Trust in others: Where Game Theory Meets Neuroscience

BY

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Abstract

Virtually every interaction in life involves trust, i.e., the notion that we believe that another person will honor an agreement. Indeed, it would be impossible to formally enforce all but a fraction of agreements within relationships we have in everyday life. This concept, in economics, is captured by the notion of an incomplete contract, which is pervasive in most relationships. For example, imagine that you contract with a builder to renovate your house. Any homeowner knows that such a project involves hundreds of decisions unanticipated at the start of the project, many of which add to its cost. From defense contracting, to high-tech startups, to inter-familial relationships, such contracts are a fact of life. The simplest model of such an incomplete contract is a trust game, in which a trustor sends money to a trustee, anticipating that the trustee will share the gains of this trust. In this paper I explore the determinants of the evaluation of trustworthiness by a trustor. I combine behavioral data in an economics experiment with physiological and psychological information to refine our knowledge regarding the decision to trust another person. My thesis is the first to combine this wide-ranging information for this question, and lays the foundation for future studies that will explore the role of biology in trust.

Résumé

Quasiment toutes les interactions humaines impliquent de faire confiance, c'est-à-dire de croire qu'une autre personne honorera un accord. En effet, il serait impossible de faire respecter formellement tous les accords qui existent implicitement au sein des relations que nous avons dans la vie quotidienne. Ce concept, en économie, est capturé par la notion d'un contrat incomplet, qui est omniprésent dans la plupart des relations. Par exemple, imaginez que vous passez un contrat avec un constructeur pour rénover votre maison. Tout propriétaire de maison sait qu'un tel projet implique des centaines de décisions imprévues au début du projet, dont beaucoup ajoutent à son coût. Que ce soit pour des contrats de défense, des startups, ou des relations interfamiliales, ces contrats se retrouvent partout. Le modèle le plus simple d'un tel contrat incomplet est le ‘jeu de confiance’, dans lequel une personne donne de l'argent à une autre, en anticipant que le récipiendaire partagera les gains de cette confiance. Dans cet article, j'explore ce qui détermine chez une personne la fiabilité du récipiendaire potentiel. Je combine les données comportementales d'une expérience d'économie et des informations psycho-physiologiques afin de compléter nos connaissances concernant les décisions de faire confiance à autrui. Mon manuscrit est le premier à combiner des informations d'une telle envergure pour explorer cette question, et jette les bases pour de futures études qui permettront d'étudier le rôle de la biologie dans les décisions de confiance.

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CHAPTER I – Theoretical Background and Literature Review

Introduction

Game theory is the mathematical study of strategic decision making. It applies to situations where the outcome of an individual’s strategy depends on the actions of others. Games are a useful tool to analyze interactive decision-making in the laboratory setting. Through their simplicity, games make behavioural measurements precise. On the other end, these behavioural measurements can help refine mathematical models of decision-making.

Game theory is applied heavily in biology, especially in the context of the evolution of cooperation. The payoff in evolutionary game theory is fitness, the ability to survive and reproduce (Haldane, 1924). Here cooperation is defined as a behaviour that incurs fitness costs to an individual to the benefit of other members of the group (Bowles & Gintis, 2003). At first glance, a fitness maximization view of natural selection does not seem compatible with acts that contribute to the public good, and could not account for the fact that a good proportion of people cooperate in such scenarios (Dawes & Thaler, 1988). Yet the evolutionary mechanisms that promote cooperative behaviour could be accounted for, provided one adopts a genes-eye view of natural selection, as opposed to an individual one. From this perspective it is inclusive fitness, the sum of the individual's reproductive success, as well as his relative's, with their varying degrees of shared genetic makeup that drives the evolution of cooperation (Hamilton, 1964).

Another hypothesis for the emergence of cooperation is reciprocity in social networks (Nowak, 2006). Axelrod (1984) demonstrated that cooperation could emerge from the formation of reciprocal relationships in a repeated game with guaranteed future encounters among non-kin. Evidence from a labour market game suggests that humans possess a trait called "strong reciprocity" a predisposition to cooperate with others at a personal cost even when it is implausible that these costs will be repaid (Fehr et al., 1997; Gintis, 2000). While human cognitive and linguistic capacities have led to the formulation of general norms of social conduct that extend beyond these simple mechanisms, the ability to predict non-contractual reciprocity in an opponent remains essential to everyday functioning in human society.

Many of our everyday interactions involve scenarios where our opponent may have more or better information about a situation, this asymmetric information[1] often leads agents to construct contractual agreements. Trust enables cooperation in risky transactions that are costly to enforce or cannot be enforced by external

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[1] Following Definition 9.21 (Nisan et al., 2007): A game with strict incomplete information for a set of n players is given by the following:

(i) For every player i , a set of strategies X_i

(ii) For every player i, a set of types T_i. A value $t_i \in T_i$ is the private information of player i.

(iii) For every player i, a *utility function* $u_i: T_i \times X_i \times ... \times X_n \to \mathbb{R}$, where $u_i\ (t_i, x_1, ..., x_n)$ is the utility achieved by player i, if his type (private information) is t_i, and the profile of actions taken by all players is $x_1, ..., x_n$.

control mechanisms. The downside of trust is that it requires agents to accept vulnerability (Deutsch, 1962). Arrow (1972) argues that there is an element of trust contained in virtually every financial transaction. Furthermore, it is widely argued that trust helps promote economic development by reducing transacting costs, which has led to raised interest in the factors that affect the likelihood of trust in economic transactions (Camerer, 2003; Knack & Keefer, 1997; Putnam, 1993; Zak, 2001). Using a computational model, Braynov et al. (2002) demonstrated that optimal trust in a society (where the level of trust that a rational agent should exhibit in transactions equals the "trustworthiness" of his/her opponent), leads to maximization of the amount of trade and of agents' utility functions[2]. Trust in one's counterpart is a belief that could be quantified by a subjective probability about whether or not he will reciprocate. On occasion we will refer to this as the opponent's level of "trustworthiness" or type.

When making a risky decision about whether or not to trust an individual, we often form a rapid belief about our opponent based on contextual information. These judgments are likely to be based on the facial appearance of our opponent. Willis & Todorov (2006) have demonstrated that a 100 ms exposure to a face is sufficient to make a variety of trait judgments, including "trustworthiness". These judgments are likely to be rooted in human evolutionary history. In 1872, Charles Darwin first argued for the evolutionary basis of human and animal emotional signalling from anecdotal evidence on the universality of facial traits and expressions. Over a century later psychologists confirmed that certain facial

[2] Utility functions are defined in Section 1.4.

expressions and traits are labelled the same way, across cultures (Ekman & Friesen, 1971; Ekman, 1982; Fridlund et al., 1987; Hassin & Trope, 2000 & Todorov et al., 2008).

In this study, we make two main contributions. First, we create a reliable instrument to assess how people make trust choices in a face-to-face encounter with an opponent. That is, we ask subjects to create a distribution of play for a set of faces that will be used in many future experiments. Previous experiments using a similar paradigm consisted of either stylized representations of faces or made use of still photographs of subjects that were not controlled for gender, age or ethnic background (Scharlemann et al., 200l; Eckel & Wilson, 1999). Second, we demonstrate irrefutably, and in a controlled setting that people form consistent beliefs about the strategy of an opponent based on facial features.

1.1 What Faces Reveal

What do stable (non-emotive) facial features reveal? One relatively obvious assertion is that faces can reveal information about reproductive health. For example, pictures of women with higher rates of late follicular estrogen are rated higher on attractiveness, health and femininity (Law Smith et al., 2006). Roberts et al. (2005) found that faces of men with major histocompatibility complex (MHC)[3] heterozygosity at three loci were rated as more attractive by women than their homozygous counterparts. Not surprisingly, Smith et al. (2009) demonstrated

[3] Proteins encoded by MHC play an essential role in regulating the immune response.

that the level of attractiveness of an individual can influence trusting behaviour towards him/her. Solnick & Schweitzer (1999) found that attractive players received higher earnings in economic games. Nonetheless, it is difficult to make an inference about how these morphological features reflect biological dispositions for traits that are not directly relevant to reproduction.

We know that in male development, a high testosterone-estrogen ratio facilitates the lateral growth of the mandibles, cheekbones and the chin, features associated with masculinity and dominance (Schaefer et al., 2005). These markers for testosterone are also associated with reduced perceived trustworthiness. Stirrat and Perret (2010) found that in the context of a game, males with higher facial-width ratios (wide faces) were more likely to exploit their counterpart's trust, and were trusted less. Furthermore, they found that participants in their study were more likely to rate images with a lower facial-width ratio as trustworthy. Testosterone is thought to influence aggression through androgen receptors in the orbitofrontal cortex, a region of the brain implicated in self-regulation (Mehta & Beer, 2010). Its effects on reciprocity and giving are direct. Van Honk et al. (2011) found that upon receiving a dose of testosterone, women rated a stranger's face as less trustworthy than when they were given a placebo. The administration of testosterone was also shown to decrease generosity in a game (Zak et al., 2009). While physiognomy, the "science" of reading character from stable facial features has been widely dismissed since the early 19th century, the fact that most individuals subscribe to a "naïve physiognomy" in their everyday interactions is not a matter of contention (Todorov et al., 2008).

