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# DECEPTIVE BEHAVIOUR MODULATION BY FEEDBACK STRATEGIES AND BY INHIBITORY POTENTIAL OF THE GENE GABRA2 (RS279858)

Research Paper

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Running title: Deception modulation by feedback and GABRA2 (rs279858)

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# Deceptive behaviour modulation by feedback strategies and by inhibitory potential of the gene GABRA2 (rs279858)


## Abstract

Some research has been done on the effect of heritability of the deceptive behaviour, but very little is known about the effect of specific genes. In this study the effect of gene GABRA2 SNP rs279858 on the propensity to lie and on reaction time (RT) in the 'Circle Game' was investigated. Significant main effect of rs279858 on RT in 'Circle Game' and a significant interaction of rs279858 and sex on the propensity to lie were discovered. A significant learning effect in the 'Circle Game' was also found and a significant RT deception effect described in numerous previous studies was confirmed.


**Keywords: Detection of deception, GABRA2, Circle Game, Reaction time, Feedback**

# Tagasiside strateegiate ning geeni GABRA2 (rs279858) pidurdava potentsiaali mõju petukäitumisele


## Kokkuvõte

Varasemalt on tehtud uuringuid petukäitumise päriliku komponendi kohta, kuid väga vähe on uuritud üksikute geenide mõju kalduvusele valetada. Käesolevas töös uuriti geeni GABRA2 SNP rs279858 mõju valetamiskalduvusele ja reaktsiooniajale (RT) Ringide mängus. Avastati SNP rs279858 oluline peamõju RT-le Ringide mängus ning oluline SNP rs279858 ja soo koosmõju kalduvusele valetada. Samuti esines oluline harjutamise efekt Ringide mängus ning kinnitust sai mitmetes varasemates uuringutes kirjeldatud petukäitumise mõju RT-le.



**Märksõnad: Pettuse tuvastamine, GABRA2, ringide mäng, reaktsiooniaeg, tagasiside**

# Introduction

Lying can be defined in several different ways. Although some authors, such as Thomas Aquinas, define lying as any communication of false information, regardless of whether the liar knows that the information presented is false, or genuinely believes it to be true (Palermo, Perracuti, & Palermo, 1996), most writers on the topic include knowing intent as a prerequisite for lying (Ford, 2006).

Meijer, Verschuere, Gamer, Merckelbach, & Ben-Shakhar (2016) have written in their review that there are numerous measures that have been used to detect deception. Most common are the autonomous nervous system measures such as electrodermal activity, respiration, heart rate, blood pressure. More recently central nervous system measures such as recorded by fMRI or ERPs have been introduced. Behavioural measures such as reaction times are also used. Studies using such psychophysiological and behavioural indices of deception typically employ more or less controlled paradigms, in which questions and/or stimuli are presented, often in large number of trials.

Using reaction times as deception indices has many advantages over autonomic and neural measures – they are cheap, easy and quick to measure (Verschuere and De Houwer, 2011, cited through Suchotzki, Verschuere, Van Bockstaele, Ben-Shakhar, & Crombez, 2017). This method is based on a cognitive approach which claims that lying requires more cognitive resources than telling the truth. Liars cannot just retrieve a story from memory, but need to fabricate it. They have to not contradict themselves or the knowledge of the person they are trying to deceive. To do so they have to retrieve the truth, keep it active in working memory, and yet at the same time prevent it from slipping out while communicating the deceptive response instead. Yet, studies on the evaluation of lying based on response times have produced very different results (Suchotzki et al., 2017). Critics have stated that RTs are under voluntary control and therefore are not suitable for investigating deception (Sip et al., 2013).

Several paradigms are available that allow a within-subject comparison between truthful and deceitful responses: Concealed Information Test, the autobiographical Implicit Association Test, the Sheffield Lie Test, and the Differentiation of Deception Paradigm (Suchotzki et al., 2017). The Concealed Information Test (CIT; Lykken, 1959) is a method designed to measure recognition of critical (e.g., crime-relevant) information. In CIT experiments participants are usually instructed to hide some sort of knowledge and are presented with stimuli that refer to this knowledge as well as with irrelevant stimuli (Suchotzki et al., 2017). The autobiographical Implicit Association Test (aIAT; Sartori, Agosta, Zogmaister, Ferrara, & Castiello, 2008) is a method designed to reveal which of the two contrasting autobiographical events is true. In the aIAT, participants are asked to classify four different types of stimuli (true statements, false statements and two contrasting autobiographical events) using two response keys (Suchotzki et al., 2017). The Sheffield Lie Test (SLT; Spence et al., 2001) is a paradigm in which participants are instructed to lie or tell the truth about a set of stimuli, depending on a cue (e.g., lie to questions in blue, tell the truth to questions in yellow). Importantly, in the SLT, participants tell the truth and lie about the same set of stimuli (Suchotzki et al., 2017). In the Differentiation of Deception Paradigm (DoD; Furedy, Davis, & Gurevich, 1988), unlike in the SLT, stimuli do not form their own control. Thus, participants are cued or instructed to lie about one stimulus set, and to tell the truth about another stimulus set (Suchotzki et al., 2017).

Test subjects with higher impulsivity have been shown to make decisions faster (and with higher rate of mistakes) (Dickman & Meyer, 1988). In addition, the response time could also indicate something about a person's overall response readiness, or the effect of inhibitory processes on motor actions.

According to an interactive view on decision-making called dynamic decision-making, feedback from the environment influences our future choices and our processing of decision outcomes (Chipman & Gonzalez, 2014). Thus, decisions are made based on experience and are dependent on feedback (Prezenski, Brechmann, Wolff, & Russwinkel, 2017). Moustafa, Gluck, Herzallah, & Myers, (2015) have shown that test subjects learn from the feedback given in the object categorization game, and negative feedback has a greater impact on learning than positive. The conducted experiment made it possible to vary the feedback strategy and see if and how the test subjects learn to change their lying behaviour for maximum benefit. Two different feedback strategies were used: Dynamic Feedback Strategy, where the frequency of feedback was dependent on the amount of lies, and Random Feedback Strategy, where the frequency of feedback was fixed and occurrences were randomized. In Dynamic Feedback Strategy, frequent lying brings along more frequent feedback, which should have a reducing effect on the amount of lying.

So far, there has been very little research on the effect of genes on the propensity to lie. Loewen et al. (2013) demonstrated that variance between individuals in perceptions of the acceptability of certain everyday dishonest activities has a genetic component. Wallace, Cesarini, Lichtenstein, & Johannesson (2007) found that genetic influences are important determinants of rejection behaviour in the ultimatum game. Approximately 25% of the variation in risk in mandatory pension investment portfolios was found to be due to genetic variation (Cesarini, Johannesson, Lichtenstein, Sandewall, & Wallace, 2010). Dreber & Johannesson (2008) found that men are significantly more likely than women to lie to secure a monetary benefit.

