Human Infants' Learning of Social Structures: The Case of Dominance Hierarchy

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Abstract

This paper investigates whether human infants go beyond learning about individual social partners and their relations, and form hypotheses about how social groups are organized. We test 15-month-olds' capacity to represent social dominance hierarchies with more than two agents. Infants find it harder to memorise dominance relations presented in an order that hinders the incremental formation of a single structure (Study 1). Thus, infants attempt to build structures incrementally, relation by relation, thereby simplifying the complex problem of recognizing a social structure. Infants also find circular dominance structures harder to process than linear ones (Study 2). These expectations about the shape of structures may facilitate learning. Our results suggest that infants attempt to represent social structures composed of social relations.

Keywords: Social Dominance, Transitive Reasoning, Social Relations, Structure Learning, Naïve sociology.

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Animal species and humans recognize social structures, such as social dominance hierarchies, without formal teaching or supervised training (Boehm, 1999; Bergman, Beehner, Cheney & Seyfarth, 2003; Fiske, 1992; Grosenick, Clement & Fernald, 2007; Paz-y-Miño, Bond, Kamil & Balda, 2004). This capacity is remarkable because the range of possible social structures is extremely vast. For example, "n" individuals all related to each others could, in theory, form "$2^{n(n-1)/2}$" different dominance structures. Assessing the likelihood of each of these theoretical possibilities seems intractable. Instead of this brute force strategy, we hypothesize that learners use heuristics to discover social structures.

Complex problems can be simplified by dividing them into series of smaller problems that can be solved separately (Simon, 1962). Dominance structures can be decomposed into sets of dyadic relations. Thus, instead of discovering a complete dominance hierarchy at once, one can do it incrementally, by uncovering separately each dominance relation and combining them in a structure. Thus, we hypothesize that if infants represent dominance hierarchies, they should find it easier to build such structures incrementally (Study 1).

Discovering a structure can also be facilitated by appropriate expectations about its shape. Social dominance structures are often linear (Boehm, 1999; Caplan, Vespo, Pedersen & Hay, 1991; Fiske, 1992; Hawley, 1999). Therefore, we hypothesize that if infants have expectations about the shape of dominance structures, they should find linear structures easier to process or more plausible than circular ones (Study 2).

To test these two hypotheses, we presented fifteen-month-olds with a looking time paradigm, capitalizing on infants' tendency to look relatively longer when previously established dominance relations are reversed rather than confirmed (Mascaro & Csibra, 2012;

Thomsen, Frankenhuis, Ingold-Smith, & Carey, 2011). We defined 'dominance' as the capacity to prevail when two agents have conflicting goals (Hand, 1986; Weber, 1946), and assumed that 'social structures' involve at least three individuals (Flack & Krakauer, 2006).

General Method

Apparatus. Infants were tested in a dimly lit soundproof room, seating on their caregiver's lap 100 cm from a 40 inch LCD monitor on which the stimuli were presented. A hidden camera (25 frames/second temporal resolution) recorded infants' looking behaviour.

Stimuli and Procedure. Parents were instructed to close their eyes during the procedure. Each subject was presented with two series of three familiarization movies and two test trials in the following order: Three familiarization-Test-Three familiarization-Test. Each child was presented with a "coherent" and an "incoherent" test (order of presentation counterbalanced across participants).

During each familiarization movie, two agents (rudimentary animal figures) competed to occupy a small marked area. The 'dominant' agent monopolized the area by repeatedly pushing the subordinate agent away (video S1). Infants saw three of these competition movies, each time with a different pair of agents. In the test, infants watched two agents who interacted during familiarization competing to collect one object. In coherent tests, the previously 'dominant' agent prevailed (video S2), and in incoherent tests, the previously subordinate agent prevailed (video S3). Details about counterbalancing are in the Supplemental Online Material (SOM).

Coding and Data Analysis. Coding and data analysis are detailed in the SOM. Statistics are two-tailed.

