Int J Primatol (2011) 32:1268–1278
DOI 10.1007/s10764-011-9524-9

Reaching a Consensus: Terminology and Concepts Used in Coordination and Decision-Making Research

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Received: 17 January 2011 / Accepted: 15 March 2011 / Published online: 25 May 2011

Abstract Research on coordination and decision-making in humans and nonhuman primates has increased considerably throughout the last decade. However, terminology has been used inconsistently, hampering the broader integration of results from different studies. In this short article, we provide a glossary containing the central terms of coordination and decision-making research. The glossary is based on previous definitions that have been critically revised and annotated by the participants of the symposium "Where next? Coordination and decision-making in primate groups" at the XXIIIth Congress of the International Primatological Society (IPS) in Kyoto, Japan. We discuss a number of conceptual and methodological issues and highlight consequences for their implementation. In summary, we recommend that future studies on coordination and decision-making in animal groups do not use the terms "combined decision" and "democratic/despotic decision-making." This will avoid ambiguity as well as anthropocentric connotations. Further, we demonstrate the importance of 1) taxon-specific definitions of coordination parameters (initiation, leadership, followership, termination), 2) differentiation between coordination research on individual-level process and group-level outcome, 3) analyses of collective action processes including initiation and termination, and 4) operationalization of successful group

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movements in the field to collect meaningful and comparable data across different species.

Keywords Animal groups · Coordination · Decision-making · Terminology

Introduction

The number of studies on group coordination, leadership, and decision-making in humans and nonhuman primates has increased considerably during the last decade (Conradt and Roper 2005; Conradt and List 2009; Fichtel *et al.* 2011; King *et al.* 2009; Petit and Bon 2010). However, integration of results from different studies has been impeded by ambiguous terminology and conceptual/methodological shortcomings (see Jacobs 2010; Petit and Bon 2010; Pyritz *et al.* 2010 for recent discussions). We discussed these inconsistencies with participants during the symposium "Where next? Coordination and decision-making in primate groups" at the XXIIIth Congress of the International Primatological Society (IPS) at Kyoto, Japan, in September 2010. As a result of the strong positive feedback, we decided to initiate a public discussion about these terms via an interactive online platform joined by participants of the symposium and associated researchers. The glossary contained 20 central terms regarding coordination and decision-making research, most of which were previously compiled in a comprehensive review by Conradt and Roper (2005). Each participant had the opportunity to contribute additional terms, definitions, references, and commentaries. Table I provides the final glossary based on the summary of all entries. In addition, we identified a number of conceptual and methodological issues that have been discussed rarely or controversially in the literature so far. We here discuss the most debated terms of the glossary and a number of crucial conceptual issues in more detail.

Terminology

Combined Decisions

Conradt and Roper (2005) defined a "combined decision" as the sum of individual group members` decisions that —unintentionally— affects the group as a whole (Table I). However, this definition is ambiguous and cannot be separated clearly from the often used and well established term "quorum decisions," in which group members also choose individually between different options until a certain threshold is reached that affects the entire group (Seeley *et al.* 2006; Ward *et al.* 2008; Table I). In fact, the mechanisms of reaching a group decision employed in a large colony of ants (*Leptothorax albipennis*) choosing between several new nest sites (Franks *et al.* 2002) are principally the same as those employed by Tonkean macaques (*Macaca tonkeana*) in a predeparture quorum (Sueur *et al.* 2010) or meerkats (*Suricata suricatta*) increasing travel speed via a vocal voting mechanism (Bousquet *et al.* 2010). In these species, each group member decides individually where and when to move, even if this decision is influenced by the behaviors of conspecifics. Further,

Table I Central terms of coordination and decision-making research and their respective definitions, selected references, and commentaries compiled by participants of the XXIIIth Congress of the International Primatological Society (IPS) in Kyoto, Japan

