An experimental study of adolescent behavior under peer observation: Adolescents are more impatient and inconsistent, not more risk-taking, when observed by peers

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Abstract
The majority of deaths in adolescence have been attributed to "risky" behaviors (Eaton et al., 2012) and therefore could be avoided had the adolescent made a different decision. In this paper, using two laboratory experiments we assess the impact of peer observation (a possible culprit of bad decision-making in adolescence) on the behavior of adolescents in risky conditions. We carefully separate risk attitudes from impatience, present bias, ambiguity attitudes, and inconsistency and in contradiction to what has been suggested in developmental psychology, we find that adolescents' risk and ambiguity attitudes are not affected by observation. Instead, when observed by peers, adolescents become more impatient and inconsistent.

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There is no conflict of interest to declare

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1. General introduction

In the presence of peers, adolescents have been documented to be more likely to make decisions leading to injury, loss of educational opportunities, and even death. Relative to older age groups, adolescents commit more crimes in groups (Zimring, 1998), and have more car accidents when driving with passengers (Chen, 2000). The results are not limited to humans — adolescent rodents drink more alcohol when peers are present (Logue et al., 2014). These effects persist in laboratory studies: when observed or merely being led to believe to be observed by a peer, adolescents were more likely to crash in a driving game (Gardner & Steinberg, 2005; Silva et al., 2016), gambled more (Smith et al., 2014), were less likely to wait for larger rewards (Silva et al., 2016; Weigard et al., 2014), and had diminished cognitive control to positive social cues (Breiner et al., 2018). Studies using functional magnetic resonance imaging (fMRI) revealed that in adolescence (but not in adulthood) the mere presence of a peer increases activity in the reward-processing areas such as orbitofrontal cortex and ventral striatum (Albert et al., 2013; Weigard et al., 2014) and evokes strong physiological arousal (Somerville, 2013; Somerville et al., 2013).

These existing papers provide still an incomplete picture of what specific behavioral traits are affected by peer observation (Hartley & Somerville, 2015). For example, the result that adolescents are more likely to crash in driving games when observed by peers is consistent with a variety of explanations. It can be that adolescents who are under observation care less about the future (are more impatient or more present-biased), or that they perceive the unknown odds of crashing as lower, or that they are more risk-tolerant, or that they are less averse to loses, or that they are more likely to make mistakes. Similar decomposition of behavior could be applied to decisions in other domains. So far, all of these theoretically separate explanations are often bundled together in the common language under the label of “reckless”, “risky”, or “erratic". However, with careful experimental design, these different explanations can be separately identified in a laboratory environment. The novelty of this paper is the use of economic theory to deconstruct what is commonly called "risky behavior" into conceptually different and separately identifiable traits and to test in incentive-compatible laboratory experiments how these traits are affected by peer observation in adolescence. We, therefore, deliver a more precise behavioral evidence of the effect of peer observation on adolescent decision-making.

According to economic theory, a chooser selects the available course of action to maximize utility subject to some decision error (see Figure 1). Specifically, when making a decision the chooser considers: the size of the reward x using the utility function $u(x)$; the subjective perception of probability, p, with which the reward will be received and the ambiguity about that probability, a, using the subjective probability function $w(a,p)$; and the delay, t, until the reward will be received using the discount function ($d(t)$). These three separate functions and the noise term give rise to a decision and can be decomposed into *seven* different traits: 1) impatience — general preference to receive rewards sooner, 2) present-bias — preference for rewards now relative to rewards at any time in the future, 3) ambiguity attitude — dislike or preference for outcomes occurring with unknown probability relative to the same outcomes occurring with known probability, 4) probability weighting — demonstrated in aggregate behavior as overweighting of small and underweighting of large probabilities, 5) risk attitude — attitude towards known risks, 6) loss aversion — tendency to perceive losses as larger than equally sized gains, 7) inconsistency of behavior with noiseless utility maximization (which could be either due to the stochastic element of random utility or inability to maximize). Distinguishing between these traits in the context of observation effects on adolescent behavior has not been explored so far but is important because different traits offer different theoretical and policy implications. This paper fills in this gap. To achieve our goal, we designed two laboratory experiments where we asked adolescents to choose between different monetary rewards received with different known and unknown probabilities and at different points in time, allowing us to measure how five different traits: impatience, present-bias, ambiguity attitude, risk attitude, and inconsistency are affected by peer observation.[1] We used monetary rewards to make sure that the design is incentive-compatible.

To date, the evidence on how peer observation in adolescence affects the five traits that we focus on is inconclusive. O'Brien et al. (2011) and Weigard et al. (2014) asked their study participants to choose between a smaller reward now and a larger reward later and found that when observed, adolescents have a stronger preference for immediate smaller rewards. It is not clear whether this change in behavior is due to a change in how teenagers discount future (that is a change in their discount function) or due to a change in relative valuation of the smaller and larger rewards (that is a change in the utility function) (see Andersen et al. (2008) for more on this point). Even if indeed the behavioral change was driven by the discount

[1] In this paper, we do not assess whether observation by a peer affects probability weighting or loss aversion, both of which would be an interesting extension.

function and not the utility function, it remains unclear whether under observation adolescents in these studies became more impatient or more present-biased or both, because in all decision scenarios the sooner reward was available immediately.

Regarding risk attitudes, Smith et al. (2014) asked participants whether they would like to play a lottery with *known* probabilities of three possible consequences: \$0, loss of \$10 and gain of \$10. Adolescents who believed to be observed by a peer chose to gamble more often, especially when losses were more likely. This suggests that adolescents' relative valuation of gains versus losses is affected by observation, but it is not clear whether this is caused by a change in the utility curvature for gains or losses, or loss aversion. None of the studies so far specifically assessed how choice quality (measured as consistency in choice) is affected by observation. The tasks that are usually used to study adolescents' risky behavior, such as the driving simulators (e.g. Gardner & Steinberg, 2005), Iowa gambling task (Bechara, Damasio, Tranel, & Damasio, 1997), Balloon Analogue Risk Task (Lejuez et al., 2002), or Columbia Card Task (Figner, Mackinlay, Wilkening, & Weber, 2009) do not allow to separately identify the five decision-making traits studied in this paper. In all of these tasks, the attitudes towards unknown risks (ambiguity attitudes) are not separately identifiable from attitudes towards known risks (risk attitudes) and decision-making inconsistencies. Furthermore, the Balloon Analogue Risk Task and driving simulator games in addition to risk involve temporal trade-offs but do not allow for separate identification of the utility and discount functions. By separately quantifying impatience, present bias, risk attitudes, ambiguity attitudes and inconsistencies in choice, our results complement the results of any study that uses these popular tasks.

In two incentive-compatible experiments, we tested hypotheses that when observed by peers, adolescents' risk attitudes, impatience, present-bias, ambiguity attitude, and inconsistency in decision-making change. We measured participants' decision-making traits using standard methods from experimental economics. Participants made a series of decisions between two monetary options that differed from one decision scenario to another in the rewards' size, the probability with which the rewards were received, the ambiguity about that probability, and the time when the rewards would be received, allowing us to identify each of the traits. Crucially, each of the participants made decisions in the same set of decision scenarios in private and when observed by one peer, permitting us to test our hypotheses in a within-subject design. We found that adolescents were more impatient and inconsistent when observed compared to when making decisions in private. The adolescents in our study were not more risk-taking, ambiguity tolerant, or present-biased when observed.

2. Study 1

In Silva et al. (2016) and Steinberg et al. (2009), adolescents chose smaller immediate rewards more frequently than larger later rewards when observed by a peer. However, this does not necessarily imply that they became more impatient (Andersen et al., 2008). Alternatively, it is possible that their valuation of rewards (*u(x)* i.e. risk attitude) changed or that they became more present-biased or random. Previous experiments cannot distinguish between these alternative explanations. Since in the previous studies the sooner reward was always available immediately, it is also unclear whether the results were driven by changes in impatience or present-bias or both. In this paper, to overcome the identification problems of the previous studies, we used established methodology to separately identify how observation affects impatience, present bias, risk attitudes, and inconsistency.

2.1 Study 1 methods

2.1.1 Experimental design

186 (71 male) adolescents participated in the study. Based on the neurobiological knowledge of brain development, developmental psychologists classify people as adolescents from puberty until the mid-20s — that is until the prefrontal cortex finally matures. Therefore, as advised in the literature (Hartley & Somerville, 2015), we incorporated a wide age range (12-24) under one experimental design to investigate age-related changes in susceptibility to peer observation throughout adolescence. Participants' average age was 18.586 years with a standard deviation of 3.261 (see age histogram in Figure 2). Participants 12 to 17 years old were recruited using announcements placed on Facebook and Instagram. Participants 18 to 24 years old were recruited from the University of Sydney student database using ORSEE (Greiner, 2004). All participants, and in the case of minors also caregivers, gave informed consent and the study was approved by the Ethics Office at the University of Sydney.

