Title

Social influence in adolescence as a double-edged sword

Authors

Lucas Molleman^{1,2,3,*}, Simon Ciranka³, Wouter van den Bos^{1,2,3}

Affiliations

¹ Amsterdam Brain and Cognition, University of Amsterdam, Amsterdam, The Netherlands

² Psychology Department, University of Amsterdam, Amsterdam, The Netherlands

³ Center for Adaptive Rationality, Max Planck Institute for Human Development, Berlin, Germany

* Corresponding author, l.s.molleman@uva.nl

Abstract

Social learning is fundamental to human development, helping individuals adapt to new conditions and cooperate in groups [1–3]. During the formative years of adolescence, the social environment shapes people’s socio-cognitive skills needed in adulthood [4–6]. Yet, peer influence during this pivotal developmental stage is generally associated with risky and unruly conduct, with eminent negative long-term effects on adolescents’ educational, economic and health outcomes[6]. Here we show, in contrast to this traditional view, that the impact of peers on adolescents’ behaviour can also be markedly positive. Exposure to disobedient peers provoked rule breaking, and selfish peers reduced prosocial behaviour, particularly in early adolescence. However, compliant peers also promoted rule-following and fair peers increased prosociality. A belief formation task further revealed that early adolescents tend to assimilate social information, while older adolescents prioritise personal views. Our results suggest that these developmental patterns reflect a decline in an underlying domain-general factor of social sensitivity during adolescence, and highlight early adolescence as a key window for peer-based interventions to improve developmental trajectories.

Main text

Learning to adequately respond to social information is a central developmental goal, essential for finding one's place in society as an independent and socially responsible adult. Observing the behaviour of others enables people to navigate the diverse interactions they face every day, helping them make socially appropriate decisions and forming accurate beliefs about the world. In childhood, parents are the main source of social information. As children enter adolescence and prepare for adult roles in society, the focus shifts to peers. Social influence among adolescents is often associated with increased risk taking and negative outcomes (e.g. crime, alcohol abuse, taking drugs and having unprotected sex [7–10]). In the long term, running with the wrong crowd can consequently set people on negative developmental trajectories, with grave implications for health, education, social and economic success, and general well-being [5,6].

Less is known about the potential of peers to have positive effects on adolescent behaviour. Recent evidence based on hypothetical scenarios and self-reports suggests that peers may reduce risk taking and promote prosociality [11–13]. However, it remains unclear whether positive and negative peer influence on adolescent behaviour follow the same developmental pathway, and how the impact of peers on belief formation changes during this life stage. Moreover, it is unknown to what extent social influence is domain-general, reflecting the same logic in different decision contexts. Understanding the development of these mechanisms is essential for facilitating adolescents' attunement to their social environment, reducing anti-social behaviour, and promoting socially desirable outcomes [6].

In this paper, we present evidence from an integrated set of incentivised behavioural experiments with 146 adolescents (ages 10-20, 45% female), examining how social influence develops across this formative period of life. We targeted three core domains of decision-making which are understudied in this age group, and in which peers may promote both desirable and undesirable outcomes: rule compliance, prosociality, and belief formation. Our experiments reveal that peers markedly influence adolescents' belief formation, and that rule compliance and prosociality can be substantially reduced by bad examples, but also be strongly increased by good examples. Our results are indicative of a general factor of responsiveness to social information which is very strong in early adolescence, but steadily declines as individuals approach adulthood. Our study highlights the potential of peers to push adolescents' behaviour in socially desirable directions, and provides fundamental insights to inform the timing and design of interventions to promote positive developmental trajectories.

Results

Rule compliance. Our first experiment examines how social information influences rule compliance. The smooth functioning of human societies critically depends on individuals following rules that facilitate social coordination and curb the spread of disorder [14,15]. While rule-breaking is a hallmark of adolescent conduct (e.g., [16]), developmental research on socially undesirable behaviour has hitherto mainly focused on risk-taking, operationalized as gambles, or hypothetical scenarios [7,9,17–21]. Although these studies provided insights in the role of peer influence when adolescents are faced with uncertainty, they provide little behavioural insight into rule violations. Our task presented a salient rule in a naturalistic context, and allowed us to compare the relative impact of observing rule violations (expected to reduce adolescents' compliance) and observing rule following (expected to increase compliance).

Participants completed an animated task (adapted from [22]) showing a red traffic light and a timer reducing their payoffs every second they waited (Methods; Fig. S1). The experimental instructions explicitly stated that “the rule is to wait until the traffic light turns green”, but participants could maximise their earnings by breaking the rule and moving before the traffic light turned green. The rule was not enforced, so compliance was voluntary and against one's self interest.

Participants first completed the task on their own. Fifty-three percent of participants complied with the rule, foregoing about €0.50 in possible earnings. This compliance rate is comparable to previous findings with this paradigm from a large adult sample (58%) [22]. We observe no age trends in this initial behaviour (Fig S2; GLM: $P=0.550$; Table S2, model 1). Subsequently, participants completed the task again, in either of two conditions. Initially compliant participants did so in the presence of three bad examples who violate the rule. Conversely, initially violating participants observed three good examples who comply with the rule. We measured participants' social information use as following the examples (i.e. switching the initial choice).

Peer effects in rule-following markedly declined with age (Fig. 1a,b; GLM: $P < 0.001$; Table S1, model 2). Overall, when observing three bad examples, 61% of participants violated the rule after having complied first (Fig. 1a). A substantially smaller portion (29%) of participants who initially violated the rule chose to comply upon observing three good examples (Fig. 1b; $P < 0.001$; Table S1, model 2). The youngest participants seemingly followed bad examples more often than good examples but we did not find a significant interaction effect between age and condition ($P = 0.275$; Table S1, model 3). For 55% (30 out of 67) of participants who followed the peers stuck with their updated behaviour in a third iteration of the task in which they completed the task alone again, suggesting that peers had

some lasting effect on compliance. These results suggest that adolescents are not particularly unruly per se and good examples can promote compliance, but it also appears that early adolescents are easily swayed by their peers to change their behaviour and break a rule.

Prosociality. Our second experiment examines social information use in prosociality, a key building block of cooperation between individuals in society [23]. Adolescence is a key period for the development of prosocial behaviour, as awareness grows about the consequences of their actions for others and for society at large [24]. Observing prosocial peers can prompt prosocial acts even when reciprocity is impossible, but exposure to selfish peers can also reduce willingness to give up resources to benefit others [25,26]. Participants completed a variant of the Dictator Game, a commonly used tool to measure prosocial preferences [27]. They were asked how many of 10 points - worth one euro - they wanted to donate to an anonymous other person (Methods, Fig. S3).

Participants first completed the task on their own. Mean initial donations were 2.7 (s.d.=2.3), and did not significantly differ across age (in line with [28–30]; LMM: $P=0.150$; Table S3, model 1). Next, participants observed the donation of another person who completed the task before. In two within-subject conditions - administered in separate sessions - we varied the donation of this peer. In the ‘fair example’ condition, the observed donation was 5 points; in the ‘selfish example’ condition, the observed donation was 0. Participants could then revise their initial donation. We characterize participants’ social information use as (i) choosing whether or not to shift donations towards the examples, and (ii) the magnitude of the shift divided by the distance between the initial donation and social information.

Peer effects on donations were substantial (Fig 1c,d; Fig. S4). After observing a selfish example, 46% of participants who initially donated more than 0 adjusted their donation downwards, reducing average donations by 0.85 (95% CI: [0.54, 1.16]). After observing a fair example, 50% of participants who initially donated less than 5 adjusted their donation upwards, increasing average donations by 0.95 (95%CI: [0.63, 1.26]; paired t-tests comparing initial and revised donations: $P<0.001$ for both conditions).

