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Oxytocin increases trust in humans

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Trust pervades human societies[1,2]. Trust is indispensable in friendship, love, families, and organizations and plays a key role in economic exchange and politics[3]. In the absence of trust among trading partners, market transactions break down. In the absence of trust in a country's institutions and leaders, political legitimacy breaks down. Much recent evidence indicates that trust contributes to economic, political, and social success[4,5]. Little is known, however, about the biological basis of trust among humans. Here we show that the intranasal administration of oxytocin, a neuropeptide that plays a key role in social attachment and affiliation in non-human mammals[6-8], causes a substantial increase in trust among humans, thereby greatly increasing the benefits from social interactions. We also show that the effect of oxytocin on trust is not due to a general increase in the readiness to bear risks. On the contrary, oxytocin specifically affects the individual's willingness to accept social risks arising in interpersonal interactions. These results concur with animal research suggesting an essential role of oxytocin as a biological basis of prosocial approach behaviour.

The neuropeptide oxytocin (OT) plays a central role in non-human mammals in behavioural regulation in general, and in positive social interactions in particular. Aside from its well-known physiological functions in milk letdown and during labor, OT receptors are distributed in various brain regions associated with behavior[9,10], including pair bonding, maternal care, sexual behaviour and the ability to form normal social attachments[6-8,11-15]. Thus, OT seems to permit animals to overcome their natural avoidance of proximity and thereby facilitates approach behaviour. Given the fact that OT appears to promote social attachment and affiliation in non-human mammals, we hypothesize that OT might also promote prosocial approach behaviour – such as trust – in humans. Recent research has shown that neuropeptides cross the blood-brain barrier after intranasal administration[16], providing a useful method for studying the central nervous effects of OT in humans[17]. Therefore, we used a double–blind study design by comparing trusting behaviour in a group of subjects who received a single dose of intranasal OT with that of subjects in a control group that received placebo.

We analyse the impact of exogenously administered OT on individuals' decisions in a trust game with real monetary stakes[18-21]. In the trust game, two subjects interacting anonymously play either the role of an investor or a trustee (Figure 1). The investor first has the chance of choosing a costly trusting action by giving money to the trustee. If the investor transfers money, the total amount available for distribution between the two players increases but, initially, the trustee reaps the whole increase. Then the trustee is informed about the investor's transfer and can honour the investor's trust by sharing the monetary increase generated by the investor's transfer. Thus, if the investor gives money to the trustee and the latter shares the proceeds of the transfer, both players end up with a higher monetary payoff. However, the trustee also has the option of violating the investor's trust. Since sharing the proceeds is costly for the trustee, a selfish trustee will never honour the investor's trust because the investor and the trustee interact only once in the experiment.

Therefore, the investor is caught in a dilemma because if he trusts and the trustee shares, the investor increases his payoff; he is also subject to the risk, however, that the trustee will abuse his trust. In this latter case, the investor is worse off than if he had not trusted at all and, adding insult to injury, the trustee has an unfair payoff advantage relative to the investor.

Substantial evidence exists showing that humans are averse to such risks[21-23]. Moreover, investors' aversion to trust abuse seems to play an important role across different human cultures in the context of our game[21,24]. Therefore, the investors have to overcome their aversion against these risks in order to trust, raising the key question whether OT modulates this trusting behaviour in humans.

Our hypothesis that OT increases investors' trusting behaviour implies that the investors in the OT group ($N = 29$) will exhibit higher transfers than those in the placebo group ($N = 29$). Our data in fact show that OT increases investors' trust considerably. In particular, 13 out of the 29 subjects (45%) in the OT group exhibited the maximal trust level, whereas only 6 of the 29 subjects (21%) in the placebo group showed maximal trust (Figure 2a). In contrast, only 21% of the subjects in the OT group exhibit a trust level below 8 MUs whereas 45% of the subjects in the control group show such low levels of trust. These differences in the distribution of trust result in higher average and median trust levels for subjects given OT (Table 1). The investors' average transfer is 17% higher in the OT group (Mann-Whitney test, $z = -1.897$, $p = .029$, one-sided); the median transfer in the OT group is 10 MUs, whereas the median for subjects with the placebo is only 8 MUs.