1.2 Neuroscience and Decision-making

Within the past few decades, neurological studies have revealed that without emotional cues the quality of our decisions can be seriously compromised. Case studies demonstrate that patients with bilateral lesions of the ventromedial prefrontal cortex (VMPFC) develop impairments related to decision-making in situations of uncertainty and complexity, even though their intellectual abilities are generally well-preserved (Barrash et al., 2000; Damasio, 1979; Eslinger & Damasio, 1985; Damasio et al., 1991; Damasio, 1994 & Bechara & Damasio, 2005; Dimitrov et al., 1999). The VMPFC is thought to incorporate visceral feedback into the decision-making process. Damasio's "somatic marker hypothesis" (1994) maintains that in making decisions under uncertainty, humans evaluate the incentive value of a choice with the help of changes in their bodily state (e.g., endocrine release, heart rate, sweating).

An fMRI study has revealed an inverse coupling between the amygdala and the VMPFC, while anatomical studies have confirmed the presence of amygdalar axonal terminations in the prefrontal cortex (Ghashghaei et al., 2007; Urry et al., 2006). The amygdala is implicated in the learning of automatic fear responses and the consolidation of emotional memories (Le Doux, 2000; McGaugh, 2004). This region sends impulses to the autonomic nervous system (via the hypothalamus), which regulates the "fight or flight" or acute stress response, inducing physiological changes that prime an organism for fighting or fleeing[4].

Patients with bilateral amygdala damage have shown deficits in the processing of threatening faces (Calder, 1996). Most notably, Adolphs et al. (1998) demonstrated that patients with bilateral amygdala damage could not distinguish between trustworthy and untrustworthy faces. Furthermore, an fMRI study has found that the amygdala is involved in evaluations of face trustworthiness in healthy subjects[5] (Engell et al., 2007). The amygdala appears to track the valence of trustworthiness, regardless of whether subjects were making trustworthiness judgments or not (Winston et al., 2002).

According to advocates of the "somatic marker hypothesis", the amygdala and orbitofrontal cortex (an area within VMPFC) are parts of an automatic neural circuit that play a critical role in decision-making under uncertainty. This is consistent with Zeeb and Winstanley's (2011) finding that rats with excitoxic lesions in the basolateral amygdala and orbitofrontal cortex consistently chose riskier gambles, with immediate rewards. As a final point, Bechara et al. (2003) have shown that human subjects with VMPFC or bilateral amygdala damage fail to produce somatic signals associated with the "fight or flight" response, in anticipation of risky gambles.

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[4] Ex: Increased heart rate or sweating.

[5] This response was best predicted by consensus ratings (as opposed to individual ratings) of this trait.

1.3 Multiple Nash Equilibria and Coordination Games

The standard solution in a finite, non-cooperative game is the Nash Equilibrium (N.E.). Following Definition 1.5 (Rasmusen, 2007) a strategy profile s^* is a N.E. if no player has an incentive to deviate from the strategy given that no other player deviates. Formally, let (S, π) be a game with n players, where S_i is the strategy set for player i ($S = S_1 \times S_2 \times \ldots \times S_n$) and $\pi = \pi_1((s), \ldots, \pi_n(s))$ is the payoff function for $x \in S$. Then,

$$\forall_i, \qquad \pi_i \in S_i, \qquad \pi_i(s*_i, s*_{-i}) \geq \pi_i(s'_i, s*_{-i}), \quad \forall\, s'_i$$

Some games include multiple admissible Nash equilibria, therefore there are several solutions that are stable. Coordination games are the simplest form of these games (See Fig. 1). In a subclass of these games called "matching tasks" or "tacit coordination games", agents are asked to match strategies or in other words, coordinate on one of potentially many strategies without direct communication.

	L	***R***
U	A, a	**C, c**
D	**B, b**	D, d

$$\pi_1 : A > B, D > C \quad \pi_2 : a > c, d > b$$

Fig. 1 Two-player coordination game. Subjects are rewarded if they coordinate on the same strategy (grey rectangles).

Whenever a human subject is asked to play a game, a label is assigned to each strategy. In the formal representation of the game the only relevant component in a game is the utility entry in the payoff matrix, not the label. If humans acted as the theory would predict then they too should be indifferent about any labels that might be attached to a strategy. And where the strategies available to each agent are entirely symmetrical, we wouldn't expect any correlation between the strategy choices of different human players. But humans possess the ability to use labels (or “salient features”, qualities that make an item stand out from its neighbours) to coordinate on outcomes (Bacharach & Stahl, 2000; Bacharach, 2006; Mehta et al., 1994 & Schelling, 1960). Such solutions are commonly referred to as “focal point” or “Schelling point” equilibria. The ability to coordinate on “salient features” is typically tied to the detection of novel visual features, common experiences or cultural repertoire among others (Krupka & Weber, 2008; Snow et al., 2008).

“Social norms” are a common explanation in economics for anomalous prosocial behaviour, and one may use tacit coordination games to identify them (Mehta et al., 1994; Krupka & Weber, 2008; Young, 1998). Social norms or conventions can be defined as shared perceptions about the appropriateness of different behaviours and beliefs. A player without any regard for social norms would always choose the payoff-maximizing action. Krupka and Weber (2008) account for how choice behaviour might change, even when choice environments are payoff equivalent, as a function of how social norms differ between two contexts.

Subjects in the Krupka and Weber study played a tacit coordination game in which their goal was to anticipate the extent to which others will rate an action as socially appropriate or inappropriate. In our study, respondents will play a tacit coordination game in which their goal is to anticipate the belief of a random player about another player, and respond accordingly. This method will establish whether there is a common belief about how a particular face would act in a game. It will also provide a monetary incentive for subjects to think harder about their responses.

We make no inference about whether these labels or "signals" (information revealed from faces) are honest. They may or may not reveal the player's actual type. In biology, signalling can simply refer to the act of revealing private information to an opponent (Johnstone, 1993). Theoretical ecologists commonly argue that a signal must be costly in order for it to be reliable (Grafen, 1990). In other words, an organism will incur fitness costs onto itself to "signal" the fact that he has excessive fitness to a potential mate (the "handicap principle"). With regards to humans, an agent "signals" his type by incurring a cost to separate himself from other types (establishes a "separating equilibrium"[6]). This is the only

[6] For the simplest example of separating equilibria, suppose there are two types of workers: high ability and low ability. There is some fraction of high and low ability workers in a population. Let y_H and y_L represent the yield produced by high quality workers and low quality workers respectively. Both types of workers can invest in

definition of “signalling” that is valid in the behavioural game theory literature. Our assumption is that humans have evolved a costless, effective communication system based on facial appearance.

1.4 Expected Utility, Risk and Ambiguity Aversion

Utility (u) is an abstract variable that is used to describe preferences over outcomes (X). The expected utility for a risky decision or gamble (G) is obtained by the following function:

$$U(G) = \sum p_i \ . u(X_i)$$

We may not always know the probabilities that are associated with different states of affairs, in which case we may assign subjective probabilities to them (Anscombe & Aumann, 1963; Savage, 1954; Howie, 2002). A risk-averse individual is one that is willing to accept a more certain gamble, with a lower expected payoff to an uncertain bargain. In 1961, Ellsberg outlined the two-colour problem where an agent is rewarded if he draws a red ball from two urns with 10 coloured balls (Urn I and II). Subjects are told that urn II is composed of 5 blue balls (B) and 5 red balls (R), but the proportion of red and blue balls in urn I is

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education $e \in \{0,1\}$. Let c_H and c_L represent the cost of education for high and low ability workers respectively, where $c_L > c_H$, where education does not increase the productivity of either type worker. Let w represent wages, therefore: $w(e = 1) = y_H \ and \ w(e = 0) = y_L$. Where $y_H - c_H > y_L > y_H - c_L$ the separating equilibrium is for all high ability workers to obtain education and all low ability workers not to, given that $w(e = 1) - c_H = y_H - c_H > y_L$ and $y_H - c_L < y_L$.

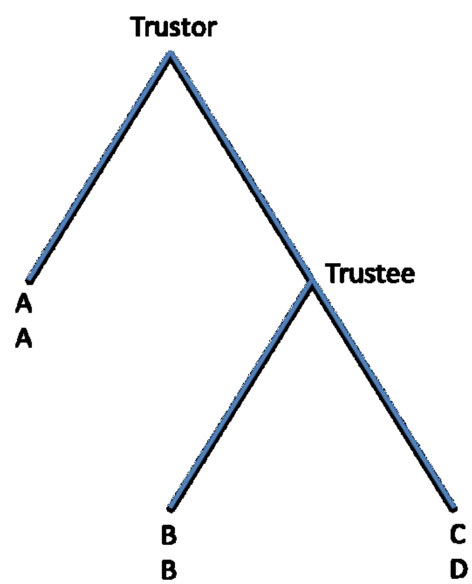
unknown. With respect to each urn, subjects are indifferent about gambles between B & R.

Consider a lottery where a ball is drawn at random from an urn ($i = I \text{ or } II$). A player will receive $50 if the colour chosen is $R \text{ or } B$. Most people are indifferent with regards to $R_I \sim B_I \text{ and } R_{II} \sim B_{II}$, but their actions reveal a preference for R_{II} over R_I and B_{II} over B_I, which necessitates the assumption that $p(R_I)$ & $p(R_{II}) < 0.50$. This relates to the human propensity of ambiguity aversion, a preference for known risks in favour of unknown ones.

Beliefs about an opponent do not directly translate to strategies. A person's decision to trust depends heavily on both beliefs about whether or not his/her counterpart will reciprocate and their levels of risk-aversion (Schechter, 2007). Subjects who rate low on ambiguity aversion are generally more optimistic about outcomes, which could mean that they are more likely to trust or reciprocate (Pulford, 2009).