Shen et al., (2016) studied the effect of single nucleotide polymorphism (SNP) variants of tryptophan hydroxylase 2 (TPH2) on individual differences in the tendency to cheat. They found that the carriers of the SNP rs4570625 G allele tended to lie more. Carriers of the G allele are also characterized by impulsivity and deficiencies in executive functions and self-control (Muraven, Pogarsky, & Shmueli, 2006; (Mead, Baumeister, Gino, Schweitzer, & Ariely, 2009). TPH2, as a rate-limiting enzyme for the synthesis of serotonin in central nervous system, plays a key role in the modulation of serotonin neurotransmission (Shen et al., 2016). Serotonin neural pathways play a key role in behavioural inhibition and executive function (Barnes, Dean, Nandam, O'Connell, & Bellgrove, 2011).

$GABA_A$ receptors are GABA-gated $Cl^-$-channels responsible for the majority of inhibition in the mammalian brain (Nakamura, Darnieder, Deeb, & Moss, 2015). Gamma-aminobutyric acid (GABA) is the inhibitory neurotransmitter in the brain playing a major role in regulating neuronal excitability (Olsen & Sieghart, 2009). The GABRA2 gene is involved in encoding the a2 subunit of the γ-aminobutyric acid A receptor ($GABA_A$) (Heitzeg et al., 2014).

GABRA2 SNP rs279858 G allele is also associated with impulsivity (Villafuerte, Strumba, Stoltenberg, Zucker, & Burmeister, 2013), although in another study this effect only existed for female subjects (Villafuerte et al., 2012). On the other hand, one might think that those who can suppress the truth more effectively, in other words, have better control over their cognitive processes, would lie more. Thus, I investigate how are the GABRA2 SNP rs279858 genotypes associated with inhibitory processes in the brain, associated with lying in our sample.

Based on the foregoing, the aim of the research is to investigate the link between the propensity to lie and the GABRA2 SNP rs279858 gene as well as the effect of the feedback strategy on correct and incorrect answers in the behavioural experiment 'Circle Game'

(Karton, 2015; Karton & Bachmann, 2011, 2017; Karton, Rinne, & Bachmann, 2014). It is also examined whether lying and telling the truth can be distinguished by reaction time.

Independent variables are sex (male, female), alleles (A and G) of GABRA2 SNP rs279858 and genotypes (A/A, A/G, G/G), feedback strategy (2 levels: random and dynamic) and sequence of blocks (dynamic or random feedback first), dependent variables are the propensity to lie (percentage of lies) and reaction time.

The following hypotheses are set:

H1: Relatively high percentage of incorrect answers indicates impulsive lying-behaviour (related to GABRA2 rs279858 G allele).

H2: A relatively high percentage of being caught relates to GABRA2 rs279858 G allele, as it refers to impulsivity. For example, GABRA2 rs279858 G allele carriers should express less inhibitory behaviour because it has been associated with higher NEO-PI impulsivity scores (Villafuerte et al., 2012).

H3: In case of Dynamic Feedback Strategy in the ‘Circle Game’, subjects lie less than in case of Random Feedback Strategy.

H4: Reaction time is longer for lies than for truthful answers.

H5: Carriers of the GABRA2 rs279858 G allele generally have quicker reaction times (shorter average reaction time over all given answers).

H6: Representatives of the GABRA2 rs279858 G allele generally have shorter reaction times in case of lying.

H7: Faster liars tend to lie more (there is negative correlation between reaction time while giving incorrect answers and percentage of incorrect answers given).

# Method

## Participants

The sample consists of 40 healthy participants with mean age 30, standard deviation (SD) 9.77; 55% female. Participants were recruited through Facebook group and mailing list of University of Tartu Institute of Psychology, the mailing list of Estonian Military Academy and directly by the experimenter. Students of Institute of Psychology received course credits that are necessary to complete their studies. All participants signed sheets of informed consent in which they were informed about the methods used in the experiment, duration of the experiment and about handling and storing of the gene samples and personal data. Participants confirmed that they were at least 18 years old, healthy and with normal or corrected to normal vision. Saliva specimens were taken from the participants to determine which alleles and genotypes of the gene GABRA2 SNP rs279858 they carry. Samples were coded anonymously and the DNA extraction was performed in the laboratory of psychophysiology of University of Tartu.

## Procedure

### Behavioural experiment

The participants were divided equally and as gender-balanced into two test groups, one group was first presented with a test condition where the frequency of feedback was dependent on the amount of lies (Dynamic Feedback Strategy) and then with a randomized test condition where the frequency of feedback was fixed and occurrences were randomized (Random Feedback Strategy), the second group had the test conditions presented to them in the opposite order.

The test consisted of playing the so called ‘Circle Game’. During the test red and blue circles are presented to the participant in quasi-random order, each time with duration of 100 ms, after which the colour of the circle had to be reported. Each experiment began with a variable length fixation period (100, 150 ms). At each test trial, a ring (diameter = 2.3 cm) was presented with a viewing distance of about 60 cm. There were two blocks of trials. In either one of the test blocks 240 circles were displayed, both colours appearing 120 times, intermixed randomly. Participants were told that the goal of the game is to score as many points as possible and that seeing and naming red circles gives one point for each occasion. In addition, in the instruction they were told that it is also possible to score one point when they lie by responding “red” in the blue circle trial. They did not get points when they responded “blue”. Participants could choose freely whether to lie and/or when to lie. The test also included controls. In one test block the participant was controlled on 40 randomly chosen trials. The trials were evenly distributed between blue and red circles. In the other test block the frequency of control trials depended on the frequency of lying (according to an algorithm deployed by the experiment program). In case of being caught lying, the participant lost 5 points. Responses were entered using the right (for red response) and left (for blue response) arrow keys on the keyboard. The score and number of trials passed were always displayed in the upper right corner on the screen. Responses given and reaction times were automatically measured and stored by the experiment program.

## Genotyping

GABRA2 rs279858

Genomic DNA was extracted from saliva samples using MN NucleoSpin® Blood Kit (740951.250; MACHEREY-NAGEL GmbH & Co. KG, Düren, Germany). The real-time polymerase chain reaction (RT-PCR) for genotyping the GABRA2 rs279858 polymorphism was performed using a TaqMan Pre-Designed SNP Genotyping Assay (Applied Biosystems; Foster City, CA, USA) C___2073557_1_ containing primers and fluorescent probes. Genotyping reactions were performed in a total volume of 10 µl with ~25 ng of template DNA. RT-PCR reaction components and final concentrations were as follows: 1:5 5 x HOT FIREPol® Probe qPCR Mix Plus (ROX) (Solis BioDyne) and 1:20 80 x TaqMan Primers Probe. Context sequence [VIC/FAM] was as follows: TTGTCATATTATGAGCTACTGATTT[C/T]TTCCCATTGTGAAAAAAGGTATCTG. Reactions were performed on the Applied Biosystems ViiA™ 7 Real-Time PCR System. The amplification procedure consisted of an initial denaturation step at 95 °C for 12 min and 40 cycles of 95 °C for 15 s and 60 °C for 1 min. Positive and negative controls were added to each reaction plate. No inconsistencies occurred. Genotyping was performed blind to all phenotypic data. The distribution by genotypes was as follows: A/A – 20%, A/G – 50%, G/G – 30%.

