Bargaining and Trust: The Effects of 36hr Total Sleep Deprivation on Socially Interactive Decisions

Clare Anderson[1,2*] & David L. Dickinson[3]

1 Sleep Research Centre, Loughborough University, Leicestershire, UK.

2 Now at Division of Sleep Medicine, Brigham and Women's Hospital, Harvard Medical School, Boston, MA.

3 Dept. of Economics, Appalachian State University, North Carolina,

Running head: Sleep deprivation & interactive decisions

*** Correspondence address**
Clare Anderson, Ph.D.
Division of Sleep Medicine,
Brigham and Women's Hospital and Harvard Medical School,
221, Longwood Avenue,
Boston, MA, 02115.
Tel: +1 617 525 8558
Fax: +1 617 732 4015
Email: canderson22@rics.bwh.harvard.edu

22 December 2008

SUMMARY

Though it is well known that sleep loss results in poor judgment and decisions, little is known about the influence of social context in these processes. Sixteen healthy young adults underwent three games involving bargaining ('Ultimatum' and 'Dictator') and trust, following total sleep deprivation (TSD) and during rested wakefulness (RW), in a repeated measures, counterbalanced design. To control for repeatability, a second group (n=16) was tested twice under RW conditions. Paired anonymously with another individual, participants made their simple social interaction decisions facing real monetary incentives. For bargaining, following TSD participants were more likely to reject unequal-split offers made by their partner, despite the rejection resulting in a zero monetary payoff for both participants. For the trust game, participants were less likely to place full trust in their anonymous partner, again affecting final payoff. Overall, we provide novel evidence that following TSD, the conflict between personal financial gain and payoff equality is focused on unfavourable inequality. This results in the rejection of unfair offers, at personal monetary cost, and the lack of full trust, which would expose one to being exploited in the interaction. As such, we suggest that within a social domain a rational decision may not prevail over more emotional options following TSD, which has fundamental consequence for real-world decision making involving social exchange.

Words: 216

Key Words: Sleep loss, trust, bargaining, social preference, interaction.

Acknowledgments

The study was supported by a European Sleep Research Society and Sanofi-Aventis Young Investigator grant. The authors thank participants at the European regional Economic Science Association meetings in Lyon, France for helpful comments, and would also like to acknowledge Charlotte Platten for help with task set-up and data collection.

INTRODUCTION

It is well established that sleep deprivation (SD) is associated with decrements in basic cognitive function, such as alertness, vigilance, and sustained attention (Van Dongen et al., 2003; Dorrian et al., 2005; Lim & Dinges, 2008). What is less well known is the impact of sleep deprivation on higher-level cognitive functions (Killgore et al., 2006), collectively referred to as the 'executive functions'. Research findings of total sleep deprivation (TSD) have revealed more understanding of links between TSD and aspects of prefrontal function (executive function) such as planning (Horne, 1988), working memory (Chee & Chuah, 2008; Turner et al., 2007), inhibition (Harrison & Horne, 1998), generation of speech (Harrison & Horne 1997, 1998), and novel goal directed behavior (Horne, 1993). Given the vulnerability of these functions to TSD, it is understandable that TSD affects the ability to make decisions per se (McKenna et al., 2007; Killgore et al., 2006; Harrison & Horne, 2000) since effective decision making relies on the ability to appreciate future events (planning), update strategies (working memory), avoid distractions/irrelevant information (inhibition), think laterally and innovatively (novel, goal directed behavior) and to communicate effectively (generation of speech) (c.f. Harrison & Horne, 2000). Whilst error in any of these TSD vulnerable behaviors may cause a poor decision judgment, what is lacking in our understanding of TSD and decision making, and fundamental to the decision making process in the real-world, is the influence of our social environment.

Much of our current understanding of TSD effects on decision-making results from different aspects of individual decision-making (e.g., Killgore et al., 2006; Harrison & Horne, 2000). However, many important occupations rely on people working together co-operatively for extended periods and under conditions of sleep loss (e.g. emergency services, military personnel, trade union leaders). While some research has looked at the impact of TSD on decision making in team vs. individual performance (Baranski et al., 2007), to our knowledge, there remains an important gap in the literature describing TSD effects in interactive environments, especially those involving social preference domains. In behavioral economics 'social preference' refers to how people rank different allocations of material payoffs to themselves and others (Fehr & Camerer, 2007). Environments of basic social interaction, such as those involving simple bargaining behavior or trust decisions between two or more people have yet to be explored in the wealth of TSD research. Yet, such environments form the building blocks of many more complicated real world decision environments that hold particular interest due to their pitting of rational versus emotional response mechanisms in weighing decision costs and benefits.

The ability to regulate emotions is integral to any decision making process, and given that most real-world decisions are not made individually, emotional response mechanisms may play a greater role in social dilemmas of various sorts. A recent study involving subject viewings of aversive pictures showed a weakened functional connectivity between the amygdala and the medial prefrontal cortex following 35 hr of TSD (Yoo et al., 2007). Thus, existing research suggests an important hypothesis for how TSD might affect decisions involving more emotion-based domains, such as social interaction environments. Specifically, the mediation of emotion-based responses (by the prefrontal cortex) may be weakened, which would lead to more irrational decision-making (i.e., ruled by emotion) than would otherwise occur. Although decisions will not automatically be worse if more emotion-based, as the quality of the decision outcome will depend on the context of the decision, there may be an important shift in the engine driving social dilemma decisions following TSD.

