Supporting Information

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SI Materials and Methods

Study 1. ***Participants.*** In addition to the 32 infants reported in the paper, 10 additional infants were excluded from analyses (six 9-mo-olds and four 12-mo-olds) because of fussiness (five infants), inattentiveness (two infants), parental interference (one infant), or experimental error (two infants).

Stimuli and procedure. The same testing apparatus was used in studies 1, 2, 3, and 4. Infants were tested in a dimly lit soundproof room. They were seated on a parent's lap 100 cm from a 40-inch LCD monitor on which the stimuli were presented, except 9-mo-olds, who were placed 70 cm away from the monitor. A hidden camera mounted under the screen recorded infants' looking behavior at 25 frames per second temporal resolution.

In the familiarization of study 1, the paths followed by the two agents in contact with the objects were mirror images of each other (one agent displaced objects from the center to the left side of the screen, and the other displaced objects from the center to the right side of the screen). The amount of time spent in contact with the objects was also the same for the two agents. Whether the subordinate agent was occupying the right or on the left side of the screen was counterbalanced within subjects.

Two combinations of agents, object kinds, and backgrounds were used to present each child with a coherent sequence (a familiarization followed by a coherent test), and with an incoherent sequence (a familiarization followed by an incoherent test). In one combination, a blue disk and a red triangle interacted on a green and gray background. They collected white spheres during the familiarization and rainbow-colored cubes during the test. In the other combination, a purple star and a yellow square interacted on a brown and blue background. They collected green pentagons during the familiarization and orange discs during the test. To alleviate children's boredom, the overall scene was taking place at a different height on the screen in each combination. Each infant saw two series of movies: one familiarization followed by a coherent movie in which one of the combination of agent/object/background was used, and a second familiarization followed by an incoherent movie in which the other combination of agents/objects/background was used. Each combination of agent/object/background was used one-half of the time for coherent movies, and one-half of the time for incoherent movies. Whether one combination was presented first to the child was counterbalanced across subjects. All geometrical agents were dominant an equal number of time.

Coding and data analysis. Coding and data analysis procedures were the same for all studies. We analyzed frame-by-frame whether the infants looked at the screen or looked away. Blinks were considered as looks away if they lasted for >0.2 s. To be included in the final data analysis, infants had to look at least at 70% of the test movie. During the test, they also had to look at the screen when one of the agents made contact with the last object (i.e., when the conflict between the agents' goals was resolved). Infants who did not fulfill these two criteria were considered "inattentive" and were not included in data analysis. Looking times were measured from the moment one of the agents made contact with the last object, up to the moment the infant looked away for >2 s or after 40 s elapsed after the end of the agents' movement. The recording was first entirely coded by the first author. Then for each group, and each study, one-half of the data was randomly selected and recoded by a second coder unaware of the hypothesis of the study (average r = 0.98, range = 0.96–1, all P values $<5.10e^{-9}$). For all doubled-coded measures, when the difference between the values from the first and the second coder exceeded 10% of the value from the first coder, the discrepancy was resolved by discussion. The resulting descriptive statistics for studies 1–4 are reported in Table S1.

Study 2. ***Participants.*** Eleven infants were excluded (four 12-mo-olds, and seven 15-mo-olds) because of fussiness (six infants), parental interference (four infants), or experimental error (one infant).

Stimuli and procedure. As in study 1, children were presented with a coherent sequence (a familiarization followed by a coherent test), and with an incoherent sequence (a familiarization followed by an incoherent test) (order of presentation counterbalanced across subjects). For each sequence, a different combination of agents, object kinds, and backgrounds was used. The combinations of agent/object/background used in study 2 were similar to the ones of study 1, counterbalanced in the same manner.

Study 3. ***Participants.*** Eleven additional infants were excluded (six 12-mo-olds, and five 15-mo-olds) because of fussiness (four infants), inattentiveness (three infants), experimental error (three infants), and because one infant jumped from her mothers' lap to the ground during the experiment (one infant).

Stimuli and procedure. The stimuli were built by taking the movies of studies 1 and 2 and replacing the subordinate agent in the familiarization by a new geometrical shape. For the red triangle/blue disk pair of agents, the subordinate agent of the familiarization was replaced by a black pentagon. For the purple star/yellow square pair of agents, the subordinate agent of the familiarization was replaced by a turquoise oval. All other aspects of stimuli and the design remained identical to what was used in study 1 and study 2.

Study 4. ***Participants.*** Post hoc analyses confirmed that the slight age difference between the two groups of infants who were used for the analysis was not significant [$t_{(30)}$ = 1.67, P = 0.1]. Fifteen additional infants were excluded (seven in the familiar pair condition, and eight in the novel pair condition) because of fussiness (10 infants), drowsiness (one infant), parental interference (three infants), or experimental error (one infant).

