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Physical Effort Exertion for Peer Feedback Reveals Evolving Social Motivations From Adolescence to Young Adulthood

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Abstract
Peer relationships and social belonging are particularly important during adolescence. Using a willingness-to-work paradigm to quantify incentive motivation, we examined whether evaluative information holds unique value for adolescents. Participants ($N = 102$; 12–23 years old) rated peers, predicted how peers rated them, and exerted physical effort to view each peer's rating. We measured grip force, speed, and opt-out behavior to examine the motivational value of peer feedback, relative to money in a control condition, and to assess how peer desirability and participants' expectations modulated motivated effort across age. Overall, when compared with adolescents, adults were relatively less motivated for feedback than money. Whereas adults exerted less force and speed for feedback when expecting rejection, adolescents exerted greater force and speed when expecting to be more strongly liked or disliked. These findings suggest that the transition into adulthood is accompanied by a self-protective focus, whereas adolescents are motivated to consume highly informative feedback, even if negative.

Keywords
adolescent, peer feedback, social, motivation, effort, open data, open materials

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The need for social belonging is a fundamental human drive (Baumeister & Leary, 1995) and is especially salient during adolescence (Somerville, 2013). Adolescence is characterized by dramatic changes in social roles and experiences (Arnett, 1999; Crone & Dahl, 2012). As individuals enter adolescence, they spend more time with peers than family (Larson, 2001) and place greater importance on peer relationships (Brown, 1990). Adolescents also exhibit heightened emotional responses to peer evaluation (Sebastian et al., 2010; Silk et al., 2012; Somerville et al., 2013). Thus, adolescence is a stage accompanied by increased social attunement and preoccupation with social belonging.

Developmental theory posits that adolescents are continuing to refine their social competency (Harter, 1988), and their developing self-concept is shaped by feedback from others (Pfeifer et al., 2009; Yoon et al., 2018). Peer relationships are particularly unstable during adolescence (Cairns et al., 1995; Poulin & Chan, 2010), resulting in more frequent signaling of acceptance and rejection than in adulthood. Thus, information pertinent to one's social standing may be especially valuable to adolescents to track their inclusionary status. We evaluated this possibility by quantifying the value adolescents and adults place on social evaluative information.

We also examined whether participants' prior judgments and expectations moderated the value of social feedback. Given previous work in adults showing motivated behavior in service of self-protection (Beauregard & Dunning, 1998; Rodman et al., 2017), we predicted that adults would value potential feedback less when they expect to be rejected. However, we expected adolescents to behave in one of two ways. On the one

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hand, they may uniformly value all peer feedback, no matter their expectations or who from. On the other hand, they could be especially motivated to receive feedback that has more potential bearing on social standing, such as when feedback is from a high-status peer or when the feedback is expected to be extreme, where being strongly liked or strongly disliked could have the greatest impact on social belonging. Thus, we examined whether the value of peer feedback is moderated by the participant's judgments of the peers giving feedback and expectations about how favorably they were rated by peers.

Value can be inferred from motivation to exert effort in pursuit of an outcome. Seminal work in adults shows how behaviors guided by *incentive motivation* manifest in greater expression of effort, tracking the value of a prospective reward (Niv et al., 2007; Salamone et al., 2007). Adults expend more physical and mental resources to obtain larger monetary rewards (Kool et al., 2010; Pessiglione et al., 2007; Schmidt et al., 2012). Our prior work demonstrated that adolescents and adults similarly exert greater physical effort for increasing monetary rewards (Rodman et al., 2021). Thus, indices of physical exertion may serve as a readout of motivational value that can be compared across adolescents and adults.

In the present study, we adapted a classic physical effort paradigm (Pessiglione et al., 2007) to examine willingness to work for social feedback, allowing us to quantify the motivational value of social evaluative information in adolescents and young adults. We examined subcomponents of motivational value, including response vigor (force and speed), along with strategic decision-making (frequency of opting out of effort exertion). Participants were told they were part of a multisite study investigating how individuals formulate first impressions. This cover story set up a reciprocal social evaluation task (Fig. 1), in which participants rated peers indicating how much they would want to be friends, predicted how they had been rated by each peer on the same question, and then squeezed a hand dynamometer to find out how that peer had rated them (i.e., acceptance or rejection). Participants also exerted effort to receive monetary rewards as a nonsocial control condition. We sought to determine (a) how the motivational value of peer feedback relative to money differed by age, (b) whether participants' predictions of being accepted—*acceptance expectancy*—impacted motivational value of peer feedback across age, and (c) whether motivational value of peer feedback varied by participants' impressions of peers—*peer desirability*—across age. Analyses followed a data-driven approach to examine nonlinear patterns of age-related change and were inherently exploratory. Analyses in R code, experimental task *PsychoPy* code, and participant data are publicly available online at OSF (https://osf.io/yf7a6/).

Statement of Relevance

Adolescence is a time of intense preoccupation with peer approval and vulnerability to the negative effects of peer rejection. During this period, adolescents must navigate new and shifting relationships with peers, which engenders signals of social inclusion or exclusion that can be used to guide their future social behavior and inform their self-views. Here, we used a physical effort task to characterize whether information about being liked or disliked by peers is especially valuable to adolescents. We found that adolescents value social evaluative information more than adults do, even when they expect to be rejected by a peer. Adults, meanwhile, devalue rejecting feedback, adding to a growing body of work suggesting self-protective biases continue to develop throughout adolescence. Although social feedback provides important learning signals about one's social standing, such tendencies could expose adolescents to repeated rejection during a developmental stage when it is particularly damaging.

Method

Participants

One hundred two healthy individuals from the Boston, Massachusetts, area completed this study. Participants were between 12.03 and 23.77 years old (M = 18.19, SD = 3.52) and 47.62% female (see Fig. S1 in the Supplemental Material available online). Distribution of gender did not vary significantly across age (logistic regression: B = 0.011, p = .849). Participants' ethnic/racial diversity reflected the local community, with 58.5% identifying as White, 17.0% as Asian, 9.4% as Black, and 8.5% as multiracial (1.9% did not report). Participants provided informed written consent/assent, and parents/caregivers of minors gave written permission for their participation. The Committee for the Protection of Human Subjects at Harvard University approved this research.