A large body of literature surrounds three often-studied social preference environments in experimental and behavioral economics: the ultimatum, dictator, and trust games. Simple bargaining is examined with the classic ultimatum game introduced by Guth et al. (1982). In this game, two players are given a pie of $X to divide. The player assigned as the proposer suggests a division of the pie to the other player (the responder). If the responder accepts the proposed division, then the pie is divided in the proposed way to yield the players' payoffs in the game. However, should the responder reject the proposal, both players earn zero. The game is over after the responder's accept/reject decision. While simplistic, the game captures the important tension between selfish behavior versus fairness or other-regarding behavior. A variation of the game called the "dictator" game (Forsythe et al., 1994) removes the option of rejection by the responder. This additional simplification was examined to help distinguish the extent to which proposals in the ultimatum game were really driven by fairness consideration rather than a simple fear of rejection. Average offers in $10 ultimatum games are about $4.00, with offers lower than $2.50 often being rejected (see summary in Holt, 2007). Dictator offers are typically lower (average of $2.33 in Forsythe et al., 1994), though average dictator offers still average above zero (modal offer is typically zero, however). Thus, strategic considerations seem to play a role in these simple bargaining environments.

The trust game (Berg et al., 1995) allows an examination of trust and trustworthiness in an environment that is not zero-sum (i.e., zero sum being where one player's gain is necessarily the other's loss) as are the ultimatum and dictator games. In this game, the first mover decides how much of an initial sum, say $10, to pass to the second mover. Whatever amount is passed is then tripled by the experimenter, and the second mover may then decide how much, if any, of the tripled amount to return to the first mover. Thus, the first mover's "pass" decision can be regarded as a measure of trust, while the second mover's pass decision is a measure of trustworthiness. (Though more recent research has highlighted the fact that first movers in the trust game may pass money out of altruism as well as trust, this recent evidence still indicates that trust is a likely component of the first mover decisions in this game (see Cox, 2004).) In Berg et al. (1995), the average amount passed was $5.16, and after tripling, about $2.79 (18% of the tripled amount) was returned. An important difference in the trust game is the risk the first-mover takes in deciding to pass money. Fear of betrayal or being taken advantage of may be aroused in making the trust decision in a way that is magnified over the fear of rejection in the ultimatum game.

Whilst no study currently exists that assesses TSD in relation to these social preference games, clues from neurological evidence suggest TSD may modify behavior choices. For example, Koenigs and Tranel (2007) examined subjects with ventro-medial prefrontal cortex lesions, and find that simple bargaining offers were rejected more frequently by these subjects (at monetary cost to themselves) focusing on unfair treatment rather than rational monetary gain. The extent to which this may be mirrored in subjects following 36hr TSD is unknown, and forms the basis of our study.

METHODOLOGY

Participants

32 young healthy participants (16m; 16f, 20.2y-24.1y) who were good sleepers (determined via actiwatch and sleep diaries) and with no complaint of daytime sleepiness (ESS≤10, Johns, 1991) were recruited following interviews and subsequent screening to exclude: those who smoked; had an average intake of alcohol more than 4units per day and/or caffeine more than 300mg per day; had any sleep or medical problems (other than minor illnesses); were on any

medication liable to cause daytime sleepiness. In addition, those who took daytime naps more than twice per month were excluded from the study. To check for stable sleep patterns actiwatches (Cambridge Neurotechnology Ltd., Cambridge, UK) were worn for an initial screening week. Those who slept 8h ±1h per night, and with consistent bed/rise times, were included in the study. The study was approved by Loughborough University's Ethical Advisory Committee. All procedures were fully explained, informed consent given, and participants were paid for their involvement.

Participants were randomly assigned to either the experimental group (n=16 8m; 8f; Av. 22.6y±1.2y) or Control group (n=16 8m; 8f; Av. 22.3y±2.1y). Using a repeated measures design, the experimental group underwent three social preference tasks twice, once following 36hr of TSD and another following normal sleep (rested wakefulness: RW). Whilst these were counterbalanced, we repeated the tests twice with the control group as a check on consistency. Groups were matched for age, sex, IQ, anxiety and personality.

Design & Procedure

In a repeated measures design, the experimental group arose at 08:00h, following a night of 'normal' sleep, at home, as determined by actiwatch (Cambridge Neurotechnology) and timed phone calls to the laboratory. For both conditions, participants arrived at the laboratory at 14:00h (actigraphy verified non-napping) where actiwatches were checked for compliance and questionnaires completed. For the RW condition, they were given a small meal at 16:00 and began testing at 19:00h on (see below). For the TSD condition, they were kept under constant supervision for a further 25h to ensure they remained awake, adhered to study protocol and for reasons of safety. They began testing at 19:00h on Day 2 following 35-36h TSD.

During TSD participants consumed only non-caffeinated drinks and were given food opportunities at 3-hourly intervals where they ate ad-lib. Foods with high sugar content were omitted due to bolus amounts of sugar having an initial alerting effect followed by a sleepiness rebound (Anderson & Horne, 2006). During the 25h laboratory period they engaged in conversation, light reading, watched TV or played board games. At the end of the trial they were escorted home and consented to undertake recovery sleep before driving, riding a bicycle, or operating machinery.

Conditions were counterbalanced so n=8 underwent TSD followed by RW and n=8 underwent RW followed by TSD. Each session was separated by one week to allow for adequate recovery sleep. Control participants were tested twice under the same protocol as the experimental RW condition, and again, each test session was separated by one week.

Test Sessions

Four participants made up each test trial. Each participant was randomly paired with one other participant in a single-blind manner (i.e. paired anonymously). They were given the following standard information: “We have matched you with another member of the group and between you, you will play a series of short, simple games. You should be aware that any financial payoff from the game is real and so you should make your decisions carefully”.