## Data analysis

Statistical analyses were conducted using IBM SPSS Statistics 20. Alpha was set to 0.05 (two tailed). Repeated-measures analysis of variance (rmANOVA) was used to find statistically significant main effects and interactions between the variables observed. When a correlation between continuous variables was made, a Pearson correlation coefficient was used. Trials with reaction time longer than +3 SD from the mean were excluded from the analysis. Trials where red circle was presented and participant answered blue were also considered erroneous and excluded (1.3 % of trials).

## Results

H1: Relatively high percentage of incorrect answers indicates impulsive lying-behaviour (related to GABRA2 rs279858 G allele). H3: In case of lying-dependent feedback in the ‘Circle Game’, subjects lie less than in case of random feedback.

Repeated Measures ANOVA (*ANalysis Of VAriance*), with within subject independent variable feedback type (dynamic, random), and between subject variables GABRA2 rs279858 genotypes (A/A, A/G, G/G), sex (male, female), sequence of blocks (dynamic first, random first) and dependent variable percentage of lies, indicated that the main effect of genotype is not statistically significant, p=.978. Hence the results of the analysis do not show the main effect of GABRA2 rs279858 genotypes on lying behaviour. Also, the main effect of feedback type was not found. The only significant interaction was between sex and GABRA2 rs279858 genotype, $F(2,28)=6.070$, $p=.006$, $\eta_p^2=.302$. Three post hoc analyses were performed, one with each genotype group in order to test the significant interaction between sex and GABRA2 rs279858 genotype. For post hoc analyses Repeated Measures ANOVA was used with within subjects independent variable feedback type (dynamic, random), between subjects independent factor sex (male, female) and dependent variable percentage of lies. It appeared that the interaction effect reported above was based on the statistically significant difference [$F(1,6)=6.679$, $p=.042$] between female and male groups with GABRA2 rs279858 genotype A/A, and between female and male groups with GABRA2 rs279858 genotype A/G [$F(1,18)=5.470$, $p=.031$]. There was no significant difference between female and male groups with GABRA2 rs279858 genotype G/G, p=.558 (see all the means from Fig. 1). This means that sex is an important factor that influences the effect of GABRA2 rs279858 genotypes in the following way: males with genotype A/A tend to lie more than females with genotype A/A and females with genotype A/G tend to lie more than males with genotype A/G. Other main effects and interactions were not significant, all p values $\geq .138$. Therefore, the feedback type did not affect the frequency of lying.

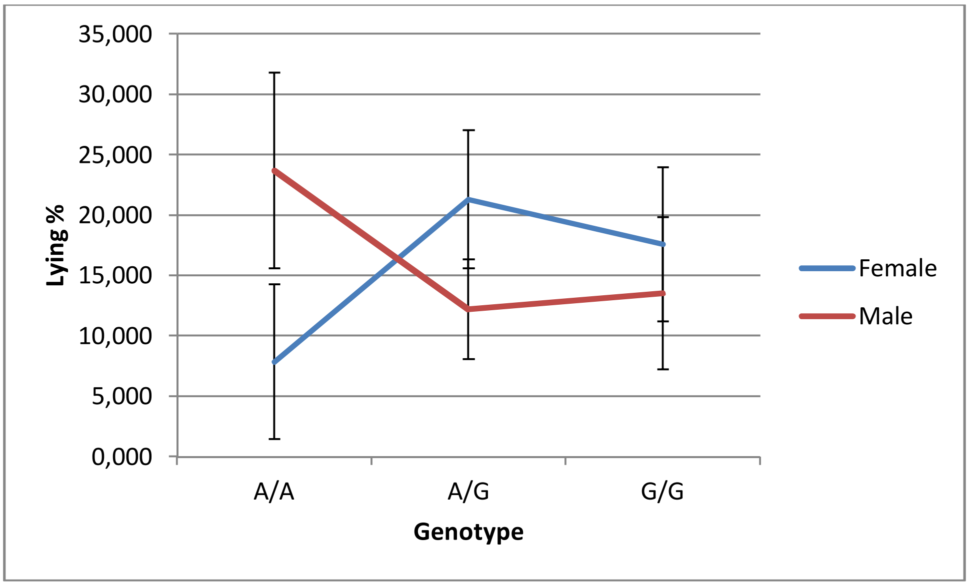


Fig. 1 Mean percentage of lies and 95% confidence intervals in GABRA2 rs279858 genotype groups divided into groups by sex.

Repeated Measures ANOVA with within subject independent variable feedback type (dynamic, random) and between subject variables GABRA2 rs279858 allele groups (A: A/A; G: A/G+G/G), sex (male, female), sequence of blocks (dynamic first, random first) and dependent variable percentage of lies, indicated also that the main effect of allele groups is not statistically significant, p=.740. Hence the results of the analysis show that lying behaviour in general is not affected by GABRA2 rs279858 alleles. The only significant interaction was between sex and GABRA2 rs279858 allele groups (A/A, A/G+G/G), F(1,32)=11,572, p=.002, $\eta_p^2$=.266. Other main effects and interactions were not significant, all p values ≥.143. For post hoc analyses Repeated Measures ANOVA was used with within subjects independent factor feedback type (dynamic, random), between subjects independent factor sex (male, female) and dependent variable percentage of lies. It appeared that the interaction effect reported above was based on the statistically significant difference [F(1,6)=6.679, p=.042] between female and male groups with GABRA2 rs279858 allele group A (A/A) and [F(1,30)=4.505, p=.042] between female and male groups with GABRA2 rs279858 allele group G (A/G+G/G) (see all the means from Fig. 2). This means that sex is an important factor that influences the effect of GABRA2 rs279858 allele groups in the following way: within genotype group A/A (A homozygotes) males tend to lie more than females and within carriers of allele G (A/G+G/G) females tend to lie more than males. Repeated Measures ANOVA, with within subject independent variable feedback type (dynamic, random) and between subject variables GABRA2 rs279858 allele groups (A:

A/A+A/G, G: G/G), sex (male, female), sequence of blocks (dynamic first, random first) and dependent variable percentage of incorrect answers given indicated that the main effect of genotype is not statistically significant, p=.910. Therefore, the results of the analysis also show that lying behaviour is affected by GABRA2 rs279858 alleles when sex factor is taken into account. Allele A homozygosity seems to increase lying for men and decrease lying for women, the results for G allele carriers are also statistically significant but a crossover effect is present, meaning that G allele seems to increase lying for women and decrease lying for men. Other main effects and interactions were also not significant, all p values ≥.131. Therefore, feedback type did not affect the frequency of lying.