Study 1

Several relations among a set of entities can be represented independently (e.g., representing ‘A>B’ and ‘B>C’, assuming that “>” denotes a dominance relation), or in a single structure (e.g., ‘A>B>C’). To assess which of these two systems infants employ, we varied the difficulty of forming an integrated representation of three relations, adapting a method from studies of adults’ reasoning (Ehrlich & Johnson-Laird, 1982; Foos, Smith, Sabol & Mynatt, 1976; Halford, Wilson & Phillips, 1998). In the “continuous chain” condition, infants saw, for example, A dominating B (A>B), B dominating C (B>C) and C dominating D (C>D). In the “discontinuous chain” condition, infants were presented with the same movies but in a different order: e.g., A>B, C>D, and B>C. The test probed infants’ memory for the relation between A and B. If infants memorize three isolated relations (e.g., ‘A>B’, ‘B>C’ and ‘C>D’), the two conditions should be equally difficult. Alternatively, if infants integrate dominance relations into a single unified structure (e.g., memorizing ‘A>B>C>D’), the discontinuous chain condition should be harder, because it requires holding two independent relations in mind (‘A>B’, and ‘C>D’), and integrating them with the third relation (‘B>C’) subsequently. Conversely, in the continuous chain condition, infants can add one agent to the structure at each step (representing first ‘A>B’, then ‘A>B>C’ and finally ‘A>B>C>D’).

Method

Participants. Two groups of 24 15-month-olds participated (continuous chain condition: M = 467 days, range = 456-481 days; discontinuous chain condition: M = 468 days, range = 455-480 days).

Stimuli and Procedure. Two orders of presentation were used in the familiarization phase of the continuous chain condition: A>B, B>C, C>D for half the participants, and B>C, A>B, C>D for the other half. In the discontinuous chain condition, infants saw the same movies, except that the presentation orders of B>C and C>D were swapped. Two orders of presentation resulted from this procedure: A>B, C>D, B>C for half the participants, and C>D, A>B, B>C for the other half. Counterbalancing orders of presentation during familiarization controlled for possible combination of serial position order effects and memory interference. The test probed the memory of the relation between A and B because this relation was presented at the same time point of the familiarization in the continuous and in the discontinuous chain conditions.

Results and Discussion

Significantly more infants looked longer at the incoherent test in the continuous chain condition than in the discontinuous chain condition (19 infants out of 24 vs. 11 infants out of 24; p = .036, Fisher exact test). Planned comparisons indicated that infants looked longer at the incoherent than at the coherent test in the continuous chain condition (17.6 s (*SD* = 9.2 s) vs. 11.6 s (*SD* = 9.5 s); p = .005, Wilcoxon signed rank test), but not in the discontinuous chain condition (15.8 s (*SD* = 9.6 s) vs. 16.0 s (*SD* = 11.1 s); p = .84, Wilcoxon signed rank test, see Fig. 1). Infants' memory for the relation between A and B was better in the continuous chain condition arguably because it made it easier to integrate several dominance relations into a single structure. Having learnt about social relations, infants integrate them into structures when they can do this incrementally, relation by relation.

