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Pupil to pupil: The effect of a partner's pupil size on (dis)honest behavior

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ABSTRACT

Being observed by others fosters honest behavior. In this study, we examine a very subtle eye signal that may affect participants' tendency to behave honestly: observed pupil size. For this, we use an experimental task that is known to evoke dishonest behavior. Specifically, participants made private predictions for a coin toss and earned a bonus by reporting correct predictions. Before reporting the (in)correctness of their predictions, participants viewed videos of partners with dilating or constricting pupils. As dilating pupils are generally perceived positively, we expected that dishonesty would be reduced when participants look into the eyes of a partner with dilating pupils, especially when their own pupil size mimics the observed pupil size. In line with this prediction, Experiments 1 and 2 showed that, when earning a bonus meant harming the interaction partner, dishonesty occurred less frequently when the partner's pupils dilated rather than constricted. That is, when the interests of the self and the other conflict, participants use the pupil of the partner as a social cue to inform their behavior. However, pupil mimicry was not observed. In Experiment 3, we examined pupil mimicry and dishonesty in a context where there was no temptation to hurt the partner. Here, pupil mimicry between partners was observed, but there were no effects of the partner's pupil on dishonesty. Thus, when dishonesty harms the interaction partner, participants use pupillary cues from their partner to inform their behavior. Pupil mimicry, however, is bound to non-competitive contexts only.

Throughout their daily lives, people are often tempted to bend ethical rules and normative standards. People cheat when filing their tax report, fail to mention defects in the car they sell, buy a second class train ticket but travel first class, download illegal software and music, and deliberately overestimate the price of their stolen camera on insurance forms (Mazar, Amir, & Ariely, 2008). Combined, these transgressions create substantial societal costs - it is estimated that in the UK, the national treasury loses £ 25 billion annually due to people underpaying their taxes (Levi, 2010). Similarly, 35% of global software is estimated to the pirated, amounting to 40 billion USD per year in foregone income (Miyazaki, Rodriguez & Langenderfer, 2009). When a person prepares to engage in such dishonest behavior, this involves a trade-off between the personal gain that can be obtained, and the ethical and moral implications of dishonesty. That is, when people act dishonestly they must justify the violation of morality (Fischbacher & Föllmi-Heusi, 2013; Haidt, 2007; Shalvi, Handgraaf, & De Dreu, 2011). Accordingly, people rarely "lie all the way" and more often strike some middle ground between outright lying and strict honesty (Shalvi et al., 2011).

Apart from justifying violations of morality as an abstract concept ("thou shalt not lie"), dishonesty also requires justifying possible negative effects it has on others. Indeed, previous research has shown that the occurrence of dishonesty is shaped by social concerns. Dishonest behavior is substantially reduced when people feel they are observed rather than anonymous (Bateson, Nettle, & Roberts, 2006; Zhong, Bohns, & Gino, 2010). Even the presence of eye-like stimuli can trigger increases in pro-social behavior (Bateson et al., 2006; Haley & Fessler, 2005; Nettle et al., 2013). These findings support a functionalist approach to morality (Haidt, 2007), which suggests that being moral and honest enables people to maintain the positive social reputation required for being part of a group (Izuma, 2012). Beyond these functionalist elements, the incidence of dishonesty is also determined by more pro-social concerns, like the effect it has on other people. The incidence of dishonesty is reduced when it has negative effects on specific others, instead of, for instance, large, abstract institutions such as tax authorities or multinational companies (Gneezy, 2005). Dishonest behavior also depends on *who* is affected by it: dishonesty is less likely when it has negative effects on those seen as part of one's in-group

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(Mealy, Stephan, & Urrutia, 2007; Mifune, Hashimoto, & Yamagishi, 2010), when it harms people who are perceived as cooperative rather than competitive (Steinel & de Dreu, 2004), or individuals with whom one shares a common fate (Shalvi & De Dreu, 2014; Weisel & Shalvi, 2015). These factors that trigger concern for those who might be harmed by dishonesty need not be observed directly, but can also be inferred from very subtle social cues (Kret, 2015).

One such subtle social cue that can influence (dis)honesty is an interaction partner's pupil size. The eyes are an important source of social information. Both infants and adults use information from their partner's eyes to identify social and emotional signals, and follow gaze (Farroni, Csibra, Simion, & Johnson, 2002). The social and communicative functions of the human eyes are supported by their unique morphology. The contrast between the exposed sclera (eye-white) and the darker iris is a feature unique to human eyes (Kobayashi & Kohshima, 1997), which draws attention to the middle of the eye, to the pupil and to changes in its size (Kret, Tomonaga, & Matsuzawa, 2014). The pupil dilates in response to changes in ambient light, but also reflects on-going cognitive effort, interest, surprise, or uncertainty, as well as other emotions (Bradshaw, 1967; Hess & Polt, 1960; Hess, 1975; Lavín, San Martín, & Jubal, 2013). Moreover, pupil size is autonomic, that is, it cannot be controlled (Prochazkova & Kret, 2017). As such changes in pupil size provide an honest reflection of the person's inner state and thus may be a particularly relevant source of information for observers when making social decisions (Kret et al., 2014; Kret & De Dreu, 2017; Kret, Fischer, & de Dreu, 2015). In the current study, we are interested in how pupil size is *interpreted* by those who observe it.

A number of studies have examined how pupil dilation is interpreted, showing that those with large pupils are generally perceived positively by their interaction partners (Kret, 2017). They are judged to be attractive, sociable, and trustworthy, and those with small or constricting pupils cold, distant and untrustworthy (Amemiya & Ohtomo, 2012; Harrison, Singer, Rothstein, Dolan, & Critchley, 2006; Hess, 1975; Kret et al., 2015; Tombs & Silverman, 2004; Weibel, Stricker, Wissmath, & Mast, 2010). In a line of studies using the Trust Game, Kret et al. (2015) showed that people are more trusting of partners with dilating pupils than those with constricting pupils. That is, people use the pupil dilation of a partner as a source of social information, to inform their behavior towards that partner. In the trust game participants rely on the partner to return a proportion of the money they have invested. That is, their concern for social cues from their interaction partner may stem ultimately from self-interested concern for their own pay-offs. Will this person exploit me or can I trust them? In the current study, participants' outcomes do not depend on the behavior of the interaction partner, and we are interested in whether in such a case their behavior will be affected by pupillary cues from the interaction partner. Specifically, we examine whether pupil cues from a partner reduce participants' tendencies to engage in dishonest behavior.

There is some evidence that the mechanism behind the effects of pupil dilation on behavior is the mimicry of pupil sizes between interaction partners (Kang & Wheatley, 2017; Kret et al., 2015). Generally, interpersonal mimicry is known to increase affiliation and liking (Hove & Risen, 2009; Lakin, Jefferis, Cheng, & Chartrand, 2003), and reduce prejudice (Inzlicht, Gutsell, & Legault, 2012). In an experiment where participants played trust-games with different partners, it was observed that participants were more likely to base their trust on changes in the pupil size of the partner when they mimicked the pupil size of that partner (Kret et al., 2015; Kret & De Dreu, 2017). Thus, when an interpersonal cue like pupil dilation is mimicked, this has positive consequences and fosters trust and shared consciousness between partners (Kang & Wheatley, 2017). However, findings from the literature on both facial and pupil mimicry have shown that mimicry occurs preferentially between people from the same group, and that mimicry is less common, and may even be reversed when interacting with out-group members (e.g. Hess & Fischer, 2013; Kret et al., 2015; Kret & de Dreu, 2017). Likewise, competition has been shown to reduce affiliative tendencies and mimicry (Chartrand & Bargh, 1999; Lakin & Chartrand, 2003). In other words, pupil mimicry is modulated by the relationship between self and other: it occurs mostly in "benevolent" interpersonal contexts. Crucially for the current study, in contexts where one is tempted to harm the interaction partner, affiliative behaviors like mimicry are undesirable (Bourgeois & Hess, 2008). These findings suggest that perhaps in competitive contexts like dishonesty, where the participant is tempted to exploit an interaction partner, pupil mimicry may not occur. Here we assess whether this is the case, and whether observed pupil dilation may affect behavior through other routes.

In the current set of studies, then, we examine whether i) interacting with a partner with dilating rather than constricting pupils reduces dishonest behavior, and ii) whether this effect is mediated by pupil mimicry. Across three independent studies, we predict that dishonest behavior is reduced when the pupils of the interaction partner dilate. Moreover, we examine whether this effect can be explained through the mimicry of pupil sizes: we predict that when dilating pupils of the interaction partner are mimicked this leads to more positive perceptions of the interaction partner, which facilitates a decrease in dishonesty. To evaluate these hypotheses, participants were asked to predict the outcomes of a series of private coin tosses. Participants could win money through dishonesty, by overstating the number of correct predictions they made (Greene & Paxton, 2009; Shalvi et al., 2011). Before reporting the correctness of their prediction, participants saw a short video of an interaction partner with either dilating or constricting pupils (Bateson et al., 2006; van der Schalk, Hawk, Fischer, & Doosje, 2011). During the task, participants' own pupil size was recorded. In this way, we examine whether the pupil size of the partner affects the tendency to win money by dishonesty, and the role played by pupil mimicry.

1. Experiment 1

The hypotheses for Experiment 1 are as follows. First, we predict that participants will be less dishonest when interacting with a partner with dilating pupils, compared to a partner with constricting pupils. With regards to pupil mimicry, we predict that the participant's pupil size will mimic the pupil size of their partners, and that this will mediate the effect of partner's pupil size on dishonesty. We also include a direct gaze and an averted gaze condition. Direct gaze facilitates eye-contact (Emery, 2000), and provides the optimal situation to observe other features of the interaction partner's eyes. Thus, direct gaze might strengthen the effects of observed pupil dilation on dishonesty.

1.1. Method

We report all measures, manipulations, and exclusions in these studies, either in this section or the supplementary materials.