It is econometrically impossible to disentangle the change in impatience from the change in the valuation of rewards (i.e. risk attitudes) because in the relevant existing experiments participants only chose between *sooner and smaller* and *later and larger* rewards (the choice between sooner larger and later smaller reward is rather obvious). To overcome this problem, we used a richer task that allowed us to assess our participants' risk attitudes and impatience and present bias using a series of incentive-compatible binary choices.

To assess participants' impatience, we asked them to make 30 choices between receiving $20 earlier and receiving a larger amount (that varied from $21 to $30 in $1 increments) 8 weeks later. The sooner dates (*front-end delays*) were either now, in 4 weeks or in 20 weeks. The later payment was always 8 weeks after the sooner date. Using a set of identical choice scenarios with the same amounts and the same 8-week delay between sooner and later option but with different front-end delays allowed us to extend previous findings by comparing the consistency of the patience estimate across time.

To assess risk attitudes, we asked participants to choose between receiving $18 with certainty (safe option) and a lottery (risky option) with two outcomes: $39 or $1. The probability of each of the lottery outcomes changed in 10% increments from scenario to scenario, resulting in a total of 9 choices.

All choice scenarios were presented on a computer screen. Participants completed the impatience assessment task first, followed by the risk assessment task. Within each task, the choice scenarios were presented in an order randomized independently for each participant. Participants could either indicate a preference for one of the options or indifference in which case they knew that the computer would choose for them at random.

Sessions were conducted at the University of Sydney School of Economics experimental laboratory, which comprises 32 individual computer stations, separated for privacy by high partition walls on the sides and the front of each station (seating map in Figure S1). While the partition walls already provide privacy, to further improve privacy we run sessions with only up to 16 participants at a time to allow for extra partition in the form of an unused computer station between participants. In the beginning of the study, participants were randomly assigned to be either Decision-Makers or Observers. Each Decision-Maker was randomly matched with one Observer. To make sure that Observers and Decision-Makers were indeed peers, high school participants were only matched with high school students and university students were only matched with university students. Decision-Makers completed the task twice, once in private and once when observed by the Observer that they were randomly matched with. The order of the private and observed sections was randomized between the sessions. Observers completed the task only once and in private. (The sequence of the experiment is summarized in Figure S2.) Our within-subject design allowed us to assess how each participant's behavior changes in the private versus observed sections of the experiment.

To complete the task in private condition, all participants remained in their seats. To complete the task in observed condition, Decision-Makers remained in their seats and Observers moved to sit to the right of the Decision-Maker that they were partnered with (compare Figure S1A and S1B). To make sure that there was an equal physical distance between all Decision-Makers and their Observers, their chairs were strapped together. To encourage Observers to pay attention to Decision-Maker's choices, we told them that later in the experiment they will be asked to recall three randomly selected choices made by the Decision-Maker and for each correct recollection they will receive an additional $1 (Test stage in Figure S2). To equalize payment opportunities, Decision-Makers completed a similar task where they were asked to guess three of the Observer's choices.

At the end of the experiment, for each participant, the computer randomly selected a single choice scenario and the participant was paid according to her choice in that scenario. In addition to the earnings from the choice task, participants received earnings of up to $3 from the recollection/guessing test and a $10 show-up fee at the end of the experimental session. To make sure that transaction costs associated with payments at different dates were equalized, all payments were made electronically. Participants 18 years old or older received their payments via bank transfers made to their mobile number. Younger participants received their payments via their preferred eGiftCard (Officeworks, JBHiFi, Big W, Coles, Kmart, or Target). All payments were made in Australian Dollars.

2.1.2 Econometric approach

Time preference — impatience: We quantify impatience as the proportion of times that the individual selected the sooner option. To distinguish impatience from present bias (preference for immediate versus delayed rewards), we calculated impatience based only on the decisions that involved choosing between two rewards received at two different dates in the future and excluded the choices between a reward *now* and a reward 8 weeks later.

To investigate the role of gender and age, we additionally ran ordered logit regressions with dependent variable equal to 1 if the participant chose the sooner option, equal to 0.5 if the participant was indifferent, and equal to 0 if the participant chose the option delivered later. When discussing changes in impatience, it is important to acknowledge that if a participant's behavior in the impatience task changes because of experimental manipulation, it can happen for three separate reasons. It is possible that the level of impatience truly changed, that is participant discounts future rewards at a different rate. Alternatively, it is because the marginal utility that the participant derives from receiving additional dollar changed or that (s)he became more or less inconsistent. The inclusion of the risk assessment task in our design allows us to overcome this problem because it captures changes in the marginal utility of money. When discussing the effects of observation on behavior in the impatience assessment task, we control for changes in behavior in the risk assessment task as well as changes in inconsistency to make sure that our results are indeed due to a change in time preference.

Time preference — present bias: To investigate present-bias, we take the difference in the impatience measures when the front-end delay is equal to zero and when it is equal to four. In other words, we compare how much additional money individuals require to wait 8 weeks longer to receive the reward when the sooner reward is received now versus when the sooner reward is received in 4 weeks. Note that the delay between the sooner and later option in our design is always equal to 8 weeks independent of the front-end delay. Therefore, for individuals who exhibit present bias, the measure should be positive, because participants who are present-biased will be more impatient when the front-end delay is zero than when it is four. For the individuals who are not present-biased our measure of present bias will be equal to zero.

Risk tolerance: We quantify participants' risk attitude as the proportion of times that they selected the lottery in the risk assessment task. Depending on the analysis, this measure either excludes the indifferent choices or counts them as a half preference for the risky option, as specified in the results section. Additionally, to investigate gender and age interactions, we ran ordered logit regressions using a dependent variable equal to 1 if the participant chose the lottery, equal to 0.5 if the participant was indifferent, and equal to 0 if the participant chose the safe option. We control for inconsistency in choice, as a potential driver of behavior, in this analysis.

Choice inconsistency and indifference: A serious confound in the preference analysis is not accounting for inconsistency in behavior (Castillo et al., 2018; Krajbich et al., 2015). It is particularly important because adolescents show a higher predisposition to inconsistent behavior than midlife adults (Tymula et al., 2013). If adolescents become more inconsistent when observed, then by experimental design we can make them look more/less patient or risk-taking. In particular, in our experiment, a random chooser would pick the lottery on average 4.5 times out of 9. A risk-neutral chooser would pick the lottery 5 times out of 9. As is usually the case, our participants were risk-averse and when in private they chose the lottery on average 3.78 times out of 9. If under observation, they started to make decisions more randomly, they would end up choosing the lottery more often than 3.78 times on average appearing to be more risk-tolerant even though the change in behavior was driven by an increase in randomness not a change in risk attitude. Therefore, it is important to control for changes in inconsistency in observed behavior when analyzing preferences. To measure inconsistency in our participants' decisions we created separate indexes for the risk assessment task and the impatience assessment task. For the risk assessment task, we ordered participants' choices by the likelihood with which they could receive high ($39) reward in the lottery. Normally, in this task, participants choose the safe option when the probability of receiving high lottery rewards is low and then switch to choosing lottery, once the probability of getting the high lottery reward is high enough according to their risk preference. A perfectly consistent chooser would either have a score of 0 (always chose the lottery or always chose the safe option), a score of 1 (first selected the safe option and then changed to consistently choosing the lottery option), or a score of 2 (first selected the safe option, then indifferent and then consistently chose lottery). Higher scores indicate that participants switched back and forth and decided inconsistently. Therefore, in the risky task, we classify participants with a switching score of two or less as consistent and those with a score of three or more as inconsistent. In the impatience assessment task, we calculated a similar inconsistency index by ordering choice scenarios by the size of the delayed reward. We did this separately for each front-end delay. These classifications are captured by a variable *inconsistent.* We then generated an index of the severity of inconsistency for each trait (and front-end delay), which is an interaction of *inconsistent* and the switching score. For each individual, we then added up these indexes for an overall characterization of an individual's *inconsistency.*

We measure indifference, simply by the proportion of indifferent choices, separately in each task.

In all regressions, standard errors are clustered on the level of the individual. To compare risk attitude, impatience, inconsistency and indifference measures, we use two-sided, paired t-tests. Assuming an effect size of d=0.35, alpha equal to 0.05 and a power of 0.90, a sample of 92 participants is sufficient to establish the significance of the results.

2.2 Study 1 results

2.2.1 Observation results

Over 80% of the Decision-Makers reported that their Observer paid attention to most or all of the decisions that they were making (Figure 3). Furthermore, Observers were significantly better at answering the three test questions about the choices of their partner than Decision-Makers who did not have a chance to observe their partners' choices (2.624 vs. 1.979, $p<0.001$)[2], consistent with the idea that Observers indeed paid attention to their partner's choices. Only 8% of the participants reported having met their session partner before.