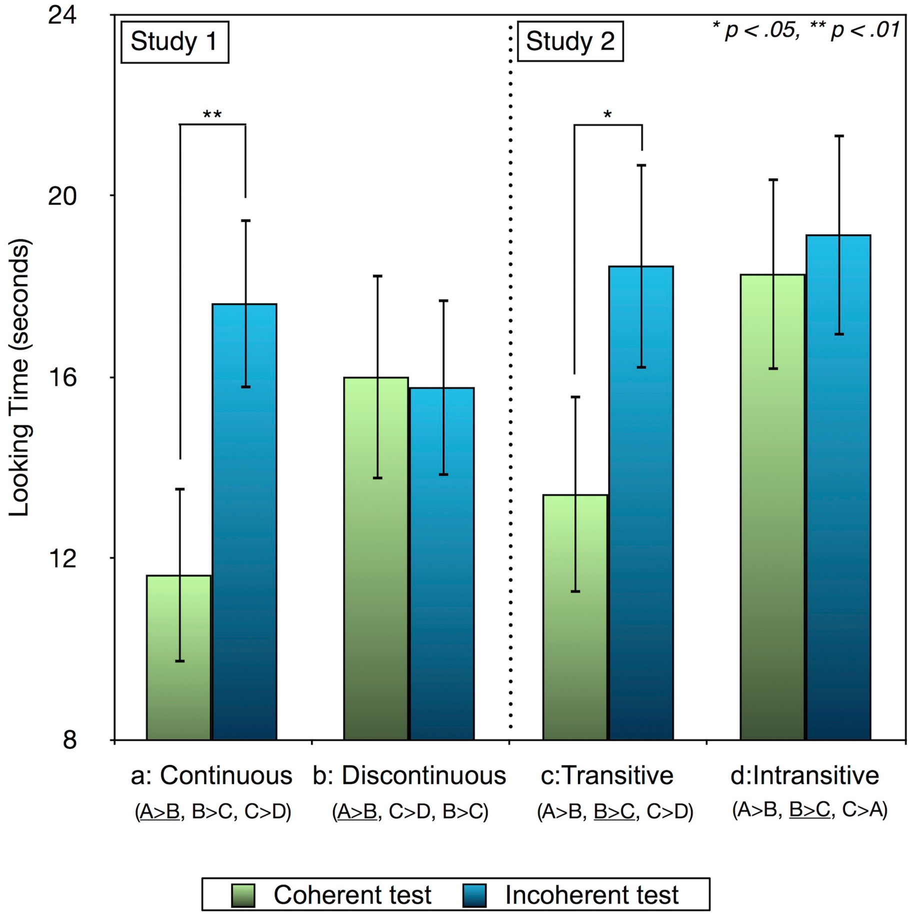

Fig 1. Mean looking times (±SEM) to test movies as a function of condition (example of dominance structure presented in familiarization in parenthesis, relation presented at test underscored).

Study 2

Study 2 investigated infants' expectations about the shape of social dominance structures. Building upon studies showing that adults find linear influence structures easier to process (De Soto, 1960; Zitek & Tiedens, 2012), we tested whether infants expect dominance structures to be linear. During the familiarization phase of the linear condition, A dominated B, B dominated C, and C dominated D. In the circular condition infants saw the same movies, except that D was replaced by A, so that dominance relations were intransitive: A dominated B, B dominated C, and C dominated A. We then assessed infants' memory for the relation between B and C. If infants find circular dominance structures less plausible, or harder to process, their recognition performance should be lower in the circular condition.

Method

Participants. Two groups of 24 15-month-olds participated (linear condition: *M* = 471 days, range = 454-483 days; circular condition: *M* = 468 days, range = 455-483 days).

Stimuli and Procedure. In the linear condition two orders of presentation were used: A>B, B>C, C>D for half of participants, and B>C, C>D, A>B for the other half of participants. In the circular condition, infants saw the same movies in the same order, but D was replaced by A. Infants' memory for the relation between B and C was probed in the test of the two conditions. B and C were both subordinate and dominant an equal number of times in the familiarization. Thus, recognizing the relation between these two agents was not possible by tracking which agent garnered more attention during the whole series of familiarization movies, by assessing which character was more likely to be a "pusher" or a "pushee", or by tracking which agent was the most dominant of all.

Results and Discussion

Infants looked significantly longer at the end of the last familiarization movie when transitivity was violated (in the circular condition) than when it was not violated (in the linear condition) (9.18 s (SD = 1.50 s) vs. 7.36 s (SD = 2.63 s); p = .012, Mann-Whitney U test, see also further analyses in the SOM). The number of infants looking longer at the incoherent test tended to be higher in the linear than in the cicular condition (18 infants out of 24 vs. 11

infants out of 24; $p = .075$, Fisher exact test). Planned comparisons indicated that infants looked longer at incoherent tests in the linear condition (18.45 s (SD = 11.14) vs. 13.41 s (SD = 10.68); $p = .032$, Wilcoxon signed rank test) but not in the circular condition (19.14 s (SD = 10.94) vs. 18.27 s (SD = 10.4); $p = .84$, Wilcoxon signed rank test, see Fig. 1)[1]. The significantly different looking behaviours observed accross conditions suggest that infants find circular dominance structures less plausible or harder to process than linear ones. Infants thus have expectations about the configuration of dominance structures. Provided that these expectations are correct, they would facilitate infants' identification of dominance structures.