In the trust game, the investor's risk is due to the uncertainty of the trustee's behaviour, i.e., a social interaction with a specific trustee constitutes the risk. This raises the question whether OT helps humans overcome a general aversion against risks or whether OT specifically affects trusting behaviour in social interactions. In order to answer this question, we conducted a risk experiment in which the investor faced the same choices as in the trust game but where a random mechanism and not a trustee's decision determined the investor's risk. The random mechanism in the risk experiment replicated the trustees' decisions in the trust experiment. Therefore, the investors faced exactly the same risk as in the trust experiment (see Methods); however, their transfer decisions were not embedded in a social interaction because there were no trustees in the risk experiment.

The investors' behaviour in the risk experiment does not differ across the OT and the placebo group (Table 1 and Figure 2b). The median transfer is 8 and the average transfer is 7.5 in both groups (Mann-Whitney test, $z = 0.022$, $p = .983$, two-sided, $N = 31$ in OT group, N

= 30 in placebo group). Moreover, there is no significant difference in the comparison of the placebo group in the trust experiment with the OT and the placebo group in the risk experiment (Kruskal-Wallis test, $\chi^2 = 0.533$, df = 2, $p = .766$), with identical median transfers across groups (Table 1). However, if we add the OT group in the trust experiment to these three samples, significant differences are observed (Kruskal-Wallis test, $\chi^2 = 8.610$, df = 3, $p = .035$) indicating that only the investors in the OT group of the trust experiment behave differently. Thus, OT increases the investors' transfer levels in the trust experiment but not in the risk experiment. This finding is illustrated by a comparison of Figures 2a and 2b which shows that only 10 percent of the subjects with OT choose the maximal transfer level in the risk experiment whereas 45 percent choose the maximal level in the trust experiment. Therefore, the differences between the OT group in the trust experiment and the OT group in the risk experiment are highly significant (Mann-Whitney test, $z = -2.563$, $p = .010$, two-sided) suggesting that OT specifically affects trust in interpersonal interactions.

The risk experiment constitutes a powerful control for the effects of OT on trusting behaviour because everything is kept constant relative to the trust experiment except that the investors' risk in the risk experiment is not generated in a social interaction. In particular, all the indirect effects of OT on a subjects' state, such as possible effects on subjects' mood or calmness, would be present in both the trust and the risk experiment. Therefore, these potential indirect effects of OT cannot be responsible for the effect of OT on trusting behaviour. Moreover, in order to provide an additional control for non-specific effects that might be associated with OT administration, we explicitly measured mood and calmness before substance administration and 50 minutes afterwards, i.e., before subjects played the trust or the risk game. We used a particularly suitable questionnaire for repeated measures within short periods of time, one which is widely used in neuropharmacological studies in humans[25] and correlates with physiological measures[26]. Statistical differences in the levels of mood and calmness before and after the administration of OT are neither observed in the trust nor in the risk experiment (Trust experiment: $z = -1.541$, $p = 0.123$ for calmness; $z = 1.452$, $p = 0.146$ for mood; $N = 29$. Risk experiment: $z = 0.620$, $p = 0.535$ for calmness; $z = -0.841$, $p = 0.400$ for mood; $N = 31$; Wilcoxon signed rank test, two-sided). This provides further support for our previous conclusion that the impact of OT on human trust is not caused by non-specific psychotropic effects of OT.

Which mechanisms might be involved in the effect of OT on trusting behaviour? One possibility is that OT causes a general increase in the investors' prosocial inclinations which implies that it should not only affect the investors' prosocial behaviour but also that of the trustees. Therefore, those trustees who are given OT should make higher back transfers at a given transfer level than the trustees who received placebo. However, trustees given OT do not exhibit more trustworthy behaviour (Figure 3); at every positive transfer level, i.e., at 4, 8 or 12 MUs, their back transfers are statistically indistinguishable from those of placebo trustees (Mann Whitney tests, $p > .243$, two-sided, for each positive transfer level). Thus, OT does not increase the general inclination to behave prosocially. Rather, OT specifically affects investors' trusting behaviour.

We hypothesize that the differing impact of OT on investors' and trustees' behaviour is related to the fact that investors and trustees face rather different situations. In particular, investors have to make the first step; they have to "approach" the trustee by transferring money. In contrast, the trustees can condition their behaviour on the investors' actions. Thus, the psychology of trust is important for investors whereas the psychology of strong reciprocity[27] is relevant for trustees. The fact that OT affects subjects' approach or trust behaviour but not their degree of reciprocity is in line with the animal literature. There is substantial evidence that OT promotes prosocial approach behaviour by inhibiting defensive behaviours[6,13,14] but there is no evidence that OT affects reciprocity in animals.

