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Toddlers prefer those who win but not when they win by force

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Social hierarchies occur across human societies, so all humans must navigate them. Infants can detect when one individual outranks another[1–3], but it is unknown whether they approach others based on their social status. This paper presents a series of seven experiments investigating whether toddlers prefer high- or low-ranking individuals. Toddlers aged 21–31 months watched a zero-sum, right-of-way conflict between two puppets, in which one puppet 'won' because the other yielded the way. Of the 23 toddlers who participated, 20 reached for the puppet that 'won'. However, when one puppet used force and knocked the other puppet down in order to win, 18 out of 22 toddlers reached for the puppet that 'lost'. Five follow-up experiments ruled out alternative explanations for these results. The findings suggest that humans, from a very early age, not only recognize relative status but also incorporate status into their decisions about whether to approach or avoid others, in a way that differs from our nearest primate relatives[4].

Human are born into a complex social world, which we must learn to navigate. This world includes hierarchical relationships, where people are ranked along some dimension such as age, wealth, prestige or authority[5–9]. Such hierarchies are found across human societies and across social settings (for example, domestic, recreational and professional)[7,10]. Hierarchies are also found in non-human species as varied as orangutans, ants, wolves, bees and cuttlefish, where individuals are ranked according to size and strength[7,11–15]. Across these contexts, an individual's status has consequences: higher status means more access to resources, territory and mates[7,16,17]. Thus, individuals who can recognize and respond to status cues have an advantage over those who cannot[18].

Theorists have distinguished between two types of social hierarchy: one type based on dominance and another based on prestige or authority[7–9,17,19–23]. In dominance-based hierarchies (found in many non-human primates as well as a range of other species) status comes from one's ability to inflict physical harm on others. Rank in these hierarchies comes from individual formidability (for example, being larger or more powerful) or from being allied with a more-formidable group (that is, having allies who are more numerous, larger or more powerful)[17,24,25]. In human social groups, people can also attain social status through prestige, which does not come from physical threats, but from the ability to provide benefits such as cultural know-how, protection or guidance[5,9,20].

Theorists do not agree on the extent to which human social rank derives from either dominance or prestige. However, one reliable cue to status across these hierarchical relationships occurs where two individuals have a conflict and only one can win (that is, a zero-sum conflict), and the conflict is resolved because one individual defers or yields to the other[7,26]. Yielding and deference are signals of rank in both dominance- and prestige-based hierarchies. When status derives from dominance, less formidable individuals and groups yield to more formidable foes in zero-sum conflicts to avoid getting hurt. Over many such interactions, relative status stabilizes: some individuals routinely claim contested food, territory and mates, and others routinely yield[7,12,27]. Thus, yielding becomes a stable signal of lower social status[13,28,29].

In prestige-based hierarchies, deference also signals relative status. Here, lower-status individuals yield, not because they are afraid of being hurt, but because they want to form or maintain relationships with people who have more authority, competence or knowledge[5,7,9,20,30]. For example, if a graduate student and their adviser wanted the same office, we would expect the graduate student to step aside (that is, to yield the resource) not because they would fear retaliation in the physical sense, but because we expect students to defer to their advisers in return for the guidance they receive. Of course, the graduate student might also be afraid that the adviser would withhold resources such as grant money, letters of recommendation and so on. In this way, human hierarchies often contain elements of both dominance and prestige[7,20,31]. And indeed, in laboratory experiments with adults, dominance and prestige are both ways that humans can attain social influence in a group[32]. Thus, whether human hierarchies are based on prestige, dominance or some combination of the two, the way that people act in conflicts is a reliable cue to their social status. Specifically, when one individual voluntarily yields to another, it signals that the two are in a hierarchical relationship and that the yielding individual is ranked lower.

Even preverbal infants make inferences about social status when they see one individual yield to another. In fact, infants use several formidability cues to predict who will yield in a zero-sum conflict. Infants 9–13 months of age expect smaller individuals to yield: when they watch two animated characters try to cross a platform in opposite directions, each blocking the other's path, they look longer (presumably indicating surprise) when the larger character yields to the smaller one than when the smaller yields to the larger[1]. In a similar setup, 6–9-month-old infants expect a character with fewer allies (that is, fewer same-coloured characters on its side) to yield to a character with more allies[2]. Moreover, older infants seem to expect that individuals who have lost one zero-sum conflict will keep losing: after 15-month-olds watch a scene where one individual pushes another out of a territory, they expect that in a subsequent scene, the individual who was pushed out will yield a contested resource to

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the 'pusher'[3]. By 17 months old, toddlers expect that a high-ranking individual will be given more resources[33]. Likewise, preschoolers respect social rank when interacting with novel individuals: they give a larger cookie to a higher-status individual (that is, the person who has made a decision for the pair)[34]. Preschoolers also endorse the testimony of someone who previously won a zero-sum conflict over one who deferred[35].

This literature suggests that infants and young children can infer and even reason about the relative social status of two individuals. But children must also form relationships. In the current studies we asked whether toddlers, having watched one novel individual yield to another, will then approach either the individual who yielded or the one who did not.

A priori, either is plausible. The deference shown by preschool-aged children in earlier studies (accepting that the boss is right, or giving the larger resource to a high-ranking individual[34,35]) could reflect a fear of high-ranking individuals, which might lead us to expect toddlers to avoid them. And indeed, studies with adults have found that people will sometimes go along with the wishes of a dominant individual whom they fear[32]. In many species including non-human primates, subordinates avoid or withdraw from dominant individuals, who may commit acts of unprovoked aggression[20,36–38]. Indeed, in some species, being able to avoid dominant individuals is associated with lower stress levels[15]. Consistent with this, preverbal infants avoid individuals who are aggressive towards others[39] and also avoid individuals who hinder others in achieving their goals[40]. Thus, if toddlers see the higher-ranking individual as potentially aggressive, they may wish to avoid it.

Conversely, one can imagine reasons why toddlers might prefer high-ranking individuals. In human societies, affiliations with high-ranking individuals can provide benefits such as coalitional strength and access to resources, including cultural knowledge. Several non-human primate species prefer dominant individuals as coalitional partners[4,41–43]. Adult bonobos prefer even novel dominant individuals: in experiments modelled on helping/hindering studies with human infants, bonobos prefer animated characters who push others out of a contested territory, and prefer characters who hinder over those who help (presumably because the hinderers are seen as dominant)[4]. Likewise, baboons compete for more dominant allies[23] and when macaques form alliances, they consistently choose allies who outrank themselves and their opponents[44]. Macaques will also pay (in fruit juice) to look at pictures of higher-ranking male macaques[45], just as adult humans prefer to look at high-ranking humans[46].

Like non-human primates, human toddlers may be motivated to approach high-status individuals to form beneficial relationships. Consistent with this, studies have shown that toddlers identify and prefer competent individuals. In one experiment, toddlers were shown a puppet who struggled to make a toy play music and another puppet who did it easily. When asked who they wanted to play with, they preferred the puppet who operated the toy easily[47]. This could reflect a preference for prestigious individuals or it could reflect a preference for individuals who can produce a desirable outcome (that is, perhaps the toddlers just liked hearing music, and so preferred the puppet who could readily produce it).

In the present study, we asked whether toddlers aged 21–31 months evaluate novel individuals by their social status and if so, whether they prefer higher-or lower-ranking individuals. We looked for this preference by showing toddlers a conflict in which one individual wins and the other loses. In one version of this conflict (explored in experiments 1.0 to 1.4), the loser voluntarily yields to the winner. In another version (experiments 2.0 and 2.1), the contest is won by force. Experiments 1.0 and 2.0 test the basic vignettes; the other experiments are follow-up studies that rule out alternative explanations.