2.2.2 Impatience and present bias

Participants were significantly more impatient when observed (Figure 4A). When choosing between the sooner option of $20 (paid in 4 weeks or 20 weeks) and a larger reward paid eight weeks later, they selected the sooner option 57.29% of the time when observed which is significantly more than 50.73% of the time in private ($p<0.001$). The size of the effect can be interpreted as medium based on the Cohen's d effect size of 0.405.[3] In terms of earnings, if paid for one of the decisions made under observation, participants would make on average about $0.40 less than if paid based on a decision made in private. Table 1 shows that the result holds in ordered logit regression model even when we control for risk preferences and inconsistency in choice as possible confounds (Model (1)) and when we include age and

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[2] A participant choosing at random would obtain a score of 1.5. Decision-Makers scored higher than a random chooser, likely because in some of the decision scenarios, those with very low or very high odds of receiving lottery rewards, or those with very low or very high delayed rewards it is easy to predict what others will choose.

[3] Cohen's d is calculated with the formula used by G*Power.

gender controls (Models (2)-(4)).[4] Moreover, Figure 5 illustrates that participants are more impatient when observed for all three front-end delays (p=0.034 for no front-end delay, p<0.001 for 4-week front-end delay, and p=0.060 for 20-week front-end delay).

Figure 5 suggests that our participants do not have the same discount rate across the three front delays and instead are more patient for choices that are pushed further to the future. Indeed, the coefficient on *the front-end delay* in the analysis in Table 1 and Table 2 is highly significant and smaller than 1. Participants were most patient when choosing between $20 in 20 weeks and a larger reward in 28 weeks. For this longest delay, their choices were significantly more patient than when they were choosing between receiving $20 today and a different amount 8 weeks later (p<0.001 in both the observed and private conditions). There was only insignificant change in impatience when subjects were choosing between rewards now or in 8 weeks and rewards in 4 weeks or 12 weeks (p=0.060 when observed, p=0.111 in private) indicating that our participants were not present-biased. Our regression analyses (Table 1 and Table 2) confirm this by revealing that our participants were not more likely to choose the sooner option if it was available now (the insignificant coefficient on *immediate reward*).

In general, we see only very weak evidence of present bias when participants decide in private (0.031, one-sided p=0.0539) and no present bias when participants decide under observation (-0.029, one-sided p=0.972). When comparing behavior under observation and in private, we see that under observation adolescents behave as if they put less weight on the present, even to the extent of becoming future-biased (p=0.001).

Finally, we replicate earlier findings (Sutter, Kocher, Glätzle-Rützler, & Trautmann, 2013) that adolescents who have more siblings are more impatient (Table 2). The number of siblings did not correlate with our participants' risk attitudes or present-bias.

2.2.3 Risk attitudes

We do not find a significant effect of observation on risk attitude (Figure 4B). In private, participants selected lottery 35.60% of the time and when observed 35.25%, a difference that

[4] The results also stay qualitatively the same when we conduct separate analyses for participants who are 12-17 years old and 18-24 yours old.

is not statistically significant (p=0.731). In private, participants selected the safe option 59.98% of the time and when observed 58.54% of the time. The result remains unchanged when we separately study male and female participants. Using ordered logit (Table 3) we confirm no effect of observation on risky choices both when including age and gender controls (Models (2-4)) and without them (Model (1)).[5]

2.2.4 Consistency and indifference in choice

More participants were inconsistent when observed than when in private in the risk assessment task (19.35% vs. 5.38%, p=0.001 and Table 4). Moreover, more participants were inconsistent in the time assessment task questions with the 20-week-long front-end delay (45.16% versus 29.03%, p=0.011 and Table 5). For questions with front-end-delay equal to 0 and 4 weeks, the proportion of inconsistent participants in observed and in private conditions was the same (22.58% vs. 22.58% and 29.3% vs. 27.96%, p=0.836). These results are robust to including own gender and age controls (Table 4 and Table 5). There were no systematic age and gender interaction effects across risk and impatience assessment tasks. In the risk assessment task, participants observed by older partners were less affected by observation.

In the risk assessment task, participants were more indifferent when observed than when in private (0.062 versus 0.044, p=0.006). No such effect occurred in the impatience assessment task.

2.2.5 General age and gender patterns

We next explored the general age and gender patterns for each of the five traits by regressing impatience, present bias, risk tolerance, inconsistency, and indifference on gender, age, age squared, and interactions of age and gender (see Table 6). To keep this analysis free of observation effects, we restricted attention to participants making decisions in private and excluded all choices made under observation. The only trait that showed age and gender-related variation in our adolescent participants is risk attitude, although later analysis reveals that this result is not robust. Given that age and gender-age interaction coefficients have different signs, we additionally separately for each gender regressed risk tolerance on age and

[5] The results stay qualitatively the same when we conduct separate analyses for participants who are 12-17 years old and 18-24 years old.

age squared (Table 7). While males in our sample did not show any age-related trajectory in risk attitudes, female participants appear to become risk-averse with age, an effect that is not monotonic as revealed by the significant coefficient on age squared. The data behind these results are presented visually in Figure 6 where we plot individual risk attitudes against age (with a slight jitter). Figure 6 reveals that both of the only two 12-year-old females in our study exhibited much higher risk tolerance than average participants in other age groups. We, therefore, checked whether the age effects on risk attitudes presented in the two left columns of Table 7 persist if we restrict the sample to all 13- to 24-year-olds. As shown in the two right columns of Table 7, among 13- to 24-year-olds in our sample we did not see any significant relationship between age and risk tolerance. Figure S3 in the supplementary material plots patience, present bias, inconsistency and indifference against age for each participant.

2.3 Study 1 discussion

We extended earlier findings (Silva et al., 2016; Steinberg et al., 2009) by removing possible confounds — risk attitudes, present bias, and inconsistency — from our estimates of patience. By adding three different front-end delays we additionally estimated present-bias. We found that under peer observation adolescents became more impatient, less present-biased and more inconsistent.

It may be surprising that adolescents did not take more risks when observed. However, our results are still consistent with earlier findings. For example, the results in Smith et al., (2014) could be attributed to a decrease in loss aversion or change in inconsistency rather than risk attitudes. The findings in Gardner & Steinberg (2005) could be alternatively explained by an increase in impatience, inconsistency, or change in beliefs about the underlying probability of the bad outcome. In study 2, we explore whether subjective beliefs about the probabilities of different events are affected by observation.

3 Study 2 introduction

Many papers have shown that people prefer risky to ambiguous options (Ellsberg, 1961) and risk and ambiguity attitudes seem unrelated (Borghans et al., 2009). In the lifespan context, adolescents were shown to be as risk-taking as older adults, but more ambiguity tolerant

(Tymula et al., 2012). These prior findings raise a not-yet-explored possibility, that adolescents' attitudes towards risk and ambiguity are differently affected by peer observation.

3.1 Study 2 method

3.1.1 Experimental design

166 (65 male) adolescents aged between 12 and 18 years old (average age: 15.3; standard deviation 1.6) participated in the study. They were recruited using paper flyers and announcements posted on Facebook and Instagram. All participants and their caregivers gave informed consent and the protocol was approved by the Ethics Office at the University of Sydney.

To measure our participants' attitudes towards unknown and known risks we asked them to make 60 binary decisions between receiving \$5 with certainty (a safe option that was always available) and a lottery offering a reward at some probability or nothing at a corresponding probability. The lottery reward changed from one decision scenario to another and ranged from \$5 to \$41. The winning probability on each trial was 25%, 50%, or 75%. All 10 rewards were fully crossed with 3 winning probabilities to form a set of 30 unique *risky* lotteries that were used to elicit the participant's *risk attitude*. To aid comprehension, probabilities were communicated to participants as bags of 100 tokens, with some of the tokens being red (winning color) and the rest being blue. Participants were shown these bags before they began the task and the bags remained untouched in the study reception area throughout the experimental session. In an additional set of 30 *ambiguous* trials, the exact probability of winning was not precisely known. This was communicated to the participants by occluding a part — 26%, 50% or 74% — of the bag contents — with ambiguity always centered at a 50% chance of winning. In the ambiguous trials, we asked participants to choose either red or blue to be their winning color to ensure that they do not suspect that the experimenter purposefully reduced the probability of winning in the ambiguous trials by putting less of the winning color tokens in the ambiguous bags. The choices were presented to participants in the form of choice list (see Figures S4 and S5 for examples).

Experiments were conducted in small consultation rooms at the University of Sydney. The rooms were equipped with a desk and two chairs. Upon arrival to the lab, participants were randomly assigned to one of three treatments: *Private*, *Observed Decides First*, or *Observed Decides Second*. 56 (21 male) participants in *Private* treatment completed the decision-making task sitting alone at the desk in the consultation room. In the *Observed* treatments, participants of the same gender were paired together. To make sure that they can observe each other's choices, they were asked to sit together in the same consultation room on chairs arranged to be at the same table corner. Participants in *Observed Decides First* treatment completed the task first while their partner observed. Once the first participant was done, the roles reversed: the participant in *Observed Decides Second* decided while their partner observed. 110 (44 male) participants completed the task in the *Observed* treatments. After finishing the task, all participants privately completed a questionnaire. To maintain privacy, in the *Observed* treatments participants were instructed to move the chairs from the table to the opposite corners of the consultation room to complete the questionnaire. The experimenter was not present in the room while participants made their choices and completed the questionnaire. Participants communicated to the experimenter that they finished the task by opening the door of the room they were in.