1.1.1. Participants

Forty-two participants (10 males, 23.8%) were recruited from amongst University of Amsterdam students. Exclusion criteria were trauma or surgery to the eyes, neurological or psychiatric conditions, and use of substances that may affect the pupil response, such as medication, drugs and coffee, less than 3 h before the experiment. The mean age was 21.4 years (min = 18 years old, max = 27 years old). Participants had (corrected to) normal vision. The experimental procedures were in accordance with the Helsinki Declaration and approved by the ethical board of the University of Amsterdam.

For this first Experiment, we based our expectations regarding effect size on those reported in Kret et al. (2015), which showed small effect sizes for pupil mimicry. Power analyses indicated that for a repeated measures within-participants design in which participants complete 72 trials each, a minimum of 40 participants was required to detect small effects at a power of $1 - \beta > 0.8$, and a p-threshold of $p = 0.05$. Once

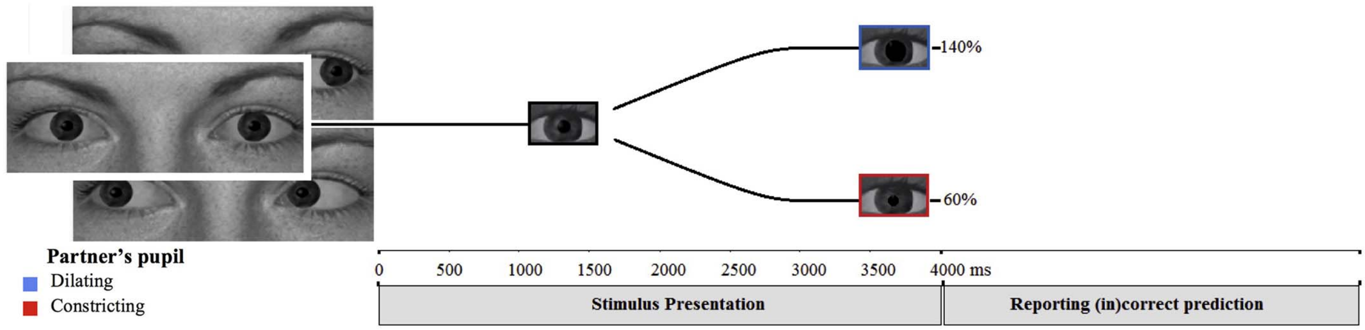

Fig. 1. The interaction partner.

this minimum number was reached, a stopping rule was applied to determine the end of data collection: in addition to the minimum number of participants required we aimed to collect an additional 5 participants to provide a power safety margin. The final sample included 42 participants. This meant that for continuous outcome measures this sample can reliably detect effect sizes of $\eta_p^2 \approx 0.006$. For binary outcome measures, this sample can detect changes in an odd's ratio of OR ≈ 0.09 (Faul, Erdfelder, Lang, & Buchner, 2007).[1]

1.1.2. Experimental design

The experiment consisted of a randomized 2 × 2 within-subjects design, where the factors were the pupil size of the interaction partner (dilating/constricting Partner Pupil) and the gaze direction of the interaction partner (averted/direct Partner Gaze). As outcome variables, we measured reports of (in)correct predictions in the coin-toss task, and participant's pupil size. Heart rate, and skin conductance were included as covariates.

1.1.2.1. Stimuli. The virtual partners in the coin-toss task were presented through a 4000 ms video. These videos were created following the procedure of Kret et al. (2015). Pictures of 3 men and 3 women were selected from the Amsterdam Dynamic Facial Expression Set (ADFES) (van der Schalk et al., 2011). Pictures were standardized in Adobe Photoshop, turned to grey scale and cropped to reveal only the eye region (Kret et al., 2015; also see Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995). We chose to use only the eye regions of the faces, because we wanted to ensure that participants attended to the eyes of the stimulus. If the whole face is presented, this attracts fixations to the mouth and nose region of the face (Barton, Keenan, & Bass, 2001; Davies, Ellis, & Shepherd, 1977), which reduces the time spent attending to the eyes. Additionally, we wished to limit participants' eye movements between different regions of the stimulus (nose, mouth, eyes), as eye movements can influence pupil size. Therefore, it is recommended to keep the stimulus as small as possible (e.g. Holmqvist et al., 2011). This research builds on previous research that used only the eye region of a face, often for these same reasons (Amemiya & Ohtomo, 2012; Demos, Kelley, Ryan, Davis, & Whalen, 2008; Kret et al., 2014, 2015; Kret & de Dreu, 2017). In other words, using only the eye region reduces ecological validity, but gives more experimental control.

After cropping each stimulus the eye-white, iris and pupil were erased. Next, the average luminance and contrast were calculated per picture, and each picture was adjusted to the mean. The eyes of all partners were then filled with the exact same eye-template, consisting of eye-white, iris and pupil. The eye-template was based on an iris pair with an intermediate brightness, and an artificial pupil was added in ADOBE After Effects. The eye-template was in grey scale so that eye color or contrast did not play a role. The position of the iris and pupil was either in the middle of the eye (direct partner gaze), shifted to the left, or to the right (averted partner gaze). To emphasize the convex shape of the eye and increase naturalness, the eye-white around the iris was made brighter than the eye white at the outer edges of the eye.

The videos showed the partner's eye-region at life-size. Crucially, the pupil size shown by the partner in the videos was manipulated, so that after static presentation for 1500 ms, the partner's pupil dilated or constricted within the normal physiological range of 3–7 mm during another 1500 ms (dilating: from 5 to 7 mm or constricting: from 5 to 3 mm). In the final 1000 ms of stimulus presentation, the pupils were static. To increase ecological validity, a slightly trembling corneal reflection was added. Although the pupil dilation or constriction was linear, the edges were rounded off with an exponential function (natural formula implemented in ADOBE After Effects) to smoothen the change. Kret et al. (2014) observed that, amongst their participants, the peak in pupil mimicry occurred after 3 s. In the current study, therefore, we ensured that the maximum or minimum of partners' pupil-change was achieved after 3000 ms, after which the pupils remained static for 1000 ms. Each video thus lasted for a total of 4000 ms, a duration consistent with the facial mimicry literature (Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001). The stimulus set consisted of 6 different actors, for each of whom there were 4 videos, representing the actor with dilating pupils and averted gaze, dilating pupils and direct gaze, constricting pupils and averted gaze and constricting pupils and direct gaze.[2] Thus, there were 24 unique videos. For a graphical representation of the breakdown of each video, see Fig. 1.

1.1.3. Outcome variables

1.1.3.1. Coin-toss task. In the coin-toss task (Greene & Paxton, 2009) participants were asked to predict the outcome of a virtual coin toss. In each trial participants played with a different partner, represented by their eye-region. If the outcome of the toss was predicted correctly, the participant earned €0.10. If the prediction was incorrect, their partner earned €0.10. The reports of (in)correct predictions served as the dishonesty measure: dishonest behavior involved over-reporting the number of correct guesses that increase one's own pay-off and reduce the interaction partner's pay-off. In other words, reporting that an incorrect prediction was actually correct helps people to dishonestly earn an extra €0.10, thereby increasing their bonus. Importantly, however, this dishonest behavior also harms the interests of the interaction partner, who would have otherwise received the €0.10. That is, the pay-off structure of this game is competitive—the more one earns for oneself, the more money is detracted from the interaction partner's earnings.

1.1.3.2. Physiological measures. Participants' pupil size was continuously sampled every 16 ms with Facelab equipment (screen-

[1] As there is no established method for conducting power analysis for multilevel designs the power analyses presented here do not take account of the multilevel structure of the data, and as such should be interpreted as *indicators* of power.

[2] Note that no further distinction is made between averted gaze direction oriented to the left (6 videos) and averted gaze direction oriented to the right (6 videos).

type ViewSonic VX2268WM, 1680 × 1050 pixels, 120 Hz). This signal was down-sampled to 100 ms timeslots. We removed trial outliers (if the pupil size between two subsequent time-samples changed more than twice the standard deviation from the mean change) and interpolated gaps smaller than 250 ms. We smoothed the data with a 10th order low-pass Butterworth filter. The average pupil size 500 ms prior to the start of changes in a partner's pupils (computed per subject, eye and trial) served as baseline (i.e., 1000–1500 ms after stimulus onset) and was subtracted from each sample during the remaining of stimulus presentation (1500–4000 ms). Heart rate (HR) was measured with three 3 M Red Dot disposable ECG electrodes placed around the heart and down-sampled to 500 ms time points. Skin conductance data was collected via a pair of curved Ag/AgCl electrodes (dimensions 20 × 16 mm) placed on the medial phalanges of the ring and middle finger of the non-dominant hand, and down-sampled to 100 ms time points.

1.1.4. Experimental procedure

Upon arrival at the lab, participants filled out a screening form and provided informed consent. The participants were seated at a distance of 75 cm from the computer screen. At this distance, eye-tracking products are most optimally designed, and pupil-mimicry is trackable (Harrison et al., 2006; Harrison, Gray, & Critchley, 2009; Hess, 1975; Kret et al., 2014, 2015). Such distance reflects a “personal” space that includes close relationships and informal contact, but typically excludes formal business-type interactions (Hall, 1966; Lloyd, 2009).

Participants began the experiment by reading instructions for the coin-toss task (Greene & Paxton, 2009). It was explained that participants would play with different interaction partners, represented by their eye region, and that they could win a bonus on top of their €3.50 participation fee or course credits. In each trial, the participant earned €0.10 if the outcome of the toss was predicted correctly. If the prediction was incorrect, their partner earned €0.10. It was stressed that the prediction was private. Following the task instructions, the physiological measures were set up (see below) a nine-point calibration of the eye-tracking system was performed. Once the calibration was complete, the first trial was presented. Each trial consisted of five stages. First, participants saw an instruction screen which asked them to make a mental prediction of a coin toss (≥ 2500 ms). Subsequently, a fixation cross was presented at the center of the screen (1000 ms). Participants then saw the coin toss (4000 ms) followed by a second fixation cross (1000 ms). The second fixation cross was followed by an image of the eye-region of their virtual partner (4000 ms) after which participants read the instruction to report whether they had predicted the outcome correctly or not (≥ 2500 ms). To minimize pupil constriction commonly associated with new information being presented on the screen, Fourier-scrambled images of each unique partner served as a background on each trial (Kret et al., 2015; Kret, Pichon, Grèzes, & de Gelder, 2011). Participants completed 72 trials in a randomized order, presented with Presentation software (Neurobehavioral Systems, San Francisco, CA, USA). The experiment took 34 min on average. For a schematic representation of a trial, see Fig. 2. After the experiment, participants were given a funneled debriefing. Participants filled out several exit questions to check whether they had any suspicions about the purpose of the experiment (see supplementary materials). Bonuses for the participants were paid out according to the number of correct predictions they reported making.