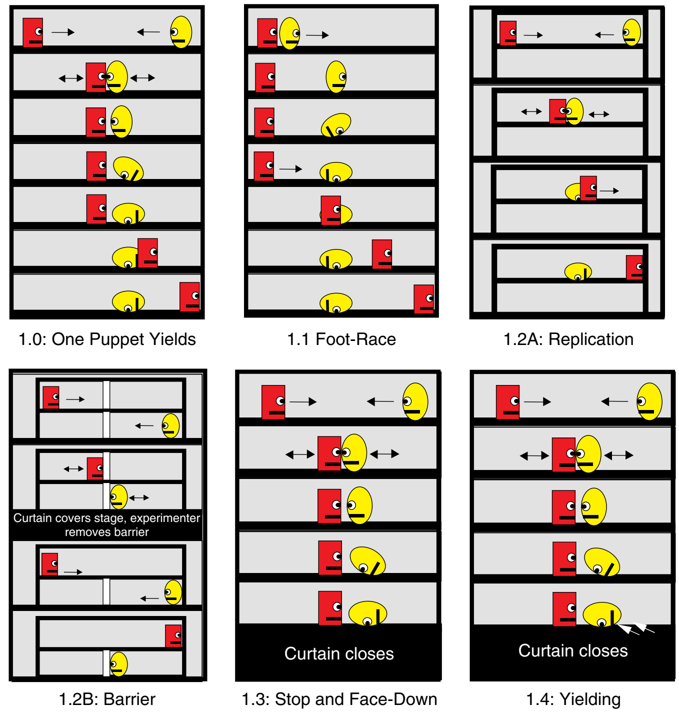

Fig. 1 | Diagrams depicting the 'action phase' of each puppet show used in experiments 1.0 to 1.4. Experiment 1.0: One Puppet Yields to the Other. Experiment 1.1: Foot-Race Follow-Up. Experiment 1.2A: Two-Level Replication. Experiment 1.2B: Barrier Follow-Up. Experiment 1.3: Stop-and-Face-Down Follow-Up. Experiment 1.4: Yielding Follow-Up. In each panel, the top depicts the beginning of the sequence and the bottom depicts the end of the sequence.

In experiment 1, toddlers watched a vignette that was closely modelled after animations used in previous studies; it featured two puppets in a zero-sum-conflict[1,2]. The vignette began with a familiarization phase: first, one puppet crossed the stage alone. Then the action was repeated: the same puppet crossed the stage again, going the same direction as before. Then the second puppet appeared. This puppet crossed the stage twice going the opposite direction. The purpose of this familiarization phase was to show that the puppets had opposing goals: they each wanted to cross the stage in opposite directions.

After the familiarization phase came the action phase: the two puppets appeared simultaneously on opposite sides of the stage and tried to cross at the same time, stopping at centre stage when they bumped into each other. Both puppets then backed up and tried to cross again, bumping again in the middle. This sequence was repeated five times. Finally, the puppets approached one another but stopped before meeting and one puppet yielded the way by rotating downwards (so that its eye faced the ground) and moving aside. The other puppet passed in front of the downward-facing puppet and continued on across the stage (see Fig. 1, experiment 1.0). This entire action phase was repeated three times. See https://osf.io/km5by/ for videos of this and all other vignettes described in this paper.

After the vignette was completed came the test question: an experimenter (who did not know which puppet had yielded during the vignette) presented both puppets to the child on a board and asked, "Which one do you like?". The dependent measure was which puppet the child reached for[40] (see Fig. 2). Parents were asked to close their eyes during this procedure.

Of the 23 toddlers who contributed data to the analysis, 20 reached for the puppet that continued across the stage (presumably seen as the winner or higher-status puppet, two-tailed binomial test $P<0.001$; 95% confidence interval (CI)= 0.664–0.977; probability of success = 0.869). The Bayes factor was 197.36 in favour of the hypothesis that toddlers chose the non-yielding puppet either more or less than 50% of the time (see Fig. 4). This is decisive evidence[48] that the toddlers preferred the winner. Data from this and all experiments are available at https://osf.io/km5by/.

The purpose of experiment 1.1 (Foot-Race Follow-Up) was to test a number of alternative explanations for why toddlers might have liked the non-yielding puppet (that is, the 'winner') in experiment 1.0. One explanation might be that toddlers prefer a puppet that reaches its goal over one that fails to do so, independent of social status. Another explanation might be that toddlers might have preferred the non-yielding puppet for some reason unrelated to social hierarchy—for example, because it moved further or moved last, because it remained visible throughout the vignette (whereas the yielding puppet was briefly occluded when the winner passed it by) or because it moved the same way during the action phase as it did during the familiarization phase—remaining upright and travelling all the way across the stage in both phases of the vignette.

In the Foot-Race Follow-Up, toddlers watched a scene where the puppets moved across the stage as in experiment 1.0, but without any social interaction. First, the familiarization phase: each puppet crossed the stage twice, alone. But unlike in experiment 1.0, both puppets travelled in the same direction. Next came the action phase: both puppets appeared together at one side of the stage. One puppet travelled halfway across the stage and stopped, rotated downwards and moved aside, just like the yielding puppet in experiment 1.0. Then the second puppet came from behind the first, passed in front of the prostrate puppet and continued on across the stage. Thus, the vignette included the same puppet movements as experiment 1.0; but without any social conflict (see Fig. 1, experiment 1.1).

Of the 24 toddlers who contributed data to this analysis, 12 chose the puppet that stayed upright and completed its journey across the stage (two-tailed binomial test $P=1.0$; 95% CI= 0.291–0.709; probability of success = 0.5). The Bayes factor was 4.02 in favour of the hypothesis that toddlers chose the non-yielding puppet 50% of the time. This is considered strong evidence in favour of a single-point null hypothesis—in this case, that participants chose each puppet 50% of the time. In other words, toddlers showed no preference for the puppet that continued across the stage in this vignette, even though like the 'winning' puppet in experiment 1.0, it (1) completed its goal of crossing the stage whereas the other puppet did not; (2) remained visible the whole time; (3) remained upright the whole time; (4) travelled further than the other puppet; (5) moved last; and (6) moved in the same way (same path and posture) in the action phase as it had during the familiarization phase (see Fig. 4). Thus, experiment 1.1 provides positive evidence that none of these low-level factors explain the findings of experiment 1.0, and also that toddlers do not necessarily prefer a puppet just because it achieves its goal of crossing the stage.

The purpose of experiments 1.2A and 1.2B was to further probe the possibility that toddlers liked the winner in experiment 1.0 because it seemed more competent in achieving its goal of crossing the stage than the loser did. Although the Foot-Race Follow-Up also tested this idea, we reasoned that in the Foot-Race Follow-Up, toddlers might have thought one puppet simply decided to stop halfway across the stage. In other words, they might see the downward-facing puppet as having adopted a new goal, rather than failing to achieve its old one. If so, then it could still be the case that toddlers prefer agents who achieve their goals. Toddlers may not have shown a preference for either puppet in experiment 1.1 because they thought that both puppets achieved their goals: one achieved its longstanding goal of crossing the stage and the other achieved its new goal of stopping halfway. To test this, in experiment 1.2B (the Barrier Follow-Up) we used a stage with two levels—one above the other, like bookshelves. The two puppets performed the same movements as in experiment 1.0, but on different levels. Instead of running into each other at centre stage, each puppet ran into a barrier. Because experiment 1.0 had not taken place on a two-level stage, we first replicated the original findings on the new, two-level stage in experiment 1.2A.

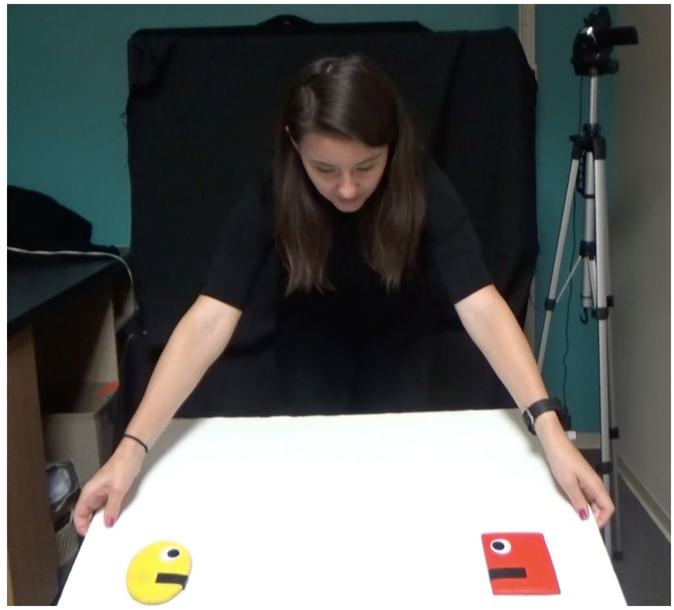

Fig. 2 | Choice procedure used in all experiments. The experimenter said, "Hi! Look!", then held the board so the infant could see the puppets, fixed her gaze in the centre of the board and asked, "Which one do you like?" before holding out the board towards the infant.