1.5 The Trust Game

Berg, Dickhaut and McCabe (1995) have developed what has now become a standard test for trust in economic decisions, the one-shot trust or investment game. This game controls for some of the alternative explanations of reciprocal behaviour such as repetition and reputation. In the Trust game the Trustor receives some endowment. Whatever the Trustor sends from this endowment will be tripled in the account of the Trustee. The Trustee then decides what amount of this investment to return. Where payoffs are equivalent to utilities ($\pi = u$), the subgame perfect N.E. (the Nash Equilibrium for every subgame) can be solved by backward induction. If the Trustor chooses to trust, the Trustee can receive the highest possible payoff of 3A by choosing D. And since A > D, the Trustor should not trust. Berg et al. (1995) found that in anonymous game the average amount repaid was about 95 percent of what was invested.



$$Trustee: D > B > A \; (C = 0, D = 3A, B = \frac{3A}{2})$$

Fig. 2. Decision tree for the trust game.

Furthermore, Berg et al. (1995) and Brulhart (2012) discovered that only a small minority of Trustors adopt the subgame perfect N.E. of no trust, and that the level of social information has a big impact on the amount reciprocated by the Trustee. Where $\pi \neq u$, a player will

$$TRUST\ iff: p\ u(B,B,\alpha) + (1-p)\ u(C,D,\alpha) \geq u(A,A,\alpha)$$

$$RETURN\ iff: u(C,D,\alpha) \leq u(B,B,\alpha)$$

Information about the type of an opponent ($T := \{t_2\ ; 1 - Trustworthy, 2 - Not\ Trustworthy\}$) should therefore be correlated with strategy choice. The Trustor's knowledge or belief about the Trustees' type assigns the subjective probabilities ($p = p(t_2 = 2)$ & $1 - p = p(t_2 = 1)$) to her utility function, whereas α represents her preference over the player's type. If participants have any preferences over different opponents, we would expect them to return the same amount to every player, as a Trustee. Such a prediction, however, is not consistent with behavioural results, and over the years many models of preference have emerged to deal with such other-regarding concerns (Bolton, 1991; Bolton and Ockenfels, 2000; Cox, et al., 2001 & Fehr and Schmidt, 1999).

In this game, the Trustee is in the position of a "dictator", he determines the allocation of $3A$ (the Trustor has no say over this). Dictator games[7] are an important paradigm for studying other-regarding behaviour, without these "exotic" preferences, the best responses is to not return any amount (Frohlich &

[7] Not formally a game because the dictator's action does not depend on the action of his counterpart.

Oppenheimer, 2001). In our experiment, we will pair information about our subject's disposition and the type of their opponent to determine what factors can account for these preferences.

1.6 General Hypotheses

We hypothesize that facial features factor into judgments about whether or not to trust someone. We also predict that our subjects will have a preference over the type of their opponent, based on his facial features and will use these features to make inferences about an opponent's other-regarding preferences. We also predict that subjects will make use of somatic markers to guide their judgments about what their opponents will do.

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CHAPTER II - Methodology

The trust game our subjects were asked to consider was described as follows:

“Two players, a Trustor and a Trustee, each receive $10. The Trustor decides whether to send $0 or all $10 to the Trustee. If the Trustor sends $0, the game ends, with each player pocketing their $10. If the Trustor sends $10 to the Trustee, the amount is tripled: the Trustor now has $0 and the Trustee receives $30.

The Trustee then decides how much money to return to the Trustor. The Trustee can:

Return $0 and Keep $30

Return $5, and Keep $25

Return $10 and Keep $20

Return $15 and Keep $15

Return $20 and Keep $10

The game is played once, and the Trustor and the Trustee never, ever, play this game with each other again.

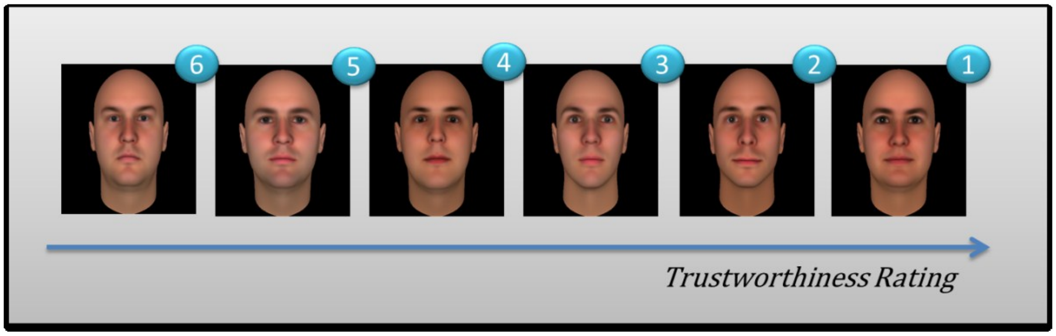
Both the Trustor and the Trustee know the rules of the game, and they both know that the other knows the rules of the game.”

2.1 The Faces

In our experiment, participants view faces of a trustee on a computer screen and are asked to report how much they thought the Trustee would return if the Trustor sent him $10[8]. The screen shows the Trustor on the left, and the Trustee on the right.

The faces were selected to have a range of trustworthiness ratings, controlling for gender and skin tone. We obtained these images from the dataset of 300 randomly generated computer faces created by Oosterhof and Todorov (2008, see Fig. 3). These faces were created on Facegen Modeller v 3.1. The Todorov group had previously identified the trait dimensions that accounted for the highest degree of variance in people's judgments based on extensive behavioural studies. Two hundred and seventy eight undergraduates subsequently rated these computer generated faces on 9 trait dimensions: attractiveness, likeability, trustworthiness, competence, extroversion, dominance, meanness, frightening and threatening. The trait judgments were measured on a 9-point Likert scale (1 = not at all to 9 = extremely). Faces from this dataset have been used in a previous behavioural game theory study (Schlicht et al., 2009).

[8] The screen might also describe one of the players in the game in words.



Face #	Attractive	Competent	Trustworthy	Dominant	Mean	Frightening	Extroverted	Threatening	Likable
[redacted]			6.10	[redacted]					
2	3.51	4.95	5.17	5.48	4.33	3.82	5.48	4.95	5
[redacted]			4.52	[redacted]					
4	3.17	4.567	4.103	6.30	5.41	5.28	4.94	5.81	5
[redacted]			3.72	[redacted]					
6	2.143	3.82	2.93	6.17	6.44	6.25	3.54	6.80	3.90

Fig. 3. The faces used in our experiment and their ratings for 9 different traits on a Likert scale (1-9). Faces were ranked from 1-6, with Face 1 ranking highest, and Face 6 ranking lowest on the Trustworthiness scale.

We restricted our selection of traits to trustworthiness due to its relevance to the research topic, and strong negative correlations between ratings (Likert-scale 1-9) on this trait and 4 other traits in the Todorov dataset: “Competence”, “Mean”, “Frightening” and “Threatening” (See Fig. 4). In fact, Oosterhof & Todorov (2008) maintain that judgments of trustworthiness and dominance are sufficient to account for much of the variance in face evaluations.

	Tr_Tru~e	Att_Tr~e	Comp_T~e	Dom_Tr~e	Mean_T~e	Fright~e	Extr_T~e
Tr_Trustee	1.0000						
Att_Trustee	0.6523	1.0000					
	0.0000						
Comp_Trustee	-0.9503	-0.7692	1.0000				
	0.0000	0.0000					
Dom_Trustee	-0.2446	0.3055	0.0691	1.0000			
	0.0000	0.0000	0.1547				
Mean_Trustee	-0.9321	-0.4824	0.8050	0.5326	1.0000		
	0.0000	0.0000	0.0000	0.0000			
Fright_Tru~e	-0.9295	-0.5105	0.8907	0.4887	0.9414	1.0000	
	0.0000	0.0000	0.0000	0.0000	0.0000		
Extr_Trustee	0.9446	0.5940	-0.8449	-0.3514	-0.9714	-0.9182	1.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Threat_Tru~e	-0.9544	-0.5071	0.8130	0.4627	0.9934	0.9281	-0.9740
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Likable_Tr~e	0.8600	0.8788	-0.8583	0.1047	-0.7599	-0.7185	0.8717
	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000

Fig. 4 Pairwise correlation between the 9 trait dimensions on the 6 faces we selected from the Todorov dataset.

2.2 Design

As mentioned, subjects were shown hypothetical players playing the trust game, and asked to report the most likely choice of the Trustee if the Trustor sends $10. Subjects are paid if their response matched the response of another randomly selected subject. There was no communication between subjects ("tacit coordination game").

The order of stimulus presentation was randomized. Our participants had to consider scenarios where either one of the faces, themselves ("you") or a "randomly-selected person in the room" was in the position of the Trustor or Trustee (See Fig. 4). After 7s exposure to the stimulus their choice alternatives appeared on the screen (See Fig. 7). This was followed by a blank screen for 20s to insure that their physiological responses returned to baseline (Banks et al., 2004).