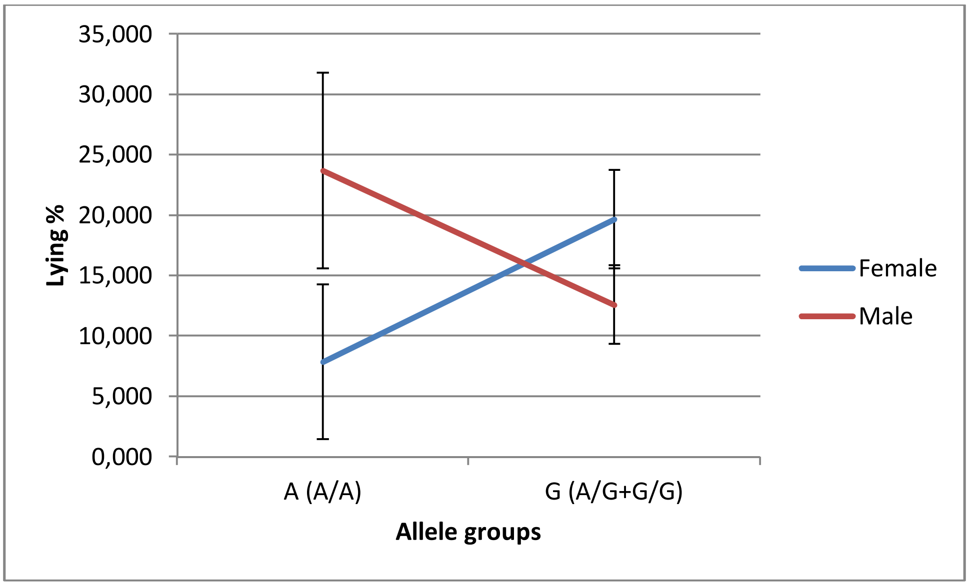


Fig. 2 Mean percentage of lies and 95% confidence intervals in GABRA2 rs279858 allele groups, shown separately for sex groups.

H2: A relatively high percentage of being caught relates to GABRA2 rs279858 G allele, as it refers to impulsivity. For example, GABRA2 rs279858 G allele carriers should express less inhibitory behaviour because it has been associated with higher NEO-PI impulsivity scores (Villafuerte et al., 2012).

Repeated Measures ANOVA with within subject independent variable feedback type (dynamic, random) and between subject variables GABRA2 rs279858 genotypes (A/A, A/G, G/G), sex (male, female), sequence of blocks (dynamic first, random first) and dependent variable percentage of being caught while lying, indicated that the main effect of genotype is not statistically significant, p=.726. The only significant interaction was between sex and GABRA2 rs279858 genotype, F(2,28)=36.801, p=.006, $\eta_p^2$=.305. Other main effects and interactions were not significant, all p values ≥.138. Three post hoc analyses were performed with each genotype group in order to test the significant interaction between sex and GABRA2 rs279858 genotype. For post hoc analyses Repeated Measures ANOVA was used with within subjects independent factor feedback type (dynamic, random), between subjects independent factor sex (male, female) and dependent variable percentage of being caught while lying. It appeared that the interaction effect reported above was based on the statistically significant difference [F(1,6)=6.025, p=.049] between female and male groups with GABRA2 rs279858 genotype A/A, mean percentage of being caught lying was for females M=1.001, SD=.815, and for males M=4.162, SD=2.401. There was no significant difference between female and male groups with GABRA2 rs279858 genotype A/G, p=.120, and genotype G/G, p=.316. This means that sex is an important factor that influences the effect of GABRA2 rs279858 genotypes in the following way: males with genotype A/A tend to get caught more than females with genotype A/A. There is no significant difference between males and females with genotypes A/G and G/G. Repeated Measures ANOVA with within subject independent variable feedback type (dynamic, random) and between subject variables GABRA2 rs279858 allele groups (A: A/A; G: A/G+G/G), sex (male, female), sequence of blocks (dynamic first, random first) and dependent variable percentage of being caught while lying, indicated that the main effect of allele group is not statistically significant, p=.523. The only significant interaction was between sex and GABRA2 rs279858 allele groups (A: A/A; G: A/G+G/G), F(1,32)=12,763, p=.001, $\eta_p^2$=.285. Other main effects and interactions were not significant, all p values ≥.066. For post hoc analyses Repeated Measures ANOVA was used with within subjects independent factor feedback type (dynamic, random), between subjects independent factor sex (male, female) and dependent variable percentage of being caught while lying. It appeared that the interaction effect reported above was based on the statistically significant difference [F(1,6)=6.025, p=.049] between female and male groups with GABRA2 rs279858 allele group A (A/A), mean percentage of being caught lying was M=1.001, SD=.815 for females, and M=4.162, SD=2.401 for males. There was no significant difference between female and male groups with GABRA2 rs279858 allele group G (A/G+G/G), p=.072. This means that sex is an important factor that influences the effect of GABRA2 rs279858 allele groups in the following way: within carriers of only allele A (A/A) males tend to get caught more than females and there is no significant difference between carriers of allele G (A/G+G/G). Repeated Measures ANOVA with within subject independent variables feedback type (dynamic, random) and between subject variables GABRA2 rs279858 allele groups (A: A/A+A/G; G: G/G), sex (male, female), sequence of blocks (dynamic first, random first) and dependent variable percentage of being caught while lying, indicated that the main effect of genotype is not statistically significant, $p=.592$. Other main effects and interactions were also not significant, all p values $\geq.052$. Therefore, the results of the analysis also show that the percentage of being caught while giving incorrect answers is affected by GABRA2 rs279858 alleles when the effect of sex is taken into account. Allele A seems to increase getting caught for men and decrease getting caught for women, the results for people with allele G were not statistically significant.

H4: Reaction time is longer for lies than for truthful answers. H5: Carriers of the GABRA2 rs279858 G allele generally have quicker reaction times (shorter average reaction time over all given answers).