Term	Definition	References (selection)	Comments
Combined decision	Members of a group choose individually (but not necessarily independently) between ≥2 actions. They do not aim for consensus, but the combined result of their decisions usually affects the group as a whole.	Conradt and Roper 2005	The distinction between a quorum threshold, e.g., in ants or Tonkean macaques, and a combined decision seems inconclusive. See text for detailed discussion.
Consensus decision	Group members choose between ≥2 mutually exclusive actions to reach a consensus on the group level.	Conradt and Roper 2005; King *et al.* 2008; Sueur and Petit 2008a,b	
Consistent leadership	The same individual always leads group actions.	Conradt and Roper 2005	Opposite of distributed/ variable leadership.
Democratic and despotic	A consensus may be reached by the averaging of preferences (democracy), or by following the choices of specific leaders (despotism). Democratic=shared decision-making; despotic=unshared decision-making.	King *et al.* 2008; King and Cowlishaw 2009	In primatology, we usually use "despotic" and "egalitarian" (or "tolerant") to characterize the social system of a species and "shared" or "unshared" to describe consensus decisions. See text for detailed discussion.
Follower	An individual that follows/ joins the initiator/leader for a certain activity.	Jacobs *et al.* 2008; Pyritz *et al.* 2010; Ramseyer *et al*. 2009a, b, c; Sueur and Petit 2008a,b	The definition of a follower (of a group movement) should be operational and taxon-specific. See text for discussion.
Hidden leadership	The same individual initiates and terminates a group activity (movement), although it is not guiding the movement in front of the group.	Kummer 1968; Pyritz *et al.* 2010	The new definition of a leader (see below) includes hidden leadership. Therefore, we no longer need this term.
Initiator	The group member that initiates a group activity.	Bourjade and Sueur 2010; Jacobs *et al.* 2008; Pyritz *et al.* 2010; Ramseyer *et al.* 2009a, b, c; Sueur and Petit 2008a,b;	The definition of an initiator (of a group movement) should be operational and taxon-specific. See text for discussion.
Leader	Individual eliciting follower behavior/exerting social influence on others, by its rank into the progression, its behavior, or its social status.	Harcourt *et al.* 2009; King 2010; Petit and Bon 2010; Pillot *et al.* 2010; Sueur and Petit 2008a,b, 2010	The definition of a leader should not be restricted by the spatial position during a group movement (Kummer 1968) but comprise the whole process of a collective action. It is also a defining characteristic of a leader that he exerts social influence on conspecifics. See text for detailed discussion.
Mimetism	The probability that an individual performs a behavior depends on	Camazine *et al.* 2001; Deneubourg and Goss 1989; Meunier *et al.* 2006;	

Table I (continued)

Term	Definition	References (selection)	Comments
	the number of individuals already performing this behavior (anonymous mimetism, allelomimetism). It can also depend on the social relationships the individual has with group members already displaying the behavior (selective mimetism).	Petit *et al.* 2009; Sueur *et al.* 2009; Sumpter 2006	
Overtaking	Followers overtake the individual at the forefront of the group without diverging >45° from the initial trajectory.	Boinski 1991; Erhart and Overdorff 1999; Pyritz *et al.* 2010; Trillmich *et al.* 2004	
Predeparture behavior	Behavior performed before the departure of the initiator, making the timing of the departure predictable and potentially indicating the direction in which individuals want to move.	Bourjade and Sueur 2010; Sueur and Petit 2008a,b	Other names: preliminary behavior, notifying behavior, voting behavior, intention movement, priming behavior.
Predeparture period	Period preceding the departure of the initiator and delineated by the presence of predeparture behaviors.	Bourjade and Sueur 2010; Sueur and Petit 2008a,b	Other names: preliminary period.
Quorum	Minimum number, i.e., threshold, of group members that need to take or favor a particular action for the whole group to adopt this action.	Bousquet *et al.* 2010; Franks *et al.* 2002; Seeley *et al.* 2006; Sueur *et al.* 2010; Ward *et al.* 2008;	In principle, the quorum could be a majority, submajority (less than a majority), or supermajority (more than a majority) of members. In practice, animals are likely to determine whether a quorum has been reached by estimating the relative numerousness of members contributing to the quorum, often by relying on indirect cues.
Recruitment behavior	Behavior that increases the probability that other group members will join a certain activity. It results in a larger number of joiners or in quicker joining of the collective action than when not performed.	Bourjade and Sueur 2010	
Self-organizing system	Individual group members follow local behavioral rules, resulting in organized behavior by the whole group without the need for global control.	Camazine *et al.* 2001; Conradt and Roper 2005; Couzin *et al.* 2002; Sueur *et al.* 2009	Emergent properties due to the interactions between individuals in self-organized systems are more complex than the emergent properties that should be observed by the sum of individual behaviors.
Shared consensus decision	All members contribute equally (and independently of individual identity) to the	Conradt and Roper 2005; Sueur and Petit 2008a,b	Opposite of unshared consensus decision.