Study visit

Pretask procedure. This study implemented a novel adaptation of a task that simulates mutual social evaluation (Rodman et al., 2017; Somerville et al., 2006) embedded in

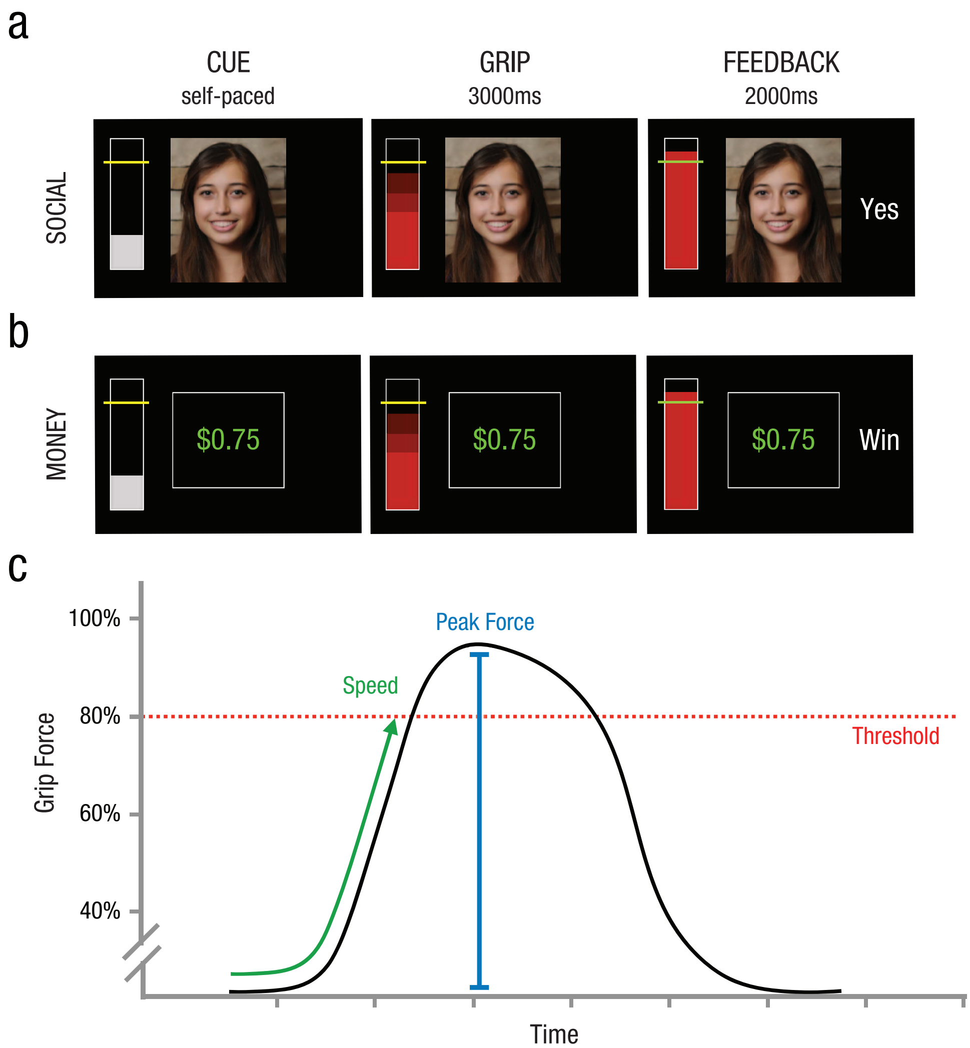

Fig. 1. Schematic representation of the experimental task and outcome measures. Participants completed a version of the task to obtain money and a version of the task to obtain peer feedback. First, participants viewed a vertical box indicating the difficulty of the trial (yellow line) and the target of effort for that trial. In the social task (a), a photograph of each peer was displayed. During the grip phase, participants were instructed to squeeze the dynamometer to reach the yellow threshold line (40% of their maximum strength for easy trials, 80% for hard trials as shown here) in order to view the feedback from that peer. Physical effort was displayed in real time by the height of the red bar, and the yellow threshold line turned green once reached. If participants reached the threshold, the peer feedback ("Yes" indicating liked, "No" indicating disliked) was displayed on the right side of the screen. In the money task (b), the amount of money that could be earned was presented for each trial ($0.05 or $0.75), and if participants successfully reached the threshold, they earned the money ("Win"). This study quantified outcome variables from the experimental task (c), including peak grip force, speed to threshold, and opt-out trials.

a classic physical effort paradigm (Pessiglione et al., 2007). Before the study visit, participants submitted a headshot to be rated by unknown, age-matched peers. In return, participants rated each peer's photograph on the basis of the prompt, "Imagine you are starting at a new school. How much do you think you would want to be friends with this person?" Response ranged from *not at all* to *very much* (output 1–100). Participants believed that their photographs were rated by peers on the basis of the same prompt (independently of participants' ratings of peers). At the study visit, participants predicted how each peer had rated their photograph, responding to the prompt, "How much did this person want to be friends with you?" using a continuous scale from *not at all* to *very much* (output 1–100). In prior work, participants similar in age remembered feedback received from 160 peers in a surprise memory test, and accuracy did not vary with age (Rodman et al., 2017). This lends confidence in participants' ability to remember their responses during the subsequent task. All peer rating (desirability) and prediction (expectancy) values were z-scored within participants and analyzed continuously to account for differences in scale usage.

Social motivation task: effort exertion for peer feedback. Participants were instructed to squeeze a hand dynamometer to a prescribed threshold to obtain the trial outcome. At the start of each trial, participants were shown a photograph of each peer and a dynamically updating progress bar displaying their grip force progress toward the threshold in real time (Fig. 1a). A yellow line across the progress bar indicated the threshold difficulty for that trial (40% or 80% of maximum grip). Participants pressed the space bar when ready to begin squeezing to isolate the execution phase of the time series, as in prior work (Kurniawan et al., 2010). Participants then squeezed the dynamometer to find out how the peer had rated them. During the grip phase (3,000 ms), participants applied force to the hand dynamometer, and if the progress bar exceeded the yellow threshold, it turned green to indicate that the participant had reached the threshold. During the feedback phase (2,000 ms), participants were shown the peer's rating ("Yes"/"No"). If participants did not reach the threshold, they were not shown any feedback. Participants were informed that "Yes" and "No" corresponded to the top and bottom half of the rating scale assessing how much the peer wanted to be friends with the participant. Thus, "Yes" feedback was a positive endorsement of interest in being friends, and "No" feedback was a negative endorsement. Following previous versions of this physical effort paradigm (Kurniawan et al., 2010; Schmidt et al., 2012), we included low and high levels of difficulty in order to induce a psychological context in which effort is made salient by varying it across trials. In addition, the current task design constrained effort exertion to the specified threshold so precise and interpretable motivational readouts could be observed and compared across conditions and age. For example, differences in peak force primarily reflect force exerted in excess of the instructed threshold. Thus, although these highly constrained measures reflect underlying value-related processing, they restrict the range of data, resulting in small-magnitude differences across conditions.