At the end of the study, each participant picked a token from a bag filled with tokens numbered from 1 to 60 to determine the decision they would be paid for. If in the payment decision they selected $5 with certainty, they received it. If they selected the lottery, it was played out. To play the lottery, the participant picked one token from the payment lottery bag without looking. If the token was of the winning color, the participant got the reward. If it was not, (s)he got $0. In addition to decision task earnings, participants received a $12 show-up fee. The payment was conducted in private, with only the experimenter present.

3.1.2 Econometric approach

We define participants' risk tolerance as the proportion of times that they selected the lottery. To calculate individuals' ambiguity attitude, we took the difference between the frequency with which they selected ambiguous lotteries and the frequency with which they selected 50-50 lottery. Since ambiguity about the probability of winning (the distribution of the red and blue tokens in the bag) was always centered at 50% winning probability, participants who were ambiguity neutral should perceive the probability of winning in ambiguous lotteries as 50%.

We test for differences in risk and ambiguity attitudes using two-sided, unpaired t-tests. Additionally, to investigate how age and gender interact with the observation treatment, we ran a set of logistic regressions with a dependent variable that is equal to 1 if the participant selected a lottery and equal to zero if (s)he selected the safe option. In this regression analysis, standard errors are clustered on the participant and we report the marginal effects.

We assessed whether the propensity to make mistakes, measured as violations of the first-order stochastic dominance (FOSD), is affected by observation. Each individual had the opportunity to violate FOSD six times in the task by choosing a lottery that pays $5 or $0 over a sure payment of $5. Our measure of individual propensity to make mistakes is the total number of times that an individual violated FOSD.

3.2 Study 2 results

The majority of participants (66%) reported that their partner paid attention to all or more than half of their choices (Figure 7). Out of all the participants in the Observed treatments, 52% indicated that they do not know their session partner at all and 40% said that their session partner is their best friend or that they know him/her very well.

3.2.1 Risk attitudes

Figure 8A illustrates the proportion of decisions in which risky lotteries were chosen in each of the treatments. There was no statistical difference between lottery choice frequencies in the Observed treatments (0.610 vs. 0.587, p=0.405), so for the ease of exposition, we combine them in the analysis that follows. A lottery was selected 55.77% (standard deviation: 17.83) of the time by participants in the Private treatment and 59.85% (standard deviation: 14.81) of the time in the Observed treatment, a difference that is not statistically significant (p=0.120). The lack of a significant result is not due to different effects for boys and girls. Girls selected the lottery 56.19% of the time in private and 59.45% of the time when observed (p=0.351). For boys it was 55.07% versus 60.46% (p=0.180).

To verify whether the lack of a strong effect is confounded by age and gender variables, we ran a set of logistic regressions with and without demographic controls (Table 8). Whether we controlled for own demographic variables (Model (2)), and partner demographic variables (Model (3)) or did not control for them at all (Model (1)) did not make a difference — lottery choices of participants who were observed were not statistically distinguishable from the decisions of those who made them in private. Focusing only on participants in the Observed treatments (Model (4)) we found that older participants took slightly fewer risks, but this effect is not significant in the whole sample that also includes those in the Private treatment (Model (2)). Partner's age did not affect the willingness to take risks.

Finally, we tested whether perhaps the effect of observation depended on whether adolescents were observed by a friend or stranger and found that the level of risk-taking was not statistically different among those who did not know their session partner and those who knew them very well (59.82% lottery choices versus 61.14%, p=0.662 in a two-sided t-test). We obtained similar results using logistic regression (the not significant coefficient on *partner's know* in the model (5) in Table 8). The risk attitudes of adolescents did not change with the perceived intensity with which they were observed (the not significant coefficient on *the partner's attention* in the model (5) in Table 8).

3.2.2 Ambiguity attitudes

Participants were on average ambiguity averse (Figure 8B) and were equally ambiguity tolerant when in private (-0.063, standard deviation: 0.168) and when observed (-0.066, standard deviation: 0.167; p=0.897) with no meaningful differences in response to observation for girls and boys (for girls: -0.083 vs. -0.066, p=0.620; for boys: -0.029 vs. 0.0659, p=0.431). The results remain the same whether we control for demographic variables or not (Table 9: Models (1)-(3)). Among those in the observed treatment, there is no evidence that their age, their partner's age, gender, knowing the observer, or the intensity of observation affected the degree to which they tolerated ambiguity (Table 9: Models (4)-(5)).

There was no difference in ambiguity attitudes between participants who did not know their partner at all and those who knew their partner very well (-0.072 versus -0.060, p=0.697).

3.2.3 Mistakes

We found that those who were in the Private treatment violated dominance less than those in the Observed treatments, but this result is not significant (0.893% versus 1.212%, p=0.7518).

3.3 Study 2 discussion

Just as in study 1 that used a within-subject design, in study 2 that used a between-subject design we found no effect of observation on risk attitudes. Previous research found that when held accountable for their choices, adults become more ambiguity averse because ambiguity aversion is the norm (Curley, Yates, & Abrams, 1986; Trautmann, Vieider, & Wakker, 2008). Consistent with this idea, in identical study design as in Study 1 (except for the task), Tymula & Whitehair (2018) found that ambiguity aversion increases in university students when they are observed by their peers as compared to when making decisions in private (risk attitudes were not affected). In contrast to these earlier studies, we do not find that adolescents are more ambiguity averse when observed, perhaps because norms of ambiguity tolerance vary across the lifespan (Romer et al., 2017; Tymula et al., 2013).

One unusual result is that adolescents were more ambiguity tolerant, the higher the ambiguity level. Contrary to this finding, previous papers documented that both adolescents and adults prefer less to more ambiguity (Tymula et al., 2013). One difference with earlier studies is that we allowed adolescents to choose their winning colors in ambiguous trials. Possibly this active choice induced a different perception of ambiguity, a methodological finding worth investigating in the future.

4 Conclusions

Impaired decision-making in the presence of peers is believed to be one of the major culprits behind welfare-decreasing outcomes in adolescence but the contributing processes are not yet fully understood (Breiner et al., 2018; Romer et al., 2017). Our results suggest that attributing the behavioral change to an increase in adolescent risk-taking in the presence of peers is imprecise. By disentangling what is commonly referred to as "risk attitudes" into five conceptually different and separately identifiable behavioral traits, we found that risk and ambiguity attitudes were *not* affected by observation. Instead, when observed adolescents became more impatient, more inconsistent, and less present-biased. These results offer a new understanding of the role of peer observation in adolescent behavior. Our findings suggest that adolescents may be more affected by peer observation when the consequences of their actions are experienced at different points in time rather than when all consequences materialize at the same time.

Our contribution has been to provide a more detailed understanding of what exact computations that underlay decision-making are affected by observation in adolescence. For this purpose, we used an economic model that decomposes a decision into four separate functions. This exercise proved, we believe, useful as it revealed, perhaps unexpected, new insights into how adolescents make decisions that will be useful for policy and theory development.

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Tables

Table 1. Time preferences and observation. Ordinal logit regressions. Dependent variable = 1 if participant chose sooner option, = 0.5 if indifferent, = 0 if selected later option. *observed* =1 if the participant is observed and 0 otherwise; *age* is the age in years; *ageXobserved, maleXobserved, partner_ageXobserved, partner_maleXobserved* are interaction terms of *observed* and, respectively, *age, male,* partner's age and whether the partner is male. Control variables are: *risk tolerance*; whether the participant is *inconsistent* in time trials; *inconsistent severity* - an interaction term of *inconsistent* and the number of times the participant switched, *later reward* in dollars; *front-end delay* (0, 4 or 20); *immediate reward* (whether sooner reward is available now).

