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BRIEF ARTICLE

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Knowing when to hold 'em: regret and the relation between missed opportunities and risk taking in children, adolescents and adults

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ABSTRACT

Regret over missed opportunities leads adults to take more risks. Given recent evidence that the ability to experience regret impacts decisions made by 6-year-olds, and pronounced interest in the antecedents to risk taking in adolescence, we investigated the age at which a relationship between missed opportunities and risky decision-making emerges, and whether that relationship changes at different points in development. Six- and 8-year-olds, adolescents and adults completed a sequential risky decision-making task on which information about missed opportunities was available. Children also completed a task designed to measure their ability to report regret when explicitly prompted to do so. The relationship between missed opportunities and risky decision-making did not emerge until 8 years, at which age it was associated with the ability to explicitly report regret, and was stronger in adults than in adolescents. These novel results highlight the potential importance of the ability to experience regret in children and adolescents' risky decision-making.

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Regret; risk; decision-making; counterfactual; cognitive development

We experience regret when we realise that we should have chosen differently (Landman, 1993; Zeelenberg & Pieters, 2007). This realisation is prompted by a comparison between the outcome we achieved and the counterfactual outcome that would have obtained had we made a different choice. Often we make choices knowing that we will never learn how things would have worked out had we made a different decision. However, sometimes information about counterfactual outcomes is available, and can have powerful effects on our decision-making. For example, consider a risk-averse poker player who, worried about the strength of her cards, decides to "fold". Imagine that she learns that she had better cards than the ultimate winner of that hand. She may regret her decision to fold as it led to a missed opportunity and thus, she may be more likely to "hold" her cards in the future. In adults, the availability of information about missed opportunities has been shown to affect risk taking either through the anticipation of regret (e.g. Larrick & Boles, 1995; Zeelenberg, Beattie, van der Pligt, & de Vries, 1996) or, as in the example above, through the effects of information about missed opportunities on subsequent risk taking (Brassen, Gamer, Peters, Gluth, & Buchel, 2012; Büchel, Brassen, Yacubian, Kalisch, & Sommer, 2011; Zeelenberg & Beattie, 1997).

In one pertinent example, Brassen et al. (2012) showed that people take greater risks if they realise that previously cautious behaviour caused them to miss an opportunity to gain a larger reward, which they take to indicate *regret responsivity* in decision-making. Brassen et al. (2012) also found developmental changes in regret responsivity with aging: healthy older adults did not take greater risks following missed opportunities, which Brassen et al. argue is due to increased emotional control with age (see also Tobia et al., 2016). This research suggests that the contribution of regret about missed opportunities to decision-making varies in important ways

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developmentally that may be linked to broader changes in emotional regulation. However, although there is great interest in the role of emotional development in decision-making, we know nothing about the developmental profile of regret responsivity at the other end of the lifespan. The primary aim of the current study is to examine regret responsivity in groups of children, adolescents and adults, with a view to shedding light on how regret responsivity may contribute to developmental changes in decision-making.

Regret, risk and the development of decision-making

By around 6 years, a substantial proportion of children, when prompted, will explicitly report feeling worse when they discover that a better outcome would have arisen had they chosen differently (O'Connor, McCormack, Beck, & Feeney, 2015; O'Connor, McCormack, & Feeney, 2012, 2014; Van Duijvenvoorde, Huizenga, & Jansen, 2014), including in tasks involving risky choice (McCormack, O'Connor, Beck, & Feeney, 2016). Recent research has revealed that at this age the experience of regret following a bad decision outcome is associated with choosing differently when presented with the same choice on the next day (O'Connor et al., 2014). Although this suggests that the experience of regret impacts on children's subsequent decision-making when they are asked to make choices that do not involve risk, we do not yet know whether or when it impacts on their tendency to take more or less risky decisions. One of our key objectives in this study is to answer that question.