Toddlers were assigned to one of two conditions: condition A replicated of experiment 1.0, with all the action occurring on either the upper or the lower stage (see Fig. 1, experiment 1.2A). In condition B, the puppets moved as they had in experiment 1.0, but on different levels—one puppet above, the other below. In the condition B familiarization phase, each puppet crossed the stage alone twice, on either the top or bottom level. In the action phase, barriers appeared on stage and the puppets approached and retreated from the barriers, mimicking the movements in experiment 1.0, to show that the barriers were obstructing them. Then the curtains closed again and re-opened to show only one barrier remaining, on either the upper or the lower stage, allowing only one puppet to continue across the stage (see Fig. 1, experiment 1.2B).

Of 38 toddlers who contributed data to this analysis, 19 were assigned to condition A (the replication) and 19 were assigned to condition B (the Barrier Follow-Up). Results from the replication matched those of experiment 1.0, with 16 of 19 toddlers choosing the non-yielding or 'winner' puppet (two-tailed binomial test $P=0.004$; 95% CI=0.604–0.966; probability of success = 0.842). The Bayes factor was 27.05, considered strong evidence in favour of the hypothesis that toddlers chose the non-yielding puppet either more or less than 50% of the time. In contrast, in the barrier condition, only 9 of the 19 toddlers chose the puppet that crossed the stage and thus achieved its goal (two-tailed binomial test $P=1.0$; 95% CI= 0.244–0.711; probability of success = 0.474.) The Bayes factor was 3.52, considered moderate evidence in favour of the single-point hypothesis that children chose both puppets equally.

Children in the Barrier Follow-Up were significantly less likely to choose the puppet that reached its goal than children in the replication condition ($\chi^2(1)=4.51$, $P=0.034$; $r=0.34$, which is the square root of the chi-square statistic (4.51) divided by $N=38$; Bayes factor = 3.46 in favour of the hypothesis that the two conditions differed). Thus, toddlers' preference for the individual who did not yield in experiment 1.0 cannot be explained by a general preference for individuals who complete their goals over ones that do not.

Experiments 1.0, 1.1 and 1.2 demonstrated that toddlers like an individual who prevails in a conflict better than an individual who yields and this is not just a preference for any individual who reaches their goal. In experiment 1.3 (Stop-and-Face-Down Follow-Up), we asked whether toddler's preference for a winner (shown in experiments 1.0 and 1.2A) is elicited as soon as one of the puppets rotates downwards to face the floor—a motion that was meant to look like the prostrations or bows practiced in many human cultures[5,49]. For this experiment, toddlers watched a vignette similar to the one in experiment 1.0, except that it ended after one puppet rotated downwards to face the ground. This replicated the first part of the yielding gesture made in experiment 1.0. The scene ended before the puppet made the second part of that gesture, which was to move aside, yielding the way for the other puppet to cross the stage. In this follow-up experiment, the upright puppet never crossed the stage, but simply stayed standing where it was, with the other puppet prostrated before it, until the curtain closed (see Fig. 1, experiement 1.3).

Of 24 toddlers who contributed data to this analysis, 10 chose the puppet that stayed upright, suggesting that toddlers liked both puppets equally (two-tailed binomial test $P=0.543$; 95% CI= 0.221–0.633; probability of success = 0.417). The Bayes factor was 2.92, which is moderate evidence in favour of the single-point null hypothesis that toddlers chose each puppet half of the time. Thus, the preference shown in experiments 1.0 and 1.2A was not elicited when one puppet merely prostrated downwards without yielding the way (see Fig. 4).

In experiment 1.4 (Yielding Follow-Up), we asked whether toddlers prefer the upright puppet when the other puppet did the whole yielding action (prostrating downwards and moving aside) and the vignette stopped there. Experiment 1.4 was like experiment 1.3 except that after one puppet rotated downwards, it moved aside, replicating the entire yielding motion from experiments 1.0 and 1.2A. As in experiment 1.3, the upright puppet never crossed the stage, but remained standing in its place until the curtains closed (see Fig. 1, experiment 1.4).

Of the 30 toddlers who contributed to the analysis, 23 chose the upright puppet (two-tailed binomial test $P=0.0052$; 95% CI: 0.577–0.900; probability of success = 0.767.) The Bayes factor was 17.01, which is moderate evidence in favour of the hypothesis that toddlers chose the non-yielding puppet either more or less than 50% of the time. In other words, toddlers liked the puppet who was yielded to more than the puppet who yielded, even when the upright puppet did not go on to reach its goal (see Fig. 4). The results of experiments 1.0 to 1.4 thus suggest that toddlers prefer those who are yielded to in zero-sum conflicts. The preference is not explained by the fact that the upright puppet reaches its goal, nor is it elicited when one puppet 'bows' (that is, rotates downwards) without yielding the way.

Experiments 1.0 to 1.4 suggest that toddlers prefer high-status individuals, even when those individuals hinder others from achieving their goals. In experiment 2.0 (One Puppet Wins by Force), we tested whether toddlers prefer any individual who wins, or only one who is yielded to. Specifically, we tested whether toddlers prefer a winner who wins by using coercive force. In this experiment, we showed toddlers a vignette that was nearly the same as in experiment 1.0. But after the puppets reached their standoff, neither puppet yielded. Instead, one puppet physically knocked the other puppet over and out of the way before crossing in front of it to continue across the stage (see Fig. 3, experiment 2.0).

Of the 22 toddlers who contributed data to this analysis, 18 reached for the puppet who was knocked down (two-tailed binomial test, $P=0.00434$, 95% CI= 0.597–.948; probability of success = 0.818; Bayes factor = 24.93 in favour of the hypothesis that children chose one puppet more often than the other). This is found

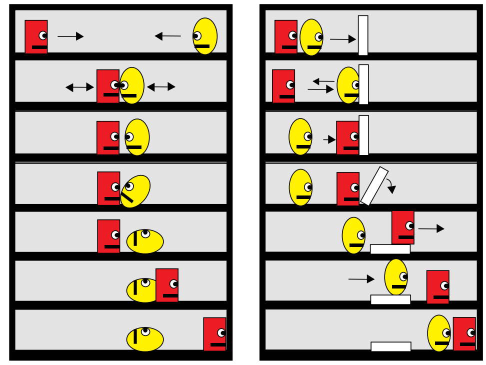

Fig. 3 | Diagrams depicting the action phase of each puppet show used in experiments 2.0 and 2.1. Experiment 2.0: One Puppet Wins by Force. Experiment 2.1: Helpful-Force Follow-Up. In each panel, the top depicts the beginning of the sequence and the bottom depicts the end of the sequence.

strong evidence that toddlers preferred the loser (who was a victim of violence) rather than the winner (who used violence to get its way). Thus, toddlers' preference for winners does not seem to extend to those who win by using force against someone else (see Fig. 4). This result is consistent with previous studies showing that younger infants avoid those who use force against others in general, or to hinder others[40,50]. It appears that toddlers care not only who wins a conflict, but also how they win. They prefer not just winners, but winners to whom others defer.