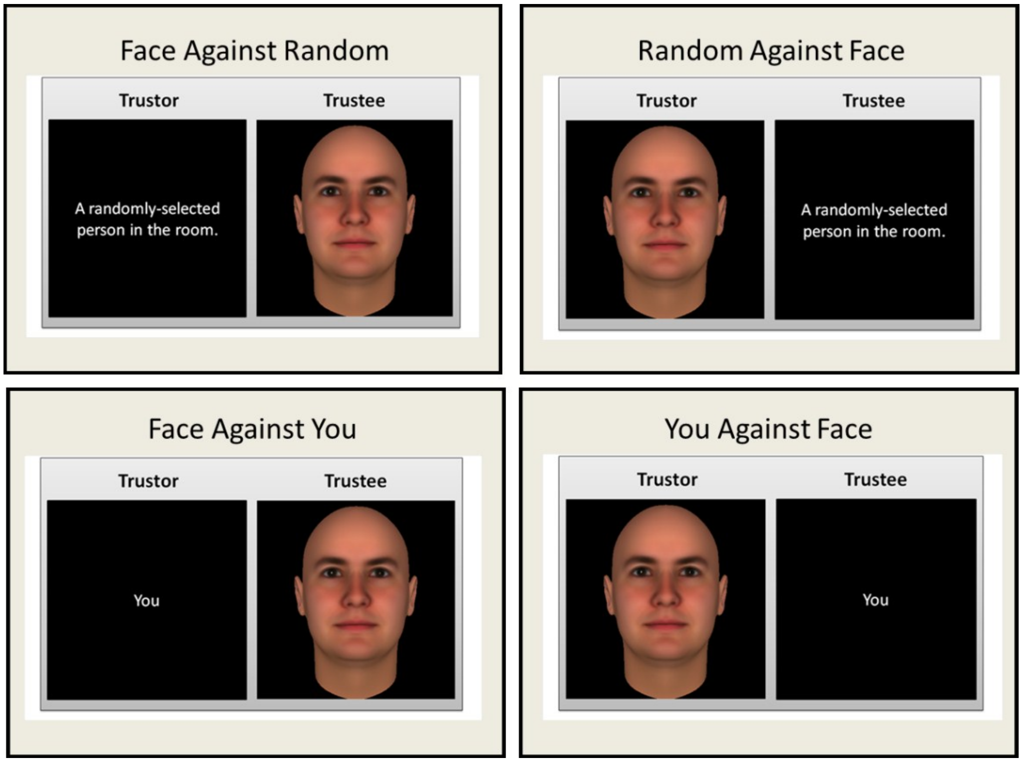


Fig. 5. 1- Face 1 as the Trustee vs. a “randomly-selected person in the room” (“Face Against Random”). **2-** A “randomly-selected person in the room” as the Trustee vs. Face 1 (“Random Against Face”). **3-** Face 1 as the Trustee vs. the subject “you” (“Face Against You”). **4-** The subject as the Trustee vs. Face 1 (“You Against Face”).

	Face	Random	You
[redacted]			
Random	6	1	1
[redacted]			

Fig. 6 This table summarizes the number of stimuli that appeared for each scenario. For example, there were 6 stimuli for "Face Against Random", which corresponds to situations where one of the six faces was the Trustee and a "randomly-selected person in the room" was the Trustor.

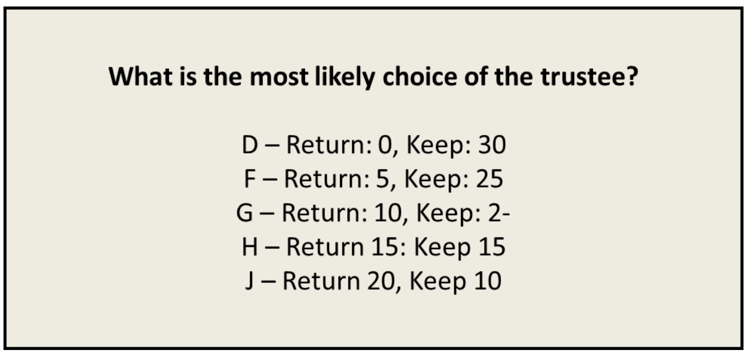


Fig. 7 The choice alternatives that appear on the screen 7s after stimulus presentation. Subjects enter their response by choosing one of the corresponding keys on their keyboard. Pressing a key prompts the 20s interstimulus interval.

Upon completing the first session of the experiment subjects were asked to fill the following scales and instruments:

Perceived Stress Scale The Perceived Stress Scale (PSS) (Cohen, 1988) is the most common instrument for measuring perceptions of stress. The PSS comes in three different versions: PSS-14, PSS-10 and PSS-4. We employed the PSS-10, a

10-item inventory with a 5 point scale where responses range from 0-4 (0 = "never" , 4 = "very often"). On the PSS, subjects are asked to report the frequency of feelings of anxiety regarding potentially stressful events. The total PSS score is obtained by reversing responses to the 4 positive items (4, 5, 7, 8) and summing across all scale items.

Risk and Ambiguity We measured subjects' risk and ambiguity preferences with standard hypothetical choices between gambles with known and unknown probabilities. This task was not incentivized. For both instruments subjects are given a choice between two lotteries (Left or Right). For the Risk Instrument subjects are told that outcomes occur with 5 chances in 10 for both lotteries. For the ambiguity instrument subjects are told that each outcome occurs in the Right lottery with an unknown number of chances out of 10. Subjects are asked to circle the option that corresponds to the lottery they prefer. These instruments were adapted from Engel-Warnick et al. (2007). The scores for both instruments are obtained by summing up all left column responses.

Choose the Lottery You Prefer In Each Row of the Table

	Left Lottery				Right Lottery	
Decision	5 Chances In 10	5 Chances In 10	Your	Choice	5 Chances In 10	5 Chances In 10
1	$26	$26	Left	Right	$24	$29
2	$24	$29	Left	Right	$22	$32
3	$22	$32	Left	Right	$20	$35
4	$20	$35	Left	Right	$18	$38
5	$18	$38	Left	Right	$16	$41
6	$16	$41	Left	Right	$14	$44
7	$14	$44	Left	Right	$12	$47
8	$12	$47	Left	Right	$10	$50
9	$10	$50	Left	Right	$8	$53
10	$8	$53	Left	Right	$6	$56
11	$6	$56	Left	Right	$4	$59
12	$4	$59	Left	Right	$2	$62

Fig. 6. The ambiguity aversion instrument adapted from Engle-Warnick (2007)

Please Answer this Hypothetical Survey Question
Choose the Lottery You Prefer in Each Row of the Table

	Left Lottery					Right Lottery		
Decision	5 Chances In 10	5 Chances In 10	Lotter y cost	Your	Choice	? Chances In 10	? Chances In 10	Lotter y cost
1	$26	$26	$1.00	Left	Right	$26	$26	$0.00
2	$24	$29	$1.00	Left	Right	$24	$29	$0.00
3	$22	$32	$1.00	Left	Right	$22	$32	$0.00
4	$20	$35	$1.00	Left	Right	$20	$35	$0.00
5	$18	$38	$1.00	Left	Right	$18	$38	$0.00
6	$16	$41	$1.00	Left	Right	$16	$41	$0.00
7	$14	$44	$1.00	Left	Right	$14	$44	$0.00
8	$12	$47	$1.00	Left	Right	$12	$47	$0.00
9	$10	$50	$1.00	Left	Right	$10	$50	$0.00
10	$8	$53	$1.00	Left	Right	$8	$53	$0.00
11	$6	$56	$1.00	Left	Right	$6	$56	$0.00
12	$4	$59	$1.00	Left	Right	$4	$59	$0.00
13	$2	$62	$1.00	Left	Right	$2	$62	$0.00

Fig. 7. The ambiguity aversion instrument adapted from Engle-Warnick et al. (2007)

2.3 Materials and Methods

There are 233 sweat glands on the palm of a human hand (Millington & Wilkinson, 1983). These sweat glands are broadly divided into two types: the apocrine glands and the ecrine glands. Electrodermal activity corresponds to the thermoregulatory activity of the sympathetic nervous system, which is regulated by eccrine glands, a system that is highly amenable to stressors. Ionic sweat leads to an increase in skin conductivity. The highest magnitude skin conductance responses (SCR) occur when the wearer's survival is threatened, although many other events can trigger an SCR.

We made use of a wireless recording system (Bionomadix PPG-EDA, Biopac Systems Inc.) for skin conductance response and heart rate measurements. This system consists of a non-invasive technique to measure heart rate, photoplethysmography (PPG), as well as a system for measuring SCR.

In PPG, the surface of the skin is exposed to infra-red LED light. Changes in reflected light are measured by a photodetector; these changes reflect variations in the level of blood pulsing under the skin. The signal measured by the photodetector subsequently passes through a high-gain stage and is amplified to produce the blood volume pulse (BVP) signal. There are many factors that affect the overall PPG response, notably: changes in ambient light, sensor movement and electrical noise in the sensor hardware (Kuboyama, 2009). We reduce the likelihood of the appearance of these artefacts by keeping light and temperature conditions constant and asking our subjects to remain still during the entire course of the experiment. Consistent with previous experiments, SCRs and BVP are recorded from the non-dominant hand (Bach et al., 2010; Doberenz et al., (2011) & Hempel et al., 2005). Pulse rate and electrodermal activity were recorded at a sample rate of 500 Hz (Figner & Murphy, in press). A PPG and SCR channel was set up for each subject on Acqknowledge. In a third channel Acknowledge extracted heart rate values in real-time from peaks in the pulse rate.

Markers denoting the absolute time (HH:MM:SS) each stimulus appeared were extracted from data stored by the stimulus presentation software using a custom script. Computer clocks were synchronized with the local server time (using Windows Time service), and were therefore identical for every subject. Before each session the difference between the server time and the clock used to record the physiological responses was noted. Markers used in the physiological analysis were corrected for this difference.

Electrodermal Activity Consistent with standard criteria, SCRs that appeared outside the 1-4 s interval after stimulus onset were excluded. The threshold level for SCRs was 0.02 uS with a 5s baseline estimation window width, these detection criteria were derived from Kim et al. (2004). SCR analysis was performed using the event-related EDA routine on Acqknowledge v 4.2 (Biopac Inc.).