As well as addressing relations between regret and risky decision-making in childhood, we will also address this relationship in adolescent decision-making. Much developmental work on risky decision-making has focussed on adolescents (see Boyer, 2006; Hartley & Somerville, 2015), who are often thought to be more risk seeking than younger children or adults (see Steinberg, 2007). Adolescents are particularly likely to take risks in so-called "hot" decision-making tasks where immediate outcome feedback is provided, consistent with suggestions that affect plays a larger role in adolescent than adult decision-making (Defoe, Dubas, Figner, & Van Aken, 2015; Steinberg, 2007). If adolescent decision-making is particularly susceptible to emotional influences, one obvious hypothesis is that regret arising out of information about missed opportunities will have a greater impact on decision-making in adolescents than in children or in adults. The findings regarding adolescents' regret in risky decision-making tasks are contradictory: Burnett, Bault, Coricelli, and Blakemore (2010) found similar levels of reported regret in adolescents as in children or adults (although adolescents reported more intense relief), whereas Habib et al. (2012) found that adults reported higher levels of regret than either children or adolescents and Habib et al. (2015) found that in competitive contexts, adolescents did not appear to experience regret whereas children and young adults did. Although adolescents do not report feeling more intense regret than children or adults, nevertheless their decision-making may be more affected by this emotion, i.e. it may be more regret responsive. We do not yet know if this is the case.

The current research

Our primary aims were (1) to investigate when children's risky decision-making begins to be regret responsive, and (2) whether regret responsiveness is greater in a sample of adolescents than in a sample of children. To do this, we adapted Brassen and colleagues' task (Brassen et al., 2012; Büchel et al., 2011). In each trial on this task participants see eight closed boxes, arranged in a line, seven of which contain a coin (exchangeable for points) and one of which contains a devil. Participants must open boxes from left to right, one after another. They win points for each box in the sequence that is opened and found to contain a coin but risk losing all the points they have accumulated on that trial if they encounter the randomly placed devil. On trials in which participants stop sufficiently early to avoid losing their points, they are shown how many additional boxes they could have opened without loss – i.e. the size of the missed opportunity. Brassen et al. showed that in young adults, but not old healthy adults, the size of the missed opportunity on trial $t-1$ predicted risk seeking on trial t, such that greater missed opportunity was associated with more subsequent risk seeking. This effect was taken by Brassen et al. to demonstrate regret responsivity in adults' decision-making.

A secondary aim of our study relates to questions about how regret is measured in childhood. Previous studies indicate that although the majority of 6-year-olds are capable of experiencing regret (O'Connor et al., 2012, 2014), the number of children reporting

this emotion increases over childhood. Given this, we might expect to see regret responsivity emerging around 6–7 years and increasing thereafter. However, one key difference between this task and the tasks used in previous studies is that it does not involve an explicit request for emotional ratings. If children experience regret before they can reflect on it explicitly, previous studies may have underestimated the prevalence of regret in 6-year-olds because of a reliance on such ratings. Alternatively, the explicit request for an emotion rating that relies on prompting the child's evaluation may have over-estimated the prevalence of spontaneously experienced regret. Thus, we examined how children's performance on the more implicit index of regret provided by Brassen et al.'s task compares to that found using a task that requires explicit reports of emotion. The implicit measure allows us to observe spontaneous unprompted experience of regret, whereas the explicit measure reveals the emotions children experience having been prompted.

Method

Participants

Based on sample sizes in previous studies (Brassen et al., 2012; O'Connor et al., 2012), 40 6–7-year-olds (18 females, $M = 82.9$ months, range = 72–93 months), 42 8–9-year-olds (23 females, $M = 107$ months, range = 96–119 months), 30 adolescents (18 females; $M = 15.0$ years, range = 14.3–15.8 years) and 29 adults (20 females, $M = 36.8$ years, range = 25.2–53.8 years) participated. The gender ratios for the first three groups did not differ from chance, $ps > .35$, but the ratio for adults almost did, $p = .061$. Gender frequencies did not differ significantly between the four groups, $\chi^2(3) = 4.16$, $p > .2$.

Tasks

Our paradigm was a computerised, child-friendly version of the devil task (Brassen et al., 2012). On each trial participants were shown eight closed boxes, one of which contained a pirate and the others a coin. Participants opened boxes left to right until they decided to stop, thus keeping all of the coins in the boxes opened up until that point, or they encountered the pirate and thus lost all of the coins on that trial. On trials where participants stopped opening boxes before they encountered the pirate, they were shown the position of the pirate, which allowed them to see the size of the missed opportunity on that trial.

Participants read onscreen instructions (the instructions were read aloud by the researcher to the 6–7-year-olds) and observed the computer complete five demonstration trials before completing four practice trials to ensure they understood the task. In each demonstration trial participants observed boxes being opened onscreen. To illustrate the prizes available on the task, the first trial ended before the pirate was encountered without revealing its location. To illustrate the pirate and the randomisation of its location, trials 2–4 showed the pirate being encountered in the eighth, first and fifth box, respectively.