One question we had about the results of experiment 2.0 was whether toddlers might avoid the puppet who used force simply because they do not like any puppet who uses force for any reason. In other words, did the toddlers avoid the winner in experiment 2.0 because it used force at all, or specifically because it used force against another individual with whom it was in conflict? In experiment 2.1 (Helpful-Force Follow-Up), toddlers watched a vignette in which one puppet knocks over a barrier, enabling both itself and the other puppet to cross the stage. The vignette began with a familiarization stage like that of experiment 1.1, where the two puppets each crossed the stage going the same direction. Then, in the action phase, a barrier appears at centre stage. As in earlier experiments, one puppet moves across the stage until it meets the barrier, backs up and moves forwards again, only to meet the barrier again. Then (unique to this experiment), the other puppet crosses in front of the first one and knocks the barrier down, using the same 'knocking down' motion as in experiment 2.0, but with the force directed against the barrier instead of against the other puppet. Both puppets then hop over the collapsed barrier and continue on their way (see Fig. 3, experiment 2.1).

Of the 22 toddlers who contributed data to this analysis, 19 reached for the puppet who knocked the barrier down (two-sided binomial test; $P<0.001$; 95% CI = 0.651–0.971; probability of success = 0.863; Bayes factor = 118 in favour of the alternative hypothesis that toddlers were choosing one of the puppets more than 50% of the time). This is strong evidence that toddlers do not automatically avoid a puppet just because it knocks something down. In fact, they showed a strong preference for the puppet who used force in a helpful way, to knock over a barrier (see Fig. 4). This is consistent with previous work showing that infants prefer those who use force to help others[40].

This series of experiments showed that toddlers prefer puppets who are yielded to by others, and that this preference is not simply for winners over losers: they care not only about who wins, but also about how they win. Toddlers prefer a puppet who is yielded to in a conflict, but not one that uses force to get its way. This preference is not simply for any puppet that achieves its goal: as shown in experiment 2.0, toddlers do not like a puppet who achieves its goal by force. Second, as shown in experiments 1.1 and 1.2, in a situation where only one puppet reaches its goal but there is no conflict between them, toddlers like the two puppets equally. Finally, as shown in experiment 1.4, toddlers do prefer a puppet who is yielded to (where 'yield' means to rotate towards the ground and move out of the way) even when they do not see that puppet continue on to reach its goal. All together, these studies suggest that toddlers like and approach high-ranking individuals.

These results are consistent with findings from a range of non-human species. For example, as mentioned above, male macaques pay fruit juice to look at pictures of high-status conspecifics[45], and they also prefer to ally themselves with higher-status others[44]. Several species including dogs, rats and prairie voles take social status into account when choosing mates[51–53]. For humans and other highly social species, affiliating with high-status others may provide access to resources, support, protection and know-how[20,54]. But if high-status others behave violently, the benefits of being near them may be outweighed by the costs.

These findings are also interesting to compare to recent reports about adult bonobos. It seems that adult bonobos prefer novel dominant individuals to subordinate individuals, even when the dominants use physical aggression[4]. Our experiment 2.0 provides a clear contrast with these findings, in showing that human toddlers reject those who use physical coercion. This is perhaps related to the different types of hierarchy in the two species. Whereas non-human primate hierarchies are largely characterized by coercive social dominance[23,38], human hierarchies involve not just coercion but also guidance, protection[5] and cultural learning[5,9,55]. Perhaps human toddlers are more sensitive to whether people are voluntarily yielded to because voluntary yielding is given to people who can provide cultural benefits. In contrast, an individual who use physical force against others may simply be dangerous to approach.

Turning our attention to human adults, the present findings have many parallels in adult social psychology. Adults who participate in a group decision-making exercise, for example, pay more attention to an individual who has been influential in that exercise than to one who has not[32]. Adults also like individuals who appear to have influence on a group because they are respected[32], those who have higher-status jobs[46,56] and those whose gaze is followed by others[57]. And adults like winners: the approval ratings of politicians go up right after they win an election[58] and adults tend to affiliate with winners rather than losers. For example, students talking about their own university's sports teams tend to use the word 'we' for victories (we won) and 'they' for losses (they lost)[59]. When adults look at novel people who have been labelled 'high-ranking' (as opposed to 'low-ranking'), there is greater activity in the ventral striatum, a brain area associated with monetary reward[60].

It is not surprising that adults prefer to affiliate with high-status people rather than low-status people. Adults may have learned from experience that it's useful to have friends in high places. A similar explanation could apply to children who endorse the testimony of high-status individuals—they may have learned from experience that high-status people in their world (that is, adults) know more than low-status people (that is, children) do.

But in the present experiments, it seems less plausible that toddlers could have learned from experience that affiliating with high-status others brings benefits, given their limited social experiences. It seems more likely to us that toddlers have an evolved, innate or early developing (implicit) preference for high-status individuals[18].

When comparing these results to the adult social psychology literature, a word of caution is in order. Much debate in social psychology (some of it cited above) has focused on the question of whether human social hierarchies are better described as dominance-based or prestige-based. Although the results of experiments 2.0 and 2.1 are

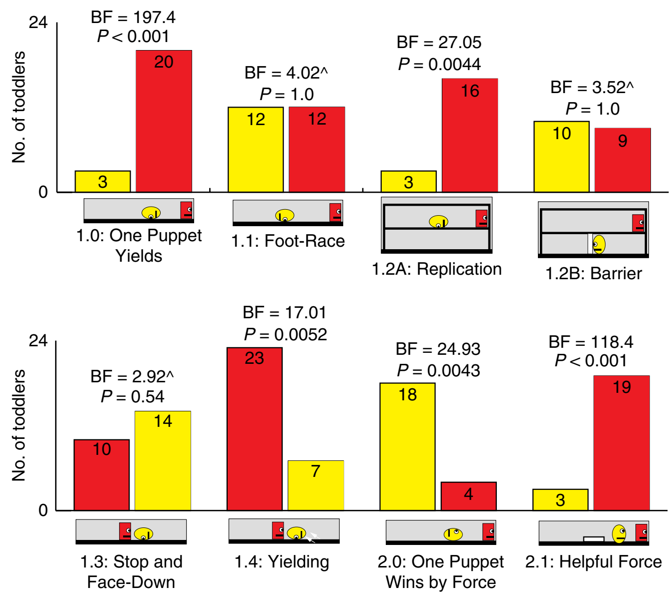

Fig. 4 | Number of toddlers who chose each puppet in all experiments. In all experiments, Bayes factors (Bfs) were computed by comparing the likelihood of the data given the null hypothesis that children chose each puppet 50% of the time against the alternative hypothesis that children chose either puppet more than 50% of the time). ^ indicates a Bayes factor in favour of the null, otherwise the Bayes factor favoured the alternative hypothesis. Two-sided binomial tests were used to calculate the P values. The diagrams below each graph depict the last segment of the action phase in each experiment. The colours of the bar graphs correspond to the role of the puppet in the diagram below each graph. However, in the experiments, we counterbalanced the roles of the puppets, as well as the direction each puppet travelled. (Experiment 1.0 95% CI= 0.664–0.977; probability of success = 0.869; experiment 1.1 95% CI= 0.291–0.709; probability of success = 0.5; experiment 1.2 A 95% CI= 0.604–0.966; probability of success = 0.842; experiment 1.2B 95% CI= 0.244–0.711; probability of success = 0.474; experiment 1.3 95% CI= 0.221–0.633; probability of success = 0.417; experiment 1.4 95% CI= 0.577–0.900; probability of success = 0.767; experiment 2.0 95% CI= 0.597–0.948; probability of success = 0.818; experiment 2.1 95% CI= 0.651–0.971; probability of success = 0.863.)

consistent with accounts of human social hierarchy that emphasize prestige, there is no reason to think that a toddler's understanding of the social world is anything like an adult's conception of a prestige-based hierarchy. Toddlers might be concerned mainly with avoiding harm (which is the central issue in a dominance-based hierarchy) and still prefer the non-violent winner of a conflict. Actual violence is not necessarily common in dominance-based hierarchies, because lower-status individuals tend to defer to higher-status ones[7,12,24,38]. This is especially true when social rank is stable. Thus, the fact that toddlers like winners and dislike those who use violence would actually make sense within either type of hierarchy.