1.1.5. Statistical analysis

The statistical models for dishonesty held a two-level structure. The data structure reflected trials (level 1), nested in participants (level 2). When modeling pupil mimicry there were two additional nesting factors: Time at which the pupil size was sampled, and left and right eye. Thus, the nesting structure of the pupil mimicry models were defined by the repeated measures, i.e., time (level 1), nested in trials (level 2), nested in eyes (level 3), nested in participants (level 4). The level Time

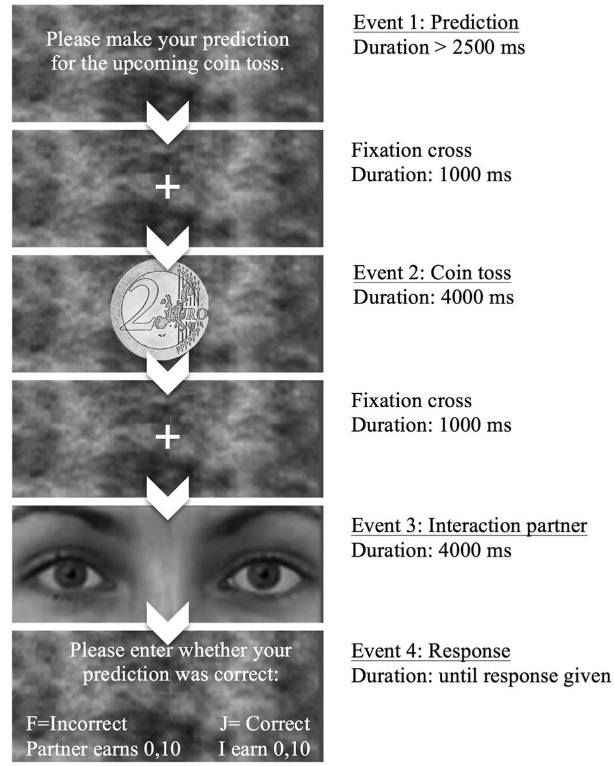

Fig. 2. Trial outline.

was included as a repeated factor with a First-Order Autoregressive (AR1) covariance structure to control for auto-correlation. To arrive at the final statistical models described, non-significant factors were dropped one by one. In some cases, the final models still include factors with a trend towards significance. In those cases, removing them resulted in significantly worse model fit. These trends are not described in the text but can be found in the tables where the full and final models are presented. For the simple comparisons, a Bonferroni correction was applied.

1.1.5.1. Dishonesty. As the dishonesty measure is dichotomous (right prediction = 1/wrong prediction = 0) it was analyzed with a generalized mixed model where a binomial distribution was selected. The fixed effects in this model were: Participant's pupil, partner's pupil, partner's gaze, and their interactions, and heart rate as a covariate.

1.1.5.2. Pupil mimicry. Data was analyzed over the final 2.5 s of stimulus presentation, i.e., from the point when the pupil size of the partner began to change to the offset of the stimulus. Our statistical model included the fixed factors partner's pupil, partner's gaze, and heart rate as a covariate. In addition, the pupil mimicry model included linear, quadratic and cubic terms to model the development of the participants' pupil size over time.

1.1.6. Preliminary analysis

Preliminary analysis showed that heart rate, but not skin conductance, predicted pupil size of the participant, so that a slower heart rate (bradycardia) was associated with a greater pupil size, $\beta = -.0011$, $F(1,\ 62{,}125) = 25.17$, $p < 0.001$ (Bradley, Miccoli, Escrig, & Lang, 2008). Therefore, heart rate was included as a covariate in the analyses described below. Exploratory analyses also revealed a random overall intercept across models, and therefore all models described include a random intercept. The video stimuli showed 6 different interaction partners across 72 trials, meaning that each interaction partner was shown 12 times (but pupils and gaze differed). We checked whether effects differed depending on whether the participant interacted with a "new" partner, or with one they have already seen on a previous trial. This was not the case: first versus later iterations of a certain partner did not produce differences in dishonest behavior, $F < 1, p = 0.598$, pupil dilation of the participant, $F < 1, p = 0.402$, or mimicry between the participant and the partner, $F < 1, p = 0.515$. All results are reported in the full and final statistical models. The exit questions showed that belief in the cover story was around the midpoint of the scale (see supplementary materials), therefore we checked whether the effects reported below depend on the extent to which participants believed the cover story. This was not the case, $Fs < 1.31$, $ps > 0.265$.

1.2. Results

1.2.1. Dishonesty

On average, participants indicated to have predicted the outcome of the coin toss correctly on 56.3% of the trials. This systematic deviation from chance indicates that participants were dishonest to increase their own pay-off, $t(2808)$[3] = 5.24, $p < 0.001$, odds ratio = 1.28. Results further show that the amount of dishonesty depended on the Partner's pupil size, $F(1, 2805) = 7.12$, $p = 0.008$, odds ratio = 0.90. In line with our expectations, participants lied less when their partner had dilating rather than constricting pupils ($M_{dilating} = 53.6\%$ reported correct, $M_{constricting} = 58.6\%$ reported correct). In addition, there was a main effect of Partner Gaze, $F(1, 2805) = 5.80$, $p = 0.016$, odds ratio = 0.88, so that participants lied less when the partner's gaze was directed at the participant compared to averted from the participant ($M_{direct} = 53.8\%$ reported correct, $M_{averted} = 58.3\%$ reported correct). As can be seen from Table 1, significant dishonesty occurred in all conditions, *except* in the condition where the pupils of the partner were dilating and gaze was direct. This effect is shown graphically in Fig. 3. In sum, a partner's direct gaze and dilated pupils reduced lying. These effects were independent of participants own pupil size. The full and final models predicting dishonesty are shown in Table 2.

1.2.2. Participant's pupil size

In contrast to what we predicted, there was no effect of the partner's pupil size on the participant's own pupil size, $F < 1$, $p = 0.575$. However, heart rate was a significant predictor of pupil size, $F(1, 106{,}237) = 7.52$, $p = 0.006$, $\eta_p^2 = 0.062$, so that slower heart rate was associated with larger pupils. Additionally, there were significant effects of the linear, $F(1, 106{,}237) = 7.27$, $p = 0.007$, $\eta_p^2 = 0.059$, and quadratic terms, $F(1{,}106{,}237) = 4.91$, $p = 0.027$, $\eta_p^2 = 0.043$, showing that participants' pupils dilated linearly at the start of the trial, and then leveled off towards the end of the trial. However, the effect sizes of these latter two terms are small given the power of this study. Finally, there was an interaction between the partner's gaze direction and the cubic trend, $F(1, 106{,}237) = 4.61$, $p = 0.032$, showing that pupil dilation followed a cubic pattern only when the partner's gaze was averted from the participant, $F(1, 106{,}237) = 4.12$, $p = 0.042$, $\eta_p^2 = 0.0004$. Again, given the small size of this effect, it should be interpreted with caution. The full and final models are presented in Table 3.

1.3. Discussion

Experiment 1 shows that participants' baseline behavior is a certain degree of dishonesty. Nevertheless, even though participants could have decided to be dishonest on all trials and earn a large bonus, the highest reported success rate was 74% correct. That is, participants behaved dishonestly, but only moderately so. This is in line with research showing that people prefer to avoid major lies in favor of more plausible 'intermediate' lies (Shalvi et al., 2011).

This Experiment further shows that this "general" dishonesty was reduced when interacting with a partner with dilating pupils and direct gaze. The effects of the partner's gaze direction and partner's pupil size were additive in nature, rather than the result of an interaction, as we had originally expected. In other words, rather than being amplified by direct gaze, the effect of pupil dilation was independent of the effect of gaze direction, suggesting that these different eye-cues should be considered separately. Nevertheless, the effect of gaze direction is in line with previous research, which has shown that being observed (direct gaze) reduces dishonest tendencies (Bateson et al., 2006). Moreover, the effect of pupil dilation is in line with our hypotheses: dishonesty was less frequent when the partner's pupils dilated.

In this study, dishonesty required people to make a trade-off between their own interests and those of the interaction partner. Can they justify harming the interaction partner in order to increase their own pay-off? Results suggest that participants use a partner's pupil dilation as input for this trade-off: when they see a partner with dilating pupils, they become reluctant to be dishonest towards the partner. The reason why this effect occurs, however, could not be tested directly in this Experiment. We suggest that it is pro-social concern for the interests of the interaction partner with dilating pupils that dissuades participants from dishonest behavior. That is, when a partner has dilating pupils, participants are more concerned for the well-being of such a partner. However, this Experiment could not provide a direct test of whether concern for the partner in fact played a role in these findings. For instance, participants may not care at all about the interests of the partner, but rather be purely motivated by self-interest, and only be affected by the partner's pupil because it signals attention (Hess & Polt, 1960), and therefore possible detection of their dishonesty (Haley & Fessler, 2005; van der Schalk et al., 2011). Thus, the reason that dilating pupils reduce dishonesty may be that participants fear detection (and possible sanctioning) when their dishonest behavior is observed by an attentive partner. Indeed, the effects of the partner's pupil size were not evident in the averted gaze conditions, suggesting that attention and interest on the part of the interaction partner might play a role in these findings. In sum, it is worthwhile to further examine

Table 1
Dishonesty per condition.

