., Beaulieu, M., Le Maho, Y., & Gilbert, C. (2009). Emperor penguin mates: Keeping together in the crowd. *Proceedings of the Royal Society B: Biological Science*, 276, 2163–2169.
- Arbeláez-Cortés, E., Rodríguez-Correa, H. A., & Restrepo-Chica, M. (2011). Mixed bird flocks: Patterns of activity and species composition in a region of the Central Andes of Colombia. *Revista Mexicana de Biodiversidad*, 82, 639–651.
- Ashton-James, C. E., van Baaren, R., Chartrand, T., Decety, J., & Karremans, J. (2007). Mimicry and me: The impact of mimicry on self-construal. *Social Cognition*, 25(4), 518–535.
- Babcock, R. C., Bull, G. D., Harrison, P. L., Heyward, A. J., Oliver, J. K., Wallace, C. C., & Willis, B. L. (1986). Synchronous spawnings of 105 scleractinian coral species on the Great Barrier Reef. *Marine Biology*, 90, 379–394.
- Beauchamp, G. (2011). Collective waves of sleep in gulls (*Larus* spp.). *Ethology*, 117, 326–331.
- Beauchamp, G. (2015). *Animal vigilance, monitoring predators and competitors* (pp. 155–172). New York: Academic Press.
- Bernieri, F. J. (1988). Coordinated movement and rapport in teacher-student interactions. *Journal of Nonverbal Behavior*, 12, 120–138.
- Bertram, B. C. R. (1980). Vigilance and group size in ostriches. *Animal Behaviour*, 28, 278–286.
- Boinski, S. (1987). Birth synchrony in squirrel monkeys (*Saimiri oerstedii*): A strategy to reduce neonatal predation. *Behavioral Ecology and Sociobiology*, 21, 393–400.
- Bon, R. (1992). Social and spatial segregation of males and females polygamous ungulates: Proximate factors. In: F. Spitz, G. Janeau, G. Gonzalez, & S. Aulagnier (Eds.), *Ungulés/Ungulates* (pp. 195–198). Paris, France: SFPEM-IRGM.
- Chartrand, T. L., & Bargh, J. A. (1999). The chameleon effect: The perception–behavior link and social interaction. *Journal of Personality and Social Behaviour*, 76, 893–910.

- Chartrand, T. L., & Lakin, J. L. (2013). The antecedents and consequences of human behavioral mimicry. *Annual Review of Psychology*, 64, 285–308.
- Chartrand, T. L., & van Baaren, R. (2009). Human mimicry. *Advances in Experimental Social Psychology*, 41, 219–274.
- Condon, W. S., & Sander, L. W. (1974). Synchrony demonstrated between movements of the neonate and adult speech. *Child Development*, 45, 456–462.
- Conradt, L. (1998). Could asynchrony in activity between the sexes cause intersexual social segregation in ruminants? *Proceedings of the Royal Society of London B: Biological Sciences*, 265, 1359–1363.
- Conradt, L., & Roper, T. J. (2000). Activity synchrony and social cohesion: A fission–fusion model. *Proceedings of the Royal Society B: Biological Sciences*, 267, 2213–2218.
- Conradt, L., & Roper, T. J. (2005). Consensus decision making in animals. *Trends in Ecology and Evolution*, 20, 449e456.
- Conradt, L., & List, C. (2009). Group decisions in humans and animals: A survey. *Philosophical Transactions of the Royal Society of London B: Biological Science*, 364, 719–742.
- Coté, S. D., Schaefer, J. A., & Messier, F. (1997). Time budgets and synchrony of activities in muskoxen: The influence of sex, age and season. *Canadian Journal of Zoology*, 75, 1628e1635.
- Couzin, I. D. (2009). Collective cognition in animal groups. *Trends in Cognitive Science*, 13, 36–43.
- Delaherche, E., Chetouani, M., Mahdhaoui, A., Saint-Georges, C., Viaux, S., & Cohen, D. (2012). Interpersonal synchrony: A survey of evaluation methods across disciplines and its application to ASD. *Neuropsychiatrie de l'enfance et de l'adolescence*, 60(5), S32–S33.
- Deneubourg, J. L., & Goss, S. (1989). Collective patterns and decision making. *Ethology Ecology and Evolution*, 1, 295–311.
- Diamond, J. M. (1981). Mixed-species foraging groups. *Nature*, 292, 408–409.
- Dostálková, I., & Špinka, M. (2007). Synchronization of behaviour in pairs: The role of communication and consequences in timing. *Animal Behavior*, 74, 1735–1742.