Finally, to illustrate how information about missed opportunities was to be made available on the task, the final demonstration trial ended after four boxes had been opened, without encountering the pirate, which was then shown to have been in the sixth box.

Participants were told that their compensation would depend on the coins they won during the game, and a running total of all coins won was displayed onscreen throughout. All children received the same "goodie" bag and adolescents and adults received an Amazon gift voucher worth £4.50 for winnings of less than 120 coins, £5.00 for 120–150 coins and £5.50 for more than 150 coins.

To permit examination of associations between regret in childhood using our implicit and explicit measures, once 6–7- and 8–9-year-olds had finished the pirates task, they also completed the regret task described by O'Connor et al. (2012). All children were trained in the use of a five-point emotion scale (see O'Connor et al., 2012 for full training procedure). The training involved two puppets receiving or losing gifts and children used a three-pronged arrow to indicate whether the puppet felt happier (leftwards prong), sadder (rightwards prong) or the same (upwards prong) over four different scenarios. The experimental trials did not commence until each child answered the four training questions correctly. There were two trials on the regret task, baseline and regret. The baseline trial was always introduced first as previous findings suggest this increases the likelihood of children experiencing regret in the regret trial (O'Connor et al., 2012; Van Duijvenvoorde et al., 2014). The procedure for both trials was identical. Children were asked to select one of the two boxes, the

chosen box was then opened and the actual prize revealed (one token in both trials). Children indicated their emotional response on the five-point scale. Next the non-chosen box was opened and the alternative prize (1 token in the baseline trial and 10 tokens in the regret trial) was revealed. Children used the three-pronged arrow to indicate whether they now felt happier, sadder or the same after seeing the alternative prize.

Results

Data coding

Trials on the pirates task were coded as *keep*, where the participant stopped before the pirate had been found, and *loss* where the participant opened the box containing the pirate. For the purposes of analysis we focus on keep-keep trials where participants do not discover a pirate on successive trials, and loss-keep trials, where a trial where the pirate is uncovered is followed by a trial where the pirate is not uncovered. We defined the size of the missed opportunity as the difference between what participants won on the first trial in a keep-keep pair, and what they could have won had they kept opening boxes, stopping just in time to avoid the pirate. We analysed the degree to which this measure predicted the number of boxes opened on the subsequent keep trial, yielding our measure of regret responsivity. We defined risk taking on the pirates task overall as the average number of boxes opened on keep trials. On the regret task, we followed O'Connor et al. (2012) in categorising only participants who felt worse upon learning the alternative outcome in the regret trial but not in the baseline trial as experiencing regret.

Initial analyses

Eight- to 9-year-old participants ($M = 3.5$, $SD = 0.7$) took fewer risks on the task than did 6–7-year-olds ($M = 3.8$, $SD = 0.9$), adolescents ($M = 4.1$, $SD = 0.7$) or adults ($M = 3.8$, $SD = 0.6$). As a consequence, 8–9-year-olds contributed more keep-keep trials ($M = 22.7$, $SD = 8.5$) to the analysis of regret responsiveness than did 6–7-year-olds ($M = 15.2$, $SD = 8.3$), adolescents ($M = 16.3$, $SD = 7.2$) or adults ($M = 18.1$, $SD = 4.9$).

An ANOVA testing for effects of gender and age on risk taking revealed no effect of gender, but an effect of age, $F(3, 137) = 4.17$, $p < .008$, $\eta_p^2 = 0.08$. Tukey *post hoc* tests on the means involved in the main effect of age showed that 8–9-year-olds took significantly fewer risks than adolescents, $p < .005$. None of the other differences between means were statistically significant.

On the regret task, significantly fewer 6–7-year-olds (25/40) than 8–9-year-olds (38/42) reported experiencing regret, $\chi^2(1) = 7.5$, $n = 82$, $p < .01$.