A second mechanism behind OT's effect on trust could be based on subjects' beliefs. Perhaps OT rendered subjects more optimistic about the likelihood of a good outcome. In order to examine this question, we measured the investor's subjective expectation about the trustee's back transfer after every transfer decision. A Mann-Whitney test indicates that these expectations do not differ significantly between groups for every feasible positive transfer level ($p > .357$, two-sided, at given transfer levels of 4, 8 or 12 MUs). Thus, the investors with OT exhibit more trusting behaviour but do not hold significantly different beliefs about others' trustworthiness. Moreover, OT also does not affect investors' beliefs about the likelihood of a good outcome in the risk experiment ($p > .128$, two-sided, Mann Whitney tests for transfer levels of 4, 8 and 12).

Finally, there is the possibility that OT helped subjects to overcome their betrayal aversion in social interactions. This explanation is consistent with the differing impact of OT across the trust and the risk experiment and it is further supported by the fact that investors faced a considerable betrayal risk: an increase in the transfer level from 4 or 8 MUs to 12 MUs decreased the investor's average payoff slightly, whereas it increased the objective risk of very low back transfers by the trustee. However, betrayal aversion alone cannot explain why investors with OT make higher transfers in the trust compared to the risk experiment because in the risk experiment betrayal is impossible. The higher transfers in the trust experiment can be reconciled with betrayal aversion if one acknowledges that investors' behaviour in the trust experiment is also likely to be driven by the motive to increase the available amount for distribution between the two players[28]. As this motive cannot operate in the risk experiment it can only increase transfers levels in the trust experiment. Our interpretation of OT's effect on trust in terms of betrayal aversion may be seen in the light of animal studies indicating that an increased central nervous availability of OT facilitates approach behaviour by linking the overcoming of social avoidance with the activation of brain circuits implicated in reward (e.g., nucleus accumbens)[12,15].

The ubiquity of trusting behaviour is perhaps one of the distinguishing features of the human species. An element of trust characterizes almost all human social interactions. Here we have sought to examine the impact of OT on trust in humans. Research in non-human mammals suggests that OT plays a key role in social attachment and affiliation. We find that intranasal administration of OT causes a substantial increase in trusting behaviour. Subjects given OT seem to be better able to overcome trust obstacles such as betrayal aversion. Of course, this finding may be misused to induce trusting behaviours that selfish actors can subsequently exploit. However, our finding may have positive clinical implications for patients with mental disorders that are associated with social dysfunctions (e.g., social phobia or autism). Social phobia, in particular, ranks as the third most common mental health disorder and is characterized by marked social deficits including persistent fear and avoidance of social interactions. Thus, our results may indicate fertile areas of research on the role of OT in several mental health disorders with major public health significance.

Methods

Subjects

A total of 194 healthy male students (mean age ± SD: 22.0 ± 3.4 years) from different Universities in Zurich participated in the study. 128 subjects participated in the trust, 66 in the risk experiment. Exclusion criteria for participation were significant medical or psychiatric illness, medication, smoking more than 15 cigarettes per day, and drug or alcohol abuse. Subjects were instructed to abstain from food and drink (other than water) for 2 hours and from alcohol, smoking, and caffeine for 24 hours before the experiment. Participants were informed at the time of recruitment that the experiment would evaluate the effects of a hormone on decision making. In total, sixteen of the original sample of 194 individuals were excluded because of incorrect substance administration (7 in the trust experiment, 5 in the risk experiment) or their stated disbelief that the opponent in the trust game was actually a human being (4 participants). The study protocol was approved by the ethics committee of the University of Zurich. All subjects gave written, informed consent prior to participation.

Substance administration

Subjects received a single dose of 24 IU OT (Syntocinon-Spray, Novartis, Basel, Switzerland; 3 puffs per nostril, each with 4 IU OT) intranasally or placebo 50 minutes before the start of the trust game or the risk experiment, respectively. Subjects were randomly assigned to the OT or placebo group (double-blind, placebo-controlled study design). In order to avoid any subjective substance effects other than those caused by OT (e.g., olfactory effects), the placebo contained all inactive ingredients except for the neuropeptide.