It is also interesting to compare these findings to research showing that infants prefer helpers over hinderers[40]. Consistent with that literature, we found that toddlers avoided a puppet who used coercive force to win a zero-sum conflict, but preferred a puppet who knocked down a barrier, allowing itself and another puppet to reach their common goal. Our findings constitute an independent conceptual replication of the original, widely cited helper/hinderer findings. This is important because although those findings have been replicated many times over by the original researchers[40,61–63], some independent replication attempts have failed[64,65].

Whereas our experiments 2.0 and 2.1 confirm the basic helper/hinderer findings, our experiments 1.0 and 1.2A diverge from them. In these experiments, the puppet that yields the way could be seen as 'helping' the other puppet by stepping aside. If toddlers viewed the scene this way and preferred helpers, then they should have preferred the puppet who yielded—but they did not. We take this to mean that toddlers are not only sensitive to prosociality (as shown by the helping/hindering studies); they are also sensitive to social status. In our experiments 1.0 and 1.2A, status was a more salient social dimension to the toddlers than prosociality.

When considering the results presented here, we should keep in mind that the participants had only recently started walking, talking and in most cases interacting with similar-age peers. Status may be a particularly salient social dimension for toddlers, whose world has recently broadened from just caregivers to include other children with whom they might compete for attention, food, space or other resources. This is consistent with observations from daycare centres suggesting that social hierarchies form among toddlers as young as 18 months and that higher-ranking toddlers become sought-after play partners[6].

Taken together, the results of these seven experiments suggest that when toddlers aged 21–31 months witness a zero-sum conflict between two novel individuals, they not only make inferences about the social status of those individuals, they also form preferences based on that status: they selectively approach the high-status individual. Several follow-up experiments tested alternative explanations, showing that toddlers do not prefer just any a puppet who successfully reaches its goal, crosses the stage, remains upright, remains visible, travels further and so on. Toddlers also do not like all winners; specifically, they do not like a puppet who wins by knocking another one down. Thus, toddlers not only care who wins, but also how they win, and both of these components affect who they like. Overall, these results suggest that human toddlers evaluate others based on social rank in ways that differ qualitatively from our nearest primate relatives.

Methods

General methods. Participants were recruited at a children's museum during regular business hours. Each experiment used a different set of toddlers. Before entering the testing room, parents gave informed consent to allow us to test their child. Parents were asked to remain quiet during the puppet show and before the test question, they were asked to close their eyes. The participating child usually sat on the parent's lap. When this was not possible (for example, because the parent was holding a younger sibling), the participant sat in a chair next to their parent. The puppet show consisted of a familiarization phase that was shown twice, an action phase that was shown three times and a test question.

In all seven experiments, one puppet at a time was visible during the familiarization phase and both puppets were visible at the same time during the action phase. Each puppet's direction of travel (leftwards or rightwards across the stage) was counterbalanced with its role in the action phase (for example, yielding or remaining upright), as was the order in which the puppets crossed the stage and the specific puppet (for example, yellow oval or red square) assigned to play each role. We also counterbalanced the position of the high-status puppet (on the child's left or right) during the test question. Participants were randomly assigned to conditions within each experiment (that is, which puppet won or lost, which direction the winner travelled etc.). In experiment 1.2 participants were randomly assigned to either experiment 1.2A or 1.2B. Videos of all the puppet shows can be viewed at https://osf.io/km5by/ and more detail can be found in the Supplementary Materials.

The test-question procedure was modelled after the helper/hinderer studies[40]. First, an experimenter who was blind to the condition asked the parent to close his or her eyes. The experimenter then held out the board with the two puppets so that the child could see, but not reach them. The experimenter looked at the child and said, "Hi! Look!" and then looked down at the board, fixing her gaze directly in the centre of the board between the two puppets. Then the experimenter said, "Which one do you like?" and moved the board towards the child so that the child could reach it. If the child reached simultaneously for both puppets (one with each hand), the trial was coded 'both'. If the child chose neither puppet, the procedure was repeated. If after three times the child had still made no choice, the trial was coded 'no response.' These exclusion criteria, along with others described below, were decided after pilot testing and before we started data collection for experiment 1.0. The video of the choices were coded by an experimenter blind to the condition.

To calculate the Bayes factor we used the calculator here: http://pcl.missouri.edu/bf-binomial. In the calculator we left prior successes as '1' and prior failures as '1'. We used a flexible stopping rule where we checked the Bayes factor after each testing session, and tested toddlers until we had a sufficiently strong Bayes factor to answer the question. During each testing session we tested between 1 and 12 toddlers (the average was around 2). Note that although frequentist statistical analyses do not allow for preferential stopping, Bayesian analyses do[66,67]. We also included frequentists statistics in the paper since more people in our field are familiar with this type of analysis.

Experiment 1.0 One Puppet Yields to the Other. *Participants.* A total of 31 toddlers participated in the experiment. Of these, eight were excluded from the analysis for the following reasons: choosing both puppets ($n=3$); not choosing a puppet ($n=3$); extreme fussiness ($n=1$) and distraction in the testing environment—a janitor noisily entered the testing room and distracted the child ($n=1$). The remaining 21 toddlers (8 girls, 13 boys) contributed data to the analysis. Their ages ranged from 21 to 31 months (mean = 24.95 months, s.d. = 2.92 months). Data collection was stopped when Bayesian analyses showed a sufficiently strong effect to answer the question (see analysis above). Note that although frequentist statistical analyses do not allow for preferential stopping, Bayesian analyses do[66,67].

Experiment 1.1 Foot-Race Follow-Up. A total of 37 toddlers participated in the experiment. Of these, 13 were excluded from the analysis for the following reasons: Choosing both puppets ($n=7$); not choosing a puppet ($n=3$); extreme fussiness ($n=2$) and experimenter error (the puppets were moved backwards in the puppet show, $n=1$). The remaining 24 toddlers (7 girls, 17 boys) contributed data to the analysis. Their ages ranged from 21 to 31 months (mean = 26.56 months; s.d. = 3.25 months).

Experiment 1.2 Two-Level Replication and Barrier Follow-Up. A total of 64 toddlers participated in the experiment. Of these, 34 were assigned to condition A. Of the children in condition A, 15 were excluded from the analysis for the following reasons: choosing both puppets ($n=8$); not choosing a puppet ($n=2$); experimenter error ($n=2$: the puppet was face-down instead of upright in one trial; the 'choice' puppets were visible to the child when they walked in); fussiness ($n=1$; the puppet show was stopped because the child started crying in one trial); interference by a sibling ($n=1$) and one child was excluded because they stood up at the end of the puppet show and did not watch the end ($n=1$). The remaining 19 toddlers (7 boys, 12 girls) contributed data to the analysis. Their ages ranged from 21 to 32 months (mean = 26.05 months; s.d. = 3.14 months.)

The other 30 children were assigned to condition B. Of those, 11 children were excluded from analysis for the following reasons: choosing both puppets ($n=6$); not choosing a puppet ($n=1$); experimenter error ($n=3$: the puppet was face-down instead of upright in one trial; the experimenter used her hands to present the puppets to the child; the puppeteer did the wrong number of sequences at the ends) and interference by a sibling ($n=1$). The remaining 19 toddlers (9 girls and 10 boys) contributed data to the analysis. Their ages ranged from 21 to 32 months (mean = 25.23 months; s.d. = 2.88 months).

Experiment 1.3 Stop-and-Face-Down Follow-Up. A total of 37 toddlers participated in the experiment. Of these, 13 were excluded from the analysis for the following reasons: choosing both puppets ($n=7$); not choosing a puppet ($n=3$); experimenter error ($n=1$: the experimenter made the wrong puppet face downwards during one trial and accidentally let the oval puppet roll onto its back in another trial); interference ($n=1$: the participant's sibling pointed to one of the puppets before the participant made a choice) and object in hand ($n=1$: the toddler had an object in their hand while choosing). The remaining 24 toddlers (12 girls, 12 boys) contributed data to the analysis. Their ages ranged from 21 to 32 months (mean = 25.25 months; s.d. = 2.96 months).