Hemodynamic activity There is a close relationship between blood pressure and QRS complexes in the EKG time series (a graph of the overall electrical activity of the heart which results from the propagation of many action potentials). QRS complexes reflect ventricular depolarization and determine the R-R interval, the distance in time from one heart contraction to the next. The peak of a systolic event coincides with R in the QRS complex; therefore the time interval between two systolic peaks is computed as the R-R interval. HR in beats per minute (BPM) is calculated by dividing 60 by this interval. Systolic events were labelled using the ABP classifier function in Acqknowledge v 4.2. Missing systoles were inserted into the waveform manually. The cycle detector function was used to calculate the R-R intervals. Where possible, HR data was extracted from the real-time HR channel. HR values were calculated within a 3s interval after the presentation of the stimulus. Due to the noisy nature of the PPG signal, values for pulse amplitude could not be extracted.

Heart Rate Variability Heart rate variability (HRV) is an index of autonomic control of the heart. It is the variation over time of the period between consecutive heart beats. HRV is a function of the balancing interaction between sympathetic and vagal (parasympathetic) inputs into the sino-artrial node (Archaya et al., 2006). Furthermore, HRV is an important physiological marker for chronic stress (Vrijkotte et al., 2000). The vagus nerve provides inhibitory input to the heart (Thayer & Lane, 2000; see also Porges, 2003), and high vagal mediation of HRV is associated with a high degree of regulation of the prefrontal cortex over subcortical activities (Thayler et al., 2009). Thayer and Siegle (2002) have further demonstrated that reduced HRV is associated with amygdalar hyperactivity and reduced PFC activity.

To look at the extent to which variations in heart rate were mediated by sympathetic and vagal inputs we derived the sympathetic-vagal ratio (S:V). S:V was obtained by performing a power spectral density analysis which describes how the power of our PPG signal is distributed with frequency. These criteria were obtained from a published report by a reputable cardiology task force (T. F. o. t. E. S. o. C. t. N. A. S. o. P., 1996). Assume that P_{LOW} is the total power in the low frequency band: 0.04-0.15 Hz (e.g. sum of power values of a PSD in that frequency range), and P_{HIGH} is the total power for the high frequency band (0.15-0.40). There is general agreement that power in the low-frequency band is an indication of sympathetic activity, and that the power in the high frequency band is an indication of vagal activity. As such, the sympathetic ratio is the percentage of the power that occurs in the low frequency band: $\frac{P_{LOW}}{P_{HIGH}+P_{LOW}}$, and the vagal ratio is the percentage of the power that occurs in the high frequency band: $\frac{P_{HIGH}}{P_{HIGH}+P_{LOW}}$. The sympathetic-vagal ratio was obtained from the raw PPG signal recorded a few seconds before the start of the experiment and terminated within 20 seconds after the presentation of the last stimulus, before the onset of any visible artefacts that may have resulted from excessive movement or removal of the device.

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CHAPTER III – Results and Conclusions

3.1 Subject Pool Characteristics

Gender Two-sample Kolmogorov-Smirnov tests for equality of distribution functions revealed that PSS, Amiguity and Risk scores did not have the same distribution functions for males and females (combined k-s $p < 0.05$). With respect to our physiological measures, gender effects were observed for the sympathetic-vagal ratio (combined k-s $p<0.05$), but not heart rate. Furthermore, there was no significant association between gender and the frequency of event-related skin conductance responses (combined k-s = 0.557).

PSS A pairwise correlation did not reveal a significant association between PSS scores and the sympathetic-vagal ratio (corr coeff. = 0.005, p = 0.8240). We found a negative and significant correlation between the vagal ratio and scores on the PSS (corr coeff. = -0.0729, p = 0.0012). Furthermore, we observed a significant association between mean heart rate and PSS scores (corr coeff. = -0.0504, p = 0.0265), although this was an average based on mean HR values within 3 seconds after stimulus presentation and not at rest.

SCR Because our stimuli were neutral faces, SCRs followed only ~7% of all presented stimuli and were randomly distributed across stimuli.

3.2 Raw Choices

The following histograms summarize the relationship between faces and the distribution of choices (n=71). As mentioned before, the stimuli are rank-ordered from highest to lowest on the Trustworthiness scale. The x-axis for the histograms represent the different choices available to our subjects (1 = Trustee Returns 0, Keeps 30 | 2 Trustee Returns 5, Keeps: 25 | 3 = Trustee Returns 10, Keeps 20 | 4 = Trustee Returns 15, Keeps 15 | 5 = Trustee Returns 20, Keeps 10), and the y-axis represents the number of people who made each of these choices.

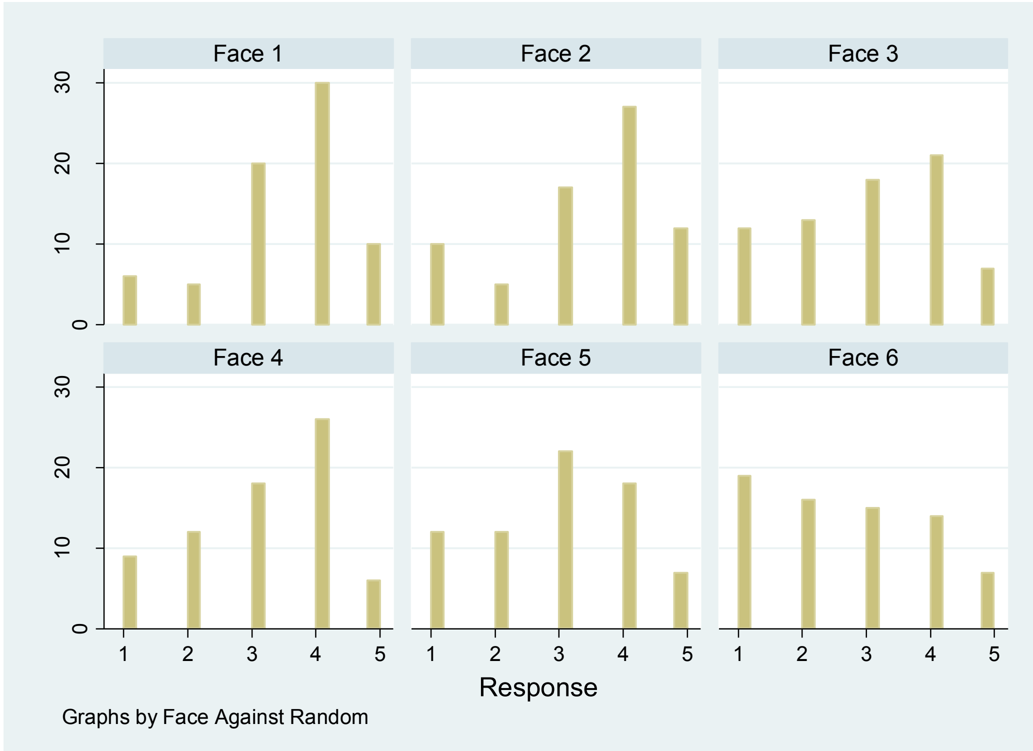

Fig. 8 Where the Trustee was a face and the Trustor was a "randomly-selected person in the room" ("Face Against Random"), a Kolmogrov-Smirnov test for equality of distributions revealed that the distribution of responses for Face 1 was significantly different than the distribution of responses for Face 6.

Smaller group	D	P-value	Corrected
1:	0.0000	1.000	
6:	-0.3380	0.000	
Combined K-S:	0.3380	0.001	0.000

The difference in the distribution of responses for Face 2 vs. 5 and Face 3 vs. 4 were not significant (combined corrected k-s $p > 0.05$).

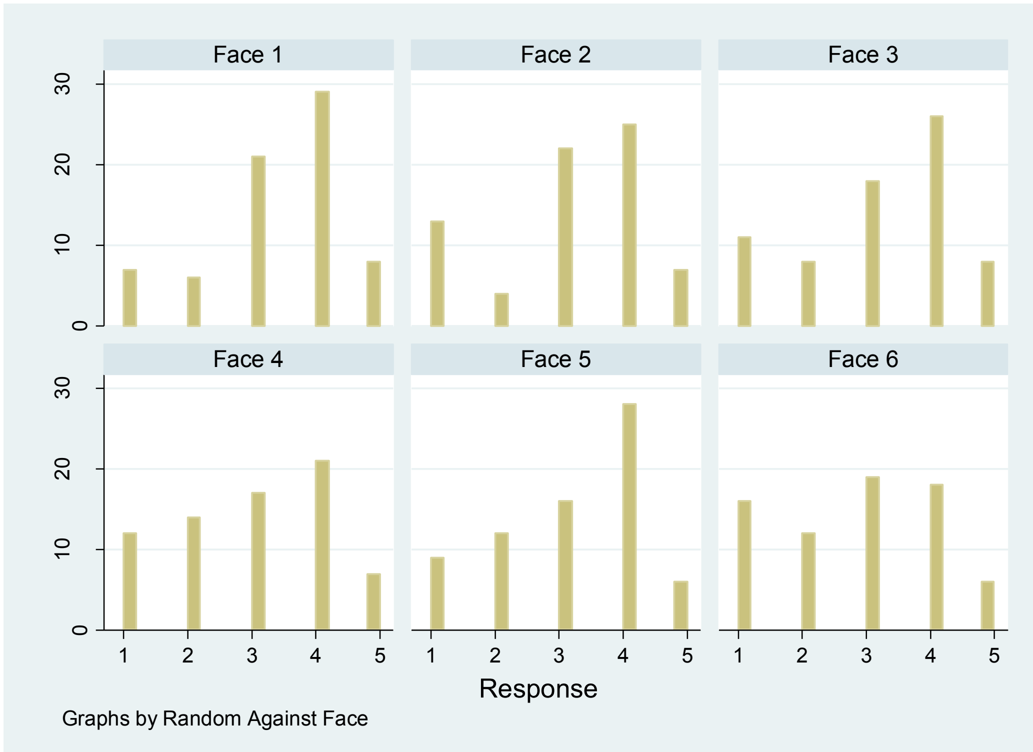

Fig. 9 Where "a randomly-selected person in the room" was the Trustee and one of the faces was the Trustor ("Random Against Face") a Kolmogrov-Smirnov test for equality of distributions revealed that the distribution of responses for Face 1 was not significantly different than the distribution of responses for Face 6, although it was nearing significance (corrected combined k-s $p = 0.059$). The difference in the distribution of responses for Face 2 vs. 5 and Face 3 vs. 4 were not significant either (combined corrected k-s $p > 0.05$).