The social evaluation task contained 60 trials, each with a different peer. Peer photographs were age-matched and equal in gender distribution, and racial/ethnic diversity was reflective of the local community (for details on stimulus development, see (Rodman et al., 2017). Feedback was constructed by experimenters with 50% positive and 50% negative feedback, which was counterbalanced, randomized, and equally dispersed among easy and hard trials.

Money motivation task: effort exertion for monetary reward. Participants also completed a version of the task in which they exerted physical effort to obtain money (Fig. 1b). The structure of this task was identical to that of the social version. On each trial, participants were shown a cue representing the monetary value at stake ($0.05 or $0.75). If successful, participants were shown "Win"; on unsuccessful trials, they were shown nothing. The money task contained 32 trials, which were randomized and equally split across levels of reward and difficulty. This task included fewer trials than the social task for two reasons. First, it had fewer conditions with only two levels of reward, whereas the social task contained a spectrum of trial types varying in expectancy and peer desirability, requiring more trials for modeling purposes. Second, we wanted to avoid including superfluous trials that could lead to fatigue, especially given limited prior work using this physical paradigm in developmental populations. At the end of the study visit, participants received performance-contingent bonus payouts in cash totaling the sum of successful trials. Participants completed a practice version of both tasks to ensure comprehension. Data from the money task have been reported previously (Rodman et al., 2021); however, this prior work does not overlap with any analyses presented here.

Participants completed the money task before the social task. For analyses directly comparing effort expended for money and social feedback, steps were taken to address any possible impacts of order or fatigue on results. First, all models included a covariate representing the cumulative count of trials across both tasks. Second, we conducted control analyses including a fatigue score as a covariate (change in maximum force calibration before and after the study session), and all findings held, mitigating concern of potential fatigue or order effects (Table S1 in the Supplemental Material).

Maximum force calibration. At the start of the study session, participants completed a stepwise calibration procedure to titrate the relative difficulty of trials to each individual's hand strength (40% or 80% of maximum), as in prior work (Kurniawan et al., 2010). See the Supplemental Material for details.

Analytical approach

We quantified the motivational value for social evaluative information via physical effort by extracting three complementary measurements of the grip time series, analyzed at the trial level (Fig. 1c). A measure of response vigor, *peak grip force* is quantified as the maximum force exerted for each trial. A second measure of response vigor is the *speed* at which participants reached the threshold. Note that neither applying force beyond the threshold nor faster speed impacted the participant's success for that trial (receiving feedback or money) and therefore reflect a noninstrumental behavior (nonstrategic). We also examined the frequency of *opting out* of trials altogether, defined as failing to engage in minimal effort to obtain feedback or money. As demonstrated in our prior work (Rodman et al., 2021), less valuable targets are more likely to evoke strategic opt-out behavior.

Three sets of analyses were conducted to examine main effects and age-related differences in motivation for the following predictors of interest: (a) peer feedback versus money targets, (b) expectancy of receiving accepting versus rejecting feedback, and (c) the desirability of the peer providing feedback. Although age was treated continuously in analyses, we generally refer to adolescents and adults when discussing broad patterns of results and their implications.

Because of the possibility of complex, nonlinear age-related differences in motivational and social processes, as well as our interest in the interaction between continuous and potentially nonlinear variables (acceptance expectancy, peer desirability by age), we implemented a generalized additive mixed-effects model (GAMM) approach using the "gamm" function of the *mgcv* package (Wood, 2017, 2019) in R (R Core Team, 2018). This approach generates a data-driven function summarizing age-dependent change through thin plate smoothing splines (Wood, 2003), which is stabilized using leave-one-out cross-validation and penalized for complexity to avoid overfitting. Although our analyses were rooted in theory that guided expectations about general directions of age-related differences, the GAMM framework used herein reveals complex, nonlinear age patterns in a data-driven way that is inherently exploratory.

We built GAMMs including the predictor of interest, age (centered), and their interaction. For interactions with categorical predictors (social vs. nonsocial targets by age), this approach fits a nonlinear function (spline) for each categorical level (Fig. S2A in the Supplemental Material), but it does not provide a direct test for the interaction term. Thus, we computed a 95% confidence interval (CI) around the relative difference in predicted fits of effort exertion for feedback compared with money targets by age using the "plot_diff" function from the package *itsadug* (Rij et al., 2020). The calculation of the 95% CI allowed us to visualize and interpret the fit of the age interaction. For interactions with continuous predictors (acceptance expectancy, peer desirability by age), we used a smoothing tensor, which fits a 3D functional plane to characterize nonlinear patterns of the two continuous interacting variables (Fig. S2B in the Supplemental Material). All models included a random effect of participant and the following covariates: *trial number* to account for potential fatigue effects (for social vs. money models, we used cumulative trial across the two tasks), *maximum force strength calibration* to account for any residual impact of participants' grip strength, and *trial difficulty level* to account for its inherent association with peak and speed. We collapsed results across difficulty level to constrain model complexity. While the GAMM framework is unable to produce standard effect sizes (Wood, 2017, 2019), we report extracted marginal means to illustrate the magnitude of effects (Table S3 in the Supplemental Material). Analyses examining peak grip force and speed—both measures of response vigor—were corrected for multiple comparisons (when analyses yielded a p value) as a sensitivity analysis, and all findings held (Table S2 in the Supplemental Material). See the Supplemental Material for details on exclusion criteria, equipment, plotting approach, outcome measures, and secondary and control analyses, as well as additional figures and tables, full reporting on statistical outcomes (Table S4), and the debriefing procedure.