Table I (continued)

Term	Definition	References (selection)	Comments
	decision outcome. The consensus is usually determined by a quorum or by averaging over all votes.		
Terminator	Individual that stops and seems to suggest the termination of a group movement.	Pyritz *et al.* 2010	Group movements can feasibly comprise 2 linked decisions: 1) initiation: when and in which direction to move and 2) termination: when and where to stop See text for detailed discussion.
Unshared consensus decision	One particular group member, e.g., the dominant, makes the decision on behalf of all group members. All other members abide by this decision.	Conradt and Roper 2005; Sueur and Petit 2008a,b	Opposite of shared consensus decision.
Variable/ distributed leadership	Different group members lead group actions on different occasions.	Conradt and Roper 2005; Jacobs *et al.* 2008; Petit and Bon 2010	Opposite of consistent leadership.
Voting	An individual communicates its individual preference with regard to the decision outcome.	Bousquet *et al.* 2010; Prins 1996; Sellers *et al.* 2007; Sueur *et al.* 2010	

there is no easy way to test whether individuals *aim* to reach a group consensus, which was the criterion Conradt and Roper (2005) used to distinguish consensus decisions from combined decisions. We therefore recommend not using the term "combined decision" in future research.

Democratic and Despotic Decisions

Researchers have used the terms "democratic" and "despotic" interchangeably with "shared" and "unshared" in a number of recent studies on decision-making (Conradt and Roper 2003; King *et al.* 2008; King and Cowlishaw 2009). "Democracy" describes a consensus reached by the majority principle, whereas "despotism" characterizes a consensus reached by following the choices of specific leaders in these studies. However, in primatology the term "despotic" is also used to characterize the social structure of a species, opposed to "egalitarian" or "tolerant" societies (Matsumura 1999), and the social structure of a species undoubtedly influences the process and outcome of consensus decision-making. For instance, Sueur and colleagues studied the decisions of 2 macaque species, with contrasting social structures, beginning a group movement after a resting period (Sueur and Petit 2008a,b). They found that egalitarian Tonkean macaques displayed an equally shared consensus whereas more despotic rhesus macaques (*Macaca mulatta*) displayed a partially shared consensus. These differences were attributable to the fact that in the despotic rhesus macaques, dominant individuals

had a disproportionate influence on the movement decisions of group-mates: they were followed more often than the lower-ranked individuals. In contrast, all individuals in the more egalitarian Tonkean macaques had a similar influence on one another's decisions to move and the decision was equally shared. However, the social structure of a primate group can more broadly be viewed as both the cause and consequence, reinforced via a feedback loop, of social interactions such as intensity of aggression, grooming, or reconciliatory patterns. These social interactions may be independent of group level decision-making processes. Thus, so as to not confound characteristics of the social system and collective decision-making in a group or causal relationships between these 2 realms, we suggest that future decision-making research should use only the terms "shared" and "unshared," and not "democratic" and "despotic."

Leadership

The definition of a leader should not be restricted to its spatial position during a group movement because individuals may also lead from behind, i.e., initiate and terminate a movement without being at the forefront of the group (Kummer 1968; called "hidden leadership" in Pyritz *et al.* 2010). Instead, a leader should be defined as an individual that elicits follower behavior (from a majority of or all group members) and exerts social influence on group members either by its rank, experience, social status/connectedness, or specific behavior (King 2010; Petit and Bon 2010; Sueur and Petit 2008b). Further, an individual that leads may not do so intentionally, i.e., leadership can be a passive process (Fischer and Zinner 2011; King *et al.* 2009; King and Sueur 2011). For instance, in sheep (*Ovis aries*), individuals triggered follower behavior by merely moving away from their group following a sound they had been trained to, thus eliciting group movements as incidental leaders (Pillot *et al.* 2010).