Partner's pupil	Partner's gaze	Reported correct (%)	df	*t*-value	*p*-value	Odds ratio
Constricting	Averted	60.2%	702	5.51	0.000	1.51
Constricting	Direct	56.9%	702	3.69	0.001	1.29
Dilating	Averted	56.4%	702	3.42	0.001	1.24
Dilating	Direct	50.7%	702	0.53	0.706	1.02

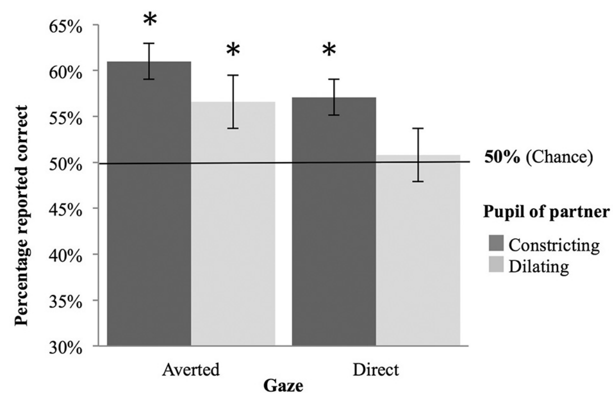

Fig. 3. Dishonesty per condition. The error bars represent 1 standard error.

[3] This test evaluates whether the intercept of the model differs from 0. As the model includes no predictors, no *F*-test was conducted and thus the t-statistic is reported.

Table 2
Fixed and random effects in a generalized linear mixed model of dishonesty.

Fixed effect	Full model				Final model			
	F-value	df	*SE*	*p*-value	*F*-value	df	*SE*	*p*-value
Intercept	2.18	2364	0.05	0.026	6.42	2805	0.05	0.002
Heart rate	2.19	2364	0.01	0.139				
Partner's pupil	5.02	2364	0.04	0.025	7.12	2805	0.04	0.008
Partner's gaze	6.37	2364	0.04	0.012	5.80	2805	0.04	0.016
Participant's pupil	1.36	109,641	0.22	0.244				
Partner's pupil * partner's gaze	0.09	2364	0.04	0.766				
Participant's pupil * partner's pupil	0.42	2364	0.22	0.516				
Partner's gaze * participant's pupil	3.64	2364	0.22	0.057				
Participant's pupil * partner's gaze * partner's pupil	0.01	2364	0.22	0.939				

Random effect		Full model						Final model					
		Estimate	*SE*	Wald's Z	*p*-value	CI lower	CI upper	Estimate	*SE*	Wald's Z	*p*-value	CI lower	CI upper
Intercept [subject = ID]	Variance	0.03	0.02	1.21	0.226	0.01	0.14	0.03	0.02	1.45	0.148	0.01	0.11
Actor [subject = ID]	Variance	0.01	0.04	0.26	0.797	0.00	20.9						

Note: dishonesty, i.e., the report of a correct or incorrect prediction, had a binary distribution function and was analyzed in a generalized mixed model implemented in SPSS. The final model was derived at via standard model selection.
Note: dependent variable = dishonesty, modulated by Participant Pupil, Partner Pupil, Partner Gaze and their interactions. All fixed factors are centered and treated as continuous (scale). Partner Pupil = dilating (coded 1) or constricting (coded − 1). Partner Gaze = direct (coded 1) or averted (coded − 1). S.E. = standard error of the mean estimate.

Table 3
Fixed and random effects in generalized linear mixed model of participant's pupil size.

Fixed effect	Full model				Final model			
	F-value	df	*SE*	*p*-value	*F*-value	df	*SE*	*p*-value
Intercept	2.39	106,227	0.011	0.001	4.52	106,237	0.011	0.000
Heart rate	7.49	106,227	0.000	0.006	7.52	106,237	0.000	0.006
Partner's pupil	0.31	106,227	0.003	0.575				
Partner's gaze	2.52	106,227	0.003	0.113	1.70	106,237	0.003	0.192
Linear	7.29	106,227	0.017	0.007	7.27	106,237	0.017	0.007
Quadratic	4.93	106,227	0.008	0.026	4.91	106,237	0.008	0.027
Cubic	1.68	106,227	0.006	0.195	1.67	106,237	0.006	0.196
Partner's pupil * partner's gaze	0.39	106,227	0.003	0.844				
Partner's pupil * linear	0.17	106,227	0.008	0.680				
Partner's pupil * quadratic	2.67	106,227	0.004	0.102				
Partner's pupil * cubic	1.37	106,227	0.003	0.241				
Partner's gaze * linear	0.05	106,227	0.008	0.819				
Partner's gaze * quadratic	1.29	106,227	0.004	0.255				
Partner's gaze * cubic	4.19	106,227	0.003	0.041	4.61	106,237	0.003	0.032
Partner's pupil * partner's gaze * linear	2.65	106,227	0.008	0.104				
Partner's pupil * partner's gaze * quadratic	1.54	106,227	0.004	0.215				
Partner's pupil * partner's gaze * cubic	1.43	106,227	0.003	0.232				

Random effect		Full model						Final model					
		Estimate	*SE*	Wald's Z	*p*-value	CI lower	CI upper	Estimate	*SE*	Wald's Z	*p*-value	CI lower	CI upper
Repeated measures	AR1 diag.	0.068	0.001	70.85	0.000	0.066	0.070	0.068	0.001	70.88	0.000	0.066	0.070
	AR1 rho	0.945	0.001	1186.01	0.000	0.943	0.946	0.945	0.001	1186.08	0.000	0.943	0.946
Intercept [subject = ID]	Variance	0.003	0.001	3.46	0.001	0.002	0.006	0.003	0.001	3.46	0.001	0.002	0.006
Actor [subject = ID]	Variance	0.002	0.0004	4.68	0.000	0.001	0.003	0.002	0.0004	4.68	0.000	0.001	0.003
Linear [subject = ID]	Variance	0.008	0.002	3.32	0.001	0.004	0.014	0.008	0.002	3.32	0.001	0.004	0.014
Quadratic [subject = ID]	Variance	0.002	0.001	2.97	0.003	0.001	0.003	0.002	0.001	2.98	0.003	0.001	0.003
Cubic [subject = ID]	Variance	0.001	0.0003	3.08	0.002	0.001	0.002	0.001	0.0003	3.08	0.002	0.001	0.002

Note: the final model was derived via standard model selection.
Note: dependent variable = baseline-corrected pupil size, modulated by partner pupil, heart rate, partner's gaze and polynomials (all centered and treated as continuous (scale)). Partner's gaze was coded as 1 (direct gaze) and − 1 (averted gaze). Partner's pupil was coded as 1 (dilating pupils) and − 1 (constricting pupils). S.E. = standard error of the mean estimate.

the role played by participants' concern for the interests of their partner. Experiment 2 is designed to replicate the behavioral findings of Experiment 1, and to provide more information on *why* this effect occurs.

In addition to the effect of the partner's pupil on dishonest behavior, we had also hypothesized that this effect would be mediated by pupil mimicry (Kang & Wheatley, 2017). That is, participants mimic the pupils of their partner, and when that is a dilating pupil, the contagion of this positive cue leads to reductions in dishonest behavior. However, there was no evidence for pupil mimicry in this experiment. The absence of pupil mimicry indicates that pupil dilation can operate as a social cue without the need for physiological contagion or mimicry.

When considering the reasons for the absence of pupil mimicry here, arousal is a likely candidate. Dishonesty produces arousal (DePaulo et al., 2003; Zuckerman, DePaulo, & Rosenthal, 1981), which in turn leads to pupil dilation (e.g. Dionisio, Granholm, Hillix, & Perrine, 2001). Thus, it may be the case that dishonesty is so arousing that any effect of the partner's pupil on the participant's pupil is overshadowed. In Experiment 3, we will further examine pupil mimicry in relation to dishonest behavior.

2. Experiment 2

In Experiment 1, we saw that participants use the pupil response of the partner as a factor in their decision to decide on whether to behave dishonestly. Gaining a bonus in Experiment 1 required harming the interaction partner: dishonesty benefits the self at the expense of the interaction partner. In Experiment 2 we further study how the effects of dishonesty on the partner affect its occurrence, by distinguishing 3 blocks of trials. In all of these, participants are observed by a partner with either dilating or constricting pupils. The blocks differ in who is affected by dishonesty: in the first block, like in Experiment 1, when the participant is dishonest, this increases their own outcomes, but decreases the outcomes of the interaction partner, that is, the interests of the partners conflict (Competitive benefit block). In the second block the participant can increase their own pay-off but this does not affect the partner (Self-benefitting block). In the third block dishonest behavior can benefit (or harm) the partner but not affect the participant's own outcomes (Other-benefitting block). These different blocks are designed to clarify the concerns that drive participants' dishonest behavior. If participants are motivated only by self-interest, we should see comparable effects in the Self-benefitting and Competitive benefit blocks. If participants are motivated only by a desire to hurt the interaction partner, we should see comparable effects in the Other-benefitting and Competitive benefit blocks. Instead, if the partner's pupil is used as input into the trade-off between self-interest and the interests of the partner, as we have argued above, we should see a reduction in dishonesty in response to dilating pupils only in the Competitive benefit block. That is, we expect to replicate the findings of Experiment 1 and see a reduction in dishonesty in response to dilating pupils *only in the Competitive benefit block*. As the effect of pupil dilation was independent of gaze direction, we used only stimuli with direct gaze in Experiment 2.

2.1. Method

We report all measures, manipulations, and exclusions in these studies, either in this section or the supplementary materials.

2.1.1. Participants

A total of 84 participants were recruited from amongst University of Groningen students. Age ranged from 17 to 29 years old (M = 21; SD = 2.101). Men comprised 47% of the sample. Three participants were excluded due to lack of variance in their responses. These participants responded by choosing the extreme lower end of all scales with which they were presented, suggesting they did not take the experiment seriously. Excluding these participants left 81 participants in the final sample.

Based on the effect sizes observed in Experiment 1, we aimed to collect a sample that would allow us to reliably detect small effect sizes. Power analyses indicated that for a repeated measures within-participants design in which participants complete 96 trials across three blocks, a minimum of 58 participants was required to detect small effects at a power of $1 - \beta > 0.8$, and a p-threshold of $p = 0.05$. Once this minimum number was reached, a stopping rule was applied to determine the end of data collection: in addition to the minimum number of participants required we aimed to collect an additional 30 participants to provide additional power for the exploratory measures of personality (described below). The final sample included 81 participants. This meant that for continuous outcome measures this sample can reliably detect effect sizes of $\eta_p^2 \approx 0.003$. For binary outcome measures, this sample can detect changes in odd's ratio of OR ≈ 0.06 (Faul et al., 2007).