Regret responsiveness

To explore regret responsiveness in each age group, on keep-keep trials we used the following exploratory multi-level linear regression model to predict risk on trial t.

$$\begin{aligned}\text{Box Reached}_t &= \beta_0^g + \beta_1^g\ \text{Missed}_{t-1} \\ &\quad + \beta_2\ \text{Box Reached}_{t-1} + \epsilon,\end{aligned}$$

$$\beta_i^g \sim \text{Normal}(b_i^g, \sigma_i^2),$$

$$b_i^g \in [b_i^{6-\text{year-olds}}, b_i^{8-\text{year-olds}}, b_i^{\text{Adolescents}}, b_i^{\text{Adults}}] \quad \text{for } i \text{ in } [0, 1],$$

where β_i^g is regression weight i, for the given participant, in group g, drawn from a normal distribution with mean b_i^g (the population-level effect) and variance σ_i. The intercept and the effect of the missed opportunity on the previous trial, b_0 and b_1, were estimated separately for each group g, while the effect of the box reached on the previous trial b_2 was held constant across groups. Regression weights were unstandardised, so that a weight of 1 would reflect a unit increase in the number of boxes opened on trial t for a unit increase in the predictor on trial $t-1$.

Across all participants, the number of boxes opened on the previous trial positively predicted the number opened on the current trial, $b = 0.21$, $t(129.5) = 6.36$, $p < .001$. Regression weights for the effect of the size of missed opportunity on the previous trial for each age group are plotted in Figure 1 (a); a 0.1 regression weight here means that participants opened 0.1 more boxes on trial t for each missed opportunity coin on the $t-1$ trial. This regret responsivity effect was absent at 6–7 years, $b < 0.01$, $t(91.81) = 0.17$, $p = .87$, but was significant at 8–9 years, $b = 0.06$, and for adults, $b = 0.1$, $t(57.72) = 2.47$, $p < .02$ and $t(110.61) = 2.85$, $p < .005$ respectively, and marginally significant for adolescents, $b = 0.07$, $t(95.24) = 1.82$, $p = .07$.