Repeated Measures ANOVA with within subject independent variables feedback type (dynamic, random), type of answer (correct, incorrect) and between subject variables GABRA2 rs279858 genotypes (A/A, A/G, G/G), sex (male, female), sequence of blocks (dynamic first, random first) and dependent variable reaction time, indicated that the main effect of feedback type is statistically significant, $F(1,24)=157.971$, $p<.001$, $\eta_p^2=.868$. Mean RT in dynamic feedback group was $M=.471$, $SD=.177$ and mean RT in random feedback group was $M=.633$, $SD=.223$. In other words, the RTs were shorter when dynamic feedback was used. The main effect of type of answer was also significant, $F(1,24)=28.798$, $p<.001$, $\eta_p^2=.545$. Mean RT for truthful answers was $M=.494$, $SD=.155$ and mean RT for lies was $M=.620$, $SD=.264$. In other words, the mean RT was longer for lies, which is consistent with what is generally known about relative speed of truthful and deceptive responses. The main effect of GABRA2 rs279858 genotypes was significant as well, $F(2,24)=3.714$, $p=.039$, $\eta_p^2=.236$. Mean RT for genotype A/A was $M=.516$, $SD=.216$, mean RT for genotype A/G was $M=.501$, $SD=.214$ and mean RT for genotype G/G was $M=.639$, $SD=.237$. For post hoc analyses LSD test was used, which indicated a statistically significant difference in mean RTs between genotypes A/G and G/G, the latter having a longer mean RT. This means that G/G homozygotes had longer RTs than A/G heterozygotes; there was no significant difference between any other groups. The following interactions were also statistically significant. First, feedback type and sequence of blocks $F(1,24)=89.205$, $p<.001$, $\eta_p^2=.788$. See all the means from Fig. 3. This shows that mean RT was shorter for random feedback condition and longer for dynamic feedback condition when random feedback condition was presented first. There was no significant difference in mean RT between feedback conditions when dynamic feedback condition was presented first. Second, feedback type and GABRA2 rs279858 genotypes, $F(2,24)=6.229$, $p=.007$, $\eta_p^2=.342$. See all the means from Fig. 4. As shown on the figure, RT was different for dynamic and random feedback type for genotypes A/G and G/G but not for genotype A/A. This means that carriers of genotype A/G and G/G had significantly longer RTs in random feedback condition than in dynamic feedback condition. Such difference was not present for carriers of genotype A/A. Third, feedback type, sex and block, $F(1,24)=7.165$, $p=.013$, $\eta_p^2=.230$. See all the means from Fig. 5. Reaction times were similar for both feedback types when dynamic feedback condition was presented first, but shorter for dynamic feedback when random feedback condition was presented first. This means that mean RTs were shorter in second block for participants that did the random feedback condition first but participants that first completed the dynamic feedback condition had no difference in RTs between first and second block. Females had shorter RTs than males when dynamic feedback condition was presented first, but there was no significant difference between genders when random feedback condition was presented first. Fourth, feedback type, sex and GABRA2 rs279858 genotypes, $F(2,24)=7.896$, $p=.002$, $\eta_p^2=.029$. This interaction contains too many groups to be meaningfully explained. Fifth, feedback type, type of answer and sequence of blocks, $F(1,24)=4.343$, $p=.048$, $\eta_p^2=.153$. See all the means from Fig. 6. Reaction times were similar for both feedback types when dynamic feedback condition was presented first but they were significantly longer for random feedback type when random feedback condition was presented first. RTs for true answers were shorter than RTs for lies in both blocks, but reaction times for both types of answers were longer in random feedback group for participants who first performed random feedback condition. For those participants even the mean RT for lying in dynamic feedback group is shorter than mean RT for true answers in random feedback group. This means there is a significant difference in RTs in the first and second block for those who performed in the random feedback condition first but there is no significant difference between first and second block for those that completed the dynamic feedback condition first. And sixth, sex, block and GABRA2 rs279858 genotypes, $F(2,24)=4.322$, $p=.025$, partial $\eta^2=.265$. This interaction contains too many groups for being meaningfully explained. Other main effects and interactions were not significant, all p values $\geq .066$. Therefore the results of this analysis show that reaction time is affected by the truthfulness of answer and by the genotypes of GABRA2 rs279858.

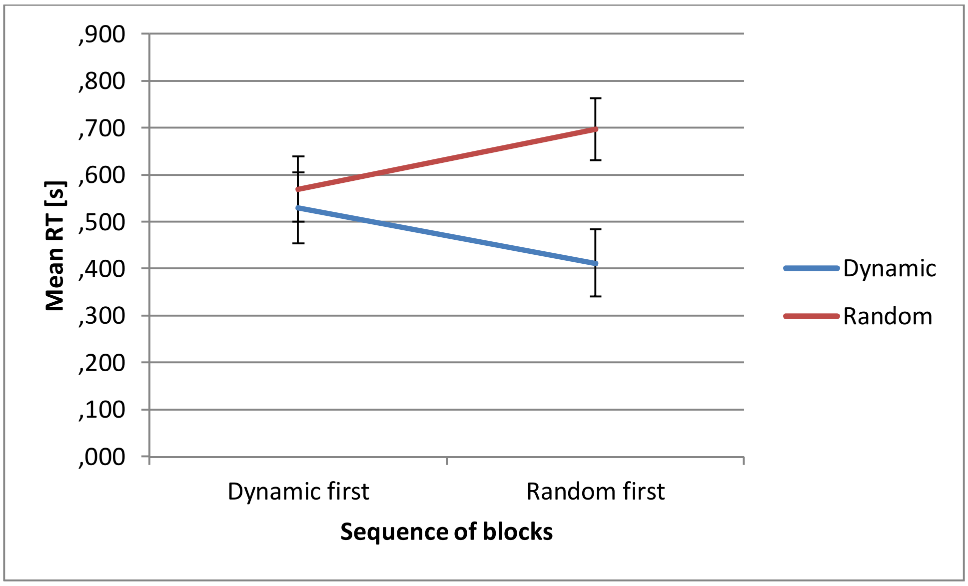


Fig. 3 Mean reaction times and 95% confidence intervals in sequence of blocks groups, dividend into feedback type groups.

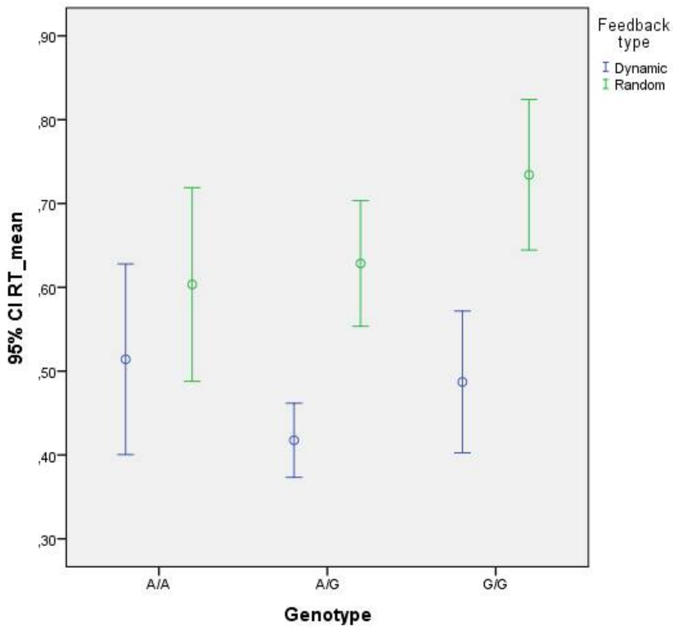


Fig. 4 Mean reaction times and 95% confidence intervals in genotype groups, dividend into feedback type groups.