Peer effects in prosociality strongly decreased with age: older adolescents were less likely to adjust their donations towards those of the peer (Fig. 1c,d; logistic GLMM: $P<0.001$; Table S2, model 2). The magnitude of donation adjustments also decreased with age ($P<0.001$; Table S2, model 2), and did not differ between conditions ($P=0.995$; Table S2, model 3). These results indicate that both selfish

and fair examples substantially modulate altruistic giving, and that their impact on behaviour steadily decreases during adolescence.

Belief formation. Our third experiment considers how social information shapes belief formation in a context where social values or preferences are irrelevant [31]. In such settings, social information can help individuals acquire useful knowledge [32] and make accurate decisions [33,34], but may also misinform [35], promote beliefs in conspiracy theories [36] or fuel group polarization [37]. However, to date developmental changes in belief formation have not been studied in adolescence. We administered a validated perceptual judgment task [38] in which participants repeatedly observed images with groups of animals and had to estimate how many animals there were. Then they observed the estimate of another participant and could revise their initial estimate. The extent of adjustment across five rounds measures an individual's tendency to use social information in belief formation (Methods; Fig. S5).

In line with previous results [38], participants tended to underestimate the number of animals, and with overwhelming frequency (94%) of cases, revised estimates were weighted averages of initial estimates and social information (Fig. S6). Again, social information use substantially decreased across adolescence (Fig. 1e; LMM: $P < 0.001$; Table S4). Ten-year-olds on average assigned about equal weight to their personal estimate and social information ($y \approx 0.5$ in Fig. 1e). Twenty-year-olds on average assigned four times less weight to social information than to personal estimates ($y \approx 0.2$). These results reveal how 'egocentric discounting', a commonly observed phenomenon in social information use in adults [38–40], emerges during adolescence.

Domain generality. In each of our tasks, we observe a downward trend in social information use across age. This suggests that there may be a common mechanism driving peer effects across domains. Our experiments allow us to test that idea. Indeed, tendencies to use social information were correlated across the three experiments (Table S5). A factor analysis suggests that the observed peer effects in each behavioural domain reflect a single underlying construct of social information use (Methods; loadings: switching in rule compliance: 0.34; mean adjustment towards examples in prosocial giving 0.41; mean adjustment in the learning task: 0.66). This factor – which we dub *S* – steadily declines during adolescence (Fig. 1f).

Discussion

Adolescence is a key formative period in which people grow into adult roles in society. Social environments are pivotal for adolescents to acquire adaptive social skills, and to learn values and social norms to guide behaviour in the increasingly varied interactions that people encounter every day [5,6,41]. A detailed understanding of the social factors that drive adolescents' behaviour for the better or worse is an essential goal for promoting positive developmental trajectories - and preventing or avoiding negative ones - as they are the next generation of people that will determine the fate of our planet [6,42].

Our paper contributes to this goal in three ways. First, we present an integrated set of novel incentivised experiments showing how social environments can negatively and positively impact adolescents' behaviour across different key domains of behaviour. In rule compliance, the effects of bad examples induce much disobedience, but good examples also substantially increase rule compliance. Prosocial behaviour was similarly increased or decreased by exposure to good (fair-sharing) or bad (selfish) examples. Peers also had a strong effect on belief formation in a setting where social values and preferences are irrelevant. Second, we show that across each of these domains, the potential of peers to impact behaviour steadily decreases throughout adolescence. Third, our results suggest that the decreasing impact of peers across adolescence reflects a developmental decline in a domain-general factor of social information use.

Our three experiments consistently show that social information use declines across adolescence (Fig. 1). Early adolescents have a high sensitivity for peer behaviour, while older adolescents prioritised personal preferences and beliefs (confirming results of [26]). In the context of rule following and prosociality, the strong impact of social information use among early adolescents might reflect high levels of uncertainty about their personal values and preferences [9]. Older adolescents might be less uncertain of these preferences, and reduced uncertainty might weaken the impact of social information on behaviour [43]. However, the results of our belief formation task indicate that this cannot be the whole story. In this task values and preferences were irrelevant but resulted in the same developmental pattern of diminishing use of social information across adolescence. Rather, our results suggest the existence of a domain-general factor of social sensitivity S , which is very high in early adolescence and decreases as people approach adulthood. This finding provides first support for the implicit assumption in previous research that developmental trends in social sensitivity would generalise across different domains of behaviour, and would shape behaviour in positive and negative directions in similar ways [5]. While our belief formation task has

been validated with multiple methods [38], testing the reliability and robustness of *S* in the real world would help strengthen its empirical foundation, delineate its psychometric structure and its significance beyond laboratory settings [44]. We believe such research would contribute to a comprehensive and more mechanistic understanding of social influence across adolescence.

Developmental research on social influence in adolescents has traditionally emphasised its negative effects, such as the encouragement of substance use and having unprotected sex [7,9]. Our study shows that peers can provide good examples to support rule compliance, prosociality and belief formation, supporting the emerging view that peers can also have a markedly positive impact and promote socially desirable behaviour in adolescents [11,13,26]. Our experiments tightly controlled the provision of social information, allowing us to quantify how good and bad examples impacted behaviour, while avoiding confounding effects of individuals influencing each other, and selecting certain people as social sources [45]. In real life, however, the social information available to an individual depends on its position in their social network. This introduces asymmetries in the social environments that individuals observe, determining, for example, whether compliance and generosity are perceived to be common, and whether rule violations and selfishness are typically disapproved of [22,46]. Exploring the interplay between behaviour and network formation is key for understanding how peers can promote and consolidate positive behaviour, and why people end up running in the wrong crowd in which socially undesirable conduct is exacerbated. This might also help understand when and why such polarising effects are amplified in algorithmically controlled online networks [47], in which some people thrive - using the swaths of available information to form accurate beliefs -, while others are sucked into the rabbit hole of conspiracy theories.

As their privileges grow, adolescents have to figure out how to relate to myriad novel social situations across many different domains of behaviour. Our results show that across domains, the behaviour of early adolescents is strongly guided by the social environment. They suggest that peer influence is a double-edged sword: it can provoke rule violations and reduce prosociality, but can also prompt rule compliance, promote prosociality, and facilitate the integration of social information to form beliefs about the world. These insights can inform the timing and design of interventions emphasising positive examples in adolescents' social networks [48]. While many interventions are based on building individuals' resistance to peer influence [49], our study highlights the potential of peers to spread prosocial norms. Both offline and on social media platforms, enhancing the salience of good examples and well-informed peers may bias norm perceptions in socially desirable ways and boost the formation of accurate beliefs. This way, social

influence among adolescents can be harnessed to positively impact developmental trajectories, reducing anti-social behaviour and false beliefs, while facilitating individuals' attunement to their social environment and promoting socially desirable outcomes.

Methods

General procedures. We recruited 146 participants aged 10-20 from the area of Berlin, Germany, with a balanced distribution across these ages and gender (Table S1). Participants completed a series of computerized tasks and questionnaires on their own, in a separate room. All tasks were programmed in LIONESS Lab [50] and were administered in the participants' native language (German). At the beginning of each session, participants received general instructions; always from the same test leader, who remained available to answer questions throughout a session.

Tasks were administered in two ~60-minute sessions, which took place approximately four weeks apart. Task order was randomized within and between sessions, independently between participants. Task-specific instructions were provided on-screen (see Supplementary Methods for screenshots of all three tasks). Tasks were incentivised such that each decision was payoff-relevant, and expected hourly wages were constant across tasks. Instructions for each task concluded with compulsory comprehension questions. After completing the second session, participants received performance-specific payment in cash (flat fee of €30 plus a performance-specific bonus between €5-€16).

Rule compliance. To measure peer effects in rule compliance, we administered a novel, stylised, animated task. Participants could choose whether or not to follow a rule, in the absence and presence of peers. They had to move a circle figure across their screen by clicking a button. In the middle of the screen stood a red traffic light (Fig. S1). The instructions stated that "the rule is to wait until the traffic light turns green". However, waiting was costly: participants started with an endowment of 20 points (total worth: one euro), and each second they spent in the task, this endowment was reduced with 1 point until it reached zero. After 12 seconds, the traffic light turned green. This setup implied that rule compliance led to lower payoffs than rule violation.