Fig. 10 Where the Trustee was a face and the Trustor was "you" ("Face Against You") a Kolmogrov-Smirnov test for equality of distributions revealed that the distribution of responses for Face 1 was significantly different than the distribution of responses for Face 6.

Smaller group	D	P-value	Corrected
13:	0.0000	1.000	
18:	-0.3239	0.001	
Combined K-S:	0.3239	0.001	0.001

The difference in the distribution of responses for Face 2 vs. 5 and Face 3 vs. 4 were not significant (combined corrected k-s $p > 0.05$).

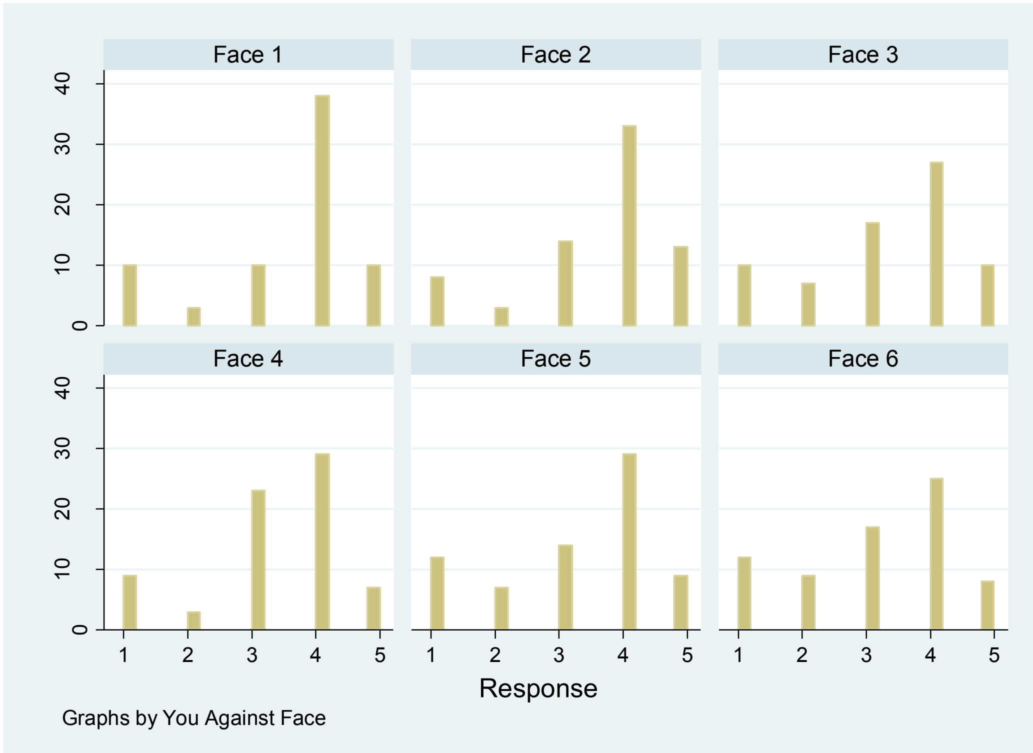

Fig. 11 Where the Trustee was "you" and the Trustor was a face ("You Against Face") a Kolmogrov-Smirnov test for equality of distributions revealed that the distribution of responses for Face 1 was not significantly different than the distribution of responses for Face 6 although it was nearing significance (combined k-s p = 0.084).

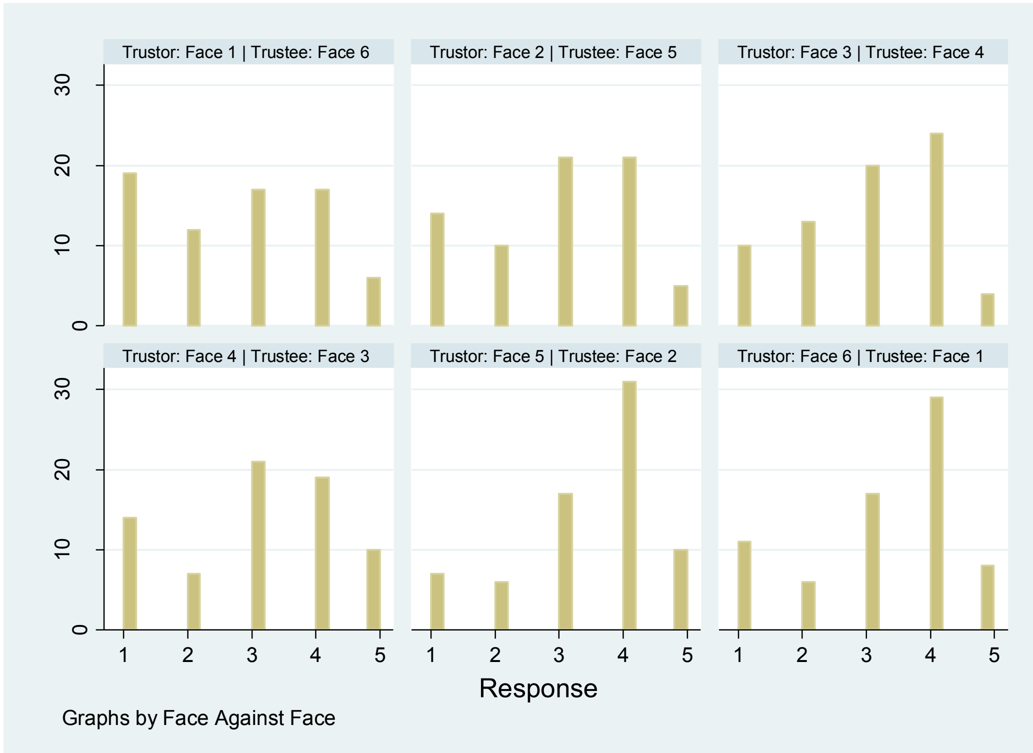

Fig. 11 Histograms (by frequency of choices) where both the Trustee and Trustor were a face ("Face Against Face").

3.3 Regression Analysis

We conducted multinomial logistic regressions to compare how different factors like the Trustworthiness rating of a face, individual scores on the PSS, the Risk and Ambiguity instruments, and heart rate affected our outcome variable ("the most likely choice of the Trustee"). This analysis does not assume normality or linearity. We eliminated multicollinearity by choosing predictor variables that were not highly correlated.

	Trustor	Trustee
"Face Against Random"	Randomly-selected person	Face
"Random Against Face"	Face	Randomly-selected person
"Face Against You"	You	Face
"You Against Face"	Face	You

With “Return 0” as the reference category for responses for “Face Against Random”, we found that higher scores on the risk-aversion instrument (RiskTotal) was associated with an increased likelihood of choosing Return 5, 10, 15 and 20 over Return 0. Higher trustworthiness ratings were associated with an increased likelihood of choosing Return 15 and 20 over Return 0. The likelihood ratio chi-square of 75.56 with a p-value < 0.0001 tells us that our model as a whole fits significantly better than an empty model.