2.1.2. Experimental design

This study has a 2 × 3 within-participants design. The first factor is the pupil response of the actor in the video: the actor's pupils either dilated or constricted over the course of the video, as in Experiment 1. The second factor reflects the different blocks; that is, the Competitive, Self-benefitting, and Other-benefitting block.

2.1.2.1. *Stimuli.* The videos used to represent the interaction partners were the same as in Experiment 1. As the factor gaze direction (averted vs. direct) was not included in this Experiment, we include only the stimulus videos that use direct gaze (N = 12).

2.1.3. Coin-toss task

Participants performed the same coin-toss task as in Experiment 1. Participants are asked to predict a coin toss, and subsequently report whether they predicted it correctly. Before they report their prediction, they see a video of an interaction partner. As correct predictions can earn them money, participants are tempted to over-report the number of correct predictions they have made. This type of dishonest behavior is reflected in percentages of correct predictions that deviate from chance (50%).

In Experiment 1, the pay-off structure of the game was competitive: participants earned €0.10 if they indicated their prediction to be correct, but if they indicated that their prediction was incorrect, the *partner* earned €0.10. That is, in Experiment 1 participants were tempted to harm their interaction partner to increase their own bonus. Here, we refer to this as the "Competitive benefit block". In addition, we also created 2 non-competitive blocks in which either the participant *or* the partner was affected by dishonesty. In the first of these, the so-called "Self-benefitting block", reporting a correct prediction meant that the participant themselves would win €0.10, but this had no financial consequences for the partner. In contrast, in the "Other-benefitting block", reporting a correct prediction meant that the partner would win €0.10, without any consequence for the participants themselves. That is, the design includes a "Competitive benefit dishonesty" block, a "Self-benefitting dishonesty" block, and a "Other-benefitting dishonesty" block. All blocks involve dishonesty, but the differences in the pay-off structure mean that only the Competitive benefit block requires a trade-off between the interests of the interaction partners. The order of the blocks was counter-balanced between participants. Each block contained 32 trials; the structure of the trials was the same as in Experiments 1. That is, participants were first asked to make a prediction for the coin toss (at least 2.5 s), then they saw the coin toss (4 s), then they saw the video of the interaction partner (4 s) and finally reported whether their prediction was correct.

2.1.4. Experimental procedure

Participants were seated behind a computer in individual cubicles. Distance from the screen was roughly 60 cm, so that the actor in the video appeared life-size. Participants provided informed consent, read instructions for the task, and completed the three blocks in randomized order. After completing the task, they completed the NEO-PI-R scale (Costa & MacCrae, 1992) to assess whether personality variables like agreeableness might impact the relationship between observed pupil response and dishonesty. They then completed a number of exit questions, including a question where they were asked to guess the hypotheses of the experiment. Finally, participants read a debriefing, were given the opportunity to ask questions, and bonuses were paid out according to the number of correct predictions participants reported.

2.1.5. Statistical analysis

The data are analyzed using the same strategy as the dishonesty measure in Experiment 1. The dishonesty measure is dichotomous (right prediction = 1/wrong prediction = 0), and therefore it was analyzed with a generalized mixed model where a binomial distribution was selected. The fixed predictors are the pay-off structure of the block (earning for the Self, earning for the Partner, or Competitive benefit), and the pupil of the partner (dilating or constricting). The model also includes a random intercept for each participant (Subject), and a random factor reflecting the different actors who appear in the videos. For the simple comparisons, a Bonferroni correction was applied.

2.1.6. Preliminary analyses

Examination of responses to the exit questions showed that none of the participants guessed the hypotheses of the experiment. Additionally, the extent to which participants believed in the cover story, did not affect the results described below, $F = 1.19$, $p = 0.274$. Finally, as in Experiment 1, the first appearance of each interaction partner did not produce differences in dishonest behavior compared to later iterations of the partner, $F < 1$, $p = 0.850$.

2.2. Results

Results showed that, overall, there was considerable dishonesty. On average, participants reported a correct prediction in 60.5% of trials. This represents a significant deviation from chance, $t(7775) = 18.88$, $p < 0.001$, $\eta_p^2 = 0.05$. The *extent* of dishonesty was affected by the pay-off structure and the pupil of the interaction partner.[4] Firstly, there was a main effect of the pay-off structure, $F(2, 7770) = 5.51$, $p = 0.004$, such that participants were more honest in the Other-benefitting block compared to the Self-benefitting block, $t(7770) = -2.98$, $p = 0.003$, odds ratio = 1.25, and the Competitive benefit block, $t(7770) = -2.74$, $p = 0.006$, odds ratio = 1.20. That is, when the participant could not win any money (but only earn money for the partner) dishonesty was less frequent. The Self-benefitting and Competitive benefit blocks did not differ in the levels of dishonesty they produced, $t < 1$, $p = 0.806$. Additionally, there was an interaction between block and the pupil of the partner, $F(2, 7770) = 4.07$, $p = 0.017$, represented in Fig. 4. Participants respond differently to the eyes of their interaction partner depending on the pay-off structure of the block. In line with our hypothesis, in the Competitive benefit block, participants were more honest to those with dilating pupils compared to those with constricting pupils, $F(1, 7770) = 4.33$, $p = 0.037$, odds ratio = 1.19, indicating that they were reluctant to harm partners with dilating pupils. In the Self-benefitting block, there was a tendency for participants to be more *dis*honest to those with dilating pupils but this difference did not reach significance, $F(1, 7770) = 3.34$, $p = 0.068$, odds ratio = 0.84. Put differently, only in the Competitive benefit block did the pupil response of the interaction partner have a significant effect on dishonesty, replicating the results of Experiment 1. The full (and final) model is presented in Table 4. An overview of the different simple comparisons can be found in Table 5a and b.

2.3. Discussion

Experiment 1 showed that dishonesty was reduced when interacting with a partner with dilating pupils. Based on these findings we argued that, when participants are tempted to engage in dishonesty that harms the interaction partner, they use cues from the interaction partner's eyes to determine whether such behavior is justifiable. Experiment 2 was designed to provide a direct test of this explanation by comparing a context in which a trade-off must be made between self-interest and the interests of the interaction partner (the Competitive benefit block, i.e., similar to the context in Experiment 1), with two blocks in which dishonesty did not require a trade-off between one's own interests and those of the interaction partner (Self-benefitting and Other-benefitting blocks).

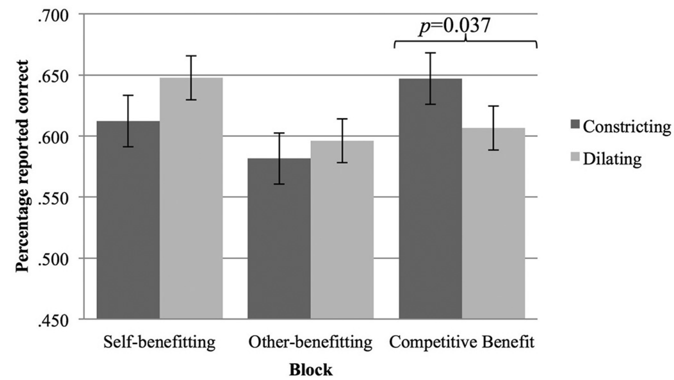

Fig. 4. Dishonesty depends on pay-off structure and pupil of the partner. Error bars represent 1 standard error.

In line with our hypothesis, results of Experiment 2 showed that the pupil response of the interaction partner affected dishonest behavior, *only* in the Competitive benefit block. Specifically, we replicated the findings of Experiment 1, showing that in the Competitive benefit block, participants are reluctant to harm those with dilating pupils compared to those with constricting pupils. In other words, in the Competitive benefit block participants' dishonesty was harmful to the interaction partner, and this reduced participants' tendencies to be dishonest *towards those with dilating pupils*. When no conflict of interest is present (the Self-benefitting and Other-benefitting blocks) these effects did not appear.

Results from this study suggest that people are more concerned about the well-being of partners with dilating pupils. Previous research provides some indication as to the reason *why* dilating pupils inspire such pro-social concerns: individuals with large, dilating pupils are perceived as more friendly, more trustworthy, more attractive, and more attentive or interested, than partners with constricting pupils (Hess, 1975; Kret et al., 2015; Tombs & Silverman, 2004; Weibel et al., 2010). Taking these findings together, we might suggest that, overall, partners with dilating pupils seem like more promising interaction partners. One alternative possibility is that dilating pupils might dissuade the participant from dishonesty because participants fear detection from partners who are attentive. However, this latter concern would be evident in both the Competitive and the Self-benefitting blocks (and to a lesser extent in the Other-benefitting block) in the current experiment. After all, in all blocks participants' dishonesty was observed by partners with dilating pupils. However, the partner's dilating pupils only produced a reduction in dishonesty in the Competitive-benefit block. In sum, it seems that the reduction in dishonesty observed in the competitive-benefit block is due to the fact that participants want to avoid harmful consequences for the partner when that partner has dilating pupils.

In addition, there are several other findings worth noting. Firstly, in the Self-benefitting block, dishonesty is marginally *higher* when the pupils of the interaction partner dilate. This could be due to the fact that partners with dilating pupils are perceived more positively (Tombs & Silverman, 2004; Weibel et al., 2010) and less likely to disapprove of the participant's dishonest behavior. Secondly, it is worth noting that, in the Other-benefitting block, participants could have deliberately *lowered* the partner's outcomes by over-reporting *in*correct predictions. However, this was not observed. Instead, participants lied to benefit their partner. This finding suggests, firstly, that in this context

[4] There was also a main effect of Extraversion on dishonesty: participants who scored higher on extraversion were likely to deceive their interaction partners, $F(1,7767) = 5.27$, $p = 0.022$. Higher order interactions involving the personality dimensions did not reach significance.

Table 4
Fixed and random effects in a generalized linear mixed model of dishonesty.