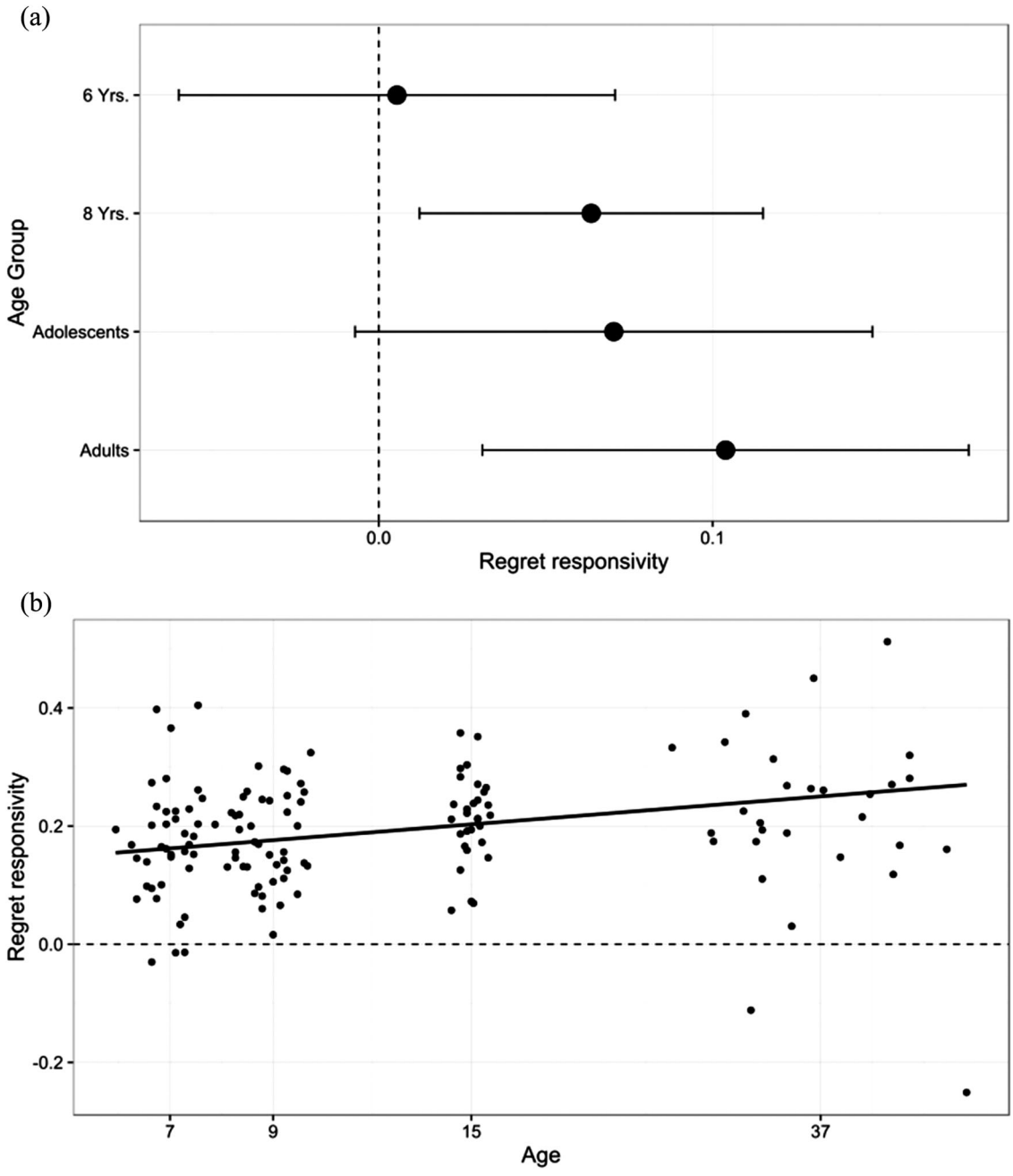

Figure 1. (a) Degree of regret responsivity estimated for each age group. Significant effects of missed opportunities on regret responsivity were observed for 8-year-olds and adults, and a marginally significant effect for adolescents. The effect for 6-year-olds did not approach statistical significance. Error bars show 95% CIs. (b) Estimated regret responsivity as a function of age, as derived from the multi-level regression model, with regret responsivity interacting with log(age). Points show estimates for each participant. Line shows the estimated age × regret responsivity interaction term. Note that the *x* axis is $\log_e$ scaled.

To quantify the impact of age on regret responsivity, we fit a second multi-level regression model including main effects of age group, boxes opened on trial *t*−1, and size of missed opportunity on trial *t*−1, and, crucially, the interaction between size of missed opportunities and log(age) as predictors. This revealed a significant size of missed opportunity × log(age) interaction, $b = 0.05$, $t(97.9) = 2.023$, $p < .05$.[1]

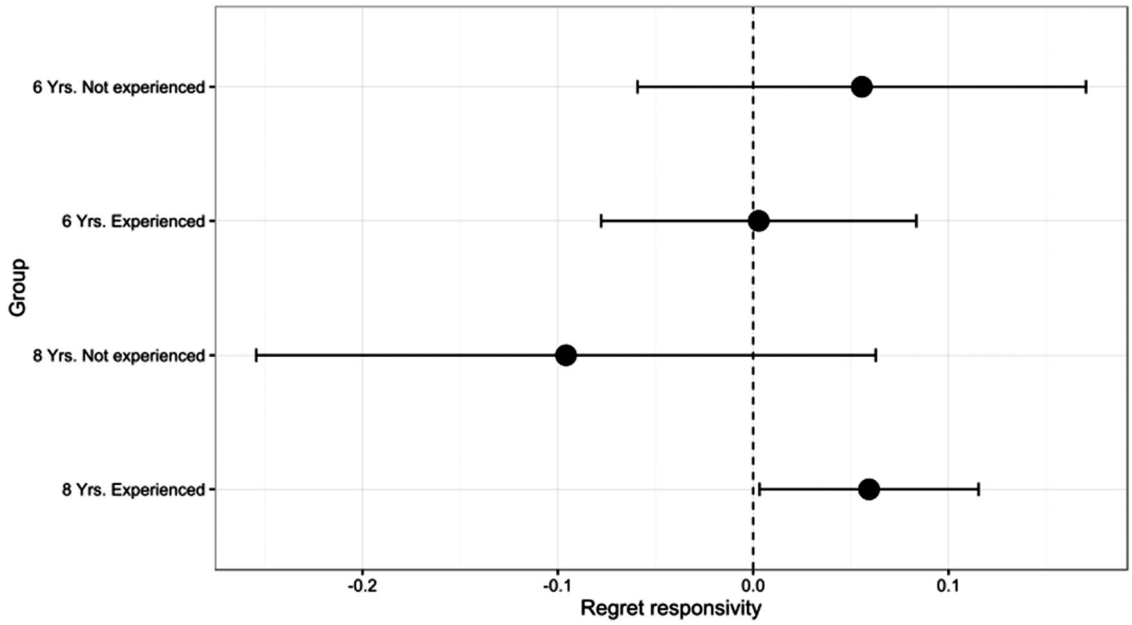

Figure 2. Estimated regret responsivity effect for 6- and 8-year-old children who did and did not report experiencing regret when explicitly prompted.