	(1)	(2)	(3)	(4)
observed	0.2755***	0.2774***	-0.2825	0.0258
	(0.0746)	(0.0750)	(0.5217)	(0.5329)
male		0.2415	0.2482	0.2477
		(0.3308)	(0.3466)	(0.3476)
age		-0.0780+	-0.0932+	-0.0944+
		(0.0467)	(0.0505)	(0.0505)
ageXobserved			0.0307	0.1266+
			(0.0300)	(0.0762)
maleXobserved			-0.0148	0.0214
			(0.1657)	(0.1705)
partner_ageXobserved				-0.1064
				(0.0768)
partner_maleXobserved				-0.2233
				(0.3359)
risk tolerance	0.7824	0.5221	0.5297	0.4177
	(0.9048)	(0.9351)	(0.9358)	(0.9315)
inconsistent	-0.2601+	-0.2231	-0.2318	-0.2453+
	(0.1433)	(0.1464)	(0.1424)	(0.1440)
inconsistent severity	0.0386	0.0535	0.0543	0.0541
	(0.0434)	(0.0424)	(0.0424)	(0.0433)
later reward	-0.2993***	-0.3032***	-0.3034***	-0.3051***
	(0.0249)	(0.0251)	(0.0251)	(0.0249)
front-end delay	-0.0223***	-0.0228***	-0.0228***	-0.0229***
	(0.0046)	(0.0047)	(0.0047)	(0.0047)
immediate reward	-0.0931	-0.0917	-0.0922	-0.0938
	(0.0767)	(0.0779)	(0.0778)	(0.0783)
N	5580	5580	5580	5580
No. Clusters	93	93	93	93

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Standard errors are clustered on the participant

Table 2. Time preferences and siblings. Ordinal logit regressions. Dependent variable = 1 if participant chose sooner option, = 0.5 if indifferent, = 0 if selected later option. *observed* =1 if the participant is observed and 0 otherwise; *age* is the age in years; *ageXobserved, maleXobserved, partner_ageXobserved, partner_maleXobserved* are interaction terms of *observed* and, respectively, *age, male,* partner's age and whether the partner is male. Control variables are: *risk tolerance*; whether the participant is *inconsistent* in time trials; *inconsistent severity* - an interaction term of *inconsistent* and the number of times the participant switched, *later reward* in dollars; *front-end delay* (0, 4 or 20); *immediate reward* (whether sooner reward is available now). Included are all Choice-Maker's and Observer's choices in private.

siblings	0.1778*
	(0.0847)
male	0.3258
	(0.2485)
age	-0.0756*
	(0.0339)
risk tolerance	0.3666
	(0.7792)
inconsistent time	-0.2691+
	(0.1546)
inconsistent severity time	0.0181
	(0.0358)
later reward	-0.3168***
	(0.0194)
front-end delay	-0.0198***
	(0.0040)
immediate reward	0.0241
	(0.0789)
N	5580
No. Clusters	186

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001
Standard errors are clustered on the participant

Table 3. Risk attitudes are not affected by observation. Ordered logit regressions. Dependent variable = 1 if the participant chose lottery, = 0.5 if chose indifferent, = 0 if chose safe option. *observed*=1 if the participant is observed and 0 otherwise; *male*=1 for males and 0 for females; *age* is the age in years; *ageXobserved, maleXobserved, partner_ageXobserved, partner_maleXobserved* are interaction terms of *observed* and, respectively, *age, male,* partner's age and whether the partner is male. Control variables: whether participant is *inconsistent* in risky trials; *severity of inconsistency* - an interaction of *inconsistent* and the number of switches; the *probability* of receiving larger lottery outcome.

	(1)	(2)	(3)	(4)
observed	-0.0359	-0.0276	-0.1056	0.3598
	(0.1047)	(0.1062)	(0.6253)	(0.6660)
male		0.1860	0.0636	0.0597
		(0.3489)	(0.3596)	(0.3635)
age		-0.0985*	-0.0977+	-0.0981+
		(0.0499)	(0.0506)	(0.0511)
ageXobserved			-0.0012	0.1181
			(0.0321)	(0.0732)
maleXobserved			0.2463	0.2409
			(0.1820)	(0.2087)
partner_ageXobserved				-0.1481+
				(0.0766)
partner_maleXobserved				0.3931
				(0.3266)
inconsistent risk	-3.3381**	-3.1933**	-3.2445**	-3.1875***
	(1.1126)	(1.0517)	(1.0938)	(0.9603)
inconsistent severity risk	1.0113***	0.9578**	0.9760**	0.9273***
	(0.3000)	(0.2954)	(0.3091)	(0.2761)
probability	8.6962***	8.8404***	8.8469***	8.9448***
	(0.7075)	(0.7050)	(0.7075)	(0.7170)
N	1674	1674	1674	1674
No. Clusters	93	93	93	93

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Standard errors are clustered on the participant

Table 4. Inconsistency in risky trials. Logistic regression with a binary dependent variable equal to 1 if the individual is inconsistent (that is made 3 or more switches in the risky task) and 0 otherwise. *observed* is a binary variable equal to 1 if participant is observed and 0 otherwise; *male* is a binary variable equal to 1 for males and 0 for females; *age* is age in years; *ageXobserved, maleXobserved, partner_ageXobserved, partner_maleXobserved* are interaction terms of *observed* and, respectively, *age, male,* partner's age and whether partner is male. Marginal effects are reported.

	(1)	(2)	(3)	(4)
observed	0.1398***	0.1316**	0.3902	0.4503
	(0.0421)	(0.0408)	(0.3076)	(0.3139)
male		-0.0735+	-0.0823	-0.0792
		(0.0435)	(0.0817)	(0.0783)
age		-0.0079	0.0003	0.0003
		(0.0063)	(0.0103)	(0.0099)
ageXobserved			-0.0111	0.0112
			(0.0111)	(0.0130)
maleXobserved			0.0123	0.0139
			(0.1127)	(0.1112)
partner_ageXobserved				-0.0243*
				(0.0123)
partner_maleXobserved				-0.0030
				(0.0465)
N	186	186	186	186
No. Clusters	93	93	93	93

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Standard errors are clustered on the participant

Table 5. Switching behavior in time trials with front-end-delay=20 weeks. Logistic regression binary dependent variable is equal to 1 if the individual is inconsistent (that is made 3 or more switches in the risky task) and 0 otherwise. *observed* is a binary variable equal to 1 if participant is observed and 0 otherwise; *male* is a binary variable equal to 1 for males and 0 for females; *age* is age in years; *ageXobserved, maleXobserved, partner_ageXobserved, partner_maleXobserved* are interaction terms of *observed* and, respectively, *age, male,* partner's age and whether partner is male. Marginal effects are reported.

	(1)	(2)	(3)	(4)
observed	0.1505*	0.1521*	-0.0584	-0.0425
	(0.0611)	(0.0617)	(0.3538)	(0.3602)
male		-0.1033	-0.0917	-0.0917
		(0.0853)	(0.1103)	(0.1103)
age		0.0097	0.0032	0.0032
		(0.0135)	(0.0168)	(0.0168)
ageXobserved			0.0119	0.0165
			(0.0190)	(0.0279)
maleXobserved			-0.0225	-0.0235
			(0.1223)	(0.1215)
partner_ageXobserved				-0.0061
				(0.0240)
partner_maleXobserved				0.0421
				(0.1058)
N	186	186	186	186
No. Clusters	93	93	93	93

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Standard errors are clustered on the participant

Table 6. General age and gender pattern for each of the traits. *Inconsistency* as an independent variable is a measure of inconsistency in time preference trials only in the model (1) and risk preference trials only in the model (3).

	(1) impatience	(2) present bias	(3) risk tolerance	(4) inconsistency	(5) indifference
male	0.2143	-0.4637	-1.4340+	16.5558	-12.7492
	(1.5945)	(0.7227)	(0.8355)	(15.7638)	(10.1228)
age	0.0459	-0.0846	-0.1276*	2.5155+	-0.8039
	(0.1159)	(0.0642)	(0.0602)	(1.3293)	(0.9562)
age^2	-0.0019	0.0025	0.0032*	-0.0674+	0.0209
	(0.0031)	(0.0017)	(0.0016)	(0.0354)	(0.0255)
maleXage	-0.0269	0.0602	0.1603+	-1.9927	1.4414
	(0.1777)	(0.0809)	(0.0924)	(1.7698)	(1.1560)
$maleXage^2$	0.0010	-0.0019	-0.0043+	0.0537	-0.0396
	(0.0048)	(0.0022)	(0.0025)	(0.0478)	(0.0321)
inconsistency	0.0039		0.0195		
	(0.0062)		(0.0119)		
risk tolerance	0.0726				
	(0.1589)				
constant	0.2750	0.7193	1.5649**	-19.3498	8.4972
	(1.0419)	(0.5685)	(0.5393)	(12.0232)	(8.7500)
N	186	186	186	186	186

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Table 7. General age patterns in risk attitudes by age and excluding outliers.

	12-24-year-olds		13-24-year-olds	
	female	male	female	male
age	-0.1270*	0.0366	-0.0867	0.0284
	(0.0594)	(0.0660)	(0.0672)	(0.0771)
age^2	0.0032*	-0.0011	0.0022	-0.0009
	(0.0016)	(0.0018)	(0.0018)	(0.0021)
inconsistency	0.0161+	0.0273	0.0174*	0.0266
	(0.0091)	(0.0211)	(0.0088)	(0.0220)
constant	1.5619**	0.0907	1.1827+	0.1707
	(0.5333)	(0.5807)	(0.6081)	(0.7002)
N	115	71	113	70

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Table 8. Risk attitudes are not affected by observation. Logistic regressions with dependent variable specified as a binary variable equal to 1 if the participant selected a lottery and equal to 0 if the participant selected the sure payment. Only choices between $5 and a risky lottery are included. *observed* is a binary variable equal to 1 if participant is observed and 0 otherwise; *male* is a binary variable equal to 1 for males and 0 for females; *age* is age in years; *ageXobserved, maleXobserved* are interaction terms of *observed* and, respectively, *age* and *male*; *partner's age* is partner's age, *partner's attention* is measured by asking choice-makers "For what proportion of your choices do you think the person observing you was paying attention?" (1=none; 5=all); *partner know* measures how well paired participants knew each other on a scale from 1 to 5 (1=not at all to 5=we are best friends); *probability* is the probability with which the lottery paid the reward; the *reward* is the lottery reward in dollars. Marginal effects reported.