Each game required a first mover and a second mover. We employ a particular procedure known as the “strategy” method to elicit a maximum amount of data from the subjects. Using this method in the ultimatum and trust games, the second responder enters a response for any possible contingency of money passed from the first mover (as opposed to just responding to one particular first mover decision). Additionally, subjects are asked to make decisions for both the first mover and second mover subject-roles in the ultimatum and trust games (as well as a first mover decision in the dictator game). Ex poste role assignment was random and, after all decisions were made, used to calculate payoffs. This method places subjects in a position to think through the social dilemma from both players’ perspectives, realizing that there is equal chance that they may be assigned in either role; their randomly assigned role may vary for each test. Finally, after role assignments are made, subjects were paired up (one first mover assigned to one second mover) randomly and anonymously, such that subjects were never aware of whom they were paired with for the decision experiments. This way of eliciting decisions does not alter play in the ultimatum game (c.f. Oxoby and McLeish (2004)

Anonymity is accomplished by recruiting subjects in groups of 4. Thus, while subjects were aware that they were randomly matched with one of the other subjects in their group, the identity of the pairings was never revealed. A key feature in this design is that subjects were keenly aware that their decisions were not hypothetical, and that a real bargaining and trust payoff would be received based on the decisions made in the random and anonymous role-assignments and pairings.

There were three games in total and these were counterbalanced to avoid order effects. Each test was approximately 5 minutes in duration, and there was a 5 minute gap between tests. Total test duration was less than 30 minutes.

Bargaining Game: Ultimatum and Dictator

The Ultimatum game (Guth et al., 1982) has been used extensively in experimental economics research (see references in Holt, 2007), as well as in the nascent field of neuroeconomics (e.g., Koenigs and Tranel, 2007). In this game, two players were allocated £5. The proposer proposed how to split this money and the responder chose whether to accept or reject the offer. If the offer is rejected both players earn zero. The purely self-interested rationale, therefore, is for the proposer to offer the smallest amount possible for the responder to accept. The most frequent offer is about 40%-50% of the sum, and about half of responders reject offers below 30% (Nowak et al., 2000). This would suggest humans consider fairness in their decisions.

In cubicle 1, the 'proposer' was given the following instruction: "We have matched you with another member of the group and between you, you will play a short, simple game. You are the first mover and must decide how much of the £5 (in 50p increments) you want to pass or keep. However, we must warn you that your partner has the choice to accept your offer or reject it. If they reject it, you will both receive nothing". Once the participant understood, they made their offer and posted it on the offer card and handed this to the experimenter in a sealed envelope.

The experimenter went to cubicle 2 and gave the following instruction: "You are the second mover and your partner has made their first move as to how much of the £5 they have chosen to give you. However, we cannot tell you the amount they have proposed but ask you to make a decision for each eventuality. Again, it is important you answer honestly, as this could be real money". The participant was given a recording sheet of every eventuality (50p, £1, £1.50 and so on) and was told "In front of you is the response sheet for you to record your decision. You can see the amount your partner has kept for themselves and how much they choose to give you. Please indicate whether you wish to accept or reject this offer. Remember if you reject you both receive nothing". The responder gave their decisions to the experimenter in a sealed envelope.

By not revealing the actual amount given, we were able to assess response for each eventuality for data analysis purposes. Importantly, this game was then repeated but with the roles reversed so each participant played both the proposer and the responder.

The ‘Dictator’ game is much the same as before; the main difference being that the responder must accept any offer. Previous research suggests offers made by the proposer are much less than the Ultimatum game (although still above zero) (Forsythe et al., 1994) suggesting the 40%-50% offer in the Ultimatum game is due to both an element of fairness as well as a fear of rejection (loss).

For the Dictator game, the proposer was given the following instruction: “You have another £5 which you can split with your partner in whichever way you choose in increments of 50p. However, this time they have no choice whether to accept or reject and so you can give them what you like. However, do remember this is real money and will be a decision used to calculate both your earnings. Please make your decision now”.

Trust Game

Here, the first mover receives £5 who then decides whether to invest in a trustee (second mover) or retain it. Any money invested, and passed to the second mover is tripled, and the second mover then decides how much to retain or pass back to the first mover.

The first mover was given the following instruction: “We have matched you with another member of the group and between you, you will play a short, simple game. There is £5 and as first mover you must decide how much of the £5 (in 50p increments) you want to pass or keep. Whatever you choose to pass will be multiplied by 3 and given to your partner. You partner will then have a choice of how much to pass back to you. Remember to answer honestly as you and your partner could receive this amount. Please indicate how much you would like to pass or keep”. The first mover recorded their response and placed in a sealed envelope.

The second mover (in cubicle 2) was then given the following instruction: “You are second mover. Your partner has opted to give you a certain portion of their £5 and we have multiplied that by 3. However, we cannot tell you the amount they have proposed but ask you to make a decision for each eventuality. Again, it is important you answer honestly, as this could be real money. Please indicate for each amount how much (if any) you would like to give back to your partner. Again, remember this is real money and may count toward your final pay off". The second mover made their decisions and placed them in a sealed envelope.

Roles were then reversed so each participant made a first mover and second mover decision. In both simple bargaining and trust, subjects were clearly explained that roles would be randomly assigned after all decisions were made, and each subject would earn the payoff associated with their decision matched with that of their randomly assigned counterpart.

Overview of Test Variables

In the bargaining games, for each subject we have three test variables: 1) an ultimatum proposer decision (i.e., a proposal), 2) an ultimatum responder decision coded as a minimum acceptable offer (MAO) from the subjects' menu of accept/reject decisions made ex ante for all possible proposal contingencies, and 3) a dictator proposal. For the trust game, each subject makes a first mover (trust) decision, as well as a second mover (trust-worthiness) decision for every possible first mover choice.