Participants completed three iterations of the task, one of which was randomly chosen for payment after the task had completed. In the first iteration, participants completed the task alone. Based on

their initial decision, we allocated them to either of two conditions that differed in the displayed movements of three peers who completed the task before. In particular, these peers always chose the opposite of a participants' own initial choice: participants who initially complied with the rule (i.e., moved after the traffic light turned green) were shown three 'bad' examples, peers who moved as soon as possible. participants who initially violated the rule (i.e., moved before the traffic light turned green) were shown three 'good examples', peers who waited until the traffic light turned green. For both conditions, we measured the proportion of participants following social information, switching their behaviour from compliance to violation (or vice versa; Fig. 1a,b).

Altruistic giving. To measure peer effects in altruistic giving, we administered an adapted version of the well-studied Dictator Game (Fig. S2) [27]. Participants received an endowment of 10 points (worth one euro) to divide between themselves and another anonymous person, who participated in a previous session. The decision situation minimizes the scope for reciprocity, and any positive donation can be interpreted as altruistic giving. In the task, participants make two decisions. First, participants made a donation decision alone (D_1). Then, they observed social information (D_5) in the form of the decision of a previous participant, and made a second donation decision (D_2). We quantify social information use as (i) whether the participant moved towards the observed social information, and (ii) the relative extent of adjustment towards social information, calculated as $(D_2 - D_1) / (D_5 - D_1)$.

In a within-subject treatment manipulation - administered in two different sessions - we varied the value of D_5 . In the 'selfish peer' condition, we showed as social information the donation of a previous participant who chose to keep all 10 points to themselves (i.e., $D_5=0$). In the 'fair peer' condition, we showed a previous participant who split the points equally (i.e. $D_5=5$). Individuals' initial donations in the 'selfish peer' and the 'fair peer' conditions were 3.1 (s.d.=2.4) and 2.3 (s.d.=2.1), respectively, and correlated across conditions ($\rho=0.323$; 95% CI=[0.167, 0.464]). Panels 1c,d show proportions of participants shifting towards social information. In the associated analyses, we only included participants whose initial decision was not identical to social information (so that any adjustments towards social information were actually possible) or moved away from social information. That is, in Fig. 1c we included participants who initially donated more than 0 (66%; 96 participants); and in Fig. 1d we included participants who initially donated less than 5 (65%; 95 participants).

Belief formation. To measure how peers impact belief formation, we administered the BEAST, a validated perceptual decision making task reliably measuring social information use [38], which has been used in adolescent samples [51]. For five rounds, participants observed an image with 50-100 animals for six seconds and had to estimate how many there were. After entering their first estimate (E_1), participants observed social information (X) in the form of the estimate from another participant who observed the same image. Then, they made a second estimate (E_2). We characterized a participant's social information use as the mean relative estimate adjustment towards the social information: $(E_2 - E_1) / (X - E_1)$.

Participants were rewarded for accuracy. If an estimate was exactly correct, earnings were 100 points. For each animal the participant was off, we subtracted 5 points (in this task, 100 points equaled €0.30). This setup ensures that participants should only use social information to adjust their first estimate if they believed it increased accuracy [38].

Social information was selected from a prerecorded pool of previous participants. We selected an estimate at intermediate distance from a participant's first estimate, being between 15% and 25% away from the participants' own first estimate, allowing for a relatively constant room for adjustment, without the social information being too far away to be ignored altogether [38,40].

We gauged whether participants found the social information believable with the exit question "What was your general impression of the previous participants?". None of the participants expressed doubts about its veracity.

Statistical analyses. All statistical analyses were conducted in R v. 4.0.2 [52]. Lines and shades in Figure 1 show predictions of regressions fitted to participants' behaviour, using 'age' as the sole predictor (see Tables S2-4 for full models). Dependent variables were decisions to follow social information (panels a-b; binomial model), to move towards social information (panels c-d; binomial model), and mean adjustment towards social information (panel e; linear model) and the factor S (panel f; linear model).

The factor analysis was conducted using the 'psych' package [53], and conducted on three variables characterizing participants' social information use in each of the three tasks. In the rule compliance task, we used a binary variable indicating whether or not a participant followed the examples (0=stuck with initial behaviour; 1=conformed to opposite social information). For the Dictator Game,

we exploited all variation present in our data by calculating for both conditions the participants' relative adjustment towards social information (as for the BEAST; see above, and in Figure S2); if for a participant both were available, we averaged the two. For the BEAST, we used the mean relative adjustment as outlined above.

Data availability. All data and code associated with this work are available from the public repository, accessible via https://github.com/LucasMolleman/Social_influence_in_adolescence. Experimental code is available (in editable form) on the LIONESS Lab platform (<https://lioness-lab.org>).

References

1. Boyd R, Richerson PJ. 1985 *Culture and the evolutionary process*. University of Chicago Press.
2. Hoppitt W, Laland KN. 2013 *Social Learning: An Introduction to Mechanisms, Methods, and Models*. Princeton University Press.
3. Henrich J. 2015 *The Secret of Our Success: How Culture Is Driving Human Evolution, Domesticating Our Species, and Making us Smarter*. Princeton University Press.
4. Blakemore S-J. 2008 The social brain in adolescence. *Nat. Rev. Neurosci.* **9**, 267.
5. Crone EA, Dahl RE. 2012 Understanding adolescence as a period of social–affective engagement and goal flexibility. *Nat. Rev. Neurosci.* **13**, 636–650.
6. Dahl RE, Allen NB, Wilbrecht L, Suleiman AB. 2018 Importance of investing in adolescence from a developmental science perspective. *Nature* **554**, 441–450.
7. Reniers RL, Beavan A, Keogan L, Furneaux A, Mayhew S, Wood SJ. 2017 Is it all in the reward? Peers influence risk-taking behaviour in young adulthood. *Br. J. Psychol.* **108**, 276–295.
8. Defoe IN, Khurana A, Betancourt LM, Hurt H, Romer D. 2019 Disentangling longitudinal relations between youth cannabis use, peer cannabis use, and conduct problems: developmental cascading links to cannabis use disorder. *Addiction* **114**, 485–493. (doi:<https://doi.org/10.1111/add.14456>)
9. Reiter AMF, Moutoussis M, Vanes L, Kievit R, Bullmore ET, Goodyer IM, Fonagy P, Jones PB, Dolan RJ. 2019 Taste uncertainty explains developmental effects on susceptibility to peer influence in adolescence. (doi:10.31234/osf.io/7u4xd)
10. Smith AR, Chein J, Steinberg L. 2014 Peers increase adolescent risk taking even when the probabilities of negative outcomes are known. *Dev. Psychol.* **50**, 1564.
11. van Hoorn J, Fuligni AJ, Crone EA, Galván A. 2016 Peer influence effects on risk-taking and prosocial decision-making in adolescence: insights from neuroimaging studies. *Curr. Opin. Behav. Sci.* **10**, 59–64. (doi:10.1016/j.cobeha.2016.05.007)
12. Telzer EH, van Hoorn J, Rogers CR, Do KT. 2018 Chapter Seven - Social Influence on Positive Youth Development: A Developmental Neuroscience Perspective. In *Advances in Child Development and Behavior* (ed JB Benson), pp. 215–258. JAI. (doi:10.1016/bs.acdb.2017.10.003)
13. Chung D, Orloff MA, Lauharatanahirun N, Chiu PH, King-Casas B. 2020 Valuation of peers' safe choices is associated with substance-naïveté in adolescents. *Proc. Natl. Acad. Sci.* **117**, 31729–31737. (doi:10.1073/pnas.1919111117)
14. Cialdini RB, Kallgren CA, Reno RR. 1991 A focus theory of normative conduct: A theoretical refinement and reevaluation of the role of norms in human behavior. In *Advances in experimental social psychology*, pp. 201–234. Elsevier.
15. Keizer K, Lindenberg S, Steg L. 2008 The spreading of disorder. *Science* **322**, 1681–1685.