Stimuli and procedure. Children saw two relations demonstrated in the familiarization (A was subordinate to B, and B was subordinate to C). Then, in the test of the familiar pair condition, two agents who interacted during familiarization (A and B, or B and C) competed to get an object. In the test of the novel pair condition, the agents who competed to get the object never interacted before (A and C). However, the test movies were exactly the same in the familiar pair condition and in the novel pair condition. This result was achieved by taking the familiarization movies used in the familiar pair condition and by substituting the shapes of the agent who interacted with the two other ones (B) with the shape of an agent who interacted only once (A or C). For example, in one of the tests, a blue ball and a red triangle competed to get an object. In the familiarization of the familiar pair condition associated to that test, children saw the blue ball interacting with the red triangle, and the red triangle interacting with a black pentagon. In the familiarization of the novel pair condition associated to that test, children saw the blue ball interacting with the black pentagon, and the black pentagon interacting with the red triangle.

SI Discussion

The format of a representation has computational consequences. First, it determines what kind of manipulations can be performed on a set of representations, how they can be performed, and with how much resources. As famously illustrated by Marr (1), it is easy to determine whether an Arabic number is a power of 10, e.g., by using a simple manipulation such as looking at whether the number is a "1" followed or preceded only by zeros. The same manipulation cannot be used for binary numbers and, as a result, determining whether a binary number is a power of 10 is arguably more computationally demanding. The same holds for the representation of social dominance. Take the evaluation of the relation between A and C, from knowing that A is subordinate to B and that B is subordinate to C. If dominance is represented as an individual property on an ordered scale, determining this relation comes for free: Once one has determined that individual A is lower than B on the scale, and that B is lower than C and the scale, then A is necessarily lower than C on the scale. Such a conclusion does not require any extra cognitive processes than those used to place A lower than B, and B lower than C on the scale. The representation of dominance as dyadic relations, however, predicts a different pattern. In that case, determining the relation between A and C requires an extra inferential step: computing the relation between A and C, on the basis of the relation between A and B, and B and C, by the assumption of transitivity.

Second, each representational format can only represent a given class of contents. Take, for example, a numeral system with only four symbols that correspond to "0," "1," "2," and "3" in the Arabic numeral system and without rules to combine numerals to represent bigger numbers. The numerosity of a set of 5 can never be represented in this—fictitious—numeral system. In a similar manner, it is impossible to represent dominance relations that are not transitive if dominance is represented on an ordered scale.

As a result, the representational format of dominance brings some empirical implications with it. If infants represent dominance on an ordered scale, they cannot establish that A's rank is lower than B's rank, and that B's rank is lower than C's rank, without establishing that A's rank is lower than C's rank. This hypothesis predicts that infants' expectations in study 4 should be as strong, or stronger, when A faces C (novel pair condition), than when A faces B, or B faces C (familiar pair condition). This hypothesis is falsified by our data. Alternatively, infants may build something akin to ordered scales, but without placing more than two individual's ranks on a scale. In this view, it would possible to build small, two-slot scales on the basis of which agents' levels of dominance could be compared, two-by-two. Crucially, for each pair of agent, infants would have to build a new scale, and the values on one scale would not be comparable the values on another scale. We believe that such two-slot scales would not be very different from what we describe as a social relation.

If dominance is represented as a relation, the evaluation of the relation between agents A and C, on the basis of the known relations between A and B, and B and C, is possible if (*i*) dominance relations are assumed to be transitive, and (*ii*) infants are capable and motivated to draw transitive inferences. Our results do not tell us why infants failed to evaluate the relation between the two agents that they had not seen together before in study 4. Thus, we cannot claim anything about infants' capability to draw transitive inferences. Our argument simply is that study 4 reveals that infants do not represent dominance by an ordered scale because it would necessarily lead them to evaluate the relation between A and C without engaging in further computations.

SI Additional Experimental Attempts

In the interest of researchers who would like to follow-up on this research, or are interested in the limits of infants' abilities, here we provide short descriptions of some experimental attempts that did not seem to produce positive results. The interested reader may contact the authors for more details.

At the end of study 1, we performed looking preference measures for the dominant and subordinate agents to investigate a potential discrepancy in the social attention given to the dominant agent (2–4). These measures did not give any interpretable pattern of results.

In an earlier attempt at testing infants' processing of dominance as a relationship, we used a scenario involving four agents (A, B, C, and D), displaying two relations (e.g., A was dominant over B, and C was dominant over D). The original plan was to test whether infants have stronger expectations when A faces B again (an agent that was subordinate of A before), than when A faces D (an agent that was subordinate before, but when facing C, not A). To do so, however, we first had to make sure that children recognized and remembered the two relations that were evidenced during familiarization. In this version, however, a pretest indicated that 15-mo-olds did not have expectations, even for the relations that they observed before (e.g., A versus B). We speculate that in this case, infants' difficulties might have arisen from the high number of agents that they had to track.