Data Analysis

Given our repeated-measures design, with counterbalanced ordering of totally sleep-deprived (TSD) and rested wakefulness (RW) conditions, we analyze the data as matched pairs. This allows us to examine causal changes in subject choice as a result TSD. Given the relatively small sample size and possible non-normality of the data, we employ nonparametric statistical methods in most instances. Our analysis assumes that decisions across experiments are independent, and adjustments are made for ties in the matched pairs data (i.e., when a subject's decision is identical in the TSD and RW conditions).

While our counterbalancing of the condition order in our sleep group helps remove any ordering effects in the matched pairs data, as noted earlier we also administered the experiment to a group of 16 control subjects. Thus the control subject data allow us to examine the pure effect of repeat administration or learning in the data. As will be seen, control subject decisions were never significantly different across the two administrations of the tasks.

All reports on statistical significance come from using the sign-test on the bivariate random sample of each pair of decisions made by a subject unless otherwise noted. This nonparametric test places no assumption of normality on the distribution of the sample data, though it does assume the data across subjects are independent. In most cases, we reject the null hypothesis of normality of the relevant matched-pairs data distribution for our various tests (Shapiro-Wilk test, $p<0.10$), and so analyze our matched-pairs data with the simple sign-test .

RESULTS

Ultimatum and Dictator results

As seen in Figure 1, first mover proposals from the Ultimatum and Dictator game reveal dictator offers were significantly less than ultimatum offers ($p \leq 0.01$). This was also evident in the control group ($p=0.05$). However, treating each subject's pair of ultimatum offers as matched pairs data, we conclude that ultimatum offers are not affected by the sleep condition (RW v. TSD, $p>0.10$) or repeat administration for the control group ($p>0.10$).

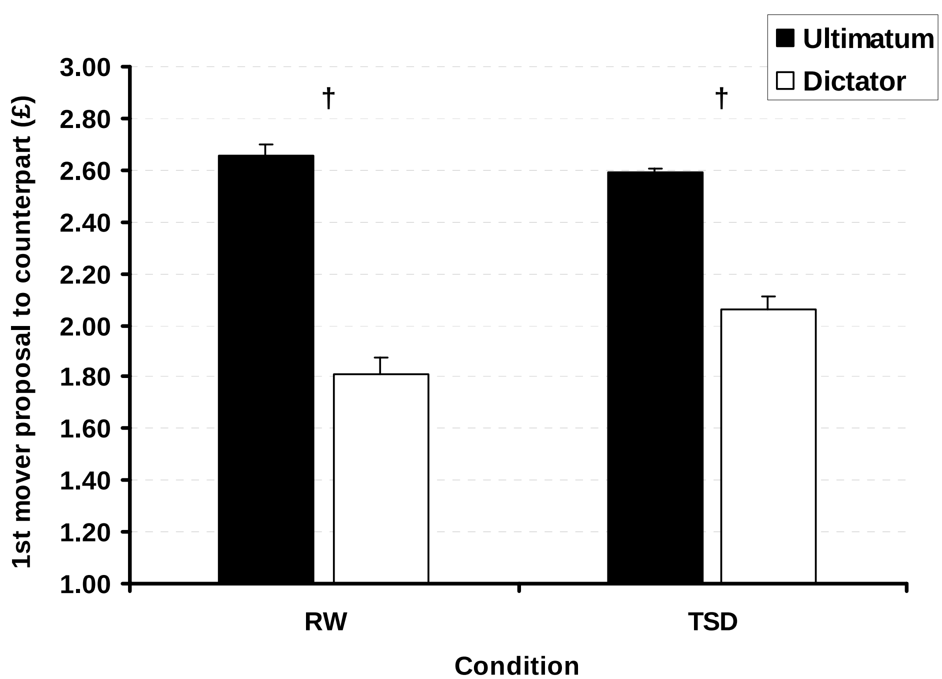

Figure 1: Average proposal decisions on the Ultimatum (black bars) and Dictator (white bars) game. S.e. bars are shown. All proposals were reduced on the dictator game. †p<0.01. There was no main effect of SD on either decision.

Figures 2 and 3 show the summarized data on ultimatum game responder decisions. From these data we calculate minimum acceptable offers (MAO) for each subject for each condition (sleep group) or administration (control group). MAO for the sleep condition are £0.84±.85 for well-rested subjects and £1.34±1.09 following 36hr total sleep deprivation. For control subjects, MAO is £1.22±.88 and £1.28±.97 on first and second administration of the task, respectively. Figures 2 and 3 also highlight the 50:50 equal-split outcome at £2.50, which is an offer rarely rejected in the ultimatum game. Examining the matched-pairs data of MAO from each subject we find that the difference in MAO was not significant across administrations in the control treatment ($p>0.10$) – see figure 2. However, we find that MAOs are significantly higher following TSD than in the RW condition of our sleep group ($p=0.05$) – see figure 3. Thus, we conclude that 36 hr of TSD leads subjects to bargain more aggressively in this simple ultimatum game, although the effect only manifests itself in responder decisions and not in first mover proposals.