16. Moffitt TE. 2018 Male antisocial behaviour in adolescence and beyond. *Nat. Hum. Behav.* **2**, 177–186.
17. Blakemore S-J. 2018 Avoiding Social Risk in Adolescence. *Curr. Dir. Psychol. Sci.* **27**, 116–122. (doi:10.1177/0963721417738144)
18. Gullone E, Moore S, Moss S, Boyd C. 2000 The Adolescent Risk-Taking Questionnaire: Development and Psychometric Evaluation. *J. Adolesc. Res.* **15**, 231–250. (doi:10.1177/0743558400152003)
19. Knoll LJ, Magis-Weinberg L, Speekenbrink M, Blakemore S-J. 2015 Social influence on risk perception during adolescence. *Psychol. Sci.* **26**, 583–592.
20. Blankenstein NE, Crone EA, van den Bos W, van Duijvenvoorde AC. 2016 Dealing with uncertainty: Testing risk-and ambiguity-attitude across adolescence. *Dev. Neuropsychol.* **41**, 77–92.
21. Braams BR, Davidow JY, Somerville LH. 2019 Developmental patterns of change in the influence of safe and risky peer choices on risky decision-making. *Dev. Sci.* **22**, e12717.
22. Gächter S, Molleman L, Nosenzo D. 2018 The behavioral logic of rule following and social norm compliance. *Unpubl. Manuscr.*
23. Axelrod R, Hamilton WD. 1981 The evolution of cooperation. *Science* **211**, 1390–1396.
24. Güroğlu B, van den Bos W, Crone EA. 2009 Fairness considerations: increasing understanding of intentionality during adolescence. *J. Exp. Child Psychol.* **104**, 398–409.
25. Thöni C, Gächter S. 2015 Peer effects and social preferences in voluntary cooperation: A theoretical and experimental analysis. *J. Econ. Psychol.* **48**, 72–88. (doi:10.1016/j.joep.2015.03.001)
26. Chierchia G, Piera Pi-Sunyer B, Blakemore S-J. 2020 Prosocial Influence and Opportunistic Conformity in Adolescents and Young Adults. *Psychol. Sci.* **31**, 1585–1601. (doi:10.1177/0956797620957625)
27. Engel C. 2011 Dictator games: A meta study. *Exp. Econ.* **14**, 583–610.
28. Gummerum M, Keller M, Takezawa M, Mata J. 2008 To give or not to give: Children's and adolescents' sharing and moral negotiations in economic decision situations. *Child Dev.* **79**, 562–576.
29. Alm\aaas I, Cappelen AW, Sørensen EØ, Tungodden B. 2010 Fairness and the development of inequality acceptance. *Science* **328**, 1176–1178.
30. Fehr E, Glätzle-Rützler D, Sutter M. 2013 The development of egalitarianism, altruism, spite and parochialism in childhood and adolescence. *Eur. Econ. Rev.* **64**, 369–383.
31. Deutsch M, Gerard HB. 1955 A study of normative and informational social influences upon individual judgment. *J. Abnorm. Soc. Psychol.* **51**, 629.
32. Boyd R, Richerson PJ, Henrich J. 2011 The cultural niche: Why social learning is essential for human adaptation. *Proc. Natl. Acad. Sci. U. S. A.* , 10918–10925. (doi:10.1073/pnas.1100290108)
33. Surowiecki J. 2004 *The wisdom of crowds: Why the many are smarter than the few and how collective wisdom shapes business, economies, societies, and nations*. New York, NY, US: Doubleday & Co.
34. Tump AN, Pleskac TJ, Kurvers RHJM. 2020 Wise or mad crowds? The cognitive mechanisms underlying information cascades. *Sci. Adv.* **6**, eabb0266. (doi:10.1126/sciadv.abb0266)
35. Pennycook G, Rand D. In press. The Cognitive Science of Fake News.
36. Sternisko A, Cichocka A, Van Bavel JJ. 2020 The dark side of social movements: Social identity, non-conformity, and the lure of conspiracy theories. *Curr. Opin. Psychol.* **35**, 1–6.
37. Molleman L, Tump AN, Gradassi A, Herzog S, Jayles B, Kurvers RHJM, van den Bos W. 2020 Strategies for integrating disparate social information. *Proc. R. Soc. B Biol. Sci.* **287**, 20202413. (doi:10.1098/rspb.2020.2413)
38. Molleman L, Kurvers RH, van den Bos W. 2019 Unleashing the BEAST: a brief measure of human social information use. *Evol. Hum. Behav.* **40**, 492–499.

39. Yaniv I, Kleinberger E. 2000 Advice Taking in Decision Making: Egocentric Discounting and Reputation Formation. *Organ. Behav. Hum. Decis. Process.* **83**, 260–281. (doi:10.1006/obhd.2000.2909)
40. Moussaïd M, Kämmer JE, Analytis PP, Neth H. 2013 Social influence and the collective dynamics of opinion formation. *PLoS One* **8**, e78433.
41. Yeager DS, Dahl RE, Dweck CS. 2018 Why interventions to influence adolescent behavior often fail but could succeed. *Perspect. Psychol. Sci.* **13**, 101–122.
42. Patton GC *et al.* 2016 Our future: a Lancet commission on adolescent health and wellbeing. *The Lancet* **387**, 2423–2478.
43. Morgan TJH, Rendell LE, Ehn M, Hoppitt W, Laland KN. 2012 The evolutionary basis of human social learning. *Proc. R. Soc. B Biol. Sci.* **279**, 653–662.
44. Pedroni A, Frey R, Bruhin A, Dutilh G, Hertwig R, Rieskamp J. 2017 The risk elicitation puzzle. *Nat. Hum. Behav.* **1**, 803–809. (doi:10.1038/s41562-017-0219-x)
45. Manski CF. 1993 Identification of endogenous social effects: The reflection problem. *Rev. Econ. Stud.* **60**, 531–542.
46. Dimant E. 2019 Contagion of pro-and anti-social behavior among peers and the role of social proximity. *J. Econ. Psychol.* **73**, 66–88.
47. Bozdog E, van den Hoven J. 2015 Breaking the filter bubble: democracy and design. *Ethics Inf. Technol.* **17**, 249–265.
48. Paluck EL, Shepherd H. 2012 The salience of social referents: A field experiment on collective norms and harassment behavior in a school social network. *J. Pers. Soc. Psychol.* **103**, 899.
49. Gifford-Smith M, Dodge KA, Dishion TJ, McCord J. 2005 Peer influence in children and adolescents: Crossing the bridge from developmental to intervention science. *J. Abnorm. Child Psychol.* **33**, 255–265.
50. Giamattei M, Yahosseini KS, Gächter S, Molleman L. 2020 LIONESS Lab: a free web-based platform for conducting interactive experiments online. *J. Econ. Sci. Assoc.* (doi:10.1007/s40881-020-00087-0)
51. Molleman L, Kanngiesser P, Bos W van den. 2019 Social information use in adolescents: The impact of adults, peers and household composition. *PLOS ONE* **14**, e0225498. (doi:10.1371/journal.pone.0225498)
52. R Core Team. 2020 *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. See <https://www.R-project.org/>.
53. Revelle W. 2020 *psych: Procedures for Psychological, Psychometric, and Personality Research*. Evanston, Illinois: Northwestern University. See <https://CRAN.R-project.org/package=psych>.

Acknowledgments. We thank Anna van Duijvenvoorde and Ralf Kurvers for helpful comments and discussions. We thank Jann Wäscher and Chantal Wysocki for data collection. L.M. and W.v.d.B. are supported by an Open Research Area grant (ID 176). L.M. is further supported by an Amsterdam Brain and Cognition Project grant 2018. W.v.d.B. is further supported by the Jacobs Foundation European Research Council grant no. (ERC-2018-StG-803338) and the Netherlands Organization for Scientific Research grant no. (NWO-VIDI 016.Vidi.185.068). S.C. is supported by the International Max Planck Research School on Computational Methods in Psychiatry and Aging Research (IMPRS COMP2PSYCH).