Experiment 1.4 Yielding Follow-Up. A total of 42 toddlers participated in the experiment. Of these, 12 were excluded for the following reasons: choosing both puppets ($n=4$); not choosing a puppet ($n=1$); fussiness ($n=1$); interference ($n=2$ parent was talking to their child during the choice procedure and did not close their eyes; in another trial the parent touched one of the puppets while the child was making their choice and the child did not watch the action sequence); experimenter error ($n=3$, the experimenter did not remind parents to close their eyes during choice procedure so parents had their eyes open) and developmental delays ($n=1$ the parent indicated that their child was on the autism spectrum on the consent form). The remaining 30 toddlers (23 girls and 7 boys) contributed data to the analysis. Their ages ranged from 21 to 32 months (mean = 24.2; s.d. = 2.4 months).

Experiment 2.0 One Puppet Wins by Force. A total of 29 toddlers participated in the experiment. Of these, 7 were excluded from the analysis for the following reasons: choosing both puppets ($n=2$); not choosing a puppet ($n=1$); extreme fussiness ($n=2$); parental interference ($n=1$) and sibling interference ($n=1$). The remaining 22 toddlers (10 girls, 11 boys, 1 parent did not specify) contributed data to the analysis. Their ages ranged from 20 to 31 months (mean = 24.91 months; s.d. = 3.13 months).

Experiment 2.1 Helpful-Force Follow-Up. A total of 36 toddlers participated in the experiment. Of these, 14 were excluded from the analysis for the following reasons: choosing both puppets ($n=5$); not choosing a puppet ($n=2$); extreme fussiness ($n=2$); parental interference ($n=1$); sibling interference ($n=1$); experimenter error ($n=2$: which puppet knocked the barrier over was different in two test sequences) and one child was excluded because she had an object in one of her hands during the choice procedure ($n=1$). The remaining 22 toddlers (12 girls, 11 boys) contributed data to the analysis. Their ages ranged from 21 to 32 months (mean = 26.48 months; s.d. = 3.18 months).

These procedures were approved by the Institutional Review Board at the University of California, Irvine.

Reporting Summary. Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Code availability. No coding was used to analyse this data. We used the binom. test function in R[68] and the Bayesian calculator available at http://pcl.missouri.edu/bayesfactor. For all experiments prior successes (a) = 1 and prior failures (b) = 1.

Data availability. All data, including pilot data and videos of puppet shows, are available at https://osf.io/km5by/.

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References

1. Thomsen, L., Frankenhuis, W. E., Ingold-Smith, M. & Carey, S. Big and mighty: preverbal infants mentally represent social dominance. *Science* **331**, 26–29 (2011).
2. Pun, A., Birch, S. A. J. & Baron, A. S. Infants use relative numerical group size to infer social dominance. *Proc. Natl Acad. Sci. USA* **113**, 2376–2381 (2016).
3. Mascaro, O. & Csibra, G. Representation of stable social dominance relations by human infants. *Proc. Natl Acad. Sci. USA* **109**, 6862–6867 (2012).
4. Krupenye, C. & Hare, B. Bonobos prefer individuals that hinder others over those that help. *Curr. Biol.* **28**, 280–286 (2018).
5. Fiske, A. P. The four elementary forms of sociality: framework for a unified theory of social relations. *Psychol. Rev.* **99**, 689–723 (1992).
6. Hawley, P. H. The ontogenesis of social dominance: a strategy-based evolutionary perspective. *Dev. Rev.* **19**, 97–132 (1999).
7. van Vugt, M. & Tybur, J. M. in *The Handbook of Evolutionary Psychology* (ed. Buss, D. M.) 1–40 (John Wiley & Sons, Hoboken, NJ, 2014).
8. Pratto, F., Sidanius, J. & Levin, S. Social dominance theory and the dynamics of intergroup relations: taking stock and looking forward. *Eur. Rev. Soc. Psychol.* **17**, 271–320 (2006).
9. Henrich, J. *The Secret of Our Success: How Culture is Driving Human Evolution, Domesticating Our Species, and Making Us Smarter* (Princeton Univ. Press, Princeton, NJ, 2015).
10. Magee, J. C. & Galinsky, A. D. Social hierarchy: the self reinforcing nature of power and status. *Acad. Manag. Ann.* **2**, 351–398 (2008).
11. Huntingford, F. A. *Animal Conflict* (Springer Science & Business Media, Chapman and Hall, New York, NY, 2013).
12. Smith, J. M. & Price, G. R. The logic of animal conflict. *Nature* **246**, 15–18 (1973).
13. Hunt, J. & Simmons, L. W. Status-dependent selection in the dimorphic beetle *Onthophagus taurus*. *Proc. R. Soc. B Biol. Sci.* **268**, 2409–2414 (2001).
14. Grosenick, L., Clement, T. S. & Fernald, R. D. Fish can infer social rank by observation alone. *Nature* **445**, 429–432 (2007).
15. Sapolsky, R. Social status and health in humans and other animals. *Annu. Rev. Anthropol.* **33**, 393–418 (2004).
16. von Rueden, C. R. & Jaeggi, A. V. Men's status and reproductive success in 33 nonindustrial societies: effects of subsistence, marriage system, and reproductive strategy. *Proc. Natl Acad. Sci. USA* **113**, 10824–10829 (2016).
17. Cummins, D. in *The Handbook of Evolutionary Psychology* (ed. Buss, D. M.) 676–697 (John Wiley & Sons, Hoboken, NJ, 2006).
18. Thomsen, L. & Carey, S. in *Navigating the Social World: What Infants, Children, and Other Species Can Teach Us* (eds Banaji, M. R. & Gelman, S. A.) 17–22 (Oxford Univ. Press, New York, NY, 2013).
19. Fiske, A. P. & Rai, T. S. *Virtuous Violence* (Cambridge University Press, Cambridge, 2014).
20. Henrich, J. & Gil-White, F. J. The evolution of prestige: freely conferred deference as a mechanism for enhancing the benefits of cultural transmission. *Evol. Hum. Behav.* **22**, 165–196 (2001).
21. von Rueden, C. & van Vugt, M. Leadership in small-scale societies: some implications for theory, research, and practice. *Leadersh. Q.* **26**, 978–990 (2015).
22. Magee, J. C. & Galinsky, A. D. Social hierarchy: the self-reinforcing nature of power and status. *Acad. Manag. Ann.* **2**, 351–398 (2008).
23. Watts, D. P. in *Mind the Gap: Tracing the Origins of Human Universals* (eds Kappeler, P. M. & Silk, J. B.)109–138 (Springer-Verlag, Heidelberg, 2010); https://doi.org/10.1007/978-3-642-02725-3_5
24. Holekamp, K. E. & Strauss, E. D. Aggression and dominance: an interdisciplinary overview. *Curr. Opin. Behav. Sci.* **12**, 44–51 (2016).
25. Kaufmann, J. H. On the definitions and functions of dominance and territoriality. *Biol. Rev.* **58**, 1–20 (1983).
26. Holekamp, K. E. & Smale, L. Dominance acquisition during mammalian social development: the 'inheritance' of maternal rank. *Integr. Comp. Biol.* **31**, 306–317 (1991).
27. Schjelderup-Ebbe, T. in *Handbook of Social Psychology* (ed. Murchison, C.) 947–972 (Clarke Univ. Press, Worcester, MA, 1935).
28. Harrison, M. E. & Chivers, D. J. The orang-utan mating system and the unflanged male: a product of increased food stress during the late Miocene and Pliocene? *J. Hum. Evol.* **52**, 275–293 (2007).
29. Ellis, L. Dominance and reproductive success among nonhuman animals: a cross-species comparison. *Ethol. Sociobiol.* **16**, 257–333 (1995).
30. von Rueden, C. R., Gurven, M., Kaplan, H. & Stieglitz, J. Leadership in an egalitarian society. *Hum. Nat.* **25**, 538–566 (2014).
31. von Rueden, C. & Van Vugt, M. Leadership in small-scale societies: some implications for theory, research, and practice. *Leadersh. Q.* **26**, 978–990 (2015).
32. Cheng, J. T., Tracy, J. L., Foulsham, T., Kingstone, A. & Henrich, J. Two ways to the top: evidence that dominance and prestige are distinct yet viable avenues to social rank and influence. *J. Pers. Soc. Psychol.* **104**, 103–125 (2013).
33. Enright, E. A., Gweon, H. & Sommerville, J. A. 'To the victor go the spoils': infants expect resources to align with dominance structures. *Cognition* **164**, 8–21 (2017).
34. Charafeddine, R. et al. Children's allocation of resources in social dominance situations. *Dev. Psychol.* **52**,1843–1857 (2016).
35. Bernard, S. et al. The boss is always right: preschoolers endorse the testimony of a dominant over that of a subordinate. *J. Exp. Child Psychol.* **152**, 307–317 (2016).
36. Goodall, J. *The Chimpanzees of Gombe: Patterns of Behavior* 409–442 (Harvard Univ. Press, Cambridge, MA, 1986).
37. Oliveira, R. F., McGregor, P. K. & Latruffe, C. Know thine enemy: fighting fish gather information from observing conspecific interactions. *Proc. R. Soc. B Biol. Sci.* **265**, 1045–1049 (1998).
38. Silk, J. B. Practice random acts of aggression and senseless acts of intimidation: the logic of status contests in social groups. *Evol. Anthropol.* **11**, 221–225 (2002).
39. Kanakogi, Y., Okumura, Y., Inoue, Y., Kitazaki, M. & Itakura, S. Rudimentary sympathy in preverbal infants: preference for others in distress. *PLoS ONE* **8**, 1–6 (2013).
40. Hamlin, J. K., Wynn, K. & Bloom, P. Social evaluation by preverbal infants. *Nature* **450**, 557–559 (2007).
41. Vervaecke, H., De Vries, H. & Van Elsacker, L. Function and distribution of coalitions in captive Bonobos (*Pan paniscus*). *Primates* **41**, 249–265 (2000).
42. Melis, A. P., Hare, B. & Tomasello, M. Chimpanzees recruit the best collaborators. *Science* **311**, 1297–1300 (2006).
43. Chapais, B. Alliances as a means of competition in primates: evolutionary, developmental, and cognitive aspects. *Am. J. Phys. Anthropol.* **38**, 115–136 (1995).
44. Silk, J. B. Male bonnet macaques use information about third-party rank relationships to recruit allies. *Anim. Behav.* **58**, 45–51 (1999).
45. Deaner, R. O., Khera, A. V. & Platt, M. L. Monkeys pay per view: adaptive valuation of social images by rhesus macaques. *Curr. Biol.* **15**, 543–548 (2005).
46. Dalmaso, M., Pavan, G., Castelli, L. & Galfano, G. Social status gates social attention in humans. *Biol. Lett.* **8**, 450–452 (2012).
47. Jara-Ettinger, J., Tenenbaum, J. B. & Schulz, L. E. Not so innocent: toddlers' inferences about costs and culpability. *Psychol. Sci.* **26**, 633–640 (2015).
48. Jarosz, A. F. & Wiley, J. What are the odds? A practical guide to computing and reporting Bayes Factors. *J. Probl. Solving* **7**, 2–9 (2014).
49. Schubert, T. W., Waldzus, S. & Seibt, B. in *Embodied Grounding: Social, Cognitive, Affective, and Neuroscientific Approaches* (eds Semin, G. R. & Smith, E. R.) 160–183 (Cambridge Univ. Press, New York, NY, 2008).
50. Kanakogi, Y. et al. Preverbal infants affirm third-party interventions that protect victims from aggressors. *Nat. Hum. Behav.* **1**, 0037 (2017).
51. Shapiro, L. E. & Dewsbury, D. A. Male dominance, female choice and male copulatory behavior in two species of voles (*Microtus ochrogaster* and *Microtus montanus*). *Behav. Ecol. Sociobiol.* **18**, 267–274 (1986).
52. Carr, W. J., Kimmel, K. R., Anthony, S. L. & Schlocker, D. E. Female rats prefer to mate with dominant rather than subordinate males. *Bull. Psychon. Soc.* **20**, 89–91 (1982).