Concepts and Methods

Taxon-Specific Definitions

It remains a major practical challenge for human observers to identify reliably and define operationally a group movement in the field. The following is the most detailed definition employed in recent studies on the coordination of group movements in different species: An individual moves a certain distance toward the edge of the group either in a defined time period, e.g., 10 m within 40 s (Leca *et al.* 2003; Stueckle and Zinner 2008; Sueur and Petit 2008a,b), or without stopping and feeding (Bourjade *et al.* 2009; Ramseyer *et al.* 2009a, b, c), and is followed by a certain number of group members. However, even in this fairly detailed definition, most parameters were not assessed empirically. In fact, a definition of group movements must account for a number of taxon-specific characteristics such as different traveling types (directed movements vs. "feed-as-you-go," ameboid-like movements that do not necessarily require an initiator or coordination among group members, e.g., bonobos [*Pan paniscus*]: Wrangham 2000); mean travel distances;

ecological conditions (resource abundance, predation risk); as well as the size, composition, and cohesion of the group. Therefore, we encourage the use of operational group movement definitions for different taxa that are built upon empirical data collected before the study period used for the analyses of group movements. In the long term, these empirical details will generate a comprehensive database for multiple species and different contexts. Researchers will then be able to compare and contrast the results to see if general patterns are shared among different species. For practical details of how to operationalize definitions see Trillmich *et al.* (2004) and Pyritz *et al.* (2010).

Individual-Level Process and Group-Level Outcome

Studies of group coordination and decision-making examine 2 different levels that should be clearly distinguished. First, studies can focus on the group level, i.e., the question of whether there is consistent or variable leadership among several group movements or other collective actions (Erhart and Overdorff 1999; Jacobs *et al.* 2008; King *et al.* 2008; Pyritz *et al.* 2011). Second, studies can focus on the level of single movements and study the process, i.e., the question of whether decisions are shared or unshared and if they are mediated by mimetism, affiliative/genetic network relations, quorum thresholds, or self-organized processes (King and Sueur 2011; Petit and Bon 2010; Sueur and Petit 2008a,b, 2010; Sueur *et al.* 2009). It is important to separate these levels and clearly highlight the level at which the research is focused. King and Sueur (2011) and Sueur and Deneubourg (2011) explain how a consistent leadership or a consistent order of individuals could be observed even though the decision process is shared. For example, imagine *n* % of group members have to follow the first-moving individual, i.e., initiator, within *n* minutes for a group movement to occur; otherwise the initiator stops moving and the whole group remains stationary. A study observing movement patterns during departure would conclude that the process is shared because multiple individuals contribute to the decision of the group to move. Researchers who observed only the order of departure when the group chose to move would observe group movements that were always led by the same individuals, and the decision appears unshared. Because the outcome at the group level, i.e., departure order, is easier to observe, it is no surprise that most early studies in the area of coordination focused on who leads (King 2010). However, identifying who leads may not tell the whole story. For instance, an individual can always, or in most cases, be the leader of a group because his energetic reserves are always the first to be depleted, and he has to move to feed, but might have the same, or at least no stronger, influence on the joining process as other group members, e.g., in the case of an anonymous mimetism. In fact, a number of recent findings, e.g., macaques (Sueur and Petit 2008a,b, 2010; Sueur *et al.* 2009), and horses (Bourjade *et al.* 2009) suggest shared consensus between group members at the movement level, even though a single leader or a few leaders, i.e., an unshared consensus with consistent leadership, has previously been reported, e.g., macaques (Reinhardt *et al.* 1987) and horses (Feist and Mc Cullough 1976). For a further discussion of this topic see Bourjade and Sueur (2010).