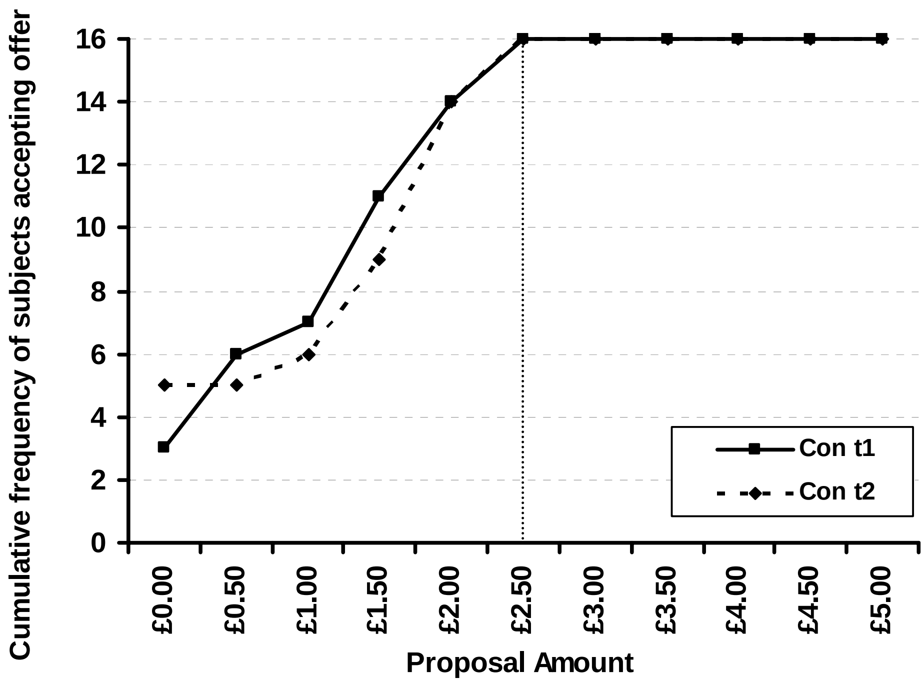

Figure 2: Cumulative frequency of participants accepting the proposer offer for the control group. The dotted vertical line marks the 50:50 equal split of the pie, which is normally accepted in this game. There were no differences in the matched pairs control.

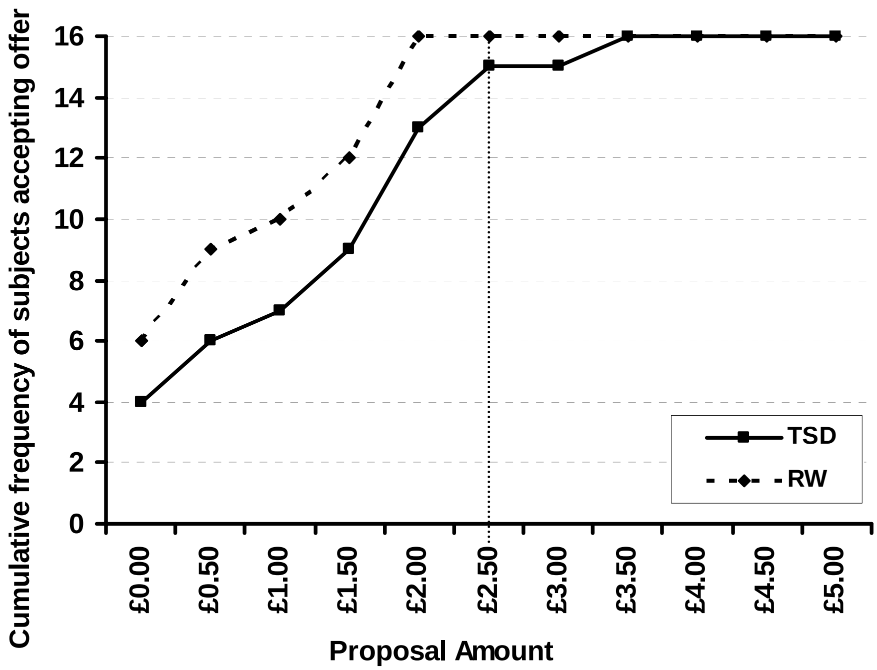

Figure 3: Cumulative frequency of participant accepting the proposer offer for the experimental group (TSD Vs RW). The dotted vertical line marks the 50:50 equal portion size, which is normally accepted in this game. There was a significant effect of TSD ($p<0.05$) on the MAO.

Trust game results

Figure 4 highlights the results for TSD Vs. RW in the trust game. Here, data indicate that well-rested subjects may keep less and pass more (i.e., trust more) than TSD subjects. Mean amount kept following TSD is £2.06±1.59, compared to £1.41±1.49 for RW (See Figure 4). For the first and second administrations of the task for the control group, mean amounts kept were £2.25±1.03 and £2.53±1.31, respectively. Sign-test analysis of the matched pairs data do not reveal any statistically significant differences, either across sleep conditions or control group administrations ($p>0.10$).

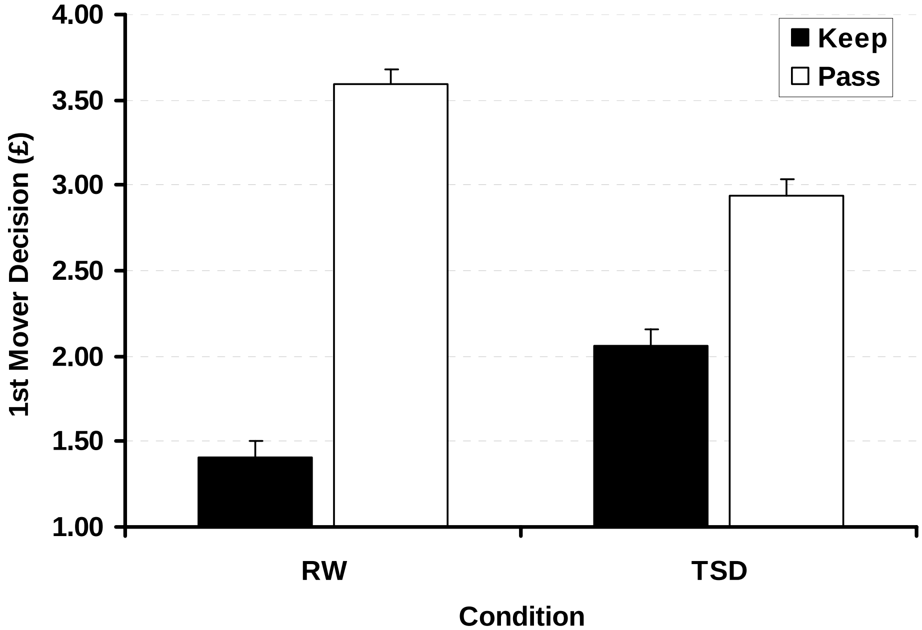

Figure 4: Average amount passed and kept by the first mover in the trust game. While it appears that the subjects in the RW group pass (trust) more, this falls below the acceptable level of significance. S.e. bars are shown.