	(1)	(2)	(3)	(4)	(5)
observed	0.0768	0.0746	0.6103		
	(0.0529)	(0.0534)	(0.4043)		
male		0.0092	-0.0188	0.0185	0.0155
		(0.0453)	(0.0866)	(0.0511)	(0.0517)
age		-0.0257+	-0.0046	-0.0375*	-0.0408*
		(0.0155)	(0.0285)	(0.0164)	(0.0165)
ageXobserved			-0.0367		
			(0.0331)		
maleXobserved			0.0369		
			(0.0973)		
partner_age				-0.0232	-0.0263
				(0.0185)	(0.0175)
partner know					-0.0080
					(0.0102)
partner's attention					-0.0118
					(0.0206)
probability	1.0775***	1.0821***	1.0845***	1.0545***	1.0555***
	(0.0837)	(0.0825)	(0.0832)	(0.1054)	(0.1052)
reward	0.0418***	0.0420***	0.0421***	0.0422***	0.0423***
	(0.0020)	(0.0020)	(0.0020)	(0.0025)	(0.0025)
N	4980	4980	4980	3300	3300
No. Clusters	166	166	166	110	110

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Standard errors are clustered on the participant

Table 9. Ambiguity attitudes are not affected by observation. Logistic regressions with dependent variable specified as a binary variable equal to 1 if the participant selected a lottery and equal to 0 if the participant selected the sure payment. Only choices between $5 and an ambiguous lottery are included. *observed* is a binary variable equal to 1 if participant is observed and 0 otherwise; *male* is a binary variable equal to 1 for males and 0 for females; *age* is age in years; *ageXobserved, maleXobserved* are interaction terms of *observed* and, respectively, *age* and *male*; *partner's age* is partner's age, *partner's attention* is measured by asking choice-makers "For what proportion of your choices do you think the person observing you was paying attention?" (1=none; 5=all); *partner know* measures how well paired participants knew each other on a scale from 1 to 5 (1=not at all to 5=we are best friends); *ambiguity level* is the level of ambiguity surrounding the probability of winning; *reward* is the lottery reward in dollars. Marginal effects reported.

	(1)	(2)	(3)	(4)	(5)
observed	0.0576	0.0551	0.6638+		
	(0.0592)	(0.0592)	(0.3623)		
male		0.0923+	0.0867	0.0895	0.0911
		(0.0541)	(0.0895)	(0.0672)	(0.0669)
age		-0.0060	0.0207	-0.0247	-0.0267
		(0.0194)	(0.0326)	(0.0242)	(0.0245)
ageXobserved			-0.0468		
			(0.0404)		
maleXobserved			0.0035		
			(0.1139)		
partner's age				-0.0086	-0.0097
				(0.0255)	(0.0248)
partner know					-0.0030
					(0.0145)
partner's attention					-0.0402
					(0.0259)
ambiguity level	0.3757***	0.3778***	0.3792***	0.4181***	0.4206***
	(0.0597)	(0.0600)	(0.0601)	(0.0723)	(0.0729)
reward	0.0435***	0.0437***	0.0439***	0.0438***	0.0440***
	(0.0023)	(0.0023)	(0.0023)	(0.0028)	(0.0028)
N	4980	4980	4980	3300	3300
No. Clusters	166	166	166	110	110

+ $p<0.10$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Standard errors are clustered on the participant

Figures

Figure 1 Economic model of risky behavior. Individual maximizes expected discounted utility, *U*, by selecting the option with the highest expected discounted utility *U.* Discount function, *d(t)*, captures that typically people prefer to receive rewards sooner. *w(a,p)* is the subjective perception of outcome probability, given the objective probability *p* and ambiguity about that probability *a* (Ellsberg, 1961; Gilboa & Schmeidler, 1989; Kahneman & Tversky, 1979). *u(x)* is the utility derived from an outcome *x*. ε is a noise term. Probability weighting and loss aversion are grayed out because they are not the focus of this paper.

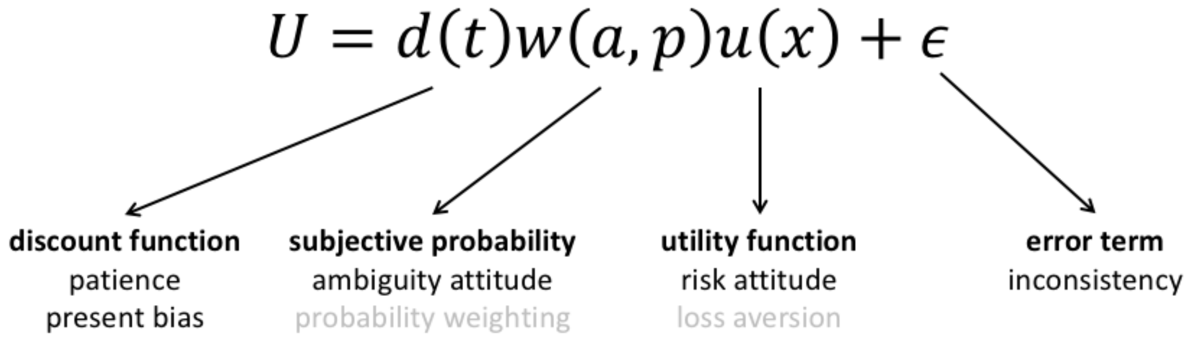


Figure 2. Distribution of age (in years) in Study 1

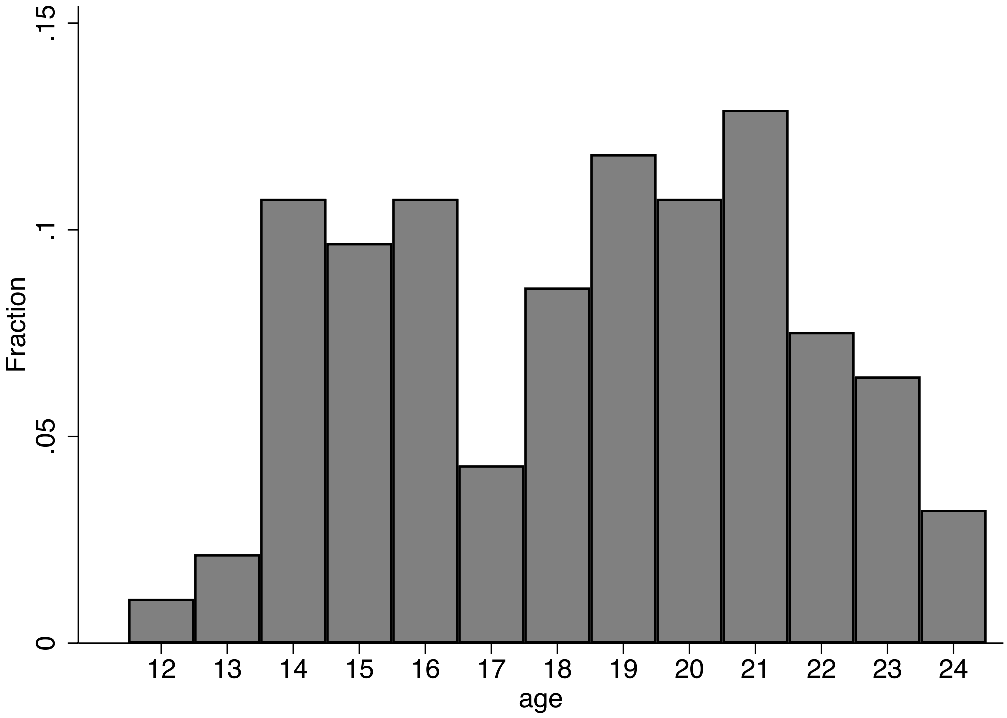


Figure 3. Observer's attention. Responses to the question "For what proportion of your choices do you think the person observing you was paying attention?"