Author contributions. L.M., S.C. and W.v.d.B. conceived of the work and designed the experiments. L.M. and S.C. coordinated data collection and analysis. L.M. and W.v.d.B. wrote the bulk of the manuscript, and S.C. provided extensive comments and edits.

Competing interests. The authors declare no competing interests.

Materials & Correspondence. Correspondence and requests for materials can be directed to L.M.

Supplementary Information

Belonging to

Social influence in adolescence as a double-edged sword

By

Lucas Molleman, Simon Ciranka and Wouter van den Bos

Contents

1. Supplementary Figures
2. Supplementary Tables
3. Experimental Procedures and Materials
 - 3.1. Rule compliance task
 - 3.2. Prosociality task
 - 3.3. Belief formation task
4. Supplementary References

1. Supplementary Figures

Figure S1 | Traffic light task measuring social information use in rule compliance. The task was adapted from [1]; see Experimental Materials below for full instructions. **a**, Participants first received instructions explicitly stating that the rule was to wait until the stop light turns green. In addition, instructions made it clear that rule compliance was against the participant's self-interest. By complying with the rule, participants forfeited €0.50 in possible earnings. Rule violations did not have any externalities on others. **b**, Decision screen in the first iteration, when participants completed the task alone. They could move the circle figure across the screen by clicking the 'Move' button. Clicking once made the circle approach the red light and stop to wait. Clicking 'Move' again made the circle move across the screen and over the finish line (vertical line on the right-hand side). On the top, there was a timer starting at 20 and counting down until participants crossed the finish line. **c**, Compliance rates in iteration 1 as a function of age. We do not observe any significant age trends (Table S1; $P=0.495$). Numbers of observations are shown at the bottom. In iteration 2, participants were shown the movements of three previous participants. These movements were taken from a prerecorded pool, and were selected to each display the opposite behaviour than the participants' iteration 1 choice. That is, participants who complied with the rule in iteration 1 (green bars) observed three violating peers who moved before the stop light turned green; participants who violated the rule (red bars) observed three compliant peers, who waited at the stop light until it turned green. **d**, Decision screen in iteration 2, where participants completed the task in the presence of three peers. In this example, the three peers violated the rule, moving before the stop light turned green. An animated gif of the task (German original) without and with peers can be viewed [here](#) and [here](#), respectively. The quantity of interest - measuring social information use - was whether or not a participant switched their behaviour upon observing peers choosing the opposite from their own (cf. Fig. 1a,b in the main text).

Figure S2 | Decisions in Iteration 1 of the traffic light task as a function of age. **a**, Distribution of timing of decisions to move the circle before (red) or after (green) the traffic light turned green in the first iteration of the task. The circle figure took about two seconds to approach the stop light (cf. Fig. S1), and the light turned green after 12 seconds. At that time, the participants' endowment had decreased from 20 to 8 points. We observe that most participants either moved directly when arriving at the traffic light (after about 2 seconds, violating the rule), or right after the traffic light turned green (after about 12 seconds, following the rule). **b**, Frequencies of rule compliance (green) and violations (red) as a function of age. We do not observe any significant age trends ($P=0.495$; Table S2). Table S1 shows the number of observations for each age.

a

You received 10 points.

Your decision

Points to self

Points to other

b

You received 10 points.

Previous participant

Points to self: **5** Points to other: **5**

Your decision

Points to self

Points to other

Figure S3 | Dictator game measuring social information use in altruistic giving. **a**, Stylised decision screen for the solo choice (see Supplementary Methods below for translations of all materials in full). Participants divided an endowment of 10 points between themselves and another anonymous previous participant. The numbers in the boxes at the bottom needed to sum up to 10 for a participant to proceed. This is the participants first donation decision (D_1) in the game. **b**, After making their solo decision, participants were matched with another previous participant, and made a second decision (D_2). Before they made this decision, they observed how another previous participant (the ‘peer’) divided their 10 points (donation X). We administered two within-subject experimental conditions, administered in two different sessions. In one condition, participants observed the decision of a ‘fair peer’, who kept 5 points for themselves and donated 5 to the other person. In the other condition, participants observed a ‘selfish peer’, who kept 10 points for themselves and donated 0 points to the other person. Then, the participant again divided the 10 points. From this task we derive two quantities of interest measuring social information use: (i) whether or not a participant changed their donation decision after observing social information; and (ii) the adjustment of donation, divided by the distance between the participant’s first donation and social information: $(D_2 - D_1) / (X - D_1)$.

Figure S4 | Behaviour in the Dictator Games without and with social information. Symbols show donation decisions after observing social information as a function of donation decisions before observing social information (in both plots, each dot represents one participant). The grey diagonal band indicates cases where both decisions were the same. **a**, Behaviour in the ‘fair peer’ condition. Peer donated 5. Most data points are either on, or above the diagonal, indicating that social information tended to increase donations. **b**, Behaviour in the ‘selfish peer’ condition. Most data points are either on, or below the diagonal, indicating that social information tended to reduce donations.

Figure S5 | Perceptual judgment task measuring social information use in belief formation. The task is based on [2]. **a**, Participants observed an image showing a number of animals. After 6 seconds, the image disappeared and participants had to estimate how many animals were shown. **b**, Participants entered their first estimate (E_1). **c**, Then they observed social information (X ; in the form of the first estimate of a previous participant who completed the task before), and entered their second estimate (E_2). This procedure is repeated for five rounds. Note that social information could be towards or away from the true value, and its distance was about 20% away from the participant's initial estimate, to ensure a relatively constant scope for adjustments (Methods). For each round, we define social information use (s) as the adjustment from E_1 to E_2 as a fraction of the distance between X and E_1 : $s = (E_2 - E_1) / (X - E_1)$; rearranging the terms makes clear that E_2 is an average of E_1 and X , weighted by s : $E_2 = (1 - s) * E_1 + s * X$. In other words, s indicates the relative weight assigned to social information. We characterise each individual's propensity to use social information as the mean value of s across the five rounds. In our analyses we focus on cases $0 \leq s \leq 1$.

Figure S6 | Estimates and adjustments in the BEAST. **a**, Distribution of first estimates as a proportion of the true value. On average, participants tended to underestimate the number of animals in the images (cf. Fig. S5), which is in line with previous research using estimation tasks, including studies using the BEAST paradigm [2–4]. **b**, Distribution of adjustments (s ; cf. Fig. S5) across all participants in all rounds of the task. The grey background indicates regions where the second estimate was not a weighted average of a participant's first estimate and social information. In 2.6% of cases (19 out of 730), participants moved away from social information ($s < 0$), and in 3.4% of cases (25 out of 730), participants moved beyond the social information ($s > 1$). In the remaining 94% of cases, adjustments were weighted averages of the participant's initial estimates and social information ($0 \leq s \leq 1$). We observe that participants were likely to keep their first estimate ($s = 0$), which is consistent with previous results obtained with this task [2–4] as well as other tasks in the literature [5–7]. **c**, Distribution of revised estimates after observing social information. To quantify social information use, we selected social information around 20% away from participants' initial estimates. Social information could therefore point towards, or away from the true value. As a result, on average, revised estimates were only very slightly (0.8% closer to the true value) more accurate than initial estimates. A linear model shows that on average, younger participants underestimated more than older participants (fitted values for E_1 / T : 10-year-olds' first estimates were 67% of the true value; for 20-year-olds this was 85%; an increase of 1.86 percentage points each year; $P < 0.001$). During the task, participants did not receive any feedback about their own accuracy and we experimentally controlled the distance between social information and participants' first estimates, ensuring a constant scope for adjustment across rounds (Methods). Importantly, In the statistical analyses fitted to adjustments (Table S4), controlling for initial deviations from the true value did not change any of the main results.