Behavioural experiment and questionnaires

After substance administration, subjects completed questionnaires on a computer to measure demographic items and psychological characteristics. Due to the crucial role of the social environment in triggering behavioural effects of OT as shown in animal research[13,29], subjects were subsequently asked to wait in the rest area while the next part of the experiment was prepared. During this 5 minute waiting period, subjects were seated at different tables. Subjects at the same table could talk to each other; however at the beginning of the

subsequent experiment they were informed that they will not interact with those subjects who sat at the same table. When subjects re-entered the laboratory in both experiments, they received written instructions (available from the authors on request) explaining the payoff structure of the experiment and the private payment procedure at the end of the experiment. Subjects were randomly and anonymously assigned to the role of investor or trustee in the trust experiment and did not know the identity of the persons with whom they were matched. After subjects had read the instructions in each experiment, we checked whether they had understood the payoff structure by means of several hypothetical examples. All subjects (with one exception) answered the control questions correctly. One subject did not answer the control questions correctly and was excluded from the data set (this subject also did not apply the substance correctly). In addition, subjects received an oral summary of the instructions. Each subject in the trust experiment made four decisions in the same player role while paired with different randomly selected interaction partners. No pair of subjects interacted twice. Subjects in the role of the investor received no feedback about the trustee's decision between the different interactions. Each investor was asked about his belief with regard to the expected back transfer from the trustee after every transfer decision. It is noteworthy that trust levels are statistically constant across the four decisions. There is neither a time trend in investors' decisions in the OT nor in the placebo group. In the risk experiment, everything was identical to the trust experiment, except that all subjects were in the role of an investor who could transfer 0, 4, 8, or 12 MUs into a project rather than to a trustee. In particular, an investor's payoff risk (i.e., the distribution of payoffs) in the risk experiment was identical to that in the trust experiment for any feasible transfer level.

To measure alterations in subjects' psychological state throughout the course of the experiment, we assessed subjects' mood and calmness at the beginning of the experiment (i.e., before substance administration) and immediately before the trust game or the risk experiment, respectively, by means of a particularly suitable questionnaire[25]. All decisions in the experiments and the answers to the questionnaires were entered on a computer using z-Tree software[30]. Subjects received a flat fee of 80 Swiss Francs (CHF) for participation in the experiment; each MU earned in the trust and the risk experiment was worth CHF 0.40.

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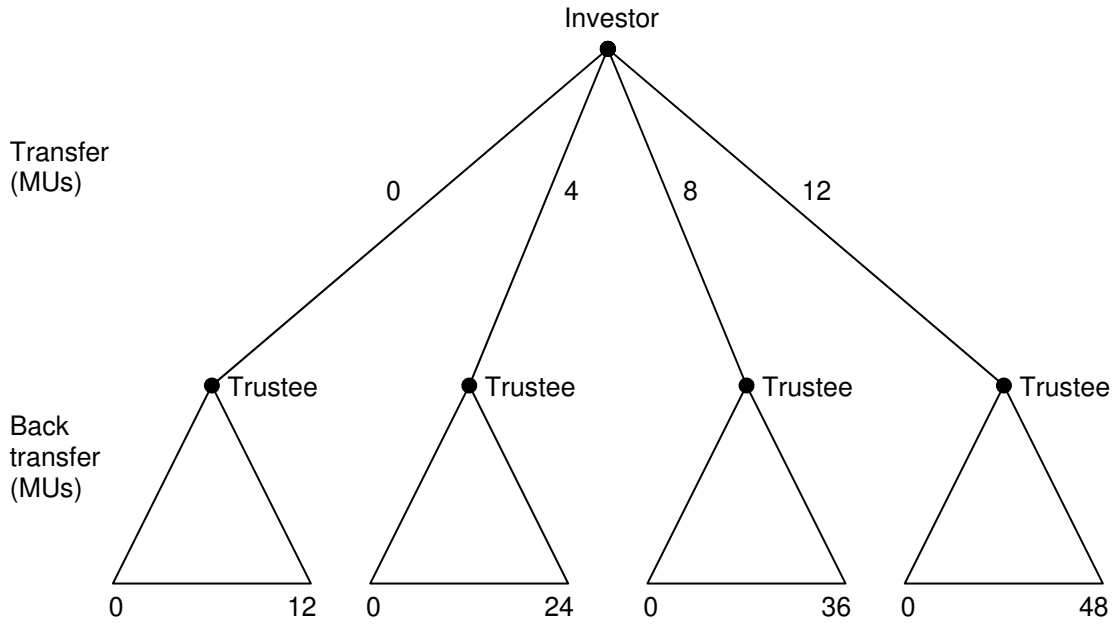
Table 1. Investors' average and median transfer behaviour (MUs)