Upon further examination of first mover trust decisions, Figure 5 highlights that though sleep condition may not affect average trust levels, the difference in sleep conditions may be largest at the extreme trust end of the distribution. If we arbitrarily define extreme trust as those instances when the first mover passed at least £4.00 of the possible £5.00 (80% of possible trust amount), then we find that 5 of 16 subjects exhibit extreme trust amount during TSD, compared to 9 of 16 subjects when well-rested. Defining extreme-trust as occurring in either subject condition with probability p, we then use the binomial test to examine the differences in probability of extreme trust in the TSD and RW sleep conditions. A baseline p could be generated from the control subject data, but such data may have group-specific effects, so we proceed by utilizing the experimental group's RW p_{rw}=.5625 (9/16) as the hypothesized probability of extreme trust for the binomial tests. In doing so, we reject the null hypothesis that the TSD subjects have a similar probability of extreme-trust against the one-sided alternative that their probability $p_{tsd} < p_{rw}$ (p-value of 0.04 for the one-sided binomial test). Had we chosen

p_{tsd}=.3125 (5/16) as the hypothesized probability of extreme-trust, we reject the null hypothesis that $p_{sd} = p_{wr}$ in favor of the one-sided alternative that $p_{tsd} < p_{rw}$ (p-value=0.01 in this instance). Thus, there is some evidence consistent with the hypothesis that subjects trust less following TSD, though the effect is concentrated in the extreme-trust end of the continuum of trust possibilities.

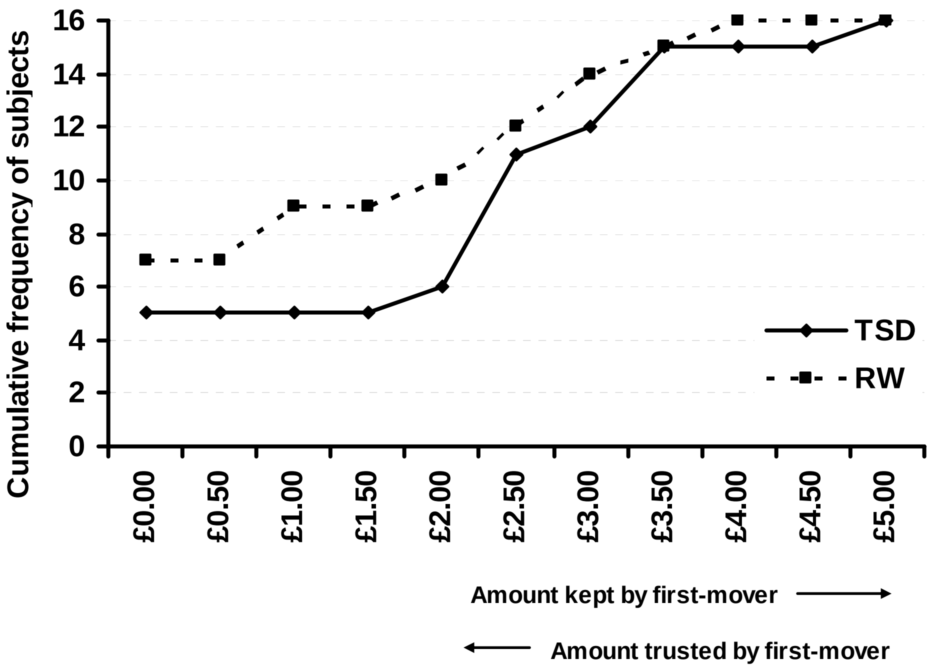

Figure 5: Cumulative distribution function (CDF) of amount kept by first-mover in trust game. Sixteen subjects (vertical axis) from the experimental group make up the entirety of the CDF. The larger difference between the TSD and RW distributions at lesser amounts kept indicates that the highest trust levels occur among significantly fewer TSD subjects compared to RW.

For second mover decisions, while some group difference exist in the RW vs. TSD group, the effects of sleep condition or repeat administration do not significantly affect a subject's trustworthiness (kolmogorov-smirnov full distribution test, p>0.10). Interestingly, while the significant result in the bargaining experiments was localized to second mover (responder) decisions in the ultimatum game, in the trust game the interesting result is with respect to first mover (trust) decisions. We examine this more in the Discussion section.

Overall monetary earnings can be seen in Table 1. As seen, though TSD did appear to lower overall experiment earnings, the difference is not statistically significant. However, for each task the TSD group made less money.

Table 1: Average earnings from the three social preference games, and total average earnings in £. Although TSD appeared to lower overall earnings, this was not statistically significant at the 0.05 level.

Group	Condition	Ultimatum	Dictator	Trust	TOTAL
Experimental Group	SD	2.19 0.22	2.94 0.21	5.38 0.58	**10.50** 0.65
	RW	2.53 0.05	3.19 0.24	6.00 0.42	**11.72** 0.42
Control	t1	2.06 0.41	3.28 0.32	5.69 0.73	**11.03** 1.01
	t2	2.34 0.15	3.56 0.26	4.88 0.49	**10.78** 0.71

DISCUSSION

Our results highlight important effects of sleep deprivation on simple 2-person social interactions that may be relevant in a real-world setting. Across two related social preference environments, we find that individuals interact more aggressively following TSD. As responders in the ultimatum game, subjects increased their minimum acceptable offers (MAOs) following TSD, perhaps indicating an increased resistance to offers perceived as unfair. In the simple trust environment, though the evidence is not uniform across all trust levels, we find that extreme levels of trust among first movers in the trust experiment are less likely following TSD. It is noteworthy that trusting one's counterpart by passing along money in this environment puts one at risk to being taken advantage of.