Fixed effect	Full model				Final model			
	F-value	df	*SE*	*p*-value	*F*-value	df	*SE*	*p*-value
Intercept	3.82	7770	0.09	0.002	3.82	7770	0.09	0.002
Partner's pupil	0.08	7770	0.08	0.783	0.08	7770	0.08	0.783
Block	5.51	7770	0.08	0.004	5.51	7770	0.08	0.004
Partner's pupil * block	4.07	7770	0.12	0.017	4.07	7770	0.12	0.017

Random effect		Full model						Final Model					
		Estimate	*SE*	Wald's Z	*p*-value	CI lower	CI upper	Estimate	*SE.*	Wald's Z	*p*-value	CI lower	CI upper
Intercept [subject = ID]	Variance	0.41	0.08	4.99	0.000	0.28	0.61	0.41	0.08	5.02	0.000	0.28	0.61
Actor [subject = ID]	Variance	0.02	0.02	0.66	0.508	0.00	0.29						

Note: dishonesty, i.e., the report of a correct or incorrect prediction, had a binary distribution function and was analyzed in a Generalized mixed model implemented in SPSS. The final model was derived at via standard model selection.
Note: dependent variable = dishonesty, modulated by Partner Pupil, Block and their interaction. All fixed factors are centered and treated as continuous (scale). Partner Pupil = dilating (coded 1) or constricting (coded − 1). S.E. = standard error of the mean estimate.

Table 5
a. Simple comparisons for differences between blocks. b. Simple comparisons for differences between the pupil responses. Significant *p*-values are shown in bold.

a

Pupil	Simple effect	Mdiff dishonesty (in %)	*SE*	*t*-value	*p*-value	Odds ratio
Constricting	Competitive benefit - self-benefitting	3.4	1.91	1.81	0.071	1.16
	Competitive benefit - other-benefitting	6.5	1.91	3.37	**0.001**	1.32
	Other-benefitting - self-benefitting	− 3.1	2.00	− 1.57	0.116	0.88
Dilating	Competitive benefit - self-benefitting	− 4.1	2.00	− 2.10	**0.036**	0.81
	Competitive benefit - other-benefitting	1.0	2.00	0.52	0.603	1.04
	Other-benefitting - self-benefitting	− 5.2	2.00	− 2.64	**0.008**	0.75

b

Block	Simple effect	Mdiff dishonesty (in %)	*SE*	*t*-value	*p*-value	Odds ratio
Self-benefitting	Constricting - dilating	− 3.5	1.91	− 1.83	0.068	0.84
Other-benefitting	Constricting - dilating	− 1.5	2.00	− 0.74	0.461	0.94
Competitive benefit	Constricting - dilating	4.0	1.91	2.08	**0.037**	1.19

the pro-social motivation to benefit the partner is stronger than the motivation to be honest. While it may seem surprising that participants are willing to jeopardize their own ethical standing to benefit a stranger, the idea that pro-social motivations can lead to dishonesty fits existing work on dishonest helping (Gino & Pierce, 2009; Gino & Pierce, 2010) and pro-social lies, which are motivated by the desire to make others feel good and foster amicable social relationships (DePaulo & Bell, 1996; DePaulo & Kashy, 1998). Moreover, it should be noted that in the present study, ethical transgressions were minor and participants may not have considered their partner-benefitting dishonesty as a serious infraction on ethical standards. In sum, findings from the Other-benefitting block are in line with the general pattern that participants do seem to give relatively strong consideration to the interests of the partner in these experiments.

Having demonstrated that the effects of pupil dilation vary depending on the pay-off structure of the block, future research might examine whether similar effects would be evident for a factor like gaze direction, which was not included in the current Experiment. For instance, following research showing that direct gaze can signal threat (Trawalter, Todd, Baird, & Richeson, 2008), we might expect that direct gaze is interpreted as more threatening in the Competitive block than in the Other-benefitting block, where the relationship between the partners is more benevolent.

Taken together, the results of Experiment 2 replicate the findings of Experiment 1, by showing that, when dishonest behavior benefits the self at the expense of the interaction partner, participants use cues from the partner's eyes as input for this trade-off.

3. Experiment 3

Above, we have shown that the pupil of a partner affects dishonest behavior when the participant's dishonesty harms the interests of their interaction partner. Additionally, in Experiment 1, we had hypothesized that this effect would be mediated by pupil mimicry. That is, participants mimic the pupils of their partner, and when that is a dilating pupil the contagion of this positive cue leads to reductions in dishonest behavior. However, there was no evidence for pupil mimicry in Experiment 1. In Experiment 3, we investigate whether the competitive nature of the task in Experiment 1, which was shown to be an important contributor to the behavioral effects observed, might also explain the absence of pupil mimicry. Indeed, there is evidence that competition reduces affiliative tendencies, which are known to be associated with mimicry (Chartrand & Bargh, 1999; Lakin & Chartrand, 2003). In other words, when one is tempted to harm the interests of another individual, affiliative behaviors like mimicry are undesirable (Bourgeois & Hess, 2008) and mimicry does not occur, as was observed in Experiment 1. Crucially for the current Experiment, this line of reasoning also suggests that when there is no motivation to harm a partner, pupil mimicry *does* occur.

In Experiment 3, we examine this possibility by studying dishonest behavior in a context that does not require the participant to harm their interaction partner to obtain a bonus. We use the Self-benefitting and Other-benefitting blocks from Experiment 2: Participants are presented with two different blocks in which either one or the other partner, but not both, were affected by dishonesty. We expect that the pupil response of the partner will affect the pupil of the participant, leading to pupil mimicry regardless of the type of block.

Additionally, we examine whether the Self-benefitting and Other-benefitting block produce different behavioral effects. In the Other-benefitting block, the participant's decision affects the outcomes of the partner, while in the Self-benefitting block the partner merely 'observes' the interaction. This distinction between the Self-benefitting and Other-benefitting block allows us to revisit the hypothesis from Experiment 1 that pupil mimicry mediates behavioral effects. For instance, we might see that when participants mimic the dilating pupils of a partner, they become motivated to behave pro-socially towards them (Lakin & Chartrand, 2003), leading them to lie to benefit the partner in the Other-benefitting block. Indeed, there was some evidence for this in Experiment 2, although the effect did not reach significance. Perhaps the fact that the current experiment takes mimicry into account might allow us to further clarify this pattern.

An alternative explanation for the absence of mimicry in Experiment 1 is that mimicry does not occur in any dishonesty context, for instance because dishonesty is arousing (Zuckerman et al., 1981), leading to pupil dilation and overriding any effects of mimicry. To examine this alternative explanation, we included a third "baseline" block in which there was no option for dishonesty: participants were asked to simply remember a coin toss and earned money not for correct predictions but for correct memory of the coin toss.[5] In this case, we might find that the dishonesty blocks do not produce pupil mimicry, but the baseline block does.

In sum, our hypotheses for Experiment 3 are as follows: In the Self-benefitting block, we expect mimicry, but no effect of the partner's pupil on behavior, because the partner is not affected. In the Other-benefitting block, we also expect mimicry, *and* that this will translate to *increased* dishonesty in the case of dilating pupils.

3.1. Method

We report all measures, manipulations, and exclusions in these studies, either in this section or the supplementary materials.

3.1.1. Participants

Thirty-six participants (18 male), with a mean age of 21.53 years (min = 19 years old, max = 26 years old), took part in Experiment 3. The experimental procedures were similar to Experiment 1, in accordance with the Helsinki Declaration and approved by the ethical board of the University of Amsterdam. Due to equipment malfunction, two participants were excluded from analysis. The stopping rule used during data collection was to continue collecting data until the sample was large enough to detect small-to-medium effect sizes identified in Experiment 1.

Based on the effect sizes observed in Experiment 1 and 2, we aimed to collect a sample that would allow us to reliably detect small effect sizes. Power analyses indicated that for a repeated measures within-participants design in which participants complete 108 trials across three blocks, a minimum of 36 participants was required to detect small effects at a power of $1 - \beta > 0.8$, and a p-threshold of $p = 0.05$. However, constraints on time and resources meant that the final sample included 34 participants. This meant that for continuous outcome measures this sample can reliably detect effect sizes of $\eta_p^2 \approx 0.007$. For binary outcome measures, this sample can detect changes to odd's ratios of OR ≈ 0.009 (Faul et al., 2007).[6]

3.1.2. Experimental design

This experiment uses a 2 × 3 within-participants design. As before, the first factor is the pupil response of the actor in the video: the actor's pupils either dilated or constricted over the course of the video as in Experiment 1 and 2. The second factor reflects the different blocks. We used the Self-benefitting block and Other-benefitting block of Experiment 2 to reflect non-competitive dishonesty: reporting a correct prediction *either* earned €0.10 for the self (Self-benefitting block) *or* earned €0.10 for the partner (Other-benefitting block). In addition, we included a condition without the option for dishonesty as a baseline for studying pupil mimicry. In this Baseline block, participants were simply rewarded for memorizing the coin toss. That is, participants watched the coin toss and reported the outcome, which they did correctly in 99.6% of cases. If participants remembered the outcome correctly, they earned €0.10. In the Baseline block there was no option for dishonesty, allowing us to establish a baseline for pupil mimicry in a condition where no strategic considerations were at play. All other aspects of this block were identical to the other two blocks in terms of what they saw on the screen, and the finger movement they had to make for each button press.

In this way, three different blocks were created, the order of which was counterbalanced between participants. Each of these three blocks (Baseline, Self, and Other-benefitting block) contained 36 trials, giving a total of 108 trials per participant. As in Experiment 1, partners were represented by their eye-region, with pupils that either dilated or constricted. As in Experiment 2, all partners gazed directly at the participant. A trial outline in this block looked the same in all blocks, showing the exact same stimuli and coin toss and requiring a button-press at the same time-point.

Bonuses for each participant were paid out at the end of the Experiment.

3.1.3. Statistical analysis

As in Experiments 1 and 2, the statistical models for dishonesty held a two-level structure. The data structure reflected trials (level 1), nested in participants (level 2). When modeling pupil mimicry, there were two additional nesting factors: Time at which the pupil size was sampled, and left and right Eye. Thus, the nesting structure of the pupil mimicry models were defined by the repeated measures, i.e., time (level 1), nested in trials (level 2), nested in eyes (level 3), nested in participants (level 4). Time (twenty-five 100-ms slots) was included as a repeated factor with a First-Order Autoregressive (AR1) covariance structure to control for auto-correlation. For the simple comparisons, a Bonferroni correction was applied.