	Trust experiment		Risk experiment	
	Oxytocin group	Placebo group	Oxytocin group	Placebo group
Mean average transfer	9.6	8.1	7.5	7.5
Median average transfer	10	8	8	8
Standard deviation of transfers	2.8	3.1	3.3	3.4
Number of observations	29	29	31	30

Figure 1 The trust game. Both subjects receive an initial endowment of 12 monetary units (MUs). The investor can opt for trust by sending 0, 4, 8, or 12 MUs to the trustee. The experimenter triples each MU the investor transfers. After the investor's decision is made, the trustee is informed about the investor's transfer. Then the trustee has the option of sending any amount between zero and his total amount available back to the investor. For example, if the investor has sent 12 MUs, the trustee possesses 48 MUs (12 own endowment + 36 tripled transfer) and can, therefore, choose any back transfer between 0 and 48 MUs. The experimenter does not triple the back transfer. The investor's final payoff corresponds to his initial endowment minus the transfer to the trustee plus the back transfer from the trustee. The trustee's final payoff is given by his initial endowment plus the tripled transfer of the investor minus the back transfer to the investor. At the end of the experiment, the earned MUs are exchanged into real money according to a publicly announced exchange rate (see Methods).

Figure 2 Transfers in the trust and the risk experiment. Each observation represents the average of an investor's transfers over four transfer decisions. **a.** Relative frequency of investors' average transfers across OT and placebo condition in the trust experiment (N = 58). Subjects with OT exhibit significantly higher transfers. **b.** Relative frequency of investors' average transfers across OT and placebo condition in the risk experiment (N = 61). Subjects in the OT and the placebo group exhibit statistically identical transfer levels.

Figure 3 Trustees' average back transfer for different levels of investors' transfers in the OT and the placebo group. The dotted line shows the level of the back transfer necessary to achieve payoff equality between the investor and the trustee. The broken line shows the level of the back transfer equal to the investor's transfer to the trustee. The trustees' back transfers are on average slightly higher than the amount sent by the investor. Trustees of both substance groups make higher back transfers for higher transfer levels of the investors. However, there is no statistically significant difference in back transfers between the OT and the placebo group.



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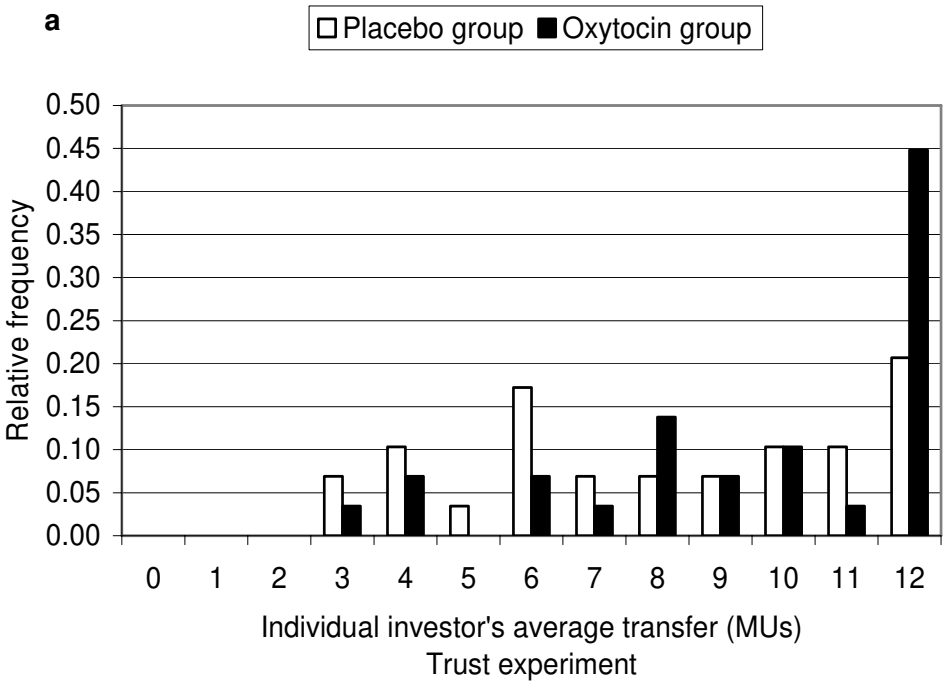