- Dostálková, I., & Špinka, M. (2010). When to go with the crowd: Modelling synchronization of all-or-nothing activity transitions in grouped animals. *Journal of Theoretical Biology*, 263, 437–448.
- Duranton, C., & Gaunet, F. (2015). *Canis sensitivus*: Affiliation and dogs' sensitivity to others' behavior as the basis for synchronization with humans? *Journal of Veterinary Behavior*, 10, 513–524.
- Ebensperger, L. A., Hurtado, M. A. J., & Ramos-Jiliberto, R. (2006). Vigilance and collective detection of predators in degus (*Octodon degus*). *Ethology*, 112, 879–887.
- Eklund, B., & Jensen, P. (2011). Domestication effects on behavioural synchronization and individual distances in chickens (*Gallus gallus*). *Behavioural Processes*, 86, 250–256.
- Emanuel, L. L. (2012). *Nonconscious behavioural mimicry: Examining the methods used to produce mimicry and the automatic nature of the effect*. PhD, School of Philosophy and Clinical Language Science.
- Engel, J., & Lamprecht, J. (1997). Doing what everybody does? A procedure for investigating behavioural synchronization. *Journal of Theoretical Biology*, 185, 255e262.
- Errard, C., & Lenoir, A. (1995). Interindividual distances in mixed-species groups of ants: An estimation of cohesion in social groups. *Journal of Ethology*, 13, 85–94.
- Farine, D. R., Aplin, L. M., Garroway, C. J., Mann, R. P., & Sheldon, B. C. (2014). Collective decision making and social interaction rules in mixed-species flocks of songbirds. *Animal Behaviour*, 95, 173–182.
- Fernandez, G. J., Capurro, A. F., & Rebores, J. C. (2003). Effect of group size on individual and collective vigilance in Greater Rheas. *Ethology*, 109, 413–425.
- Fernández-Juricic, E., Smith, R., & Kacelnik, A. (2005). Increasing the costs of conspecific scanning in socially foraging starlings affects vigilance and foraging behaviour. *Animal Behaviour*, 69, 73–81.
- Focardi, S., & Pecchiol, E. (2005). Social cohesion and foraging decrease with group size in fallow deer (*Dama dama*). *Behavioural Ecology and Sociobiology*, 59, 84e91.
- Foster, W. A., & Treherne, J. E. (1981). Evidence of the dilution effect in the selfish herd from fish predation on a marine insect. *Nature*, 293, 466–467.
- Garber, P. A. (1988). Diet, foraging patterns, and resource defense in a mixed species troop of *Saguinus mystax* and *Saguinus fuscicollis* in Amazonian Peru. *Behaviour*, 105(2), 18–34.
- Gautrais, J., Michelena, P., Sibbald, A., Bon, R., & Deneubourg, J. L. (2007). Allelomimetic synchronization in merino sheep. *Animal Behaviour*, 74, 1443–1454.
- Ge, C., Beauchamp, G., & Li, Z. (2011). Coordination and synchronisation of anti-predation vigilance in two crane species. *Plos One*, 6, e26447.
- Gerlach, T. P., & Vaughan, M. R. (1990). *Guidelines for the management of pronghorn on the Píoñ Canyon Maneuver Site, Colorado*. Final Report, U.S., Army. Directorate of Environmental Compliance and Management, Fort Carson, CO.
- Goodale, E., Ratnayake, C. P., & Kotagama, S. W. (2014). Vocal mimicry and alarm-associated sounds by a drongo elicits flee and mobbing responses from other species that participate in mixed-species bird flocks. *Ethology*, 120, 266–274.
- Gregg, M. A., Bray, M., Kilbride, K. M., & Dunbar, M. R. (2001). Birth synchrony and survival of pronghorn fawns. *Journal of Wildlife Management*, 65, 19–24.
- Guéguen, N., Jacob, C., & Martin, A. (2009). Mimicry in social interaction: Its effect on human judgment and behavior. *European Journal of Social Sciences*, 8(2), 253–259.
- Gunnarsson, T. G., Gill, J. A., Sigurbjörnsson, T., & Sutherland, W. J. (2004). Arrival synchrony in migratory birds. *Nature*, 431, 646.
- Hernández-Matías, A., Jover, L., & Ruiz, X. (2003). Predation and common tern eggs in relation to sub-colony size, nest aggregation and breeding synchrony. *Waterbirds*, 26(3), 280–289.
- Hoppitt, W., & Laland, K. N. 2008. Social processes influencing learning in animals: A review of the evidence. *Advances in the Study of Behavior*, 38, 105–165.
- Ims, R. A. (1990). The ecology and evolution of reproductive synchrony. *Trends in Ecology and Evolution*, 5(5), 135–140.