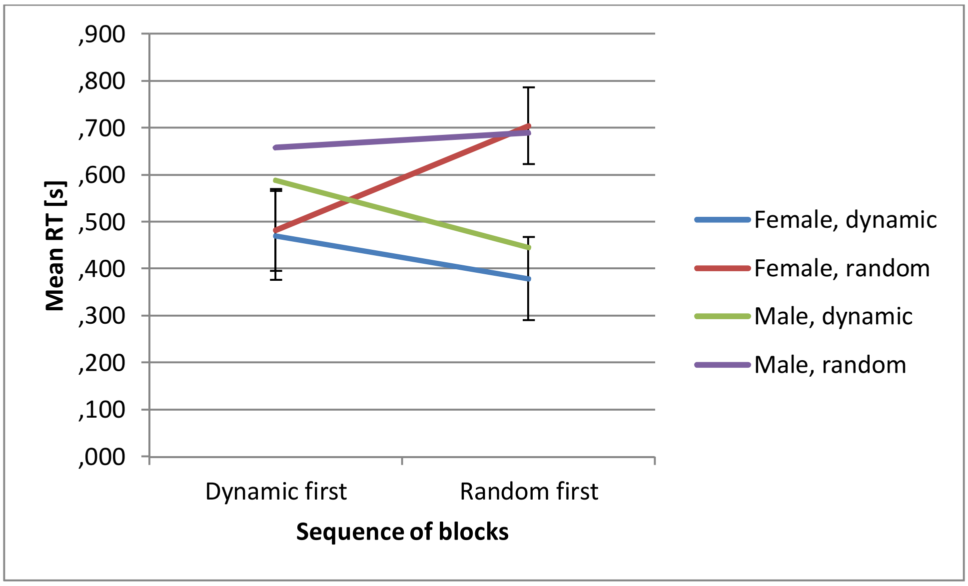


Fig. 5 Mean reaction times and 95% confidence intervals in sequence of blocks groups, dividend into sex and feedback type groups.

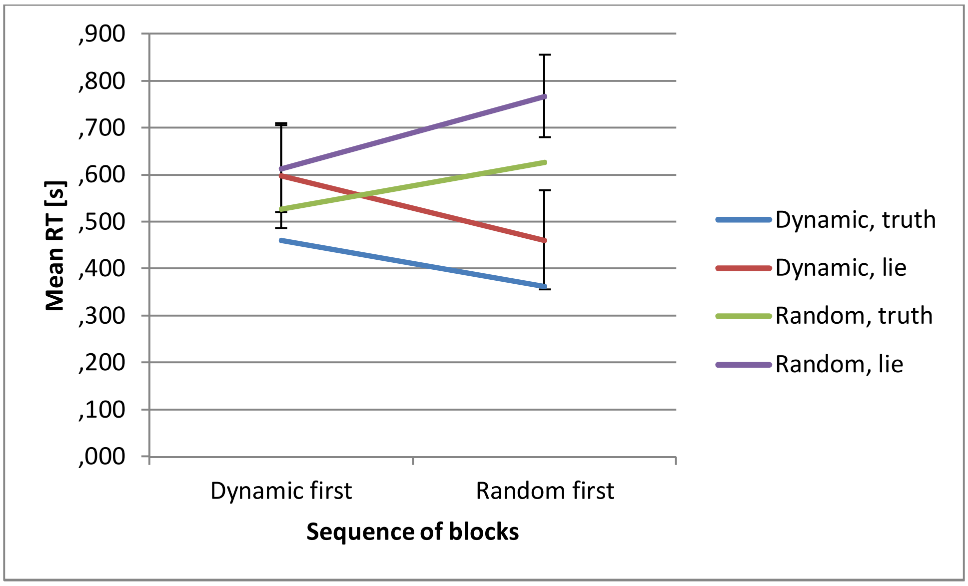


Fig. 6 Mean reaction times and 95% confidence intervals in sequence of blocks groups, dividend into feedback type and type of answer groups.

The analysis by the allele groups (A: A/A, G: A/G+G/G) is not reported because it did not reveal any new results.

Repeated Measures ANOVA with within subject independent variables feedback type (dynamic, random), type of answer (correct, incorrect) and between subject variables GABRA2 rs279858 allele groups (A: A/A+A/G, G: G/G), sex (male, female), sequence of blocks (dynamic first, random first) and dependent variable reaction time, indicated that the main effect of feedback type was statistically significant, $F(1,28)=122.159$, $p<.001$, $\eta_p^2=.814$. Mean RT for dynamic feedback condition was shorter ($M=.490$, $SD=.177$) than the mean RT for random feedback condition ($M=.675$, $SD=.223$). The main effect of type of answer was also significant, $F(1,28)=30.027$, $p<.001$, $\eta_p^2=.517$. Mean RT for true answer was shorter ($M=.517$, $SD=.155$) than the mean RT for lying ($M=.647$, $SD=.264$). The main effect of sex was significant as well, $F(1,28)=5.447$, $p=.027$, $\eta_p^2=.163$. Mean RT for males was longer ($M=.646$, $SD=.261$) than the mean RT for females ($M=.518$, $SD=.175$). And finally, the main effect for GABRA2 rs279858 allele groups was significant, $F(1,28)=4.278$, $p=.048$, $\eta_p^2=.133$. Mean RT for A (A/A+A/G) allele group was shorter ($M=.526$, $SD=.214$) than the mean RT for G (G/G) allele group ($M=.639$, $SD=.237$). The following interactions were also statistically significant: feedback type and sequence of blocks, $F(1,28)=63.829$, $p<.001$, $\eta_p^2=.695$ (this interaction was explained in the section discussing the effects of genotype), as well as feedback type and GABRA2 rs279858 allele groups, $F(1,28)=4.283$, $p=.048$, $\eta_p^2=.133$ (see all the means from Fig. 7). This means that RTs were shorter in dynamic feedback condition inside both allele groups, but RTs had no significant difference between random feedback condition in allele group A (A/A+AG) and dynamic feedback condition in allele group G (G/G). Other main effects and interactions were not significant, all p values $\geq .061$. Therefore the results of this analysis show that reaction time was affected by the truthfulness of answer given and by the allele groups of GABRA2 rs279858. The aforementioned analyses show that reaction times were longer for lying compared with the truth and that GABRA2 rs279858 seems to affect reaction time so that carriers of two G alleles have longer RT than carriers of at least one A allele.

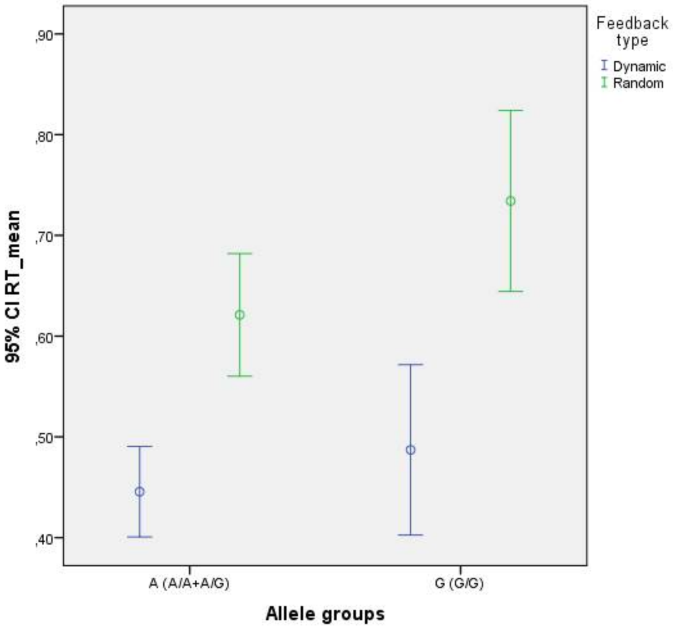


Fig. 7 Mean reaction times and 95% confidence intervals in allele groups, dividend into feedback type groups.