Recent advances in behavioral economics research suggest the issue of equality may be an important factor in these decisions. Fehr and Schmidt (1999), for example, introduce a theory that models how people care about payoff inequity (i.e., fairness) in social interactions, and not just their own payoff. Thus, any deviation from equal payoffs is assumed to lower one's value or utility function over outcomes. Other theories introduce notions of fairness into individual preference functions (e.g., Rabin, 1993; Bolton and Ockenfels, 2000). Fehr and Schmidt (1999) assume that individuals are inequity averse, but also that individuals would still rather have inequity in their favor than vice versa. In other words, there is a stronger aversion to unfavorable inequity (i.e., your payoff higher than mine) than favorable inequity (i.e., my payoff higher than yours). For our TSD group, the conflict between personal financial gain and payoff equality seemed to focus subjects on unfavorable inequity, and as such many made a decision to reject offers despite this being at a loss to themselves, a finding present in those with ventro-medial PFC damage (Koenigs & Tranel, 2007-see below).

The present evidence is thus consistent with the hypothesis that sleep deprivation increases the parameter on unfavorable payoff inequity, as if one becomes more sensitized to the threat of being "outdone" in the social interaction [Though the threat may exist in some sense in the Dictator game, there is no response option, and so nothing behavioral to examine such a hypothesis in this extreme game]. This threat may be more salient to an ultimatum responder who can choose what level of payoff inequity she accepts, compared to the proposer who either gets more than half the pie (typically) or an equal-payoff outcome of zero in the event of rejection. On the other hand, in the trust environment, it becomes the first mover who faces the largest threat of being exploited. A second mover in the trust experiment is less likely to feel exploited given that he/she can choose to always pass zero of whatever amount the first mover trusts. Thus, it seems that the threat of exploitation looms largest for ultimatum responders and first-move trusters and, if TSD leads to a heightened fear of being taken advantage of, this may generate the data patterns we observe.

Neural activation evidence for both ultimatum and trust experiments has recently been examined in the emerging area of neuroeconomics. Fehr and Camerer (2007) report that the striatum is a consistently implicated brain region in those engaged in making fair or trusting behaviors. Additionally, they report that the prefrontal cortex (PFC) is typically implicated in cognitive control and emotional processing. There is a key dilemma involved in making a social preference decision: the comparison of self-serving and social motives. The PFC is considered the key region in making this comparison and resolving the conflict. Koenigs and Tranel (2007) examine ultimatum game play in subjects with ventro-medial PFC brain lesions, and find that such subjects reject ultimatum offers with higher frequency. Such a result is consistent with the hypothesis that the cost of rejection is given less weight in the brain's cost-benefit analysis of the decision scenario (Fehr and Camerer, 2007). It is also consistent with the hypothesis that the emotional reaction more likely dominates the decision to reject unfair offers given that the regulatory function of the PFC in the selfish/social preference dilemma is compromised.

In Yoo et al., (2007), subjects viewed a standardized set of emotional pictures either well rested or following total sleep deprivation of 35 hours. TSD subjects displayed a larger amygdala response to the pictures than those viewing them well-rested. Additionally, Yoo et al., (2007) report decreased functional connectivity between the amygdala and the medial PFC following TSD. These findings suggest that the amygdala may be more dominant in the decision making of TSD subjects. Subjects playing the same trust game were intranasally infused with the synthetic neuropeptide oxytocin (OT) in Kosfeld et al. (2005). The OT-infused subjects were more trusting than the control (placebo) group. This finding is of particular interest not just because we administer the same trust game, but primarily because OT has been shown to decrease amygdala activity in Kirsch et al., (2005). Together, these studies suggest that TSD would lead to less trusting social choices given that it enhances amygdala activity, which appears detrimental towards exhibition of trust. Insel and Young (2001) provide corroborative (animal) data showing that OT may reduce defensive behavior (e.g., fear of betrayal reduced). Thus, the hypothesis that increased amygdala dominance in the social decision process will increase fear of betrayal and thereby lower trust is consistent with our evidence.

Our results suggest that individuals' social preferences are more concerned with avoiding betrayal of different sorts, even by anonymous counterparts. In both simple bargaining and trust experiments, significant behavioral effects are found on only one side of the interaction, but in both environments the result is consistent with an increased defensiveness following TSD. If trust is an important component of a well-functioning modern society, then reduction of trust in an increasingly sleep deprived society holds significant implications. Indeed, many important institutions function on a certain level of trust (e.g., banks for solvency, informal credit markets, marriage). Clearly, the full cost of TSD effects on the quality of social interactions is beyond the scope of this study, but our results are merely illustrative of a behavior that has been unexamined in a TSD context. They indicate that mistrust and defensiveness may become more prevalent as our social preference decisions become more controlled by the emotional part of the brain that has heightened awareness of possible exploitation when under TSD.

These experiments are a first step in examining social preferences (allocation of resources between self and others) and TSD. Whilst real-world sleep loss may not be as extensive as 36hr, further work may address the extent to which one must be sleep deprived before such behavioral effects set in. Furthermore, we do not examine the importance of the actual face-to-face interaction present in real-world negotiations and many trust environments. Here, we do this explicitly so as to reduce the potential confounds of unquantifiable aspects of face-to-face interactions (e.g., body language), yet recognize these are clearly interesting components of real world social interactions. In short, there is a wealth of important aspects of social interactions that remain unexplored by sleep researchers. Nevertheless, these experiments are a first step toward a more comprehensive examination of decision making within a social domain, and are the first indicators that a rational decision may not prevail over more emotional options following one night of sleep loss.