In Study 2, 15-month-olds displayed sensitivity to the intransitivity of dominance relations by rejecting circular structures. Yet, in Mascaro and Csibra (2012), we found no evidence of transitive inferences on dominance relations in infants. In that study, 15-month-olds observed A dominating B, and B dominating C in one context during familiarization. They expected these two relations to be maintained in a novel context. Yet, there was no evidence that infants formed an expectation about the relationship between A and C in this same novel context. This discrepancy can be explained in two ways. First, in Study 2 the relations that served as potential premises (A>B, and B>C) and the relation violating transitivity (C>A) were presented in the same context (in which agents competed to occupy an area). Conversely, in Mascaro and Csibra (2012), the relation violating transitivity was presented in a novel context, thus requiring infants both to draw a transitive inference and to generalize their expectation accross contexts. Second, it is also possible that infants have expectations about, or representational constraints on, the shape of dominance structures

[1] Looking times at test in the discontinuous chain and in the circular conditions, in which one may assume that infants have low expectations about whom would prevail, were relatively long. They were not unlike the looking times in the unexpected test trials in the continuous chain and linear conditions. Subsequently, in our studies, looking time differences could be driven more by facilitated processing of expected events in coherent tests than by violation-of-expectation in incoherent tests.

without actively drawing transitive inferences. This would explain why, when they witness A dominating B, and B dominating C, infants display no expectations about the relation between A and C (Mascaro & Csibra, 2012), but find circular structures harder to process or less plausible (in Study 2).

Infants' sensitivity to transitivity evidenced here is much more precocious than in studies of domain-general reasoning, which found no evidence of transitive reasoning before four years (Bryant & Trabasso, 1971; Piaget, 1947; Wright, 2012). This difference could come (i) from the fact that, in our study, infants' memory, and not active inferences, were tested, (ii) from the use of a different method (looking time as opposed to explicit questions), or (iii) from earlier development of sensitivity to transitivity in the social dominance domain compared to other domains (for a similar discrepancy in the preference recognition domain, see Mou, Province & Luo, 2010).

Conclusion

Children participate in social dominance hierarchies from an early age (Caplan et al., 1991; Hawley, 1999). Our findings demonstrate that infants also represent dominance structures using two heuristics: They combine representations of several dyadic relations, and they have expectations about the shape of the resulting structures. Importantly, our data do not establish whether the mechanisms underpinning infants' representations of structures are domain-general or specific to social dominance (for similar issues see, Grosenick et al., 2007; Paz-y-Miño et al., 2004). In particular, future research should investigate the relation between infants' capacity to represent dominance structures, and mechanisms supporting representations of "more" and "less" in domains such as number, size, or duration (Brannon, 2002; Fiske, 2004; Lourenco & Longo, 2011).

Interestingly, dimensions organized on ordered scales, such as number, typically show symbolic distancing effects, so that elements that are farther away on the scale are more easily discriminated (Libertus & Brannon, 2009). Infants' representations of dominance structures have shown the opposite effect. After witnessing A dominating B, and B dominating C, infants were less certain about the relation between A and C than about the relation between A and B, or between B and C (Mascaro & Csibra, 2012). Thus, infants may not represent dominance structures on an ordered scale (e.g., on a line). A directed graph (i.e., a network in which nodes represent agents, and edges represent asymmetric relations of dominance) may be a better analog of infants' representations of dominance structures. This representational format would be more flexible than an ordered scale. For example, it would allow representing incomplete structures, in which not all individuals are related by dominance relations, such as despotic structures, in which one alpha agent dominates all other individuals, but subordinates do not have defined dominance relations.

Our findings are consistent with the proposal of early development of a 'naïve sociology' involving conceptual representations of social entities (Kinzler & Spelke, 2007; Mascaro & Csibra, 2012; Platten, Hernik, Fonagy & Fearon, 2010; Thomsen & Carey, 2013). We found two signatures of the representation of social structures. First, infants' representations of structures could not be reduced to a set of isolated representations of dyadic relations. Second, infants expected dominance structures to have properties that none of the individual dominance relationships can possess, such as linearity. Combining simple elements into more complex patterned structures is crucial in domains as diverse as language, action planning, or scientific discovery. This capacity is evidenced early in the social domain.

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