Initiation and Termination of Collective Actions

During the course of a group movement, animals have to make 2 basic decisions, 1) initiation: when and in which direction to move and 2) termination: when and where to stop. Theoretically, the decision where to stop may be a second consensus decision independent from the decision during initiation, and the 2 decisions can be initiated by the same or different leaders (Boinski 1991; Erhart and Overdorff 1999; Pyritz *et al.* 2010). Although this issue has been addressed rarely, it yields important implications for the decision type, i.e., there could be unshared decision-making at departure that is mitigated by individuals overtaking the initial leader and terminating the movement, resulting in a shared decision-making with regard to the whole movement process. Accordingly, we suggest making a distinction between these 2 events and exploring the consistency of leadership during travel. For instance, one might classify leadership as "stable," i.e., the initiator leads the movement until termination, or "unstable," i.e., the terminator is different from the initiator (Pyritz *et al.* 2011). In general, it is important to study the entire process of group movements from initiation to termination to gain a realistic image of coordination, leadership, and decision-making in a given species (Fichtel *et al.* 2011; Pyritz *et al.* 2010; Trillmich *et al.* 2004). Indeed, such detail will be crucial if we are to determine the temporal scale over which decisions are made, and outcomes occur. Take an example where the same individual, X, both initiates and terminates the movement. This could imply that 1) X made the decision to move and the decision to stop, which was followed by group-mates, or 2) X made the decision to move in a particular direction of travel (Noser and Byrne 2007; Sueur *et al.* 2010) in a "goal-directed fashion" toward a particular destination, and was first to arrive, but did not make the decision to terminate the movement, because all group-mates that followed were aware of the target destination at the initiation (Pyritz *et al.* in prep.). In other words, the decision of where to terminate had been made at the initiation.

Successful Group Movements

Early studies set a threshold of 50% of group members having to follow an initiator, within a certain time frame, to consider a movement as successful (Erhart and Overdorff 1999). More recent studies considered an initiation attempt as failed only if no individual followed (Jacobs *et al.* 2008; Sueur and Petit 2008a; Trillmich *et al.* 2004). However, the mean number of followers that determines a successful group movement is presumably taxon-specific and may change with ecological season or resource abundance (King *et al.* 2008; Pyritz *et al.* 2011). Further, fission into subgroups —and an accordingly lower number of followers for single initiators— may represent the most beneficial group decision under certain conditions (Jacobs 2010; Kerth 2010). Hence, it is difficult to provide a general definition for successful or unsuccessful movements. We suggest giving a taxon- (and season-) specific threshold of success regarding followers below which the initiator does not stop and show recruitment behavior (Table I), or "give-up" on the movement entirely, e.g., 5 followers in chacma baboons (*Papio hamadryas*: Stueckle and Zinner 2008); 3 followers in Verreaux's sifakas (*Propithecus verreauxis:* Trillmich *et al.* 2004),

white-faced capuchins (*Cebus capucinus*: Petit *et al.* 2009), meerkats (*Suricata suricatta*: Bousquet *et al.* 2010), and Tonkean macaques (Sueur and Petit 2010). Combining this with operational group movement definitions for different taxa, it may be possible to uncover a common threshold —a universal— to primate group movements. In fact, examination of the aforementioned studies indicates that a threshold of approximately 3 followers seems to be sufficient to elicit a group movement, whatever the species. This number may provide sufficient protection against predators or enough collective knowledge to orientate within the home range and detect resources, for example.

Conclusion

After a public discussion about terms used in coordination and decision-making research via an interactive online platform, we have come to a number of conclusions that will aid future research on this topic. First, we highlighted a number of ambiguous terms ("combined decision"; "despotic/democratic decision") and suggested that these not be used in future coordination research. We also suggest maintaining the terms "leader" and "leadership" because although they can sometimes be ambiguous, as long as an operational definition is provided these terms are useful to broader scientific communication and integration (King 2010; Pyritz *et al.* 2010). Further, we discussed a number of conceptual issues: group vs. movement level; operationalized successful group movements; collective action process including initiation and termination. Ultimately, the implementation of our suggestions should provide comparable data on coordination and decision-making in different species and facilitate the identification of general patterns that are shared among different taxa.

Acknowledgments We thank the participants of the symposium "Where next? Coordination and decision making in primate groups" at the XXIIIth Congress of the International Primatological Society (IPS) for valuable discussions and comments on the glossary and conceptual issues. Henning Lahmann kindly implemented the online glossary. We also thank Joanna Setchell and the *International Journal of Primatology* for providing financial support and making this special issue possible. L. W. Pyritz is funded by the German Research Foundation (DFG: KA 1082/16-1), A. J. King by a NERC Postdoctoral Fellowship (NE/H016600/2), and C. Sueur by the Japan Society for the Promotion of Science. Joanna Setchell and 2 anonymous reviewers provided valuable comments on the manuscript.

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