3.1.3.1. Dishonesty. The model of dishonesty included the same fixed effects as Experiment 1, except that the factor Partner's gaze was replaced with the factor Block, which represents the Self-benefitting block, Other-benefitting block, and Baseline block. Thus the fixed effects in this model were: Participant Pupil, Partner Pupil, Block, and their interactions, and heart rate as a covariate. This model constituted the full model described below. As in Experiment 1, non-significant factors were dropped one by one to arrive at the final model.

[5] The decision of which blocks to include in this experiment was constrained by a maximum number of trials that we could administer (based on the number of repetitions of available stimuli and total duration of the study). This meant that we had to choose between including a Competitive benefit block (as in Experiment 2), and including the baseline block (which we ultimately preferred). Although the Competitive benefit block would have served to confirm the finding from Experiment 1 that mimicry does not occur in Competitive benefit blocks, the baseline block could exclude the alternative explanation that mimicry does not occur *at all* in contexts where people are tempted to be dishonest. Therefore, we believed the contribution of the baseline block to be more informative here.

[6] As there is no established method for conducting power analysis for multilevel designs the power analyses presented here do not take account of the multilevel structure of the data, and as such should be interpreted as *indicators* of power.

3.1.3.2. Pupil mimicry. Data was analyzed over the final 2.5 s of stimulus presentation, i.e., from the point when the pupil size of the partner began to change to the offset of the stimulus. Our statistical model included Participant Pupil, Partner Pupil, Block, and their interactions, and heart rate, as well as linear, quadratic and cubic terms and interactions with the previously mentioned factors in order to model the curvilinear relationship between participants' pupil size and time. The linear, quadratic and cubic terms were also included as random effects. As in Experiment 1, non-significant factors were dropped one by one to arrive at the final model.

3.1.4. Preliminary analysis

As before, the first versus later iterations of a certain partner did not produce differences in dishonest behavior, $F = 2.17$, $p = 0.141$, pupil dilation of the participant, $F = 2.60$, $p = 0.108$, or mimicry between the participant and the partner, $F = 1.21$, $p = 0.272$. Moreover, as before, the extent to which participants believed in the cover story, did not affect the results described below, $Fs < 1$, $ps > 0.503$.

3.2. Results

3.2.1. Dishonesty

Participants reported a number of correct responses higher than chance in both the Self-benefitting block ($M_{\text{Self-benefitting block}} = 60.9\%$ correct), $t(2446) = 4.53$, $p < 0.001$, odds ratio = 1.59, and the Other-benefitting block ($M_{\text{Other-benefitting block}} = 58.4\%$ correct), $t(2446) = 3.52$, $p < 0.001$, odds ratio = 1.44. The extent of dishonesty was the similar in both blocks, $F = 1.58$, $p = 0.209$. Interestingly, this indicates that participants lied both to benefit themselves *and* to benefit their partners. The decision to lie was not affected by changes in the pupil size of the partner, $F < 1$, $p = 0.347$, or by the participant's own pupil size, $F = 2.48$, $p = 0.116$. This is in line with Experiment 1 and 2, where the partner's pupils impacted on the decision to lie *only* in competitive contexts (which was not included in the current Experiment). The full and final models are presented in Table 6.

3.2.2. Participant's pupil size

In line with our prediction, participants' pupils were larger when the partner's pupils dilated versus constricted, $F(1, 138{,}896) = 16.05$, $p < 0.001$, $\eta_p^2 = 0.002$. The slope of the dilation was also more positive, indicating that participants' pupil sizes increased faster over stimulus presentation time when the pupils of their partner dilated as compared to constricted, as shown by an interaction between partner's pupil and the linear term, $F(1, 138{,}896) = 13.57$, $p < 0.001$, see Fig. 5. With a context that is less competitive than in Experiment 1, heart rate was no longer a significant predictor of the participant's pupil size, $F < 1$, $p = 0.793$, supporting the idea that here, participant's pupil size did not just reflect task-induced arousal, but rather the pupil size of their partners. Additionally, the interaction between block and Partner Pupil was not significant, $F < 1$, $p = 0.953$, indicating that mimicry was consistent across the three non-competitive blocks. The full and final models are shown in Table 7.

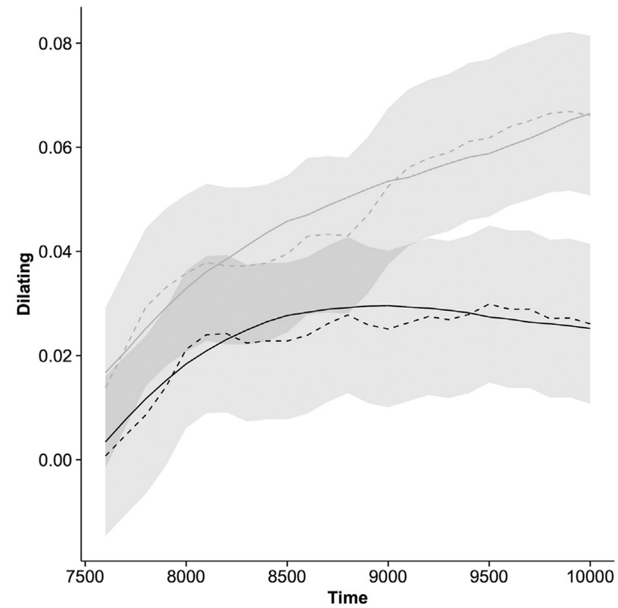

Fig. 5. Pupil response following changes in the pupil of the interaction partner. The shaded areas represent confidence intervals.

3.3. Discussion

Findings from Experiment 3 revealed evidence for pupil mimicry across blocks, that is, participants' pupils are larger when interacting

Table 6
Fixed and random effects in generalized linear mixed model of dishonesty.

Fixed effect	Full model				Final model			
	F-value	df	*SE*	*p*-value	*F*-value	df	*SE*	*p*-value
Intercept	1.57	1901	0.10	0.001	4.10	2018	0.09	0.000
Heart rate	0.00	1901	0.02	0.959				
Partner's pupil	0.88	1901	0.07	0.347				
Block	1.32	1901	0.10	0.251				
Participant's pupil	3.72	1901	0.43	0.054	2.48	2018	0.29	0.116
Block ∗ partner's pupil	0.15	1901	0.10	0.703				
Participant's pupil ∗ partner's pupil	0.88	1901	0.43	0.347				
Block ∗ participant's pupil	1.13	1901	0.60	0.288				
Participant's pupil ∗ block ∗ partner's pupil	0.91	1901	0.60	0.342				

Random effect		Full model						Final model					
		Estimate	*SE*	Wald's Z	*p*-value	CI lower	CI upper	Estimate	*SE*	Wald's Z	*p*-value	CI lower	CI upper
Intercept [subject = ID]	Variance	0.12	0.07	1.76	0.078	0.04	0.37	0.17	0.07	2.64	0.008	0.08	0.37
Actor [subject = ID]	Variance	0.08	0.06	1.52	0.129	0.02	0.30						

Note: dishonesty, i.e., the report of a correct or incorrect prediction had a binary distribution function and was analyzed in a generalized mixed model implemented in SPSS. The final model was derived via standard model selection.
Note: dependent variable = dishonesty, modulated by Participant Pupil, Partner Pupil, Block, and their interactions. All fixed factors were centered and treated as continuous (scale). Partner Pupil = dilating (coded 1) or constricting (coded − 1). S.E. = standard error of the mean estimate.

Table 7
Fixed and random effects in a generalized linear mixed model of participant's pupil size.

Fixed effect	Full model				Final model			
	F-value	df	*SE*	*p*-value	*F*-value	df	*SE*	*p*-value
Intercept	4.45	98,620	0.014	0.000	5.78	138,896	0.013	0.000
Heart rate	0.07	98,620	0.000	0.793				
Block	4.09	98,620	0.004	0.043	3.98	138,896	0.003	0.046
Partner's pupil	14.46	98,620	0.003	0.000	16.05	138,896	0.003	0.000
Linear	12.28	98,620	0.013	0.000	9.99	138,896	0.014	0.002
Quadratic	1.05	98,620	0.008	0.305	8.40	138,896	0.007	0.004
Cubic	0.50	98,620	0.004	0.481	2.73	138,896	0.004	0.098
Block * linear	0.00	98,620	0.008	0.969	0.01	138,896	0.007	0.939
Block * quadratic	1.07	98,620	0.004	0.301				
Block * cubic	7.12	98,620	0.003	0.008	4.01	138,896	0.002	0.045
Partner's pupil * block	0.00	98,620	0.004	0.953	0.03	138,896	0.003	0.862
Partner's pupil * linear	14.29	98,620	0.006	0.000	13.57	138,896	0.006	0.000
Partner's pupil * quadratic	2.25	98,620	0.003	0.134	2.78	138,896	0.003	0.096
Partner's pupil * cubic	0.18	98,620	0.002	0.669	0.00	138,896	0.002	0.963
Partner's pupil * block * linear	2.91	98,620	0.008	0.088	3.15	138,896	0.007	0.076
Partner's pupil * block * quadratic	0.22	98,620	0.004	0.642				
Partner's pupil * block * cubic	2.37	98,620	0.003	0.124	2.74	138,896	0.002	0.098