- Inman, A. J., & Krebs, J. (1987). Predation and group living. *Trends in Ecology and Evolution*, 2(2), 31–32.
- Isabella, R. A., Belsky, J., & von Eye, A. (1989). Origins of infant–mother attachment: An examination of

- interactional synchrony during the infant's first year. *Developmental Psychology*, 25, 12–21.
- Jacob, C., & Guéguen, N. (2013). The effect of employees' verbal mimicry. *International Journal of Hospitality Management*, 35, 109–111.
- James, W. T., & Gilbert, T. F. (1955). The effect of social facilitation on food intake of puppies fed separately and together for the firsts 90 days of life. *British Journal of Animal Behaviour*, 3(4), 131–133.
- Kendon, A. (1970). Movement coordination in social interaction: Some examples described. *Acta Psychologica*, 32, 100–125.
- King, A. J., & Cowlishaw, G. (2009). All together now: Behavioural synchrony in baboons. *Animal Behaviour*, 78, 1381–1387.
- Kubinyi, E., Pongrácz, P., & Miklósi, Á. (2009). Dog as a model for studying conspecific and heterospecific social learning. *Journal of Veterinary Behavior: Clinical Applications and Research*, 4, 31–41.
- Lakin, J. L., Jefferis, V. E., Cheng, C. M., & Chartrand, T. L. (2003). The chameleon effect as social glue: Evidence for the evolutionary significance of nonconscious mimicry. *Journal of Nonverbal Behaviour*, 27, 145–162.
- Linnell, J. D. C., Aanes, R., & Andersen, R. (1995). Who killed Bambi? The role of predation in the neonatal mortality of temperate ungulates. *Wildlife Biology*, 1, 209–223.
- Longland, W. S., & Jenkins, S. H. (1987). Sex and age affect vulnerability of desert rodents to owl predation. *The American Society of Mammalogists*, 678(4), 746–754.
- Louwerse, M. M., Dale, R., Bard, E. G., & Jeuniaux, P. (2012). Behavior matching in multimodal communication is synchronized. *Cognitive Science*, 2012, 1–24.
- Mabille, G., & Berteaux, D. (2014). Hide or die: Use of cover decreases predation risk in juvenile North American porcupines. *Journal of Mammalogy*, 95(5), 992–1003.
- Mariette, M. M., & Griffith, S. C. (2012). Nest visit synchrony is high and correlates with reproductive success in the wild zebra finch *Taeniopygia guttata*. *Journal of Avian Biology*, 43, 131–140.
- McIntosh, D. N. (2006). Spontaneous facial mimicry, liking and emotional contagion. *Polish Psychological Bulletin*, 37, 31–42.
- Michelena, O., Bouquet, P.-M., Dissac, A., Fourcassie, V., Lauga, J., Gerard, J.-F., & Bon, R. (2004). An experimental test of hypotheses explaining social segregation in dimorphic ungulates. *Animal Behaviour*, 68, 1371–1380.
- Michelena, P., Noël, S., Gautrais, J., Gerard, J.-F., Deneubourg, J.-L., & Bon, R. (2006). Sexual dimorphism, activity budget and synchrony in sheep group. *Oecologia*, 148, 170e180.
- Michelena, P., & Deneubourg, J.-L. (2011). How group size affects vigilance dynamics and time allocation patterns: The key role of imitation and tempo. *Plos One*, 6, e18631.
- Muller, B. C. N., Maaskant, A. J., van Baaren, R. B., & Dijksterhuis, A. (2012). Prosocial consequences of imitation. *Psychological Reports*, 110(3), 891–898.
- Neuhaus, P., & Ruckstuhl, K. E. (2004). Can the activity budget hypothesis explain sexual segregation in desert bighorn sheep? *Behaviour*, 141, 513–520.
- Oäst, M., & Tierala, T. (2011). Synchronized vigilance while feeding in common eider brood-rearing coalitions. *Behavioral Ecology*, 22, 378–384.
- Paukner, A., Anderson, J. R., Borelli, E., Visalberghi, E., & Ferrari, P. F. (2005). Macaques (*Macaca nemestrina*) recognize when they are being imitated. *Biology Letters*, 1, 219–222.
- Pays, O., Jarman, P. J., Loisel, P., & Gerard, J. F. (2007a). Coordination, independence or synchronization of individual vigilance in the eastern grey kangaroo? *Animal Behaviour*, 73, 595–604.
- Pays, O., Renaud, P. C., Loisel, P., Petit, M., Gerard, J. F., & Jarman, P. J. (2007b). Prey synchronize their vigilant behaviour with other group members. *Proceedings of the Royal Society B: Biological Sciences*, 274, 1287–1291.