2. Supplementary Tables

Table S1. Age and gender distribution in our sample and across panels of Fig. 1 of the main text. All participants were recruited from the Berlin area and had German as their native language. We aimed for a sample balanced across ages, and within each age group, balanced gender balance. For the traffic light task (measuring rule following), we obtained a measure of social information from all participants, and assignment to experimental conditions depended on a participant's behaviour in the first iteration, where they completed the task alone. That is, a participant observed either three bad examples or three good examples (Methods). For Dictator Game (measuring prosociality), each participant was exposed to both experimental conditions (in separate sessions), observing a selfish peer or a fair peer. We could only measure social information use for those participants whose initial donation was not identical to the donation of the peer. For belief formation we could calculate a measure of social information use for all participants. For calculating factor *S* for each participant, we required a measure of social information use in each of the three tasks (rule following: did or did not follow the examples; prosociality: an initial donation different from the social information in at least one of the conditions; and an average adjustment towards social information in the BEAST). The bottom row in the table shows the number of observations for each column. in accordance with GDPR rules we did not collect further demographic or cognitive variables about which we did have any hypothesis.

				rule following		prosociality		belief formation (Fig. 1E)	factor <i>S</i> (Fig. 1F)
				bad example (Fig. 1A)	good example (Fig. 1B)	selfish peer (Fig. 1C)	fair peer (Fig. 1D)		
age	total	males	females						
10	16	10	6	9	7	15	8	16	15
11	21	7	14	10	11	15	12	21	19
12	18	10	8	10	8	13	12	18	17
13	9	4	5	6	3	5	5	9	9
14	13	10	3	7	6	8	8	13	11
15	13	9	4	8	5	7	11	13	12
16	13	7	6	7	6	5	10	13	12
17	12	7	5	7	5	8	7	12	12
18	9	5	4	4	5	5	8	9	9
19	12	7	5	3	9	11	7	12	12
20	10	5	5	6	4	4	7	10	10
sum	146	81	65	77	69	96	95	146	138

Table S2. Determinants of rule compliance. Numbers show estimates from binomial regressions fitted to decisions in the traffic light task. Model 1 was fitted to decisions to either comply with the rule (coded as 1) or to violate the rule (coded as 0). We observe no significant effects of age or gender. Models 2 are fitted to decisions to conform to peers displaying the opposite behaviour or a participant's own initial behaviour. Conforming is coded as 1, and sticking to own initial behaviour is coded as 0. We observe that participants are significantly more likely to conform to bad examples than to good examples. Furthermore, the overall likelihood of conforming to peers decreases with age. Model 3 is similar to Model 2, but tests the visual impression from Fig. 1a and 1b from the main text, that the difference in conforming to bad examples was particularly strong in early adolescence. This model does not support this visual impression: the interaction effect 'age x condition' is not significant.

Model #	1	2	3
Dependent variable	Compliance in solo condition	Following the examples	
condition (0=good examples, 1=bad examples)		1.379 (0.629, 2.130) p < 0.001	3.310 (-0.258, 6.878) p = 0.069
female	0.635 (-0.030, 1.300) p = 0.062	0.388 (-0.349, 1.126) p = 0.303	0.404 (-0.339, 1.146) p = 0.287
age	-0.032 (-0.135, 0.072) p = 0.550	-0.232 (-0.354, -0.110) p < 0.001	-0.161 (-0.332, 0.009) p = 0.065
age x condition			-0.137 (-0.381, 0.108) p = 0.275
constant	0.286 (-1.280, 1.853) p = 0.721	2.223 (0.449, 3.998) p = 0.015	1.243 (-1.211, 3.697) p = 0.321
Observations	146	146	146
Log Likelihood	-98.971	-84.505	-83.905
AIC	203.9	177.0	177.8

Table S3. Determinants of prosociality in the Dictator Game. Numbers show estimates of models fitted to donations across both conditions of the Dictator Game (which were administered in separate sessions). Each model includes ‘participant’ as random intercept. Model 1 is a linear mixed model fitted to initial donations in both conditions. We observe that, unexpectedly, initial donations happen to be slightly lower in the ‘selfish peer’ condition. More importantly, however, we observe no age effects in initial donations. Model 2 is a logistic generalized linear model fitted to decisions to adjust initial decisions towards the social information (where keeping the initial donation is coded as 0, and moving towards social information is coded as 1). We observe that the likelihood to move towards social information significantly decreased with age. Model 3 is a linear mixed model fitted to absolute adjustments. We observe that adjustments were of similar magnitude across both conditions, and, again, that this magnitude of adjustment decreased with age.

Model #	1	2	3
Dependent variable	Initial decision	Revision: Move (1) or keep (0)	Absolute adjustment
condition (0=fair example; 1=selfish example)	-0.762 (-1.195, -0.330) p = 0.001	0.122 (-0.406, 0.650) p = 0.651	0.001 (-0.361, 0.364) p = 0.995
age	-0.069 (-0.164, 0.025) p = 0.150	-0.269 (-0.376, -0.161) p < 0.001	-0.136 (-0.203, -0.070) p < 0.001
female	-0.140 (-0.743, 0.464) p = 0.650	0.376 (-0.202, 0.955) p = 0.203	0.038 (-0.387, 0.463) p = 0.860
Constant	4.901 (3.333, 6.469) p < 0.001	3.102 (1.413, 4.791) p < 0.001	3.081 (1.938, 4.225) p < 0.001
Observations	287	287	287
Log Likelihood	-635.5	-175.1	-561.2
AIC	1,282.9	360.2	1,134.3
BIC	1,304.9	378.5	1,156.3

Table S4. Determinants of adjustments in belief formation. Numbers show estimates of models fitted to estimate adjustments in the BEAST. Model 1 is a linear model fitted to mean adjustments across the five rounds of the task. We observe that adjustments significantly decrease with age. Model 2 is a linear mixed model fitted to adjustments in individual rounds, with ‘participant’ as random intercept. This model confirms the result from Model 1, that adjustments decrease with age. This model also highlights that across rounds of the task, individuals were consistent in their adjustments, with a repeatability (estimated with *rpt* function in R) of $R = 0.36$ [0.28, 0.44]. Model 3 confirms the robustness of Model 2, fitting a logistic rather than a linear model to adjustments in individual rounds. Controlling for participants’ initial accuracy in individual rounds (by entering E_1 / T as an additional predictor in model 2 and 3; cf. Fig. S6) does not change any of the reported results.

Model #	1	2	3
Dependent variable	Mean adjustment	Round-wise adjustment	
age	-0.021 (-0.032, -0.011) p < 0.001	-0.021 (-0.031, -0.011) p < 0.001	-0.181 (-0.243, -0.119) p < 0.001
female	0.035 (-0.031, 0.101) p = 0.301	0.036 (-0.029, 0.101) p = 0.281	0.220 (-0.148, 0.588) p = 0.242
Constant	0.643 (0.486, 0.799) p < 0.001	0.641 (0.486, 0.795) p < 0.001	1.449 (0.551, 2.348) p = 0.002
Observations	146	685	685
R ²	0.110		
Adjusted R ²	0.098		
Log Likelihood		-53.1	-380.5
AIC		116.2	769.1
BIC		138.9	787.2
Residual Std. Error	0.203 (df = 143)		
F Statistic	8.834 (df = 2; 143)		

Table S5. Relationships between social information use across domains. Model 1 is a logistic model fitted to decisions to conform to peer behaviour (coded as 1) or to stick to one's own initial behaviour (coded as 0). We observe that conformity in the traffic light task positively correlates with average adjustments in the belief formation task (BEAST). The predictor 'condition in the traffic light task' captures the effect that bad examples are more likely to be followed. Model 2 is a logistic generalized linear model fitted to decisions in both conditions of the Dictator Game to move towards social information (coded as 1) or to stick with one's initial donation (coded as 0), using 'participant' as random intercept. We observe that adjustments in the belief formation task positively correlate with decisions to move towards social information in the Dictator Game. Model 3 has the same structure as Model 2, but has as the key predictor whether a participant did (coded as 1) or did not (coded as 0) conform to examples in the traffic light task. We observe that conformity in the traffic light task is positively associated with decisions to move towards peer behaviour in the Dictator Game. Overall, the results from this analysis show that social information use is correlated across the domains of rule compliance, prosocial giving and belief formation.