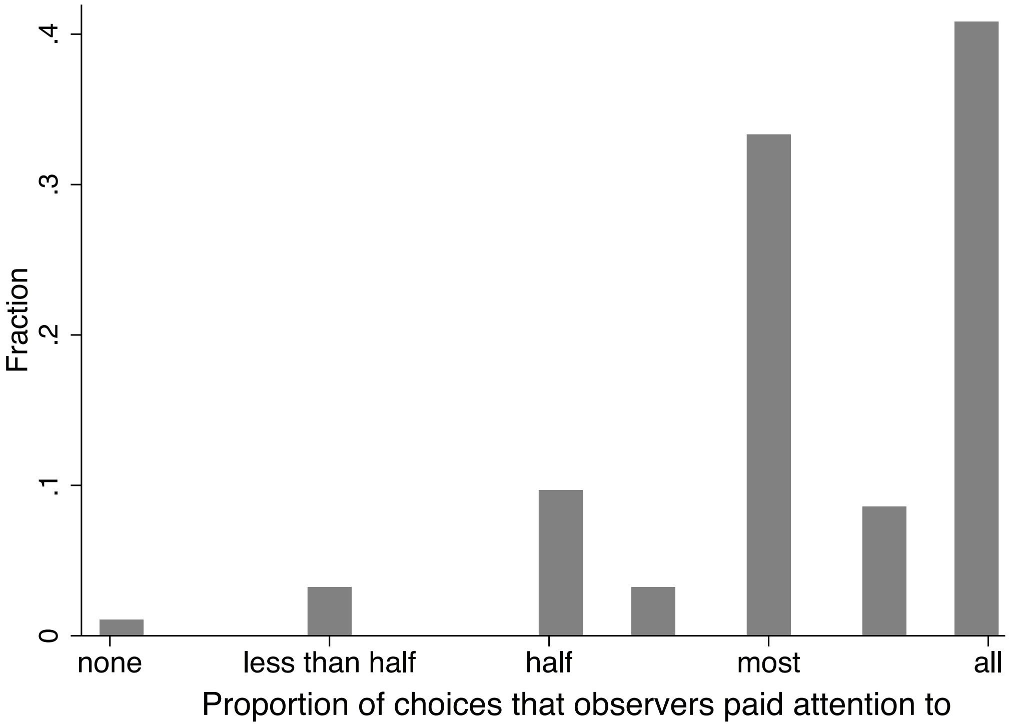


Figure 4. A: Time preference (proportion of later, indifferent, and sooner choices) and B: Risk attitudes (proportion of safe, indifferent, and risky choices) and in private and under observation.

A **B**

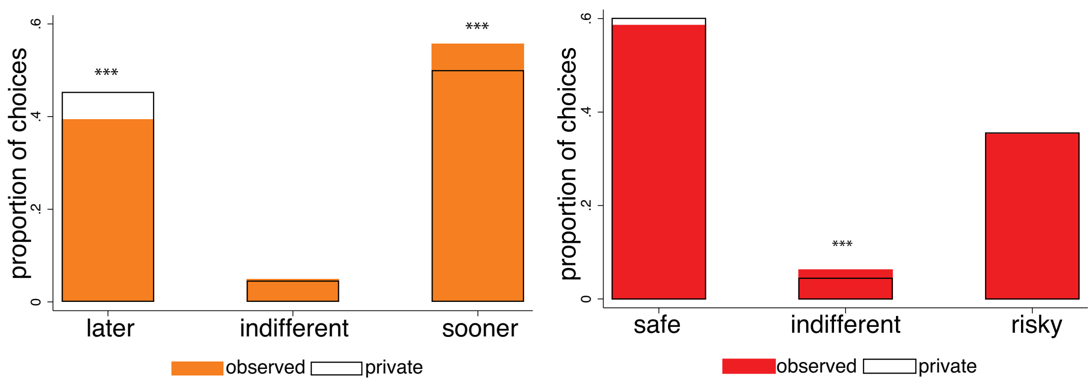


Figure 5 Temporal consistency. Impatience (proportion of sooner choices) under observation and in private is drawn separately for three front-end delays.

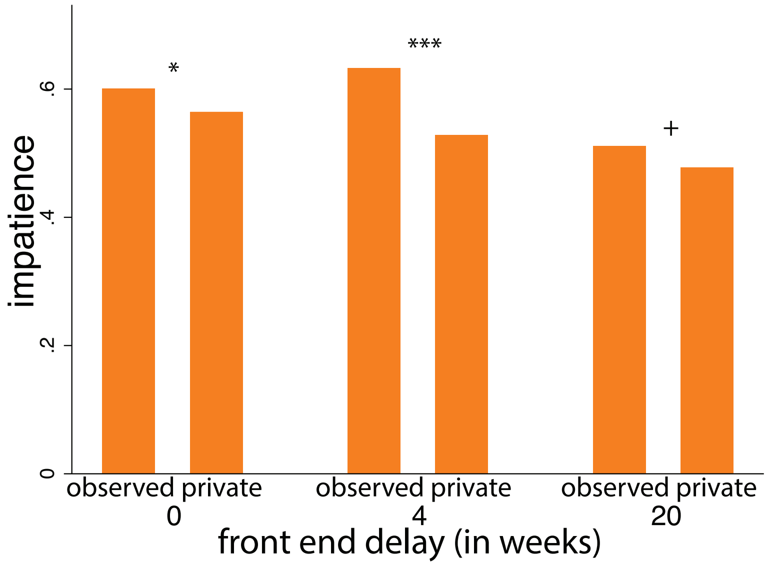


Figure 6. Age and risk attitude. Each circle (triangle) represents one participant's risk attitude plotted against her (his) age.

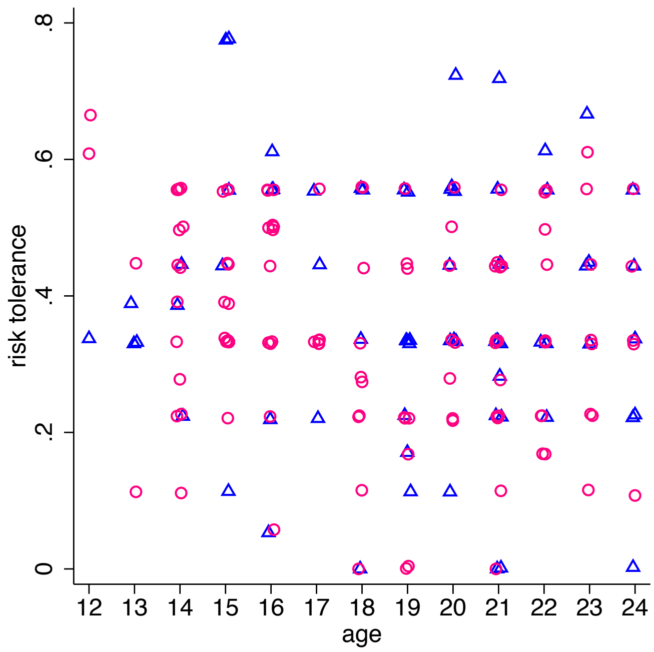


Figure 7. Observer's attention. Responses to the question "For what proportion of your choices do you think the person observing you was paying attention?"

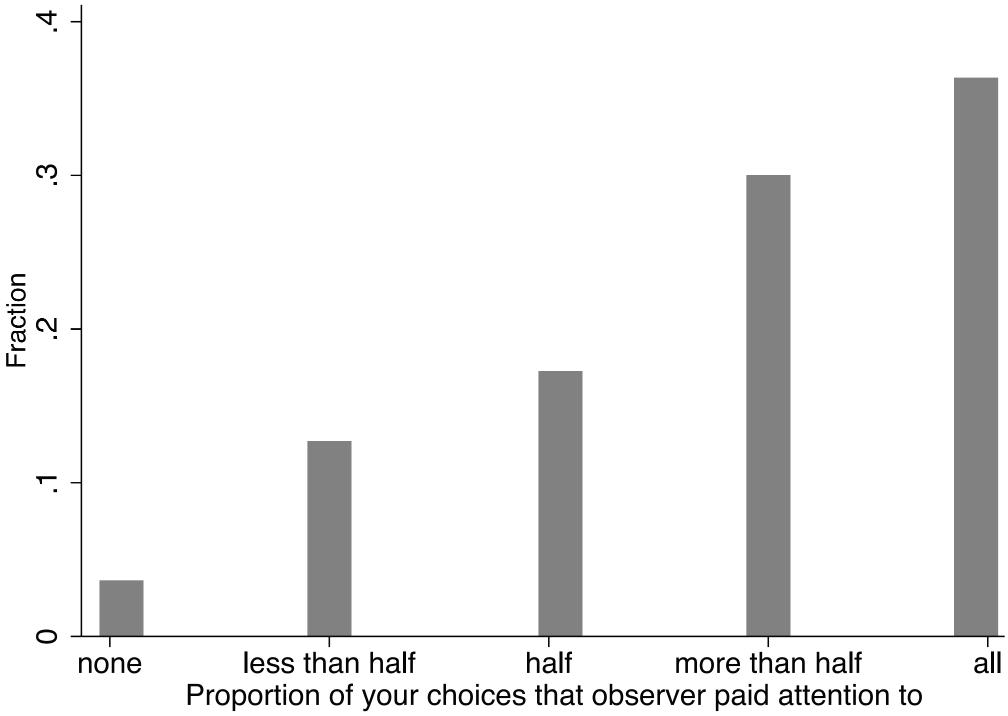
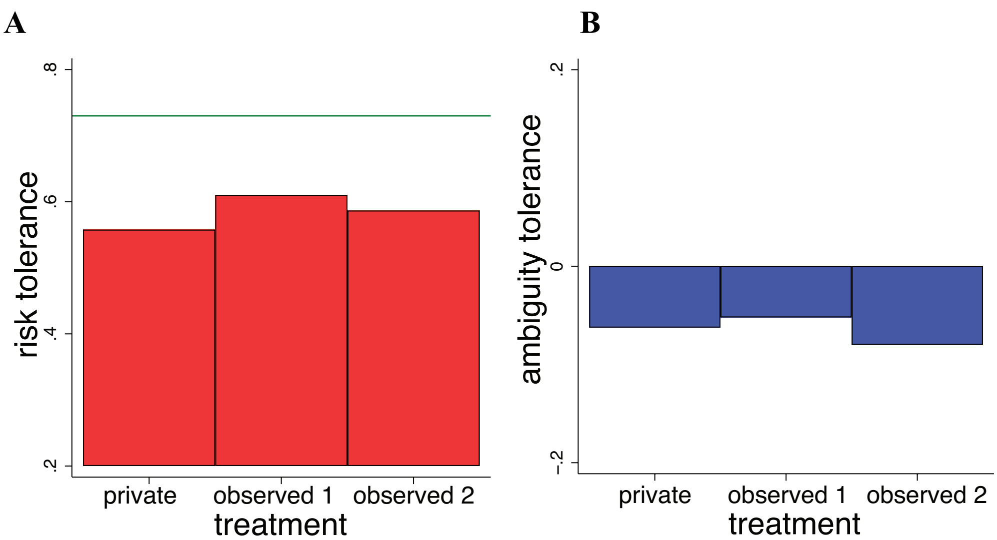