In an earlier attempt at probing infants' capacity to perform transitive inferences, we attempted to contrast two cues: body size and success in competitive contexts. We showed a small agent (A) prevailing against a big agent (B). Then, in the test, the same small agent either prevailed or deferred when facing a second small agent (C). We reasoned that infants might establish that the first small agent (A) was dominant over the big agent (B), because he prevailed when their goals where conflicting. Moreover, we speculated that infants might expect the big agent (B) to be dominant over the new small agent present during the test (C), because of their size difference (5). Using these two cues, children could have established that A was dominant over B, and that B was dominant over C. In the test, if children had expected A to be dominant over C, this result could have been taken as evidence for a transitive inference. However, in the pretest using this procedure, 15-mo-olds appeared to react at chance at the test movies.

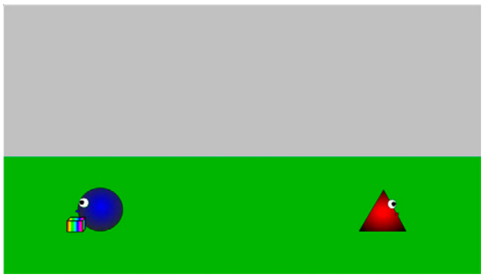
1. Marr D (2010) *Vision: A Computational Investigation into the Human Representation and Processing of Visual Information* (MIT Press, Cambridge, MA).
2. Chance MRA (1967) Attention structure as the basis of primate rank orders. *Man (Lond)* 2:503–518.
3. Abramovitch R (1976) *The Social Structure of Attention*, eds Chance MRA, Larsen RR (John Wiley & Sons, London), pp 153–176.
4. Henrich J, Gil-White FJ (2001) The evolution of prestige: Freely conferred deference as a mechanism for enhancing the benefits of cultural transmission. *Evol Hum Behav* 22: 165–196.
5. Thomsen L, Frankenhuis WE, Ingold-Smith MC, Carey S (2011) Big and mighty: Preverbal infants mentally represent social dominance. *Science* 331:477–480.

Table S1. Mean looking time and SD before and after log-transformation per group and per study

		Looking time, s				Log-transformed looking time			
		Coherent test		Incoherent test		Coherent test		Incoherent test	
Study	Parameter	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	9 mo	19.95	10.25	17.98	12.35	1.23	0.29	1.13	0.39
	12 mo	9.67	10.32	14.00	9.50	0.78	0.43	1.06	0.29
2	12 mo	13.48	8.76	14.84	11.13	1.02	0.36	1.04	0.37
	15 mo	12.66	8.48	19.47	10.17	0.99	0.34	1.23	0.25
3	12 mo	15.50	12.17	13.37	9.24	1.11	0.37	0.93	0.37
	15 mo	16.11	10.62	15.70	9.06	1.12	0.29	1.01	0.34
4	Familiar pair	15.52	9.52	22.21	10.99	1.10	0.31	1.28	0.26
	Novel pair	16.76	8.43	16.20	9.60	1.16	0.27	1.12	0.31

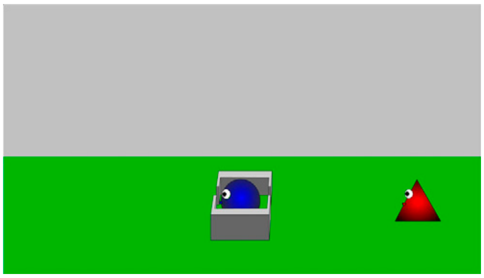
Movie S1. Familiarization of study 1 (example).

Movie S1



Movie S2. Test of all studies (example).

Movie S2

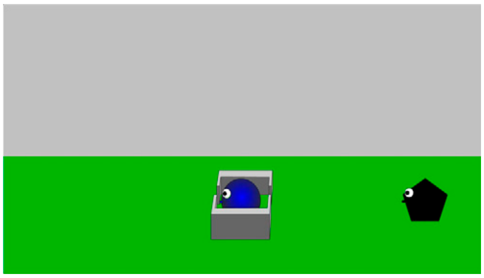


Movie S3. Familiarization of study 2 (example).

Movie S3

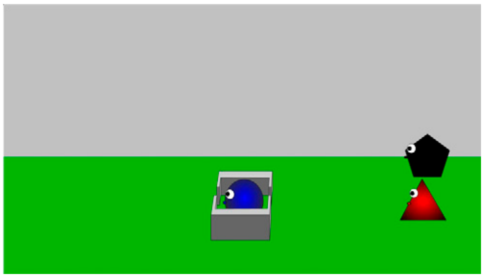
Movie S4. Familiarization of study 3 for 12-mo-olds (example).

Movie S4



Movie S5. Familiarization of study 3 for 15-mo-olds (example).

Movie S5



Movie S6. Familiarization of study 4 (example).

Movie S6