Model #	1	2	3
Dependent variable	Conformity in traffic light task	Moved towards peer donation	
adjustments in the belief formation task	2.723 (0.907, 4.539) p = 0.004	2.285 (0.705, 3.865) p = 0.005	
following			0.745 (0.030, 1.459) p = 0.042
condition in traffic light (0=good examples, 1=bad examples)	1.505 (0.768, 2.242) p < 0.001		-0.447 (-1.137, 0.242) p = 0.204
condition in Dictator Game (0=fair example; 1=selish example)		-0.145 (-0.741, 0.451) p = 0.635	-0.136 (-0.742, 0.469) p = 0.660
Constant	-1.944 (-2.852, -1.036) p < 0.001	-0.728 (-1.451, -0.005) p = 0.049	-0.011 (-0.614, 0.592) p = 0.971
Observations	146	204	204
Log Likelihood	-88.192	-136.095	-138.150
AIC	182.384	280.191	286.300
BIC		293.463	302.891

3. Experimental Procedures and Materials

Below you find English instructions of the behavioural experiments reported in our paper. Original instructions were in German (the native language of all participants), and are available upon request from the corresponding author. The behavioural tasks reported were administered two separate sessions which took place approximately four weeks apart. The tasks were part of a larger battery of tasks and questionnaires. The elements of the battery not reported in this paper which were part of a separate study designed to test a model of reward sensitivity. These included a number of questionnaires (e.g., measuring IQ and emotional intelligence) and an incentivized two-alternative forced choice task. The order of tasks was randomized between participants, with the constraint that the two sessions each contained only a single condition of the Dictator Game. The value of points varied between tasks to hold the expected hourly earnings constant across tasks and keeping the initial numbers of points in each task as multiples of ten.

Where appropriate, clarifying comments on task screens are added in grey boxes. On-screen buttons are indicated [between square brackets]. New screens are indicated with double horizontal lines.

3.1. Task measuring social information use in rule compliance

Instructions

This task consists of several parts.
In each part, you can earn points.

How many points you earn, will depend on your decisions.

Once you are ready, the computer will choose one of the parts to determine your earnings. That is, the number of points you earned in that part will be converted into real money, and will count towards your total earnings (**20 points = €1.00**).

This means that only one of the parts will be chosen for payment for this task.

[Continue]

Instructions part 1

In part 1 of this task you control a circle figure that you have to move across the screen and over the finish line.

When you click on the 'Move' button at the bottom of your screen, the circle will approach the traffic light and stop to wait.

To move the circle again, again click the **Move** button.

The rule is to wait at the stop light until it turns green.

Your earnings for part 1 depend on the amount of time it takes you to move your circle across the finish line.

You start with an endowment of 20 points.

Each second, this endowment decreases with 1 point, until your circle has crossed the finish line.

After part 1 you will receive the instructions for part 2.

Please click 'Continue' when you understood these instructions.

Before part 1 starts, a brief quiz will test whether you understood the task.

[Continue]

Control questions

Please remember, that your earnings for part 1 depend on how much time you take to move your circle across the finish line.

You start with 20 points, and each second, this endowment is reduced with 1 point, until you reach the finish line.

Please answer the following questions.

1. Imagine that you wait at the stop light and move until it turns green.

You finish the task in 15 seconds.

How many points would you earn? *[numeric input field]*

2. Imagine you do not wait until it turns green.

You finish the task in 4 seconds.

How many points would you earn? *[numeric input field]*

[Continue]

[Back to instructions]

Ready to start

That is correct! Please click below to start part 1.

[Continue]

Upon screen load, the following fade-in popup was shown. Participants had to click 'OK' before they could start the task itself.

Reminder:

- Press the **Move** button to move your circle
- The rule is to wait at the stop light until it turns green.

[OK]

Impression of the animated task at five time points in the game. For an animated gif (German original), see http://54.236.133.145/videos/stop_light_task_solo_DE.gif

End of part 1

This is the end of part 1.
Please click below to continue to part 2.

[Continue]

Instructions part 2

Part 2 of this task is similar to part 1. Again, you control a dark blue circle figure that you have to move across the screen and over the finish line.

In this part, you will also see light blue circles. These circles show the movements of other participants.

Like in part 1, your circle will approach the stop light when you press the 'Move' button. The move your circle again, you again have to click the 'Move' button.

The rule is to wait at the stop light until it turns green.

Again, you start with an endowment of 20 points. Each second, your endowment will be reduced with 1 point until your circle has crossed the finish line.

After part 2 you will receive instructions for part 3.

Please click 'continue' to start part 2.

[Continue]

This is a screenshot of the start point of the task. For an animated gif (German original), see http://54.236.133.145/videos/stop_light_task_social_DE.gif

Your endowment: **20** points

Move

End of part 2

This is the end of part 2
Please click 'Continue' to proceed to part 3.

[Continue]

Instructions part 3

Part 3 of this task is similar to part 1. You control a circle figure that you have to move across the screen and over the finish line.

Like in part 1, the circle will approach the stop light when you click 'Move'. To move your circle again, again click the 'Move' button.

The rule is to wait at the stop light until it turns green.

Again, you start with an endowment of 20 points. Each second, your endowment will be reduced with 1 point until your circle has crossed the finish line.

After part 3 this task is over.

Please click 'Continue' to start part 3.

[Continue]

The animated decision screen of part 3 is identical to part 1.

End of part 3

This is the end of part 3.

Please click 'Continue' to finish the task and see what you have earned.

[Continue]

Your earnings in this task

The computer has selected part X to determine your earnings.

In this part you earned X points.

These points are worth **€X**.

Please ask the test leader for further instructions.

Task measuring social information use in prosocial behaviour: Dictator Game

Instructions

In this task you will make a number of decisions.
With these decisions, you can earn **points**.
Your decisions can also influence the earnings of other participants.

How many points you earn, will depend on your decisions.
At the end of this session, your points will be converted into money.

20 points are worth €1.00.

[Continue]

A brief game

In this task you will play a brief game.
You will be matched with **another person**.
This person has participated in a previous session. You have not interacted with this person before.

In the game you are either **player 1** or **player 2**.
Player 1 receives 10 points and can decide how to divide these **10 points** between **player 1** and **player 2**.

Once **player 1** has made a choice, the game is over.
Player 1 and player 2 receive the points that player 1 has allocated.
At the end of this session, these points will be converted into money and will be given to you, and the money for the other player will be transferred to them.

Before we start, we want to make sure that you understood the rules.
Please indicate whether the following statements are correct or incorrect.

Player 1 decides how the 10 points will be divided between themselves and player 2.

[correct] [incorrect]

Player 1 receives the most points when they give all 10 points to themselves and 0 points to player 2.

[correct] [incorrect]

Player 2 earns most points when player 1 gives all points to player 2.

[correct] [incorrect]

[Continue]

Correct!

You have answered all control questions correctly.
Please click below to continue.

[Continue]

Make your decision

You are **player 1**. You receive 10 points.

Please decide how you want to divide these 10 points between you and player 2.

Points for yourself

Points for player 2

[numeric input field]

[numeric input field]

[Continue]

A second brief game

Thank you. Your decision has been recorded.

Now you will play a **second** brief game.
Again, you will be matched with a **new person**.

This person has participated in a previous session and you have not interacted with this person before.

In the game you will again be **player 1**.
The other person will be **player 2**.
You will receive 10 points and can decide **how to divide these 10 points between you and player 2**.

This time, therefore you make your decision, you will see the decision of another **player 1**.
This person has participated in a previous session and also had to divide 10 points between themselves and another participant.