Figure 8. A: Risk tolerance (proportion of risky lottery choices) across the experimental conditions. The green line indicates the frequency with which a risk-neutral chooser would pick lotteries. **B: Ambiguity attitude across the experimental conditions.** 0 indicates ambiguity neutrality, negative (positive) values correspond to ambiguity aversion (seeking).



Supplement

Figure S1 Seating map of the experimental room. Each cell represents one computer station separated by high partitions on the sides and the front. X indicates where participants were allowed to sit in the: A) private and B) observed conditions.

A. Private condition

x		x		aisle	x		x	
x		x			x		x	
x		x			x		x	
x		x			x		x	

B. Observed condition (example)

xx				aisle	xx			
		xx			xx			
xx							xx	
xx							xx	

Figure S2 The sequence of the experiment.

Session Structure				
	Order 1		Order 2	
Stage	Choice-Maker	Observer	Choice-Maker	Observer
1	Instructions			
2	Observed	Observer	Private	Private
3	Private	Private	Observed	Observer
4	Test			
5	Questionnaire			
6	Payment			

Figure S3 A: Patience, B: present-bias, C: inconsistency and D: indifference by age and gender. Patience is calculated as the proportion of sooner choices when both options are in the future.

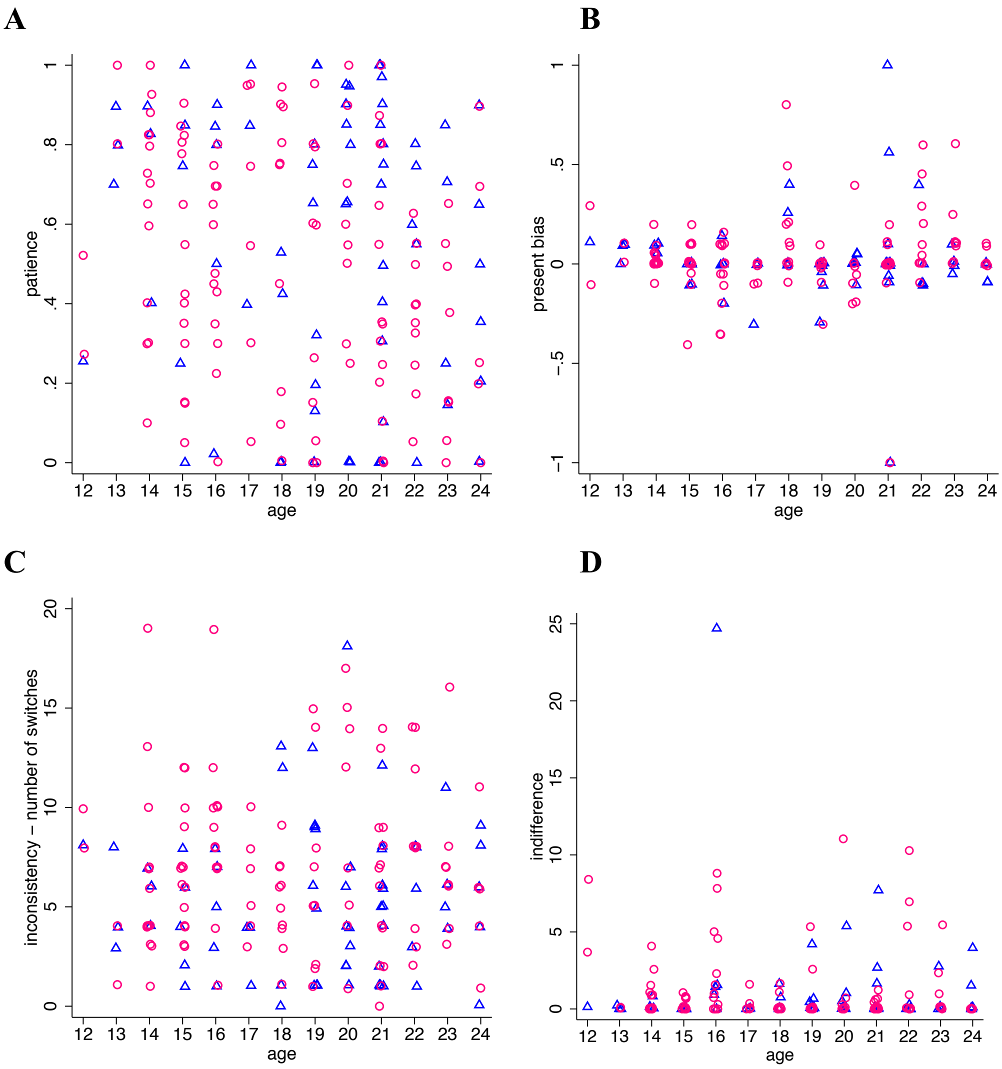
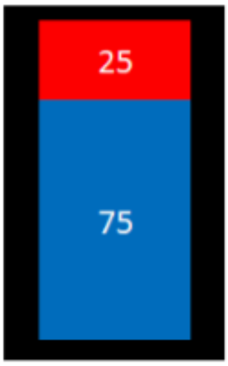


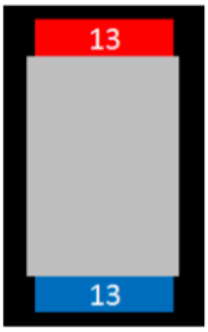
Figure S4 Example of a risky choice list



There are 25 red and 75 blue chips in this bag. Which option do you prefer?

Decision number		Option 1			Option 2
1		Red pays you $5 Blue pays you $5	or		Red pays you $5 Blue pays you $0
2		Red pays you $5 Blue pays you $5	or		Red pays you $8 Blue pays you $0
3		Red pays you $5 Blue pays you $5	or		Red pays you $11 Blue pays you $0
4		Red pays you $5 Blue pays you $5	or		Red pays you $15 Blue pays you $0
5		Red pays you $5 Blue pays you $5	or		Red pays you $19 Blue pays you $0
6		Red pays you $5 Blue pays you $5	or		Red pays you $23 Blue pays you $0
7		Red pays you $5 Blue pays you $5	or		Red pays you $29 Blue pays you $0
8		Red pays you $5 Blue pays you $5	or		Red pays you $33 Blue pays you $0
9		Red pays you $5 Blue pays you $5	or		Red pays you $37 Blue pays you $0
10		Red pays you $5 Blue pays you $5	or		Red pays you $41 Blue pays you $0

Figure S5 Example of an ambiguous choice list



There are 100 chips in this bag. At least 13 are red and at least 13 are blue. The remaining 74 chips hidden behind the grey bar are of some unknown combination of red and blue. So you don't know whether there is more of red or more of blue colour in this bag. In the following options you can choose which colour is the one that wins. Then if you draw your colour from the bag you win the specified amount of money, if you pick the other colour you get $0.

I choose the winning colour to be: RED / BLUE (circle which one is your colour of choice)

Decision number		Option 1			Option 2
31		Red pays you $5 Blue pays you $5	or		Your colour pays you $5 Other colour pays you $0
32		Red pays you $5 Blue pays you $5	or		Your colour pays you $8 Other colour pays you $0
33		Red pays you $5 Blue pays you $5	or		Your colour pays you $11 Other colour pays you $0
34		Red pays you $5 Blue pays you $5	or		Your colour pays you $15 Other colour pays you $0
35		Red pays you $5 Blue pays you $5	or		Your colour pays you $19 Other colour pays you $0
36		Red pays you $5 Blue pays you $5	or		Your colour pays you $23 Other colour pays you $0
37		Red pays you $5 Blue pays you $5	or		Your colour pays you $29 Other colour pays you $0
38		Red pays you $5 Blue pays you $5	or		Your colour pays you $33 Other colour pays you $0
39		Red pays you $5 Blue pays you $5	or		Your colour pays you $37 Other colour pays you $0
40		Red pays you $5 Blue pays you $5	or		Red pays you $41 Other colour pays you $0