The relationship between age and regret responsivity is to be seen in Figure 1(b). The regression weight, $b = .05$, indicates that a doubling in age corresponds to an increase in regret responsivity of $b \times \log(2) = 0.036$.

We also tested the effect of a loss on trial $t-1$ on risk taking at trial t by examining whether participants opened more boxes on trial t following a loss or a gain on trial $t-1$. This difference was not significant, $t(140) = 1.01$, $p = .31$. In other words, although actual and fictive losses on trial $t-1$ predicted risks taken on trial t, actual losses did not lead to more risk taking than fictive ones.

Associations between measures of regret in childhood

To examine relationships between the ability to explicitly report regret when prompted to do so and the implicit measure of regret provided by the pirate task, we refit the model to the children's data only, and allowed regret responsivity to differ both between the age groups, and between participants who did and did not explicitly report experiencing regret on the separate task. Of the four groups, only the 90% of 8–9-year-olds who explicitly reported experiencing regret showed significant regret responsivity, $b = -0.06$, $t(31.8) = 2.115$, $p < .05$, all other groups $ps > .2$. Estimates of regret responsivity for each subgroup are shown in Figure 2.

Discussion

Regret over missed opportunities impacts children's risky decision-making, but not until they reach 8 years of age. Furthermore, despite previous evidence that the effects of emotion on risk taking are greater in adolescence than in adulthood (Defoe et al., 2015), the impact of missed opportunities, an implicit measure of regret, was greatest in a group of adults. In other words, the effects of regret responsivity on risk taking continue to increase into adulthood.

In line with previous studies (O'Connor et al., 2012, 2014), a majority of the 6-year-olds were categorised as experiencing regret on the explicit regret task, whereas this age group did not show regret responsivity on the pirate task. Moreover, at 6 years performance on the explicit regret task was not associated with regret responsivity. Taken together, these findings suggest that, in childhood, the tasks measure quite different things. The lack of regret responsivity in the 6-year-olds suggests that given information about missed opportunities, they fail to spontaneously compare the actual and counterfactual outcomes. By contrast, in the explicit regret task children are directly

encouraged to make such a comparison. Simply providing children this age with information that would allow them to see the size of the opportunity they have missed may not be sufficient to prompt them to generate the counterfactual or to compare it with what actually happened.

The observed increase in regret responsivity across childhood and adolescence into adulthood is consistent with previous work showing that regret intensity is also greater in adults than in adolescents (Habib et al., 2012). Our results, alongside Habib et al.'s findings, suggest that regret may have a different status in adolescent decision-making than emotions stemming from information about actual outcomes. Indeed, Habib et al. (2015) demonstrated that in competitive contexts, adolescents appear not to experience regret at all, which they attribute to adolescents failing to question the appropriateness of decisions that lead to negative outcomes. Future research could disentangle whether less pronounced regret responsivity in adolescents than adults reflects lower levels of regret in adolescents, or reflects a reduced tendency in adolescents to make use of this counterfactual emotion in subsequent decision-making.

In summary, we investigated when missed opportunities begin to impact children's decision-making and how that impact developed across adolescence and into adulthood. Our findings suggest that missed opportunities begin to impact risk taking at 8 years and that their effects increase into adulthood. As well as suggesting avenues of future study, these findings further emphasise the potential importance of the ability to experience regret in children's decision-making.

Note

1. One adult participant (aged 53) opened considerably fewer boxes as their missed opportunity increased, the opposite of the regret effect seen for the rest of the sample, and is plotted in the lower right corner of Figure 1(b). Excluding this participant from the analysis increased the observed missed opportunity × log(age) interaction, $b = 0.06$, $t(105.4) = 2.311$, $p < .05$. This trend did not differ significantly between males and females; model fit was not significantly improved by allowing this term to vary by gender, $\chi^2(1) < .1$, $p > .8$, and remained significant when gender differences in average risk taking were controlled for.

Disclosure statement

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