Results

Effort exertion for social and nonsocial targets

Peak grip force. To examine the effect of social versus money targets on peak grip force, we computed a GAMM with target type, age, and their interaction as predictors of interest. Accounting for key nuisance regressors, we found that participants overall exerted greater peak grip force to obtain peer feedback compared with money (71.04% vs. 69.38%), $F(1, 8963.77) = 32.92$, $p < .001$. The main effect of age on overall force exerted was not significant, $F(1, 8966) = 2.25$, $p = .134$. To examine the interaction between age and target type, we visualized the age interaction fit and calculated a 95% CI. The plot revealed that younger participants (~12–20 years old) showed greater grip force for peer feedback than money (71.67% vs. 69.75%, respectively), which began to diminish around the transition into adulthood (~18–21 years old). Older participants (23 years old) showed comparable force for feedback compared with money (69.16% vs. 68.50%, respectively; Fig. 2a). See Table S3 for extracted marginal means.

Speed. When examining whether grip speed differed on the basis of target type, the GAMM revealed that participants overall were significantly faster to obtain money than peer feedback (Ms = 729 ms vs. 847 ms, respectively),[1]

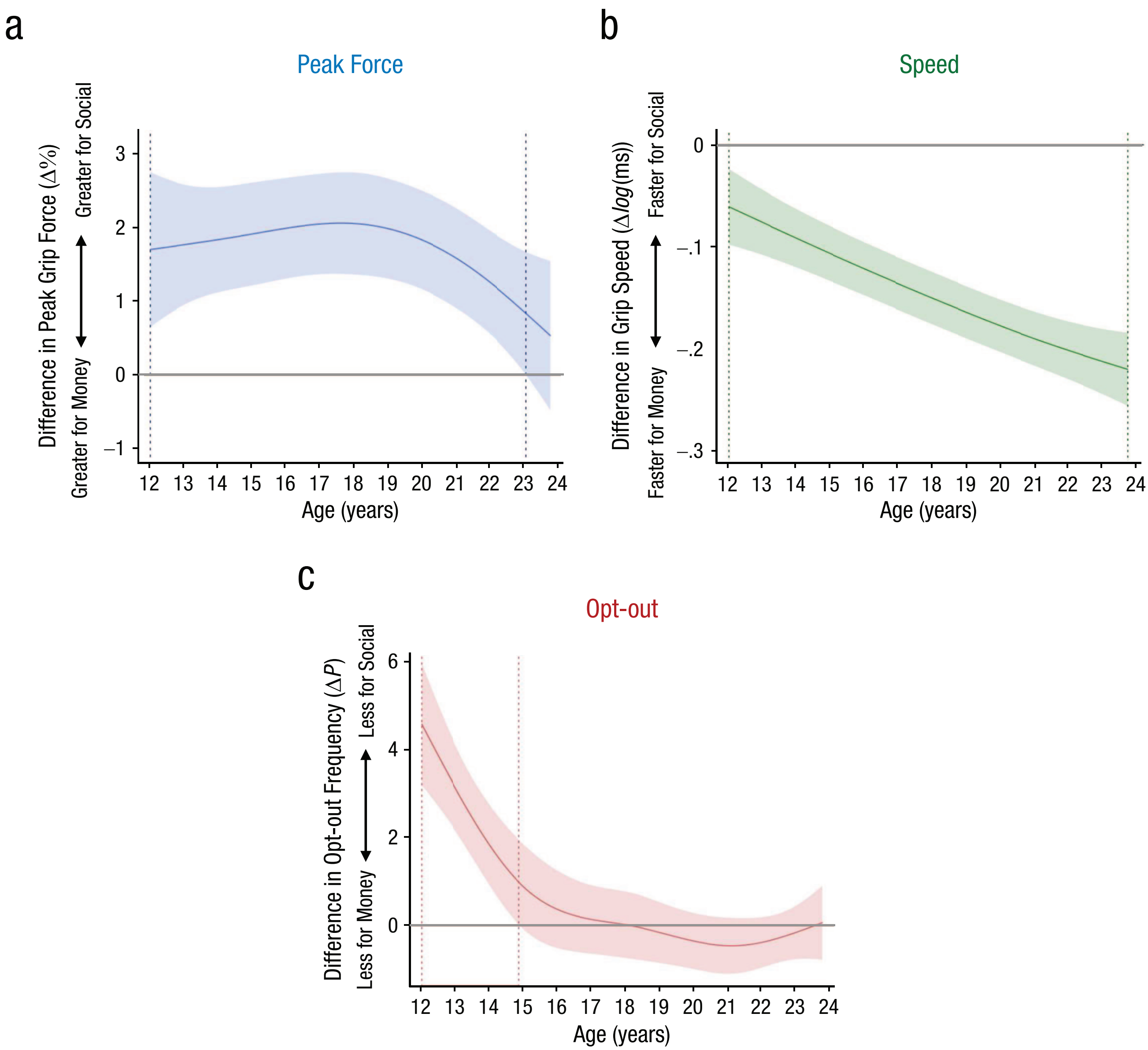

Fig. 2. Age-related effects of social versus nonsocial targets on effort exertion, as indexed by (a) peak force, (b) speed, and (c) opt-out behavior. The figure demonstrates the relative difference in marginal effects of effort exertion for money compared with peer feedback across age. Whereas older participants showed comparable effort (peak force, opt-out behavior) or greater effort (speed) for money compared with peer feedback, adolescents showed a pattern that was diminished (speed) or reversed (peak force, opt-out behavior). The *x*-axis displays continuous age, and the *y*-axis displays the difference in marginal effects of effort exertion for social versus money tasks—peak grip force in units of percentage of maximum grip, speed in units of log(milliseconds), and opt-out behavior is units of probability. Shading indicates 95% confidence intervals (CIs), and dashed lines identify sections where the 95% CI does not contain zero.

$F(1, 8647.58) = 151.47$, $p < .001$. The main effect of age on overall grip speed was not significant, $F(1, 8649) = 1.20$, $p = .274$. To examine the age interaction, we again visualized the interaction fit and computed the 95% CI. Although all participants were faster to obtain money relative to peer feedback, this effect was diminished in early adolescence (~12–15 years old; *M*s = 730 ms vs. 793 ms, respectively) and most pronounced in older participants (~20–23 years old; *M*s = 730 ms vs. 893 ms, respectively), suggesting relatively weaker vigor for social feedback with increasing age (Fig. 2b).