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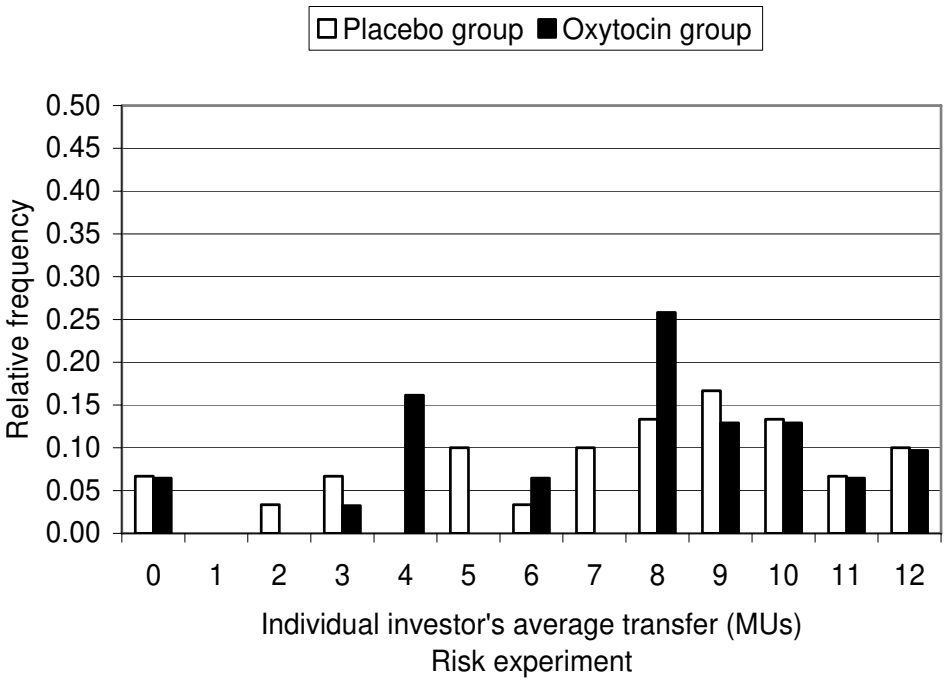

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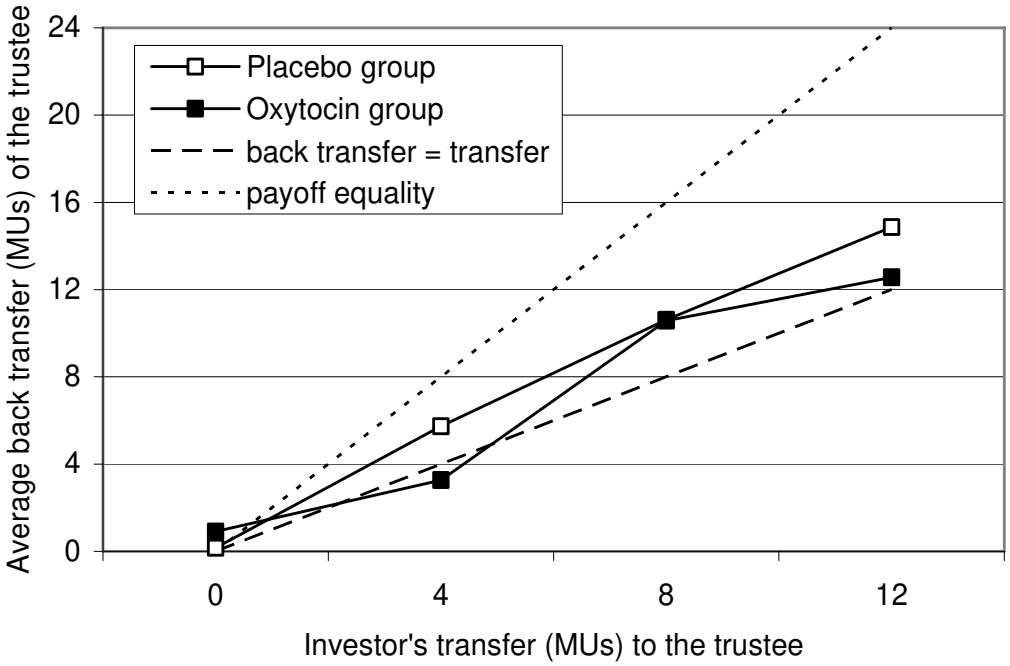

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