In order to better understand the effect of practice to the interaction of feedback type and sequence of blocks, a separate ANOVA with only the results of 2nd block that were divided into four sections (trials 1-60; 61-120; 121-180 and 181-240) was performed. Second block was chosen because during the first block participants had no way of knowing the difference between feedback types and therefore no way of adjusting their response strategy accordingly. Within subject variables were type of answer (correct, incorrect), section (1, 2, 3, 4), between subjects variables sequence of blocks (dynamic first, random first), sex (male, female), GABRA2 genotypes (A/A, A/G, G/G) and dependant variable reaction time. Three statistically significant main effects were found. First, type of answer, $F(1,19)=14.294$, $p=.001$, $\eta_p^2=.429$. Mean RT for truthful answer was shorter (M=.440, SD=.120) and mean RT for lying was longer (M=.524, SD=.246). Second, section, $F(3,57)=4.791$, $p=.005$, $\eta_p^2=.201$. For post hoc analyses pairwise comparisons were performed. There was significant difference between 1st and 3rd sections as well as 3rd and 4th sections. Mean RT for section 1 was longer (M=.486, SD=.188) than mean RT for section 3 (M=.456, SD=.169) but, mean RT for section 4 was longer (M=.493, SD=.235) than mean RT for section 3. And for feedback type, $F(1,19)=19.878$, $p<.001$, $\eta_p^2=.511$. Mean RT for dynamic feedback condition was shorter (M=.384, SD=.182) than mean RT for random feedback condition (M=.580, SD=.185). Statistically significant interaction was section, feedback type and GABRA2 rs279858 genotype, $F(6,57)=3.854$, $p=.003$, partial $\eta^2=.289$, but that interaction has too many groups to be meaningfully interpreted. Therefore there seems to be an effect of practice between sections 1 and 3 but the effect disappears in section 4 (possible reasons for that are tiredness, decay of sustained attention, risk aversion or a combination of them).

H6: Representatives of the GABRA2 rs279858 G allele generally have shorter reaction times in case of lying.

Repeated Measures ANOVA with within subject independent variable feedback type (dynamic, random), and between subjects variables GABRA2 rs279858 genotypes (A/A, A/G, G/G), sex (male, female), sequence of blocks (dynamic first, random first) and dependent variable reaction time, indicated that the main effect of feedback type was statistically significant, $F(1,24)=50.953$, $p<.001$, $\eta_p^2=.680$. Mean RT for dynamic feedback condition was shorter (M=.530, SD=.177) than mean RT for random feedback condition (M=.690, SD=.223). Three interactions were also statistically significant. First, feedback type and sequence of blocks, $F(1,24)=42.297$, $p<.001$, $\eta_p^2=.638$, (see all the means from Fig. 8). This means that RT was shorter in the dynamic feedback condition when random feedback condition was performed first but there was no significant difference between dynamic and random feedback condition when dynamic feedback condition was presented first. Second, feedback type, sex and sequence of blocks (dynamic first, random first), $F(1,24)=6.219$, $p=.020$, partial $\eta^2=.206$, (see all the means from Fig. 9), which means that females that performed random feedback condition first had longer RTs in random feedback condition than females in any other condition and also had longer RTs than males, who performed random feedback condition first. Third, feedback type, sex and GABRA2 rs279858 genotypes, $F(2,24)=5.355$, $p=.012$, $\eta_p^2=.309$, but this interaction contains too many groups for being meaningfully explained. Other main effects and interactions were not significant, all p values $\geq.068$. Therefore the results of this analysis show that reaction times for lying were not affected by the genotypes of GABRA2 rs279858.

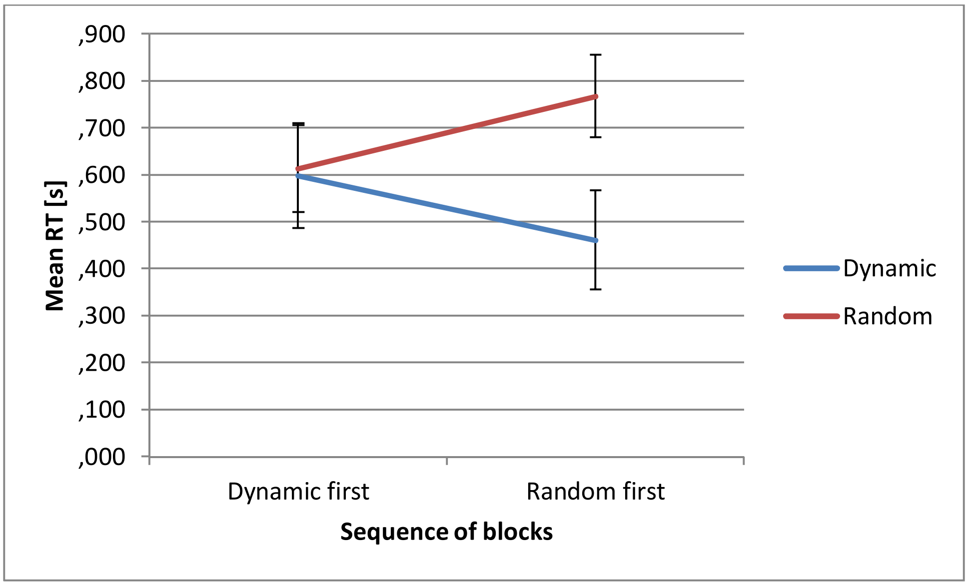


Fig. 8 Mean reaction times and 95% confidence intervals in sequence of blocks groups, dividend into feedback type groups.

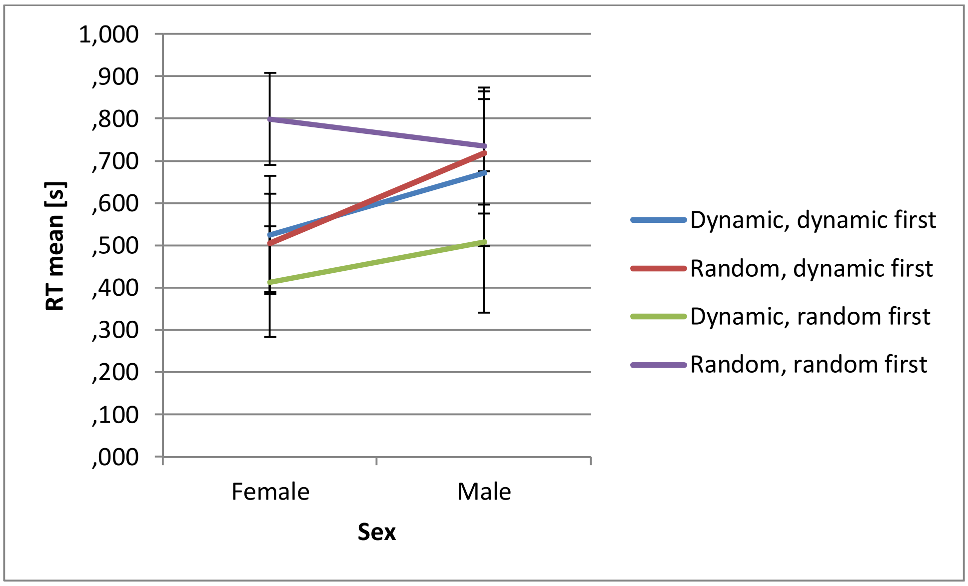


Fig. 9 Mean reaction times and 95% confidence intervals in sex groups, dividend into feedback type and sequence of blocks groups.