Opt-out behavior. We investigated strategic opt-out behavior, in which participants did not exert effort, effectively declining the chance to receive money or social feedback. The GAMM showed that overall, participants were more likely to opt out of social compared with money targets (0.43% vs. 0.33% probability), $F(1, 9374.74) = 4.270$, $p = .039$. Additionally, a significant effect of age was found, $F(1, 9378) = 9.11$, $p = .003$; specifically increasing age was associated with more frequent opt-out behavior overall (0.33% vs. 0.65% probability in 12- to 15-year-olds and 20- to 23-year-olds, respectively). We again evaluated the task-by-age interaction by visualizing the fit and calculating a 95% CI. Whereas younger participants (~12–15 years old) opted out of money trials more often than feedback trials (0.63% vs. 0.03% probability), older participants (~15–23 years old) showed a similar tendency to opt out of social and money trials (0.38% vs. 0.43% probability; Fig. 2c).

Summary. Taken together, we found evidence that adolescents express greater relative motivation for social feedback compared with adults. Across all three measures, adolescents' expressed motivation was enhanced for social targets relative to the motivation expressed by adults. Young adults consistently show greater or equivalent motivation for money compared with feedback, whereas this pattern either diminished or reversed for adolescents.

Effort exertion for peer feedback

Next, we examined whether participants' expectations of being liked, termed acceptance expectancy, and impressions of peers, termed peer desirability, modulated the motivational value of peer feedback across age. See the Supplemental Material for descriptive, gender, and age analyses of raw ratings.

Acceptance expectancy.

Peak grip force. We examined whether effort exertion (force) for peer feedback differed by participants' expectations of being liked. Findings from the GAMM indicated a significant nonlinear main effect of acceptance expectancy: Participants exerted greater force when they had more extreme expectations of being strongly liked or strongly disliked than when they expected neutral feedback (74.05%, 71.65%, 69.59%, respectively) but especially when they believed they would be liked, $F(3.23, 5673.44) = 6.72$, $p < .001$ (Fig. S3A in the Supplemental Material). The overall effect of age on force was not significant, $F(1, 5673.44) = 2.74$, $p = .098$.

Findings revealed a significant expectancy-by-age interaction, $F(2.33, 5673.44) = 3.20$, $p = .029$. A 3D heat map visualizing the nonlinear relationship between the continuous variables expectancy and age was used to interpret the nature of the interaction. Whereas older participants (~22–23 years old) exerted more force for feedback when they expected acceptance rather than neutral or rejection feedback (74.23%, 68.35%, 68.16%, respectively), younger participants (~12–18 years old) exerted more force when they had more extreme expectations of being strongly liked or strongly disliked than when they expected neutral feedback (74.28%, 73.38%, 70.43%, respectively; Fig. 3a).

Speed. Examination of grip speed yielded similar results. The GAMM revealed a nonlinear effect of expectancy: Overall, participants exerted force at slightly faster speeds when they expected neutral compared with rejection feedback (*M*s = 843 ms vs. 871 ms) but were especially fast when they expected acceptance ($M = 730$ ms), $F(2.70, 5444.30) = 6.43$, $p = .002$ (Fig. S3B in the Supplemental Material). The overall effect of age on grip speed was not significant, $F(1, 5444.30) = 3.32$, $p = .068$.

Findings revealed a significant expectancy-by-age interaction effect on grip speed, $F(1, 5444.30) = 7.42$, $p = .006$. The heat map demonstrated that older participants (~20–23 years old) exerted force more quickly for peer feedback when they expected acceptance compared with neutral or rejection feedback (*M*s = 741 ms, 893 ms, 975 ms, respectively), whereas younger participants (~12–16 years old) exerted force more quickly when they had more extreme expectations of being strongly liked or strongly disliked than when they expected neutral feedback (*M*s = 717 ms, 760 ms, 787 ms, respectively; Fig. 3b).

Opt-out behavior. Finally, we examined whether participants strategically opted out of more trials depending on their expectations of being accepted by the peer. The GAMM revealed significant main effects of expectancy and age. Participants opted out of fewer trials when they expected acceptance compared with neutral or rejection feedback (0.08%, 0.27%, 1.46% probability), $F(1, 5993) = 5.44$, $p = .020$ (Fig. S3C in the Supplemental Material). In addition, increasing age was associated with a greater tendency to opt out of trials (0.06% vs. 1.31% probability in 12- to 15-year-olds and 20- to 23-year-olds, respectively), $F(1, 5993) = 7.79$, $p = .005$. The interaction between expectancy and age on opting out was not significant, $F(1, 5993) = 0.792$, $p = .374$. Thus, older participants opted out of more trials overall, and participants opted out less when they expected to be accepted (Fig. 3c).

Summary. These findings suggest that early adolescents exerted greater force and speed for peer feedback when they had more extreme expectations of being strongly liked or strongly disliked. By contrast, adults overall exerted greater force and speed for peer feedback when they expected to be liked and opted out of more feedback trials. Thus, the transition into adulthood