Multinomial logistic regression 1 — Number of obs = 350
LR chi2(24) = 77.59
Prob > chi2 = 0.0000
Log likelihood = -495.53261 — Pseudo R2 = 0.0726

Response	**Coef.**	**Std. Err.**	**z**	**P>|z|**	**[95% Conf.**	**Interval]**
1	(base outcome)					
2						
Tr_Trustee	-.2497383	.235641	-1.06	0.289	-.7115861	.2121095
RiskTotal	**.2227301**	**.0638126**	**3.49**	**0.000**	**.0976596**	**.3478005**
AmbigTotal	-.0123466	.0527013	-0.23	0.815	-.1156392	.090946
PSSTotal	.0482106	.0333937	1.44	0.149	-.0172398	.113661
Mean_HR	-.0030194	.0173954	-0.17	0.862	-.0371137	.0310749
Gender	1.410406	.4628793	3.05	0.002	.5031789	2.317632
_cons	-2.769715	1.947344	-1.42	0.155	-6.586439	1.047009
3						
Tr_Trustee	.340098	.1900899	1.79	0.074	-.0324713	.7126674
RiskTotal	**.1257863**	**.0543204**	**2.32**	**0.021**	**.0193203**	**.2322523**
AmbigTotal	.0074346	.0435448	0.17	0.864	-.0779117	.0927809
PSSTotal	.0255624	.0288056	0.89	0.375	-.0308956	.0820204
Mean_HR	.0243782	.0150013	1.63	0.104	-.0050238	.0537803
Gender	**1.184999**	**.3922698**	**3.02**	**0.003**	**.4161639**	**1.953833**
_cons	-5.479635	1.631769	-3.36	0.001	-8.677843	-2.281427
4						
Tr_Trustee	**.5287637**	**.1829416**	**2.89**	**0.004**	**.1702048**	**.8873225**
RiskTotal	**.1142877**	**.0518528**	**2.20**	**0.028**	**.0126582**	**.2159172**
AmbigTotal	-.0240742	.0407493	-0.59	0.555	-.1039413	.0557929
PSSTotal	-.0030811	.0282074	-0.11	0.913	-.0583667	.0522045
Mean_HR	.0264579	.0146608	1.80	0.071	-.0022768	.0551925
Gender	.4282647	.3763334	1.14	0.255	-.3093352	1.165865
_cons	-4.373863	1.550924	-2.82	0.005	-7.413618	-1.334108
5						
Tr_Trustee	**.5356673**	**.2203401**	**2.43**	**0.015**	**.1038087**	**.967526**
RiskTotal	**.1989393**	**.0638109**	**3.12**	**0.002**	**.0738723**	**.3240063**
AmbigTotal	.0405817	.0524536	0.77	0.439	-.0622253	.1433888
PSSTotal	-.0002104	.0341215	-0.01	0.995	-.0670873	.0666665
Mean_HR	.0085974	.0178188	0.48	0.629	-.0263268	.0435217
Gender	.4689395	.4542704	1.03	0.302	-.4214141	1.359293
_cons	-4.942356	1.917015	-2.58	0.010	-8.699636	-1.185076

Where 1 = Return 0, 2 = Return 5, 3 = Return 10, 4 = Return 15 and 5 = Return 20.

With “Return 0” as the reference category for “Random Against Face”, we found that higher scores on the risk-aversion and the Perceived Stress Scale (PSSTotal) were associated with an increased likelihood of choosing Return 5, 10 and 15 over 0. Unlike the risk-aversion instrument, higher ratings on the Perceived Stress Scale were not associated with an increased likelihood of choosing Return 20 over 0. On the other hand, higher ratings on the Ambiguity instrument was associated with a decreased likelihood of choosing Return 5, 10 and 15 over 0. The likelihood ratio chi-square of 89.95 with a p-value < 0.0001 tells us that our model as a whole fits significantly better than an empty model.

```
Multinomial logistic regression 2                 Number of obs   =        346
                                                  LR chi2(24)     =      89.95
                                                  Prob > chi2     =     0.0000
Log likelihood = -475.03178                       Pseudo R2       =     0.0865
```

Response	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
1	(base outcome)					
2						
Tr_Trustor	-.1907962	.2282656	-0.84	0.403	-.6381885	.2565961
RiskTotal	**.2007665**	**.0672306**	**2.99**	**0.003**	**.0689969**	**.3325361**
AmbigTotal	**-.1493567**	**.0560128**	**-2.67**	**0.008**	**-.2591397**	**-.0395736**
PSSTotal	**.1385607**	**.0377601**	**3.67**	**0.000**	**.0645522**	**.2125692**
Mean_HR	.00337	.0174447	0.19	0.847	-.0308209	.0375609
Gender	.3089915	.4713388	0.66	0.512	-.6148156	1.232799
_cons	-2.363744	1.976651	-1.20	0.232	-6.237909	1.510422
3						
Tr_Trustor	.2038969	.1858236	1.10	0.273	-.1603107	.5681045
RiskTotal	.196918	.0576813	3.41	0.001	.0838648	.3099712
AmbigTotal	-.124436	.0470919	-2.64	0.008	-.2167344	-.0321376
PSSTotal	.0979023	.0331159	2.96	0.003	.0329964	.1628083
Mean_HR	-.0250685	.0152282	-1.65	0.100	-.0549152	.0047783
Gender	.8270986	.4100125	2.02	0.044	.0234889	1.630708
_cons	-1.32801	1.650874	-0.80	0.421	-4.563663	1.907642
4						
Tr_Trustor	.3057689	.168768	1.81	0.070	-.0250104	.6365481
RiskTotal	**.1785782**	**.0535773**	**3.33**	**0.001**	**.0735686**	**.2835879**
AmbigTotal	**-.102228**	**.0425854**	**-2.40**	**0.016**	**-.1856939**	**-.0187621**
PSSTotal	**.0740881**	**.0309812**	**2.39**	**0.017**	**.0133661**	**.1348101**
Mean_HR	-.0093471	.0137649	-0.68	0.497	-.0363258	.0176316
Gender	-.2456683	.3681716	-0.67	0.505	-.9672713	.4759348
_cons	-.4715821	1.459622	-0.32	0.747	-3.332388	2.389224
5						
Tr_Trustor	.2652824	.2163957	1.23	0.220	-.1588452	.6894101
RiskTotal	.3019446	.068305	4.42	0.000	.1680692	.43582
AmbigTotal	-.0372702	.0573755	-0.65	0.516	-.1497241	.0751838

PSSTotal	.0500043	.0387383	1.29	0.197	-.0259213	.1259299
Mean_HR	-.0140389	.017224	-0.82	0.415	-.0477975	.0197196
Gender	.3004463	.464107	0.65	0.517	-.6091868	1.210079
_cons	-2.617153	1.950345	-1.34	0.180	-6.439759	1.205453

With “Return 0” as the reference category for “Face Against You” we found that higher ratings on the Risk instrument was associated with an increased likelihood of choosing Return 5, 10 and 15 over Return 0. Higher ratings on the Perceived Stress Scale were associated with an increased likelihood of choosing Return 5 and 10 over Return 0. Higher trustworthiness ratings were associated with an increased likelihood of choosing Return 10, 15 and 20 over Return 0. The likelihood ratio chi-square of 64.10 with a p-value < 0.0001 tells us that our model as a whole fits significantly better than an empty model.

Multinomial logistic regression	Number of obs	=	342
	LR chi2(24)	=	64.10
	Prob > chi2	=	0.0000
Log likelihood = -488.01479	Pseudo R2	=	0.0616

Response	**Coef.**	**Std. Err.**	**z**	**P>|z|**	**[95% Conf.**	**Interval]**
1	(base outcome)					
2						
Tr_Trustee	.0671319	.2407616	0.28	0.780	-.4047521	.5390159
RiskTotal	.1815538	.068764	2.64	0.008	.0467789	.3163287
AmbigTotal	-.0232322	.0579994	-0.40	0.689	-.136909	.0904446
PSSTotal	.0703722	.0359352	1.96	0.050	-.0000595	.140804
Mean_HR	-.0000877	.0195446	-0.00	0.996	-.0383943	.0382189
Gender	1.147919	.5007338	2.29	0.022	.1664987	2.129339
_cons	-4.255467	2.167463	-1.96	0.050	-8.503617	-.0073169
3						
Tr_Trustee	**.4709281**	**.196435**	**2.40**	**0.017**	**.0859226**	**.8559336**
RiskTotal	.1448315	.0564187	2.57	0.010	.0342529	.25541
AmbigTotal	-.0806242	.0462052	-1.74	0.081	-.1711847	.0099363
PSSTotal	.0593173	.030267	1.96	0.050	-5.00e-06	.1186396
Mean_HR	.0193014	.0165401	1.17	0.243	-.0131166	.0517194
Gender	.6655158	.4009243	1.66	0.097	-.1202815	1.451313
_cons	-5.14022	1.777882	-2.89	0.004	-8.624804	-1.655636
4						
Tr_Trustee	**.5617749**	**.1822745**	**3.08**	**0.002**	**.2045234**	**.9190263**
RiskTotal	.1111794	.052094	2.13	0.033	.0090771	.2132818
AmbigTotal	-.0640699	.0421968	-1.52	0.129	-.1467741	.0186344
PSSTotal	.0172316	.0284132	0.61	0.544	-.0384572	.0729205
Mean_HR	.0083801	.0152817	0.55	0.583	-.0215715	.0383316
Gender	.1726425	.3704399	0.47	0.641	-.5534064	.8986913
_cons	-2.706635	1.603481	-1.69	0.091	-5.8494	.4361295
5						
Tr_Trustee	**.7192635**	**.2066687**	**3.48**	**0.001**	**.3142003**	**1.124327**
RiskTotal	.1068842	.058758	1.82	0.069	-.0082794	.2220479
AmbigTotal	-.074939	.0484793	-1.55	0.122	-.1699567	.0200787
PSSTotal	-.004378	.0334974	-0.13	0.896	-.0700317	.0612757
Mean_HR	-.0192925	.0176176	-1.10	0.273	-.0538225	.0152374
Gender	.2626894	.4274292	0.61	0.539	-.5750564	1.100435
_cons	-1.789112	1.847466	-0.97	0.333	-5.410079	1.831855

With “Return 0” as the reference category for “You Against Face”, we found that higher scores on the Risk instrument were associated with an increased likelihood of choosing Return 10, 15 and 20 over Return 0. On the other hand, higher ratings on the Ambiguity instrument were associated with a decreased likelihood of choosing Return 5, 10, 15 and 20 over Return 0. The likelihood ratio chi-square of 89.19 with a p-value < 0.0001 tells us that our model as a whole fits significantly better than an empty model.

```
Multinomial logistic regression                   Number of obs   =        352
                                                  LR chi2(24)     =      89.19
                                                  Prob > chi2     =     0.0000
Log likelihood = -459.59825                       Pseudo R2       =     0.0884
```