The analysis by the allele groups (A: A/A, G: A/G+G/G) and (A: A/A+A/G, G: G/G) are not reported because they did not reveal any new results.

H7: Faster liars tend to lie more (there is negative correlation between reaction time while giving incorrect answers and percentage of incorrect answers given).

Bivariate correlation with variables reaction time for lies and percentage of lies indicated that correlation between the two variables is not statistically significant, p=.191 and therefore the results of this analysis show that faster liars do not lie more.

# Discussion

The two main ideas of this study were investigated: the effect of the inhibitory potential of gene GABRA2 SNP rs279858 and the effect of feedback strategies on propensity to lie.

All together seven hypotheses were set, four of them about the effect of the gene GABRA2 SNP rs279858, one about the effect of feedback strategies, one about the cognitive complexity of lying (lying takes longer time) and one about the relation between cognitive adaptness (shorter RT while lying would show more adaptness) and lying frequency (the percentage of lies).

There was no main effect of GABRA2 SNP rs279858 unlike the H1 stated, but when sex factor was taken into account, significant differences appeared. Previous studies have found significant main effect of GABRA2 SNP rs279858 G/G allele on impulsivity (Villafuerte et al., 2013), and that the effect of G allele only exists on female subjects (Villafuerte et al., 2012). Similarly, in this study, female participants carrying allele G (AG+GG) lied more than male participants. Interestingly, the comparison between male and female A homozygotes (A/A) revealed that male participants lied more than female participants.

The percentage of getting caught while lying yielded quite similar results to the analyses of percentage of lying, which was somewhat expected, as in the random feedback condition getting caught happens randomly and therefore should correlate with percentage of lying. In the dynamic feedback condition different strategies used could return different percentages of getting caught but as there was no significant interaction of feedback type and GABRA2 SNP rs279858 there can be no effect of GABRA2 SNP rs279858 on the likelihood of being caught while lying in the ‘Circle Game’.

The feedback type did not alter the frequency of lying, so it seems that propensity to lie is a rather stable personality trait and is not significantly affected by the situational factors of lying.

There was a significant difference in RTs between answering truthfully and lying. It corroborates the theories that claim that lying is cognitively more demanding than truth telling (Christ, Van Essen, Watson, Brubaker, & McDermott, 2009, Walczyk, Harris, Duck, & Mulay, 2014). Verschuere, Suchotzki, and Debey (2015, cited through Suchotzki et al., 2017) have argued that meaningful RT measurement must meet three criteria: it needs to be precise (i.e., computer based), participants should be able to respond immediately after stimulus presentation (and instructed to respond as fast as possible) and at least 20 trials per condition must be measured. In this experiment all the criteria were met except participants were not instructed to respond as fast as possible. As the results still reflected significant difference in RTs between lying and truth telling one might argue that such instruction is not necessary. Not giving such instructions might even be beneficial as instructing to respond as fast as possible might motivate some participants to deliberately alter their response times, as non-reflectory reaction times are under voluntary control (Sip et al., 2013).

There was a significant effect of allele groups on RT, namely the G homozygotes had significantly longer RTs than A allele carriers (A/A+A/G). The results are contradictory to what was hypothesized (H5). It seems that higher NEO-PI impulsivity scores do not correlate negatively with RTs in the 'Circle Game', although test subjects with higher impulsivity have been shown to make decisions faster (and with higher rate of mistakes) (Dickman & Meyer, 1988). One reason for this might be that it was more difficult for participants with high impulsivity to focus on the relatively simple task for such a high number of trials. Lack of perseverance is also one of the component traits of the multidimensional behavioural construct impulsivity (Whiteside & Lynam, 2001). Previous studies have found that carriers of the gene TPH2 SNP rs4570625 G allele are also characterized by both impulsivity and deficiencies in executive functions and self-control (Muraven et al., 2006, Mead et al., 2009). One might argue that in this case the RTs should have been longer towards the end of the block but that might not be the case as the number of trials was known to the participants beforehand and so might have had a demotivating effect for the high impulsivity participants from the start.

There was also a significant interaction of feedback type and sequence of blocks. Interestingly, participants that performed the dynamic feedback condition first had no significant difference in RTs between first and second block but there was a difference among participants that performed the random feedback condition first, namely their mean RTs in the second block were shorter than in the first block, which possibly indicates the effect of practicing. One possible explanation for this effect only existing in the group that performed random feedback condition first is that participants in this group learned that answering strategy has no effect on the point score in the 'Circle Game' and responded more randomly also in the second (dynamic) block so the effect of practicing was clearly visible. Participants in the dynamic feedback strategy first group on the other hand learned that answering strategy is important for gaining a better score in the 'Circle Game' and therefore were more considerate in the second round which increased reaction times and cancelled the effect of practicing. To further investigate the effect of practicing a second analysis was performed with only the results from second block for all participants included. The block was divided into 4 sections and it appeared that there was a significant difference in mean RT between first and third section (the latter having shorter mean RT) which confirms the effect of practicing. Interestingly though, in the fourth block mean RT was no different from first and second block but was longer than mean RT in third block. That may be explained by risk aversion (Kahneman & Tversky, 1979) – higher value is placed on the points they own than was placed on the points they did not own (but could gain) in the earlier sections. Yet, as the order effects possibly emerging from the accumulating practice on the one hand and tiredness/boredom on the other hand were not directly controlled in this study, the above considerations remain rather speculative.

## Conclusions

This experiment revealed a significant RT deception effect and thus showed that RT is an effective measure for the study of deception. There was also a significant effect of gene GABRA2 SNP rs279858 on the RT in the 'Circle Game'. No significant main effect of gene GABRA2 SNP rs279858 on the propensity to lie was discovered but there was a significant interaction between genotypes and sex - allele A homozygosity increases lying for men and decrease lying for women, but a crossover effect is present, meaning that G allele seems to increase lying for women and decrease lying for men. No correlation between the propensity to lie and RT while lying was found. And finally a significant interaction between feedback strategy and sequence of blocks appeared that would need further research to be fully understood.

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