- Pays, O., Dubot, A. L., Jarman, P. J., Loisel, P., & Goldizen, A. W. (2008). Vigilance and its complex synchrony in the red-necked pademelon, *Thylogale thetis*. *Behavioral Ecology*, 20, 22–29.
- Pays, O., Ekor, A., & Fritz, H. (2014). On the advantages of mixed-species groups: Impalas adjust their vigilance when associated with larger prey herbivores. *Ethology*, 120, 1207–1216.
- Peres, C. A. (1993). Anti-predation benefits in a mixed-species group of Amazonian tamarins. *Folia Primatologica*, 61, 61–76.
- Polansky, L., & Wittemyer, G. (2011). A framework for understanding the architecture of collective movements using pairwise analyses of animal movement data. *Journal of the Royal Society Interface*, 8, 322–33.
- Porter, T. A., & Wilkinson, G. S. (2001). Birth synchrony in greater spear-nosed bats (*Phyllostomus hastatus*). *Journal of Zoology*, 253, 383–390.
- Quérouil, S., Silva, M. A., Cascão, I., Magalhães, S., Seabra, M. I., Machete, M. A., & Santos, R. S. (2008). Why do dolphins form mixed-species associations in the Azores? *Ethology*, 114, 1183–1194.
- Ramseyer, F., & Tschacher, W. (2006). Synchrony: A core concept for a constructivist approach to psychotherapy. *Constructivism in the Human Sciences*, 11, 150–171.
- Richardson, M. J., Marsh, K. L., Isenhower, R. W., Goodman, J. R. L., & Schmidt, R. C. (2007). Rocking together: Dynamics of intentional and unintentional interpersonal coordination. *Human Movement Science*, 26, 867–891.
- Richardson, D. C., Dale, R., & Shockley, K. (2008). *Synchrony and swing in conversation: Coordination, temporal dynamics, and communication*. Oxford, UK: Oxford University Press.
- Robinson, S. K. (1985). Coloniality in the yellow-rumped cacique as a defense against nest predators. *The Auk*, 102, 506–519.
- Rook, A. J., & Penning, P. D. (1991). Synchronisation of eating, ruminating and idling activity by grazing sheep. *Applied Animal Behaviour Science*, 32, 157–166.
- Rosas-Rosas, O. C., Bender, L. C., & Valdez, R. (2008). Jaguar and puma predation on cattle calves in Northeastern Sonora, Mexico. *Rangeland Ecology & Management*, 61(5), 554–560.
- Ross, M. D., & Menzler, S. (2008). Rapid facial mimicry in orangutan play. *Biology Letters*, 4, 27–30.

- Roy Nielsen, C. L., Parker, P. G., & Gates, R. J. (2008). Partial clutch predation, dilution of predation risk, and the evolution of intraspecific nest parasitism. *The Auk*, *125*(3), 679–686.
- Ruckstuhl, K. E. (1998). Foraging behaviour and sexual segregation in bighorn sheep. *Animal Behaviour*, *56*, 99–106.
- Ruckstuhl, K. E., & Neuhaus, P. (2002). Sexual segregation in ungulates: A comparative test of three hypotheses. *Biological Review*, *77*, 77e96.
- Sakai, M., Morisaka, T., Kogi, K., Hishii, T., & Kohshima, S. (2010). Fine-scale analysis of synchronous breathing in wild Indo-Pacific bottlenose dolphins (*Tursiops aduncus*). *Behavioural Processes*, *83*, 48–53.
- Sanchez-Burks, J., Bartel, C. A., & Blount, S. (2000). Performance in intercultural interactions at work: Cross-cultural differences in response to behavioral mirroring. *Journal of Applied Psychology*, *94*(1), 216–223.
- Šárová, R., Špinková, M., & Arias Panamá, J. L. (2007). Synchronization and leadership in switches between resting and activity in a beef cattle herd – A case study. *Applied Animal Behaviour Science*, *108*, 327–331.
- Schmidt, R. C., Morr, S., Fitzpatrick, P., & Richardson, M. J. (2012). Measuring the dynamics of interactional synchrony. *Journal of Nonverbal Behavior*, *36*, 263–279.
- Schmitt, M. H., Stears, K., Wilmers, C. C., & Shrader, A. M. (2014). Determining the relative importance of dilution and detection for zebra foraging in mixed-species herds. *Animal Behaviour*, *96*, 151–158.