53. Cafazzo, S., Bonanni, R., Valsecchi, P. & Natoli, E. Social variables affecting mate preferences, copulation and reproductive outcome in a pack of free-ranging dogs. *PLoS ONE* **9**, e98594 (2014).
54. Fiske, A. P. & Rai, T. S. *Virtuous Violence: Hurting and Killing to Create, Sustain, End, and Honor Social Relationships* (Cambridge Univ. Press, Cambridge, 2014).
55. Boyd, R. & Richerson, P. J. *Culture and the Evolutionary Process* (Univ. Chicago Press, Chicago, IL, 1988).
56. Ratcliff, N. J., Hugenberg, K., Shriver, E. R. & Bernstein, M. J. The allure of status: high-status targets are privileged in face processing and memory. *Personal. Soc. Psychol. Bull.* **37**, 1003–1015 (2011).
57. Capozzi, F. et al. Followers are not followed: observed group interactions modulate subsequent social attention. *J. Exp. Psychol. Gen.* **145**, 531–535 (2016).
58. Cohen, J. E. Everybody loves a winner: on the mutual causality of Presidential approval and success in Congress. *Congr. Presidency* **40**, 285–307 (2013).
59. Cialdini, R. B. et al. Basking in reflected glory: three (football) field studies. *J. Pers. Soc. Psychol.* **34**, 366–375 (1976).
60. Zink, C. F. et al. Know your place: neural processing of social hierarchy in humans. *Neuron* **58**, 273–283 (2008).
61. Hamlin, J. K., Mahajan, N., Liberman, Z. & Wynn, K. Not like me = bad: infants prefer those who harm dissimilar others. *Psychol. Sci.* **24**, 589–594 (2013).
62. Kiley Hamlin, J., Wynn, K. & Bloom, P. Three-month-olds show a negativity bias in their social evaluations. *Dev. Sci.* **13**, 923–929 (2010).
63. Hamlin, J. K., Wynn, K., Bloom, P. & Mahajan, N. How infants and toddlers react to antisocial others. *Proc. Natl Acad. Sci. USA* **108**, 19931–19936 (2011).
64. Salvadori, E. et al. Probing the strength of infants' preference for helpers over hinderers: two replication attempts of Hamlin and Wynn (2011). *PLoS ONE* 10, e0140570 (2015).
65. Margoni, F. & Surian, L. Infants' evaluation of prosocial and antisocial agents: a meta-analysis. Dev. Psychol. **54**, 1445–1455 (2018).
66. Csibra, G., Hernik, M., Mascaro, O., Tatone, D. & Lengyel, M. Statistical treatment of looking-time data. *Dev. Psychol.* **52**, 521–536 (2016).
67. Schönbrodt, F. D. & Wagenmakers, E. J. Bayes factor design analysis: planning for compelling evidence. *Psychon. Bull. Rev.* **25**, 128–142 (2018).
68. R Core Team R: *A Language and Environment for Statistical Computing* (R Foundation for Statistical Computing, Vienna, 2017); https://www.R-project.org

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Author contributions

A.J.T. designed the experiments, oversaw data collection, analysed the data and wrote the manuscript. L.T. contributed to the experimental design and writing the manuscript. M.A. assisted in data collection, experiment designs and entering data. A.F.L. helped in recruiting participants, designing experiments and writing the manuscript. B.W.S. contributed to the experimental design and writing the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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Our web collection on statistics for biologists may be useful.

Software and code

Policy information about availability of computer code

Data collection	no software was used
Data analysis	R was used to calculate the binomial tests; the calculator found here: http://pcl.missouri.edu/bf-binomial was used to calculate Bayes Factors. (the function 'ProportionBF' in the the Bayes Factor Package in R can also be used). To calculate the X2 test we used R and the Bayes Factor Package using the function 'contingencyTableBF'.