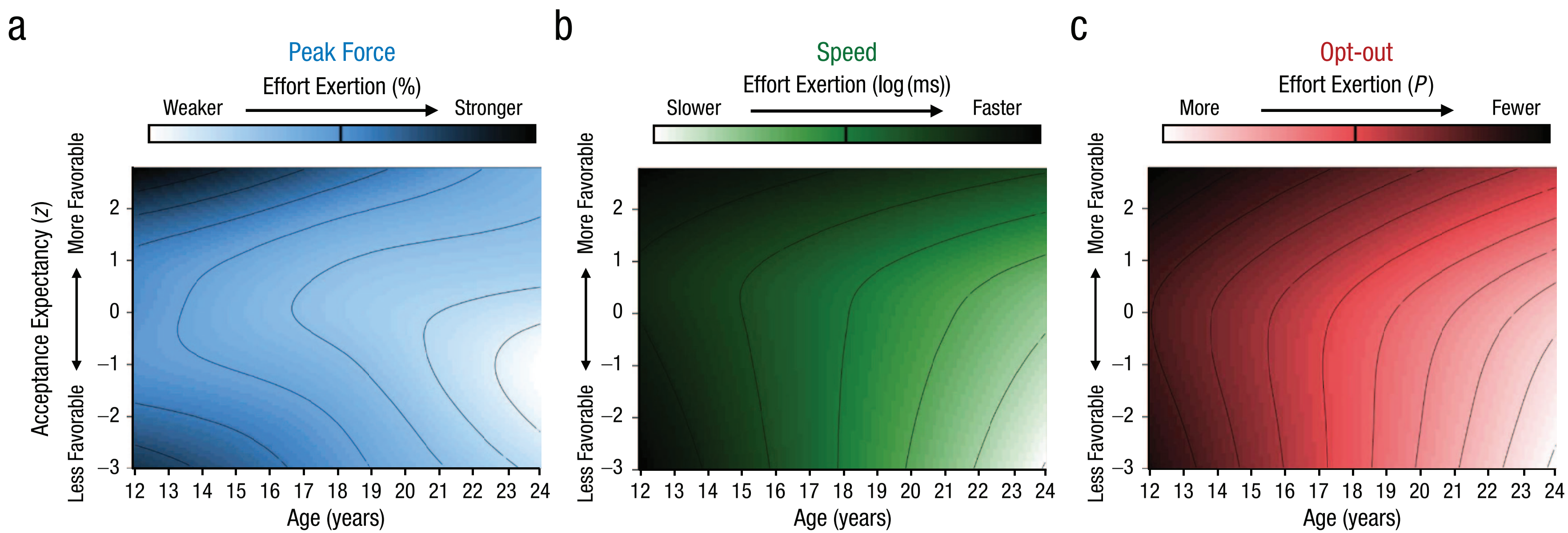

Fig. 3. Age-related effects of acceptance expectancy on effortful behavior for peer feedback, separately for (a) peak force, (b) speed, and (c) opt-out behavior. Heat maps display the fitted effects of the generalized additive mixed-effects model (GAMM), including both main and interaction effects. The dependent variable is in color on a scale from less to more effort exertion (light to dark). Acceptance expectancy is on the *y*-axis, and age is along the *x*-axis. Young adults exerted greater effort (peak grip, speed) for feedback from peers when they had a greater expectation of being accepted, as reflected by the change in color gradient (blue, green) from light to dark up the *y*-axis at the far right end of the *x*-axis. Early adolescents, meanwhile, exerted more effort when they had more extreme expectations of peer feedback, as reflected by the change in color gradient from dark to light to dark again up the *y*-axis at the far left end of *x*-axis. Participants opted out less when they believed they would be accepted, as reflected by the color gradient from light to dark up the *y*-axis. Participants also opted out of more trials with increasing age, shown by the change in color gradient (red) from dark to light along the *x*-axis.

is marked by diminishing motivation for peer feedback, especially when they expect to be disliked.

Peer desirability.

Peak grip force. In parallel analyses involving participants' ratings of peers, we computed a GAMM examining the effects of peer desirability, age, and their interaction on grip force. Findings revealed a linear effect of desirability: Participants exerted greater force for feedback from more desirable peers (71.55%) than from less desirable peers (66.86%), $F(1, 5618.24) = 22.28$, $p < .001$ (Fig. S4A in the Supplemental Material). The interaction between desirability and age was not significant, $F(1.76, 5618.24) = 2.68$, $p = .159$. These findings suggest that, regardless of age, participants exerted greater force for feedback from peers whom they rated more favorably (Fig. 4a).

Speed. We then examined the effects of peer desirability, age, and their interaction on grip speed. The GAMM revealed that participants exerted effort faster for peer feedback from more desirable peers (M = 754 ms) than from less desirable peers (M = 800 ms), $F(2.33, 5384.26) = 7.37$, $p < .001$ (Fig. S4B in the Supplemental Material). The interaction between peer desirability and age was not significant, $F(1.41, 5384.26) = 0.273$, $p = .758$, suggesting that the tendency to grip faster for feedback from more desirable peers was similar across age (Fig. 4b).

Opt-out behavior. Finally, we examined whether participants strategically opted out of more trials on the basis of peer desirability. We found a significant effect of peer desirability on opt-out behavior: Participants were less likely to opt out of receiving feedback from more desirable peers (0.05% probability) than from less desirable peers (5.38% probability), $F(1, 5933) = 7.65$, $p = .006$ (Fig. S4C in the Supplemental Material). The interaction between desirability and age on opt-out behavior was not significant, $F(1, 5933) = 2.40$, $p = .122$ (Fig. 4c).

Summary. Together, these findings suggest that participants exert greater effort (greater force, more speed, and less opting out) for feedback from peers they consider more desirable and that this pattern is stable across age.

Discussion

Adolescence is marked by increased preoccupation with social approval (Somerville, 2013) and vulnerability to negative effects of peer rejection (Prinstein & Aikins, 2004; Rodman et al., 2017). In line with our hypotheses, results showed that across our measures of grip force, speed, and opt-out behavior, young adults expressed relatively less motivational value for peer feedback than adolescents and exerted less force and speed when they expected to be disliked. By contrast, early adolescents were highly motivated to receive peer feedback overall and exerted greater force and speed when they had more extreme expectations of being liked or disliked. More desirable peers elicited similarly enhanced motivation from adolescents and adults. Thus, the motivational value of social feedback is elevated during adolescence and becomes increasingly shaped by hedonic principles (i.e., self-protection) into young adulthood. By contrast, adolescents exhibit motivated effort less yoked to hedonic outcomes and more to the informational value of the feedback.

Although social information is considered intrinsically valuable (Tamir & Hughes, 2018), social *evaluative* information may hold particular value, as it can resolve uncertainty related to social status and belonging (Leary & Baumeister, 2000). Work in humans and nonhuman primates has demonstrated that receiving social information (viewing attractive faces, conspecifics), including evaluative information (how other people describe us), is worth incurring a cost (juice, money, effort; Deaner et al., 2005; Hayden et al., 2007; Wang & Ma, 2020) and engages similar anticipatory and consummatory responses in reward-related neural circuitry (Izuma et al., 2008; Powers et al., 2013; Spreckelmeyer et al., 2009).