After you have seen the decision of the other participant, you can make your own decision.
Once you have made your decision, the game is over.
You and player 2 receive the points that you allocated.

Before we start, we want to make sure that you understood the rules.
Please indicate whether the next statements are correct or incorrect.

In the second game, you again have to divide 10 points between yourself and player 2.

[correct] [incorrect]

Before you make your decision, you will see the decision of another player 1, who participated in a previous session.

[correct] [incorrect]

[Continue]

Correct!

You have answered all control questions correctly.
Please click below to continue.

[Continue]

Make your decision

You are **player 1**. You receive 10 points.

Player 1 in the previous session made the following decision:

Points for themselves

5

Points for player 2

5

Please decide how you want to divide the 10 points between you and player 2.

Points for yourself

[numeric input field]

Points for player 2

[numeric input field]

[Continue]

The above information was given in the 'fair peer' condition. In the 'selfish peer' condition, we showed the following distribution of player 1 from the previous session: **10** for themselves and **0** for player 2.

Task completed

This is the end of the task.

You have earned **X points**.

(Points from your decision in the first game *plus* points from your decision in the second game.)

These points are worth €X.

Please call the test leader for further instructions.

Task measuring social information use in belief formation: BEAST

This task is based on the validated paradigm developed by Molleman et al (2019) [2].

Instructions

In this task you will make a number of estimates.

The number of points you will earn in this task depends on *how accurate* your estimates are.

[Continue]

Instructions 1/3

This task consists of 5 rounds.

At the beginning of each round, an image will be displayed, showing a certain number of animals.

The image will disappear after 6 seconds. After these 6 seconds, you have to estimate how many animals were shown.

The better your estimate, the more points you can earn

[Continue]

Instructions 2/3

Once the image has disappeared, you will have to enter your estimate of how many animals were displayed.

This will be your estimate for part A of a round.

Once you have entered your estimate, part B of the round begins.
You can see the part A estimate *of another participant*.

Over 100 people have completed this task before you.

In each round, you can see the part A estimate of another participant of that round.

The previous participant saw the exact same image as you. They also saw it for 6 seconds.

Once the image had disappeared, they also had to estimate how many animals were displayed.
They could also earn a larger bonus when their estimates were more accurate.

Then you have to enter your estimate for **part B** of that round.

After you have entered your estimate for part B, the round is over, and a new round will start.

[Continue]

[Go back]

Instructions 3/3

Your bonus in this task

The better your estimate, the more points you can earn in this task.

Your bonus in Task X will be calculated as follows:

In each round you can earn points.

If your estimate of the number of animals is exactly correct, you earn 100 points.

For each animal you were off, 5 points will be subtracted.

Your points in a round cannot become negative.

At the end of this session, your points will be converted into real money.

In this task, **100 points are worth €0.30.**

During the task you will not receive information about your current earnings.

The total number of points will be shown at the end of the session.

Click 'Continue' if you understood the task.

A brief quiz will follow to check whether you understood the task.

If you have any further questions, please ask the test leader!

[Continue]

[Go back]

Did you understand everything?

To test if you understood the task, please indicate whether the following statements are correct or incorrect:

In each round of this task you will see an image. You have to estimate how many animals are shown in the image.

[correct] [incorrect]

Once you have entered your estimate, you will see the estimate of another participant, who completed this task before. You can then enter a second estimate.

[correct] [incorrect]

The better your estimate, the more points you will earn.

[correct] [incorrect]

The more points you earn, the more money you get at the end of the session

[correct] [incorrect]

[Continue]

[Back to instructions]

Round X of 5

In round 1, the following text was displayed

Thank you! You have answered all questions correctly. The task starts now.

In rounds 2-5, the following sentence was displayed as the first sentence

A new round starts now.

When you click 'Continue', an image will be displayed, showing a number of [animal_name]

In rounds 1-5, the placeholder [animal_name] showed the respective animal name from the following 5 animal species: ants-bees-flamingos-cranes-cricket; always shown in this fixed order.

After 6 seconds, the image will disappear.

Then you can enter your estimate of how many ants/bees/flamingos/cranes/cricket were displayed.

Click 'Continue' when you are ready.

[Continue]

This is the stimulus for round 1; below we show the stimuli for rounds 2-5 (smaller sized). The screen also showed a countdown from 6 to 0 seconds.

Round 1: part A estimate

How many ants/bees/flamingos/cranes/crickets were displayed?

[numeric input field]

[Continue]

In contrast to Molleman et al 2019 (which used an adult sample), we did not use any timers in this experiment as to not hurry the younger participants in our sample.

Round 1: part B estimate

You estimate of **[your_estimate]** has been recorded.

Now we show you the part A estimate of another participant who completed this task before you.

This participant saw the exact same image as you did, and also saw it for 6 seconds.

The estimate of the other participant was: **[social_information]**.

Below you can enter your estimate for part B.

How many **[animal_name] were displayed?**

[numeric input field]

The placeholders **[your_estimate]** and **[social_information]** showed the estimates of the current participant and the estimate of a previous participant, respectively. The placeholder **[animal_name]** displayed the name of the animal shown in the stimulus in the current round. Again, we did not use any timers in this experiment as to not hurry the younger participants in our sample.

[Continue]

End of this round

This is the end of round X.

Please click 'Continue' to proceed.

[Continue]

End of task

You have finished the task.

Your earnings will be shown to you at the end of this session.

Below you find a few questions about this task.

Please answer these questions.

How hard did you find this task?

[very easy] [easy] [not easy, not hard] [hard] [very hard]

Did you use a certain 'rule' or 'tactic' to make your estimates after you saw the estimate of the previous participants?

[text input field]

What was your general impression of the previous participants?

[text input field]

If you have any further comments on this task, please write them below:

[text input field]

[Continue]

Task finished

You have finished this task.

Your earnings will be shown to you after this session has finished.

You can now take a short break.

Click below when you are ready to start the next task.

[Continue]

Your earnings in this task

In this task, you have completed 5 rounds in which you estimated how many animals were shown on an image.

In each round you first made an estimate ('part A') and then saw the estimate of a previous participant. Then you entered a second estimate ('part B').

In each round you could earn 100 points if your estimate was exactly correct.

For each animal you were off, we subtracted 5 points.

In this task you earned X points.

In this task, 100 points were worth €0.30. So, your bonus earnings for this task are X.

On average your estimates were X away from the real number.

Your most accurate estimate was X animals off (round X, part X).

Your least accurate estimate was X animals off (round X, part X).

Please ask the test leader for further instructions.

Supplementary References

1. Gächter S, Molleman L, Nosenzo D. 2018 The behavioral logic of rule following and social norm compliance.
2. Molleman L, Kurvers RH, van den Bos W. 2019 Unleashing the BEAST: a brief measure of human social information use. *Evol. Hum. Behav.* **40**, 492–499.
3. Molleman L, Kanngiesser P, Bos W van den. 2019 Social information use in adolescents: The impact of adults, peers and household composition. *PLOS ONE* **14**, e0225498. (doi:10.1371/journal.pone.0225498)
4. Molleman L, Tump AN, Gradassi A, Herzog S, Jayles B, Kurvers RHJM, van den Bos W. 2020 Strategies for integrating disparate social information. *Proc. R. Soc. B Biol. Sci.* **287**, 20202413. (doi:10.1098/rspb.2020.2413)
5. Yaniv I. 2004 Receiving other people's advice: Influence and benefit. *Organ. Behav. Hum. Decis. Process.* **93**, 1–13. (doi:10.1016/j.obhdp.2003.08.002)
6. Moussaïd M, Kämmer JE, Analytis PP, Neth H. 2013 Social influence and the collective dynamics of opinion formation. *PloS One* **8**, e78433.
7. Moussaïd M, Herzog SM, Kämmer JE, Hertwig R. 2017 Reach and speed of judgment propagation in the laboratory. *Proc. Natl. Acad. Sci.* **114**, 201611998.