REFERENCES

Anderson, C & Horne, J.A. A high sugar content, low caffeine drink does not alleviate sleepiness but may worsen it. Hum Psychopharmacol., 2006, 21(5): 299-303.

Baranski, J.V., Thompson, M.M., Lichacz, F.M.J., McCann, C., Gil, V., Pastò, L., & Pigeau, R.A. Effects of sleep loss on team decision making: motivational loss or motivational gain? Hum. Factors, 2007, 49(4): 646-660.

Berg, J., Dickhaut, J., and McCabe, K. Trust, reciprocity, and social history. Games and Econ. Behav., 1995, 10: 122-142

Bolton, G., and Ockenfels, A. ERC—A theory of equity, reciprocity and competition. Am. Econ. Rev., 2000, 90: 166-193.

Chee, M.W. & Chuah L.Y. Functional neuroimaging insights into how sleep and sleep deprivation affect memory and cognition. Curr Opin Neurol, 2008, 21(4): 417-423.

Cox, J. C. How to identify trust and reciprocity. Games and Econ. Behav., 2004, 46: 260-281.

Dorrian, J., Rogers, N.L. & Dinges, D.F. Psychomotor vigilance performance : a neurocognitive assay sensitive to sleep loss. In Kushida, C.A. (ed) Sleep Deprivation: Clinical issues, pharmacology and sleep loss effects. New York, NY: Marcel Dekker, Inc., 2005: 39-70.

Fehr, E., and Camerer, C.F. Social neuroeconomics: the neural circuitry of social preferences. Trends Cogn. Sci., 2007, 11: 419-427.

Fehr, E., and Schmidt, K.M. A theory of fairness, competition, and cooperation. Q. J. Econ., 1999, 114: 817-868.

Forsythe R, Horowitz JL, Savin NE & Sefton M. Fairness in simple bargaining games. Games and Econ. Behav., 1994, 6: 347-369.

Guth, W., Schmittberger, R., and Schwarze, B. An experimental analysis of ultimatum bargaining. Journal of Economic Behavior and Organization, 1982, 3: 367-388.

Harrison, Y. & Horne, J.A. Sleep deprivation affects speech. Sleep, 1997, 20(10): 871-877.

Harrison, Y. & Horne, J.A. Sleep loss impairs short and novel language tasks having a prefrontal focus. J Sleep Res., 1998, 7(2): 95-100.

Harrison, Y. & Horne, J.A. The impact of sleep deprivation on decision making: A review. J. Exp. Psychol. Appl., 2000, 6(3): 236-249.

Holt, C. Markets, games, & strategic behavior, Pearson Education, Inc, 2007: 147-157.

Horne, J.A. Sleep loss and “divergent” thinking ability. Sleep, 1988, 11(6): 528-536.

Horne, J.A. Human sleep, sleep loss and behaviour. Implications for the prefrontal cortex and psychiatric behaviour. Br J Psychiatry, 1993, 162: 413-419.

Insel, T.R. & Young, L.J. The neurobiology of attachment. Nat. Rev. Neurosci. 2001, 129-136.

Johns, M.W. A new method for measuring daytime sleepiness: the Epworth Sleepiness Scale. Sleep, 1991, 14(6): 540-545.

Killgore, W.D.S., Balkin, T.J. & Wesensten, N.J. Impaired decision making following 49 h of sleep deprivation. J. Sleep Res., 2006, 15: 7-13.

Kirsch, P., Esslinger, C., Chen, Q., Mier, D., Lis, S., Siddhanti, S., Gruppe, H., Mattay, V.S., Gallhofer, B., Meyer-Lindenberg, A. Oxytocin modulates neural circuitry for social cogniiotna dn fear in humans, J. Neurosci. 2005, 25(49): 11489-11493.

Koenigs, M., and Tranel, D. Irrational economic decision-making after ventromedial prefrontal damage: evidence from the ultimatum game. J. Neurosci., 2007, 27: 951-56.

Kosfeld M., Hienrichs, M., Zak, P.J., Fischbacher, U. & Fehr, E. Oxytocin increases trust in humans. Nature, 2005, 435(7042): 673-676.

McKenna, B.S., Dickinson, D.L., Orff H.J., & Drummond, S.P.A. The effects of one night of sleep deprivation on known-risk and ambiguous-risk decisions. J Sleep Res, 2007, 16(3): 245-252.

Nowak, M.A., Page, K.M. & Sigmund, K. Fairness versus reason in the ultimatum game. Science. 2000, 289(5485): 1773-1775.

Oxoby, R.J., and McLeish, K.N. Specific decision and strategy vector methods in ultimatum bargaining: evidence on the strength of other-regarding behavior. Econ. Lett., 2004, 84: 399-405.

Rabin, M. Incorporating fairness into game theory and economics. Am. Econ. Rev., 1993, 83: 1281-1302

Turner, T.H., Drummond, S.P.A., Salamat, J.S. & Brown, G.G. effects of 42h total sleep deprivation on component processes of working memory. Neuropsychology, 2007, 21(6): 787-795

Van Dongen, H.P.A., Maislin, G., Mullington, J.M., and Dinges, D.F. The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. Sleep, 2003, 26: 117-26.

Yoo, S-S., Gujar, N., Hu, P., Jolesz, F.A., and Walker, M.P. The human emotional brain without sleep—a prefrontal amygdale disconnect. Curr. Biol., 2007, 17: 877-878.