To investigate the value of social evaluative information across age, we examined age-related differences in effort exertion for peer feedback. Across measures of grip force, speed, and opt-out behavior, we found that social motivation (compared with money) attenuates from adolescence to adulthood. Whereas adults showed greater (~160 ms faster) or comparable (grip force, opt out) effort exertion for money compared with peer feedback, adolescents demonstrated a diminished (only ~60 ms faster for money) or reversed pattern (2% greater force and an 18 times smaller likelihood of opting out for peer feedback). These patterns were largely driven by participants at the ends of our sample's age range, with 15- to 20-year-olds showing a profile reflecting transition.

These findings are aligned with prior results in adults showing greater speeding and neural activation in reward-processing brain regions to money compared with social rewards (Ethridge et al., 2017; Spreckelmeyer et al., 2009). By contrast, adolescents have shown the opposite pattern (Ethridge et al., 2017; Wang et al.,2017, 2020). The current findings echo the notion that adolescents demonstrate heightened sensitivity to social rewards (Altikulaç et al., 2019; Foulkes & Blakemore, 2016). This may be especially true of social evaluative information, given that the importance of social approval and social status is at its height during adolescence

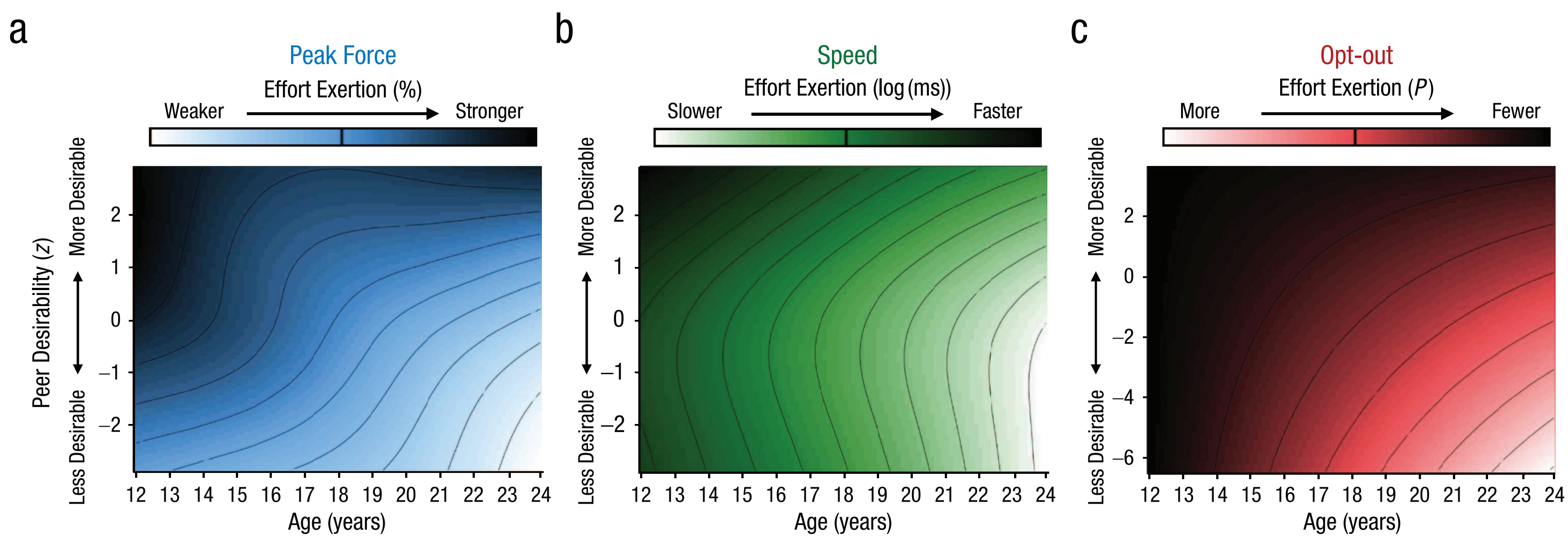

Fig. 4. Age-related effects of peer desirability on effortful behavior for peer feedback, separately for (a) peak force, (b) speed, and (c) opt-out behavior. Heat maps display the fitted effects of the generalized additive mixed-effects model (GAMM), including both main and interaction effects. The dependent variable is in color on a scale from less to more effort exertion (light to dark). Peer desirability is on the *y*-axis, and age is along the *x*-axis. Participants of all ages exerted more effort to receive peer feedback from more desirable peers, as reflected by the color gradient from light to dark up the *y*-axis for grip peak force, grip speed, and opt-out behavior.

(LaFontana & Cillessen, 2010). Indeed, recent work using an explicit choice paradigm found that adolescents show greater motivation for social information than adults (Bos et al., 2021). The current study extended prior work by leveraging novel tools (i.e., hand dynamometer, simultaneous work-for-reward transaction) and a data-driven approach to characterizing nonlinear, continuous age-related changes, which revealed more nuanced age-related patterns of these evolving social motivations. Analyses comparing willingness to work for money and social feedback benchmark adolescents' heightened motivation for peer feedback relative to adults, serving as a foundation for subsequent questions of how other factors (e.g., expectations and judgments) impact the motivational value of peer feedback.

When examining the impact of peer desirability on willingness to work, we found that adolescents and adults demonstrated greater willingness to work for feedback from peers they judged as more desirable, as evidenced by greater force (~5% stronger), speed (~50 ms faster), and less opting-out (~100 times smaller likelihood than for undesirable peers). This finding aligns with previous work in adolescents and adults showing that acceptance is more rewarding from highly desirable peers (Davey et al., 2010; Guyer et al., 2012) and that social information from high-status peers and conspecifics is worth incurring greater cost (Bos et al., 2021; Deaner et al., 2005; Morelli et al., 2018) and is more influential in shaping learning and self-views (Will et al., 2017). Our findings demonstrate that whereas peer feedback is relatively less valuable to young adults, adolescents and adults are similarly attuned to social desirability, perhaps in service of calibrating their own social status.