Random effect		Full model						Final model					
		Estimate	*SE*	Wald's Z	*p*-value	CI lower	CI upper	Estimate	*SE*	Wald's Z	*p*-value	CI lower	CI upper
Repeated measures	AR1 diag.	0.061	0.001	65.73	0.000	0.060	0.063	0.064	0.001	70.60	0.000	0.062	0.066
	AR1 rho	0.965	0.001	1774.84	0.000	0.964	0.966	0.967	0.000	1997.58	0.000	0.966	0.967
Intercept [subject = ID]	Variance	0.005	0.001	3.35	0.001	0.003	0.008	0.004	0.001	3.34	0.001	0.002	0.008
Actor [subject = ID]	Variance	0.001	0.0002	3.47	0.001	0.001	0.002	0.002	0.0002	4.36	0.000	0.001	0.002
Linear [subject = ID]	Variance	0.003	0.001	2.74	0.006	0.002	0.006	0.004	0.001	3.11	0.002	0.002	0.008
Quadratic [subject = ID]	Variance	0.001	0.0002	2.90	0.004	0.001	0.003	0.001	0.0002	3.05	0.002	0.001	0.002
Cubic [subject = ID]	Variance	0.0004	0.0002	2.29	0.022	0.0003	0.001	0.000	0.0002	2.69	0.007	0.0003	0.001

Note: the final model was derived via standard model selection.
Note: dependent variable = baseline-corrected pupil size, modulated by partner pupil, heart rate, block, and polynomials (all centered and treated as continuous (scale)). Partner's pupil was coded as 1 (dilating pupils) and − 1 (constricting pupils). S.E. = standard error of the mean estimate.

with a partner who has large pupils (Harrison et al., 2006; Kret et al., 2015). These findings support our first hypothesis, showing that dishonesty does not preclude mimicry per se. Rather, it seems that it is the harmful effect of dishonesty on the partner that was responsible for the absence of mimicry in Experiment 1. Combined with the results reported in Kret et al. (2015), the findings of this study suggest that pupil mimicry emerges in more benign contexts (e.g., when own and other's outcomes are not antagonistic) and is reduced or absent when own and other's interests conflict (Bourgeois & Hess, 2008).

Moreover, Experiment 3 showed no evidence that pupil mimicry mediates behavioral effects. We had hypothesized that, in the Other-benefitting block, pupil mimicry would mediate effects of the partner's pupil on dishonest behavior: when participants mimic the dilating pupils of a partner, they become motivated to behave pro-socially towards them, leading them to lie to benefit the partner in the Other-benefitting block. However, there was no evidence that participants use cues from the partner's eyes to inform their behavior in the Other-benefitting block. That is, our second hypothesis was not supported. The reason for this is perhaps that in the Other-benefitting block, behavior is 'cheap', the participant can help the partner at no cost to themselves.

In sum, Experiment 3 showed that, when dishonest behavior does not harm the interests of the interaction partner, pupil mimicry occurs. However, there was no evidence that pupil mimicry mediates behavioral effects.

4. General discussion

Across 3 experiments, we showed that observed pupil response of a partner affects dishonest behavior: people are less likely to deceive an interaction partner with dilating pupils. Importantly, however, this effect of a partner's pupil response on dishonesty occurred only when participants' dishonesty hurt the interaction partner, that is, in the Competitive benefit block. In the Competitive benefit block participants must make a trade-off between their own interests and those of the interaction partner. Cues from the partner's eyes are used as input for this trade-off. When the partner has dilating pupils, the decision to hurt them becomes more difficult, and dishonesty is less prevalent. These studies could not speak directly to *why* dilating pupils had this effect. On the one hand, previous research has suggested that dilating pupils signal (sexual) interest and attention (Hess & Polt, 1960; Tombs & Silverman, 2004; Verney, Granholm, & Marshall, 2004). Other studies argue that dilating pupils are perceived positively (Kret, 2017), indicating trustworthiness or sociability (Kret et al., 2015; Weibel et al., 2010). Importantly, we believe these two lines of evidence about how pupil dilation is interpreted can be integrated by suggesting that perceived trustworthiness, perceived sociability and perceived interest are all factors which contribute to an interaction partner with dilating pupils making a favorable impression. They seem like promising interaction partners, which in turn elicits pro-social behavior, like reduced dishonesty, from the participant. Similarly, it is worth noting that the Competitive benefit block was also the only block where pupil mimicry did *not* occur. There are 2 possible mechanisms that might explain this effect. Firstly, it may be the case that the temptation to hurt a partner produces a great deal of arousal, overshadowing pupil mimicry. However, an alternative explanation may be a more motivated *suppression* of mimicry when it is not desirable. Mimicry is known to lead to interpersonal affiliation (Hove & Risen, 2009; Lakin et al., 2003), and such affiliation is likely to be undesirable when the participant is tempted to harm the interaction partner. This issue of whether pupil mimicry may be suppressed through motivational processes is an interesting area for further research.

When dishonesty does not harm the partner, no trade-off is necessary: increasing one's own pay-off does not harm the other (in the Self-benefitting blocks), and helping the other incurs no cost to the self (in the Other-benefitting blocks). In these cases the decision to be dishonest becomes easier, and participants need not scrutinize subtle social cues from the interaction partner. However, this more benevolent context also means that there is no obstacle to pupil mimicry, as evidenced by the occurrence of pupil mimicry in these conditions.

In sum, it seems that the fact that dishonesty (often) has detrimental effects on others is a crucial factor in the findings of this study, both in terms of behavior and pupil mimicry.

4.1. Similarities and differences with previous studies

This study adds to a growing body of literature that examines how pupil dilation affects those who observe it. Generally speaking, findings from these studies are in line with findings from previous studies showing that observed pupil dilation of a partner can function as a social cue (Harrison et al., 2006; Kret et al., 2015; Kret & De Dreu, 2017). Specifically, our findings support the notion that partners with dilating pupils elicit pro-social behavior (Kret et al., 2015). However, our focus on dishonest behavior also provides evidence for a number of informative differences. Most importantly, the behavioral effects in these studies were not mediated by pupil mimicry, illustrating that pupil dilation can function as a social cue, and produce effects on behavior, through routes other than physiological contagion. In addition, results from this study add to previous studies focusing on dishonesty. Firstly, although levels of dishonesty varied somewhat across experiments, overall participants avoided 100% dishonesty. That is, even in a context where they could have easily lied without repercussions, they prefer not to do so (Shalvi et al., 2011). Aside from this general tendency to avoid all-out lies, behavior was also affected by features of the interaction partner, and the effect dishonesty has on that interaction partner. That is, observing dilating pupils (and, in Experiment 1, observing direct gaze) can encourage honest behavior.

Additionally, this study shows that participants use pupil dilation of a partner as a social cue, even when there is no benefit to themselves in caring about the partner. In the trust game, used by Kret et al. (2015), participants rely on the partner to return a proportion of the money they have invested. That is, their concern for social cues from their interaction partner may stem ultimately from self-interested concern for their own pay-offs. Will this person exploit me or can I trust they will return the money? In the current study, however, participants' outcomes did not depend on the behavior of the interaction partner, but still their behavior was affected by social cues from that partner. These findings underscore the pro-social motivation underlying participants' behavior in this study.

One interesting direction for future research would be to examine these effects in contexts where participants do not earn rewards. Previous research has shown that providing participants with rewards can increase empathic accuracy, because participants are more motivated to do well in the task (Hess, Blaison, & Dandeneau, 2017). In the current experiment, then, participants may attend to the eyes of their partners only in the blocks where they can earn money, as these blocks increase motivation. Indeed, Experiment 2 showed that the effect of observed pupil dilation was stronger in the blocks where the participant could earn a bonus, that is, the Self-benefitting and Competitive benefit blocks (although in opposite directions) than in the Other-benefitting block, where the participant could not earn anything. As such, we believe it would be worthwhile to examine the effect of observed pupil dilation in a context where there are no rewards associated with dishonesty.

4.2. Limitations

The principal methodological limitation of the current study is the fact that predictions in the coin-toss task were private, and it was therefore not possible to know on which trials participants lied, only that the total number of correct guesses deviated from chance. This option was preferred because unethical acts are less likely when the risk of being discovered is high (Shalvi et al., 2011; Zhong et al., 2010). Moreover, if the participant suspected that the experimenter might somehow have access to their predictions, the experimenter could arguably be seen as a 'secondary observer' alongside the interaction partner, and obscure the effect of the interaction partner on participants' decisions.

The aim of this study was to examine how pupil dilation in an interaction partner affects social decision-making. However, in day-to-day life, pupil dilation does not occur in isolation, but is part of a set of cues that a person obtains from an interaction partner, including posture, facial expression, gaze direction, and verbal cues. As such, future work in this line might examine the effects of pupil dilation on decision making when it is part of several different cues.

Additionally, the studies described here were conducted in the controlled environment of a laboratory, where attention to the eye region of the stimuli was ensured. As such, the current study cannot speak to the role of observed pupil dilation in more naturalistic contexts. Nevertheless, previous studies indicate that pupil dilation of interaction partners does indeed affect behavior in daily life. For instance, a study by Wiseman and Watt (2010) assessed how the pupil size of a cover model affected book sales, and showed that the book that featured the model with large pupils enjoyed higher sales. Such studies suggest that pupil dilation cues do also affect behavior outside the context of the laboratory.

Although we believe our analytical strategy has a number of important advantages (such as increased power), it also has some drawbacks. For instance, like ANOVA and linear regression models, our analysis relied on Fixed Effects, which are limited in their generalizability to the broader population from which the sample is drawn. At the population level, there might be differences as a result of participants' age (see e.g. Kret, 2017) or personality (see e.g. Harrison et al.'s, 2006 findings on empathic concern).

Finally, it is worth noting that the exit questions showed that participants were somewhat sceptical with regards to the cover story (see supplementary materials). Specifically, participants were sceptical about the assertion that the videos of the interaction partners were based on photos from previous participants. This may reflect a general scepticism on behalf of our participants, or might be due to the fact that the videos were clearly edited, presenting only the partner's eye-region in grey-scale.

4.3. Conclusions

Taken together, findings from this study show that the trade-off between self-interested dishonesty, and the harmful effects it has on the partner, drives the influence of the partner's pupil size on social decision-making. When one prepares to engage in behavior that harms the interests of an interaction partner, this leads both to attention to the subtle social cues from the partner, but also reduces pupil mimicry. When there is no motivation to harm the partner, the influence of social cues from that partner on decision-making is reduced, but also gives more space for the positive interpersonal effects of pupil mimicry. We believe that the current study underlines the importance of studying the subtle physiological cues that influence human social behavior.

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Appendix A. Supplementary data

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