- Semeniuk, C. A. D., & Dill, L. M. (2006). Anti-predator benefits of mixed-species groups of cowtail stringrays (*Pastinachus sephen*) and whipprays (*Himantura uarnak*) at rest. *Ethology*, *112*, 33–43.
- Sirota, E., & Touzaline, F. (2009). Coordination and synchronization of vigilance in groups of prey: The role of collective detection and predators' preference for stragglers. *The American Naturalist*, *173*, 47–59.
- Souris, A., Kaczensky, P., & Julliard, R. (2007). Time budget, behavioral synchrony and body score development of a newly released Przewalski's horse group *Equus ferus przewalskii*, in the Great Gobi B strictly protected area in SW Mongolia. *Applied Animal Behaviour Science*, *107*, 307–321.
- Sridhar, H., Beauchamp, G., & Shanker, K. (2009). Why do birds participate in mixed-species foraging flocks? A large-scale synthesis. *Animal Behaviour*, *78*, 337–347.
- Stensland, E., Angerbjörn, A., & Berggren, P. (2003). Mixed species groups in mammals. *Mammal Review*, *33*, 205–223.
- Stoye, S., Porter, M. A., & Stamp Dawkins, M. (2012). Synchronized lying in cattle in relation to time of day. *Live-stock Science*, *149*, 70–73.
- Takahashi, A., Sato, K., & Nishikawa, J. (2004). Synchronous diving behavior of Adélie penguins. *Journal of Ethology*, *22*, 5–11.
- Terborgh, J. (1990). Mixed flocks and polyspecific associations: Costs and benefits of mixed groups to birds and monkeys. *American Journal of Primatology*, *21*, 87–100.
- van Baaren, R. B., Holland, R. W., Steenaert, B., & van Knippenberg, A. (2003). Mimicry for money: Behavioral consequences of imitation. *Journal of Experimental Social Psychology*, *39*(4), 393–398.
- van Baaren, R. B., Holland, R. W., Kawakami, K., & van Knippenberg, A. (2004). Mimicry and prosocial behavior. *Psychological Science*, *15*(1), 71–74.
- van der Meer, E., Mpofu, J., Rasmussen, G. S. A., & Fritz, H. (2013). Characteristic of African wild dog natan dens selected under different interspecific predation pressure. *Mammalian Biology*, *78*, 336–343.
- van Ulzen, N. R., Lamoth, C. J. C., Daffertshofer, A., Semin, R., & Beek, P. J. (2008). Characteristics of instructed and uninstructed interpersonal coordination while walking side-by-side. *Neurosciences Letters*, *432*, 88–93.
- Villerette, N., Helder, R., Angibault, J.-M., Cargnelutti, B., & Gerard, J.-F. (2006). Sexual segregation in fallow deer: Are mixed-sex groups especially unstable because of asynchrony between the sexes? *Comptes Rendus Biologies*, *329*, 551–558.
- West, S. A., Griffin, A. S., & Gardner, A. (2007). Social semantics: Altruism, cooperation, mutualism, strong reciprocity and group selection. *Journal of Evolutionary Biology*, *20*, 415–432.
- Yasaka, M., Terazawa, K., Koyama, H., & Kon, H. (2003). Masting behavior of *Fagus crenata* in northern Japan: Spatial synchrony and pre-dispersal seed predation. *Forest Ecology and Management*, *184*, 277–284.

Web references

- Daily Mail* (2013). Retrieved from <http://www.dailymail.co.uk/news/article-2282274/Care-monkey-massage-Grey-langurs-spotted-treating-wild-dog-grooming-session-India.html>
- National Geographic* (2013). Retrieved from <http://channel.nationalgeographic.com/wild/unlikely-animal-friends/videos/the-orangutan-and-the-hound/>
- The Times* (2011). Retrieved from <http://www.thetimes.co.uk/tto/news/world/europe/article2988482.ece>

About the authors



Charlotte Duranton is a M. D. in Ethology. She is currently a PhD student at the Laboratoire de Psychologie Cognitive (Centre National de la Recherche Scientifique / C.N.R.S. and Aix-Marseille University) and the Association d'Aide aux Vieux Animaux. Her research interests are mainly dog cognition and dog-human interactions. She is currently studying the existence and modalities of behavioural synchronization between humans and dogs.



Florence Gaunet received her Ph.D in 1996. She is a senior researcher at the Laboratoire de Psychologie Cognitive (Centre National de la Recherche Scientifique / C.N.R.S and Aix-Marseille University). After a specialization on spatial cognition in humans and in dogs (navigation of guide dogs), her current investigations focus on the social cognition of dogs: dog and human interaction in cities, referential and intentional communication and behavioral synchronization.