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All data used in the paper, along with pilot data are available here: https://osf.io/km5by/

April 2018

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Behavioural & social sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	Quantitative
Research sample	Participants were recruited at a children's museum during regular business hours. Each experiment used a different set of toddlers. Experimenters approached parents inside the museum and asked if they would like to hear about an experiment on children's understanding of social relationships. 135 parents indicated their child was a boy; 140 indicated their child was a girl, and 1 parent did not fill out the question. 150 of the parents indicated their child was White, 52 did not answer the question, 38 answered Asian, 16 answered Asian and White, the rest of the racial groups had less than 5 particpants that fell into that category.
Sampling strategy	We used a flexible stopping rule where we checked the Bayes Factor after each testing session, and tested toddlers until we had a sufficiently strong Bayes Factor to answer the question. During each testing session we tested between 1 and 12 toddlers (the average was around 2). Note that although frequentist statistical analyses do not allow for preferential stopping, Bayesian analyses do49,50. We also included frequentists statistics in the paper since more people in our field are familiar with this type of analysis.
Data collection	Participants were recruited at a children's museum during regular business hours. Each experiment used a different set of toddlers. Before entering the testing room, parents were asked to remain quiet during the puppet show; before the test question, they were asked to close their eyes. The participating child usually sat on the parent's lap. When this was not possible (e.g., because the parent was holding a younger sibling), the participant sat in a chair next to their parent. The puppet show consisted of a familiarization phase that was shown twice, an action phase that was shown three times, and a test question. In all seven experiments, one puppet at a time was visible during the familiarization phase, and both puppets were visible at the same time during the action phase. Each puppet's direction of travel (leftward or rightward across the stage) was counterbalanced with its role in the action phase (e.g., yielding or remaining upright), as was the order in which the puppets crossed the stage and the specific puppet (e.g., yellow oval or red square) assigned to play each role. We also counterbalanced the position of the high-status puppet (on the child's left or right) during the test question. Participants were randomly assigned to conditions within each experiment (i.e. which puppet won or lost, which direction the winner traveled etc.). In Experiment 1.2 participants were randomly assigned to either Experiment 1.2A or 1.2B. Videos of all the puppet shows can be viewed at https://osf.io/km5by/?view_only=6357573739eb4fc1a722921c3a3039f1. The puppet stage used in all experiments was 75 cm tall, 32.5 cm deep, and 95 cm long. It was made of black PVC pipe. It sat on a table covered with black fabric. There were black curtains hanging at the left and right sides of the stage, and a black curtain was used to cover the stage between scenes. Another black curtain hung behind the stage to hide the experimenter who was manipulating the puppets. There was also a black piece of fabric that was hung on the wall behind the stage, and the puppeteer wore a large long sleeved black sweater that covered the experimenters hands. These were to ensure that the toddler did not know that there was a person manipulating the puppets, while also allowing the puppeteer to see the puppets they were manipulating. In all the experiments, the puppets were 12.5cm tall and made of polymer clay. They each had one plastic craft eye (with a fixed pupil so that the puppet always seemed to be looking straight ahead) and a black rectangle for a mouth (which was black electrical tape fixed to the puppet). One puppet was a yellow oval and one was a red square. The puppets were moved by means of black wooden dowels. After the puppet show, two puppets identical to those used in the puppet show were presented to the toddler. These puppets were hidden from view from the toddler until it was time to do the choice procedure. In Experiment 1.2 (The barrier experiment) we used a two level black shelf purchased at a local store. The barrier use in the experiment was made of cardboard with white paper glued to it. Participants were recruited at a children's museum during regular business hours. Each experiment used a different set of toddlers. Experimenters approached parents inside the museum and asked if they would like to hear about an experiment on children's understanding of social relationships. Parents who agreed were given the consent form to fill out while the experimenter interacted with the child before leading the parent and child to the testing room. The testing room was a room off the main floor of the museum. Before entering the testing room, parents were briefed about the procedure. They were asked to remain quiet during the puppet show and to close their eyes during the choice procedure. The participating child usually sat on the parent's lap. When this was not possible (e.g., because the parent was holding a younger sibling), the child sat in a chair next to their parent. When siblings were in the room with the child, they sat next to the parent and were asked to remain quiet and to close their eyes during the choice procedure. In the cases that they inteferred the participating child's choice was not included in the analysis. The puppet show consisted of a familiarization phase that was shown twice, an action phase that was shown three times, and a test question. In all experiments, one experimenter stood behind the stage (hidden from view) and acted as the puppeteer. A second experimenter who was blind to the condition (i.e., could not see what the puppets were doing onstage) stood to the side of the stage and opened and closed the curtain between segments, saying "Down goes the curtain!" or "Up goes the curtain!" each time. (See supplementary materials for dimensions of stage, etc.) In all seven experiments, one puppet at a time was visible during the familiarization phase and both puppets were visible during the entire action phase. The puppets' direction of travel (left to right or right to left across the stage) were counterbalanced with their roles

in the action phase (e.g., yielding or remaining upright), as was the order in which they crossed the stage and the specific puppet (e.g., yellow oval or red square) assigned to play each role. We also counterbalanced the position of the high-status puppet (left or right) was on during the test question.
The test-question procedure was modeled after Hamlin et al, 2007. First, an experimenter who was blind to the condition asked the parent to close his or her eyes. The experimenter then held out the board with the two puppets so that the child could see, but not reach them. The experimenter looked at the child and said, "Hi! Look!" and then looked down at the board, fixing her gaze directly in the center of the board between the two puppets. Then the experimenter said, "Which one do you like?" and moved the board toward the child so that the child could reach it.
The experimenter mentally counted off 30 seconds. If the child had not made a choice after 30 seconds, the experimenter (keeping her gaze fixed on the center of the board) encouraged the child by saying, for example, "It's OK to choose one," or "You can grab one.") If the child still made no choice, the experimenter returned the board back to its starting position and repeated the test-question procedure. If the child reached simultaneously for both puppets (one with each hand), the trial was coded 'both.' If the procedure was done three times and the child still made no choice, then the trial was coded 'no response.' After the puppet show, each child was allowed to choose a prize (e.g., a rubber duck). Parents were invited to ask questions about the study and were given information about the lab to take home.

The choices of the toddlers were recorded (on a written data sheet) at the time of the experiment, and then a blind researcher assistant (i.e. someone who did not know the roles of the puppets) coded the videos (e.g. for 'both', 'none', 'yellow' or 'red'). In cases where these two pieces of information disagreed the video coder would re-watch the entirety of the video to check the other aspects of the puppet show. If they were unsure a third researcher would settle the dispute.

Timing

pilot data was collected in june, 2015, Experiment 1.0 data was collected in October-November 2015; Experiment 1.1 was collected in December 2015 January 2016 Experiment 1.2 data was collected in April/May 2016; Experiment 1.3 was collected in May-July 2016; Experiment 1.4 was collected in march/april 2018. Experiments 2.0 and 2.1 were collected in April-June 2017. Experiment 1.4 was added to address reviewer comments.

Data exclusions

Exclusion criteria, including if the child chose both puppets, chose neither puppet, experimenter errors (e.g. orienting a puppet incorrectly during the puppet show, or forgetting to remind the parents to close their eyes), interference (if a sibling or parent interfered in the choice) or disturbances in the testing environment, were decided after pilot testing and before we started data collection for Experiment 1.0. One of the excluded data points was not decided ahead of time (that if the 'choice puppets') were visible to the child when they entered the testing room then their data should be excluded. However, we hid them from the child so that they never saw both pairs of puppets at the same time, and in Experiment 1.1A, the 'choice puppets' were left uncovered by accident and the child saw them, thus we excluded this child from the data set. Including or excluding this child did not alter the results from this experiment. In general, it is helpful to keep in mind that we were testing in a museum. The room we were using was off the main floor and quiet, but it was a less controlled environment than in a laboratory.

Non-participation

see above

Randomization

children were randomly assigned to the conditions within each experiment (e.g. which puppet won, which direction the winning puppet moved etc.)

Reporting for specific materials, systems and methods

Materials & experimental systems

n/a	Involved in the study
☒	☐ Unique biological materials
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology
☒	☐ Animals and other organisms
☐	☒ Human research participants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Human research participants

Policy information about studies involving human research participants

Population characteristics

See above

Recruitment

See above. Children's who have parents take them to museums or who are more willing to participate in voluntary experiments may have specific characteristics that do not completely represent the population.