Last, we investigated whether participants' expectations of being accepted impacted motivation for peer feedback across age. Young adults (~20–23 years old) expressed the strongest reduction in willingness to work (less force and speed) for feedback when they expected rejection (~6% weaker and ~230 ms slower than when they expected acceptance). Shielding oneself from rejection is a self-protective strategy (Beauregard & Dunning, 1998; Hughes & Beer, 2012) that orients individuals toward attainment of hedonically positive feedback at the expense of complete or realistic information, which is theorized to maintain favorable self-views and greater well-being (Alloy & Abramson, 1979). Adults' preferential motivation for positive peer feedback aligns with previous findings showing a self-reported desire for (Hepper et al., 2011) and enhanced neural reward response to (Spreckelmeyer et al., 2009; Wang & Ma, 2020) positive over negative feedback. Because adults have a more consistently positive self-concept (Sebastian et al., 2008) and stable social network (Cairns et al., 1995), and because they perceive themselves as more socially competent (Neemann & Harter, 1986), they may have less of a need to continually consume realistic feedback.

Adolescents did not show this pattern, a finding that adds to a growing body of work suggesting that self-protective biases continue to develop throughout adolescence (Rodman et al., 2017). Rather, early adolescents (~12–15 years old) exhibited greater force and speed to receive peer feedback they expected to be strongly positive or negative compared with feedback they expected to be neutral (~3–4% stronger, ~30–70 ms faster). These differences suggest that stronger feedback signals are more important to adolescents. Given the changes in social roles and relationships accompanying the transition to adolescence, it may be especially important for adolescents to monitor and learn from feedback (Crone & Dahl, 2012). We speculate that these more extreme feedback cues may constitute stronger reinforcement signals (Jones et al., 2011; Will et al., 2017) that prompt feedback-based learning about one's own social inclusionary status and reputation. Therefore, it may be adaptive for adolescents to gauge social standing through learning-based mechanisms that benefit from strong feedback signaling in the social environment.

While informative, negative peer feedback can also cause harm. On the one hand, adolescents' motivation to receive stronger feedback that includes positive and negative evaluations could ultimately enhance social competency (Harter, 1988). Adolescents may heavily consume evaluative information from peers to learn desirable social behavior, adjust in response to new social information, and inform one's own self-concept (Pfeifer et al., 2009; Yoon et al., 2018). However, consuming social evaluation also increases exposure to peer rejection, which can have deleterious effects for adolescent mental health (Prinstein & Aikins, 2004). Even in healthy populations, adolescents, especially early adolescents (12–15 years old), are more likely to internalize rejection and adopt negative self-views than adults (Rodman et al., 2017). Thus, negative feedback is an important signal for adaptive adjustment of social behavior, but it may degrade self-esteem and increase clinical risk.

Limitations and future directions

Our findings should be interpreted in light of several limitations. First, it was not possible to mirror the money and social task designs exactly. The money task had two levels of reward (high, low) and required fewer trials, whereas the social task necessitated more trials because they varied on expectancy and desirability. The social task also presented different peers on each trial, whereas the money task repeated the same high or low monetary amounts. Nonetheless, there are many direct parallels between the tasks, including identical instructions, structure, timing, physical demands, and reinforcement schedule of receiving a notice of outcome (feedback or money) for each successful trial. Thus, we judged the money and social tasks as sufficiently similar to compare directly, but there is less precision in this comparison than other comparisons reported. Future work should vary the monetary outcomes to mimic aspects of the social feedback differently (e.g., incorporating monetary losses for unsuccessful trials rather than zero gain).

While our findings consistently show across all measures that adults are relatively less motivated for social feedback compared with adolescents, overall expression of grip force and speed in response to social versus money targets were discordant. Whereas participants overall squeezed harder for social feedback, participants overall were faster for money targets. This was unexpected, given that both force and speed represent response vigor (a marker of motivational value). This inconsistency may reflect increased processing demands due to the greater complexity of the nonrepeating social stimuli compared with the simpler monetary stimuli. Importantly, evaluating the age-related differences of interest holds this potential confound constant, lessening concern that it impacted the key age-related findings.

This study explored age-related differences cross-sectionally, limiting evaluation of how such phenomena develop at the within-person level. Future work should examine such questions in a longitudinal design. Additionally, this study included healthy participants between the ages of 12 and 23 years old from the community, limiting the generalizability of these findings to individuals of other ages or those with clinical conditions (e.g., social anxiety). Future work should characterize fatigue curves using a longer paradigm to examine a complementary facet of these motivational processes across conditions and age. The data-driven approach used herein is semiparametric and inherently exploratory, limiting our ability to conduct traditional power analyses or confirmatory analyses. Finally, future work should examine age-related differences when participants receive feedback from peers of varied social relationship strength (e.g., friends, acquaintances).

Conclusions

Leveraging measures of effort exertion that reflect response vigor (force, speed) and strategic decision-making (opt-out behavior), the current study revealed changing motivational value for social evaluative information, which is at its height during adolescence. The transition into adulthood is accompanied by a hedonic, self-protective focus, whereas adolescents are motivated to consume highly informative social feedback, even if negative. This evolving motivation may reflect enhanced expression of self-relevant social learning during adolescence. Although normative, such tendencies may expose adolescents to repeated rejection at a time when it is particularly harmful.

Transparency

Action Editor: Andrew Fuligni
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Author Contributions

A. M. Rodman: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing.

K. E. Powers: Conceptualization; Investigation; Methodology; Project administration; Supervision; Writing – review & editing.

E. K. Kastman: Resources; Software; Writing – review & editing.

K. E. Kabotyanski: Investigation; Visualization; Writing – review & editing.

A. M. Stark: Investigation; Visualization; Writing – review & editing.

P. Mair: Resources; Software; Validation; Writing – review & editing.

L. H. Somerville: Conceptualization; Funding acquisition; Methodology; Project administration; Resources; Supervision; Visualization; Writing – review & editing.

Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

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Open Practices

All data, analysis code, and task code have been made publicly available via OSF and can be accessed at https://osf.io/yf7a6/. The design and analysis plans for the study were not preregistered. This article has received the badges for Open Data and Open Materials. More information about the Open Practices badges can be found at http://www.psychologicalscience.org/publications/badges.

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Supplemental Material

Additional supporting information can be found at http://journals.sagepub.com/doi/suppl/10.1177/09567976221121351

Note

1. Values reflect predicted fits that were back-transformed from log milliseconds and are displayed in millisecond units for descriptive purposes only. All analyses and figures use log-transformed values of speed.

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