Response	**Coef.**	**Std. Err.**	**z**	**P>|z|**	**[95% Conf.**	**Interval]**
1	(base outcome)					
2						
Tr_Trustor	-.26983	.2669369	-1.01	0.312	-.7930168	.2533567
RiskTotal	.1162932	.079319	1.47	0.143	-.0391693	.2717556
AmbigTotal	**-.1796611**	**.0680747**	**-2.64**	**0.008**	**-.3130852**	**-.0462371**
PSSTotal	**.1379148**	**.0417108**	**3.31**	**0.001**	**.0561632**	**.2196664**
Mean_HR	.0353043	.021695	1.63	0.104	-.0072171	.0778256
Gender	.2325669	.5518921	0.42	0.673	-.8491217	1.314255
_cons	-4.238735	2.42266	-1.75	0.080	-8.987061	.5095911
3						
Tr_Trustor	-.0682409	.1993797	-0.34	0.732	-.459018	.3225362
RiskTotal	**.1551053**	**.0596364**	**2.60**	**0.009**	**.0382201**	**.2719905**
AmbigTotal	**-.229084**	**.0531169**	**-4.31**	**0.000**	**-.3331912**	**-.1249767**
PSSTotal	.042534	.0338697	1.26	0.209	-.0238495	.1089174
Mean_HR	.0072803	.0166971	0.44	0.663	-.0254455	.0400061
Gender	.2816064	.423516	0.66	0.506	-.5484697	1.111682
_cons	-.1312391	1.784976	-0.07	0.941	-3.629728	3.36725
4						
Tr_Trustor	.2473338	.1708438	1.45	0.148	-.0875138	.5821815
RiskTotal	**.1325896**	**.0538746**	**2.46**	**0.014**	**.0269973**	**.2381819**
AmbigTotal	**-.1736667**	**.0476684**	**-3.64**	**0.000**	**-.267095**	**-.0802384**
PSSTotal	**.0693386**	**.0290352**	**2.39**	**0.017**	**.0124306**	**.1262466**
Mean_HR	-.0056067	.0147508	-0.38	0.704	-.0345177	.0233044
Gender	.1689376	.3704957	0.46	0.648	-.5572207	.8950959
_cons	-.1367952	1.561754	-0.09	0.930	-3.197777	2.924187
5						
Tr_Trustor	.2662642	.2054299	1.30	0.195	-.1363711	.6688995
RiskTotal	**.2592133**	**.0651599**	**3.98**	**0.000**	**.1315023**	**.3869243**
AmbigTotal	**-.112617**	**.057042**	**-1.97**	**0.048**	**-.2244173**	**-.0008167**
PSSTotal	.0532239	.0346092	1.54	0.124	-.014609	.1210567
Mean_HR	.0102283	.0176554	0.58	0.562	-.0243756	.0448321
Gender	-.49206	.4415949	-1.11	0.265	-1.35757	.3734501
_cons	-2.340475	1.908487	-1.23	0.220	-6.08104	1.40009

Discussion

One of the main goals of this experiment was to construct a distribution of responses for each face, so that we could use these faces to play against human participants. We also receive beliefs and preferences regarding play in the trust game for each face, because each face plays both roles. This gives us a complete economic model of play for each player in each game: beliefs plus preferences equals a strategy in game theory.

Hypothesis 1 – Facial Features factor into judgments about whether or not to trust someone.

The histograms demonstrate the extent to which responses varied with respect to different faces. Not surprisingly, the most striking differences were between the distributions of faces that rates highest and lowest on the "trustworthiness" scale. The difference in distribution where "you" or a "randomly-selected person in the room was the Trustee was not a striking.

Overall we found that the facial features people use to make judgments of trustworthiness in individuals had a significant impact on people's belief about their opponents. As expected, these features did not have a statistically significant impact on the outcome variable when the face was in the position of the Trustor.

The same result appeared after controlling for other variables (see regressions for "You Against Face" and "Random Against Face").

Hypothesis 2 – Participants have a preference over the type of an opponent, based on his facial features and Hypothesis 3 – Participants will use facial features to make inferences about their opponent's other-regarding preferences.

Any difference between the distribution of responses to different faces for any Trustee demonstrates that our subjects believe that the Trustee has a preference over the type of the Trustor (has other-regarding preferences). Differences in the distribution of responses for "You Against Face" and "Random Against Face" indicates that our subjects have a preference over the type of their opponent as revealed by his face, paired with a belief that others ("randomly-selected people") have similar other-regarding preferences (Hypothesis 2). Any difference in the distribution of responses when the Trustor is "You" as opposed to a "Randomly-selected person in the room" indicates that our subjects believe that the faces have a preference over their own type.

Hypothesis 4 – Subjects will make use of somatic markers to guide their judgments about different opponents.

Overall our biological variables did not have a significant impact on the outcome variable. The positive correlation we found between scores on the PSS and vagal ratio is consistent with findings from previous studies (Crowley et al., 2011).

Unfortunately there were no consistent findings about the effect of perceived stress on our outcome variable. We were unable to identify whether participants used somatic markers to make their judgments, this was probably because our participants were not engaged in a risky gamle. A second session where subjects play against the distribution of play created for these faces will likely yield much stronger physiological responses.

One surprising and consistent finding was the extent to which risk aversion and ambiguity aversion affected our outcome variable for "You Against Face" and "Random Against Face". One way to make sense of this is to assume that our subjects apply a repeated game logic to a one-shot game. This may be because humans evolved in environments where one-shot interactions were rare. A risk-averse dictator may return more if he assumes that in future encounters this will enhance the likelihood that the same opponent will reciprocate, or if she is concerned about her reputation. The issue of whether human subjects adopt repeated games logic in a one shot game is a contentious one. Camerer (2003) criticizes such arguments on the grounds that a) they're generally unfalsifiable, b) surveys seem to suggest that people are aware of the strategical differences between one-shot and repeated games, and c) on occasion people reciprocate less in repeated games with reputation vs. one-shot games. The fact of the matter is that although humans don't quite act how they should in a one-shot game, they don't apply repeated games logic either. The consistent and negative relation between ambiguity aversion and higher returns is more difficult to make sense of.

We will attempt to address this finding in subsequent experiments using different instruments.

One surprising and consistent finding was the extent to which risk aversion and ambiguity aversion affected our outcome variable where the Trustee was the subject or a random person in the room. One way to make sense of this is to assume that our subjects apply a repeated game logic to a one-shot game. A risk-averse dictator may return more if he assumes that in future encounters this will enhance the likelihood that the same opponent will reciprocate, or if she is concerned about her reputation. The issue of whether human subjects adopt repeated games logic in a one shot game is a contentious one. Although humans don't quite act how they should in a one-shot game, they don't act as they would in repeated games either. The consistent and positive relation between ambiguity aversion and higher returns is more difficult to make sense of …

Overall we found that the facial features people use to make trustworthiness judgments in individuals had a significant impact on people's beliefs about their opponents. As expected, these features did not have a significant impact on the outcome variable when the face was in the position of the Trustor. This result emerged even after controlling for other variables.

Concluding Remarks & Future Directions.

Studies making use of the instrument we have developed will immediately follow this experiment. They will address genetic contributions to trusting behaviour in a clinical and normal population. As mentioned, one of the main goals of this experiment was to construct a distribution of responses for our faces that will likely be used in many subsequent experiments. We are specifically interested in genetic markers for two neurohormones: oxytocin and vasopressin.

The behavioural effects of the neurohormones Vasopressin (AVP) and Oxytocin (OXT) are directly relevant to face-to-face interactions. OXT has been identified as a physiological correlate, or "biomarker," of trust. In a seminal study, Kosfeld et al. (2005) showed that administration of intranasal OXT selectively enhanced trusting behavior. In humans, OXT is thought to modulate the neural circuitry for social cognition, and enhances the capacity to recognize social signals from conspecifics (Domes et al., 2007). OXT receptors were found in areas of the brain implicated in social cognition, most notably the central amygdala and the prefrontal cortex. AVP on the other hand, is thought to enhance the expression and learning of fear and avoidance through the amygdala.

Based on information we obtained from an extensive review of the molecular biology and genetics literature (beyond the scope of this thesis), we predict that subjects with single nucleotide polymorphisms[9] for the OXT receptor gene will show impairments in trusting a "trustworthy" face. Subjects with polymorphisms in AVPR1A and 1B gene are likely to show deficits identifying defectors. These impairments will be reflected in their levels of initial investment as a Trustor. This is a radical hypothesis, given that polymorphisms for OXTR and AVPR are implicated in the same behaviours (stress-reactivity, anxiety, autism), but it is consistent with previous findings. Studies confirm that OXT administration facilitates the recognition of happy faces and positively-valenced words (Guastella and MacLeod, 2012; Lischke et al., 2011; Marsh et al., 2010 and Unkelbach et al., 2008). The findings of the proposed research will contribute to evidence for a putative role of oxytocin and vasopressin in pharmacotherapy.

In the past 20 years economists have parted from standard game theoretical models and have made use of evidence from neuroscience and behaviour to inform their models of decision-making (Camerer et al., 2005). Much of the foundations of economic theory followed the trend of behaviourism and Samuelson's "revealed preference" which maintained that preferences and beliefs could only be revealed by actions (one prefers A over B when he chooses A over B). Decision theorists were rarely concerned with how intrinsic motivations factor into decision-making. This project fits into a large body of work that attempts to look at the brain to make sense of people's decisions in the hope that such findings may improve existing decision theory models.

[9] A variation in a single base pair for a gene.

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