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Divergent processing of monetary and social reward in behavioral variant frontotemporal dementia and Alzheimer's disease

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Keywords

Frontotemporal dementia; Alzheimer's disease; reward

INTRODUCTION

Reward processing comprises what individuals will work for, such as food, money, or social approval. Patients with behavioral variant frontotemporal dementia (bvFTD) exhibit overeating and poor financial decisions, including overspending and impulsive purchases in spite of negative consequences. On gambling tasks bvFTD patients choose options with high risk of monetary loss but with large possible gains[1, 2]. Social functions are particularly affected in bvFTD and patients are often cold and withdrawn, suggesting a lack of reward through interpersonal interaction. By contrast, early in Alzheimer's disease (AD) social skills tend to be more intact. AD patients also make financial errors, but for different reasons[3]. Amnestic mild cognitive impairment patients who may develop AD are more motivated by avoiding monetary loss than by monetary gain[4].

The mechanisms underlying decision-making deficits in bvFTD and AD are potentially different, reflecting differing contributions from a heightened desire for gain, loss insensitivity, or cognitive deficits related to executive function. In addition, the impact of social rewards may differ between disorders. An association between reward and social cognition is plausible, since reward processing involves a distributed network including ventral striatum, orbitofrontal cortex, insula, and anterior cingulate, and there is some overlap between these regions and those required for social cognition. Experimental comparison of monetary and social reward processing anatomy showed largely overlapping results[5]. Little is known about how systems mediating rewards and social cognition interact to impact behavior.

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Conflicts of interest

Supplemental Digital Content

Supplemental Digital Content 1. Text that gives details of study subjects and description of the study task. Pdf

Our objective was to apply a modified version of an established reward task, the Monetary Incentive Delay (MID)[6], including social and monetary rewards[5] to bvFTD and AD patients to determine whether they are motivated more by seeking potential gain or avoiding potential loss, and whether this differs if the reward is monetary or social. We hypothesized that bvFTD patients would be less sensitive to potential monetary loss based on their real-life financial decisions[3] and gambling task performance and would be unmotivated by social rewards, whereas AD patients would be more motivated by avoiding monetary loss.

METHODS

Subjects

Patients with bvFTD, AD, and normal controls were recruited to participate (Supplemental Digital Content 1 for subject diagnostic evaluation and inclusion criteria). Written informed consent was obtained from patients or surrogates according to procedures approved by the UCSF Committee on Human Research. 66 subjects completed the task successfully and were included in the analysis, 14 with bvFTD, 11 AD, and 41 controls. Demographic features of the three groups are listed in Table 1.

Procedure

Subjects participated in a computer-based reaction time task adapted from the MID[6] (Figure 1 and Supplemental Digital Content 1 for task details). Two task blocks evaluated monetary rewards: a monetary win and a monetary loss condition. The other two assessed social rewards: social win and social loss. Subjects were instructed to push the spacebar immediately when a target appeared onscreen. Success on each trial was based on responding before the target disappeared and feedback was given after each trial. The duration the target remained onscreen was adjusted throughout the task to ensure a 66% success rate. Subjects were paid cash based on total earnings during the monetary blocks. Feedback on social blocks consisted of smiling faces, angry faces, or neutral ovals.

Statistics

Statistics were performed using IBM SPSS Statistics 20. The main analysis was a mixed-model, repeated measures analysis of covariance with reward type (money or social) and reward direction (gain or loss) as independent variables. Reaction time after target appearance was the dependent variable. Groups were compared by univariate analysis of variance for age, education, and Mini Mental State Examination (MMSE)[7] with between group differences assessed post hoc with Bonferroni correction for multiple comparisons. Gender was compared by chi squared analysis. Factors that significantly varied among the three groups were included as covariates. Data were excluded for subjects who failed to press the button during at least 20% of trials, which suggested they were not correctly following task directions. This occurred in one control, three bvFTD, and five AD subjects (not included in number of subjects listed above or Table 1).

RESULTS

Education differed among groups with controls being significantly more educated than bvFTD (p=.033). Gender did not differ significantly among groups. Age varied significantly and controls were older than bvFTD (p<.001) and AD (p<.05). MMSE varied among all groups with each group significantly differing from the others (all p<.001). Age, education, and MMSE were included as covariates in subsequent analyses.

There was a significant main effect of reward type (F(1,60)=5.97, p<.05) with shorter reaction times on monetary trials than social trials. Main effects of reward direction were not significant (p>.05). There was a significant diagnosis X reward type X reward direction interaction (F(2,60)=3.29, p<.05). Among bvFTD patients, reaction times were faster for monetary win than monetary loss. Among AD patients, reaction times were faster for monetary loss than monetary win. These patterns reversed when the social blocks were considered. The bvFTD patients reacted faster for social loss than for social win. AD patients reacted faster for social win than social loss. Mean reaction times and the interaction are illustrated in Figure 2.

Additional analyses were performed looking only at bvFTD and AD. On social trials there was a significant diagnosis X reward direction interaction (F(1,20)=0.88, p<.05), again illustrating that AD subjects reacted faster for social win than social loss and bvFTD performed the opposite. On the social win block, AD subjects were faster than bvFTD, though not reaching significance (F(1,20)=3.18, p=.09). On monetary trials, there was a trend for the diagnosis X reward direction interaction (F(1,20)=3.09, p=.094), suggesting that bvFTD subjects react faster for monetary win than monetary loss and AD show the opposite pattern. Consistent with that trend, AD subjects reacted significantly faster than bvFTD subjects on the monetary loss block (F(1,20)=5.20, p<.05).

DISCUSSION

The study's main finding was a significant interaction between diagnosis, reward type (monetary or social), and reward direction (gain or loss). Though patients with bvFTD were slower than the other groups, they reacted more quickly when a monetary win was possible than for any other outcome. Their reactions were comparably slow in both loss conditions, but even slower to attain social reward. AD patients showed the opposite pattern to bvFTD. They reacted more quickly to avoid monetary loss than to gain monetary reward. In the social conditions they reacted faster to gain social reward than to avoid negative social feedback. Controls showed little difference between win and loss trials, but were slightly faster to win money than to avoid losing it.

These findings suggest an imbalance in bvFTD between sensitivity to monetary reward and loss. The pattern exhibited by bvFTD patients during the monetary conditions is consistent with their risky decisions in gambling tasks[1, 2]. Unlike gambling tasks, which require widespread cognitive function[8], the MID assesses reward behavior without requiring conscious decisions or learned strategies. The indifference to social reward also corresponds

with personality changes in the illness and suggests an additional reason for patients' socially inappropriate behaviors.

The results among AD patients on the monetary conditions are similar to a prior study in mild cognitive impairment that showed more motivated performance when monetary loss is threatened than for gain[4]. AD patients in this study were also motivated by positive social reinforcement. Patients with AD are more socially intact than those with bvFTD, displaying more empathy and mutual gaze with partners[9], consistent with seeking smiling faces as rewards.

This opposite pattern of reward sensitivity between bvFTD and AD reflects differing anatomic susceptibility between the two pathologies. AD patients, who show degeneration in default mode network structures have preserved or enhanced connectivity of the ventral salience network, which is important for socioemotional functioning. The reciprocal pattern occurs in bvFTD; salience network structures including frontal insula and anterior cingulate cortex are affected early with the default mode network preserved. Insular degeneration might relate to bvFTD patients' greater motivation to gain money than avoid losing it, as this structure has been implicated in representing negative consequences and anticipating loss.

Controls' reactions differed little between win and loss blocks for each reward type. Their slightly faster performance for monetary win compared to monetary loss is consistent with prior MID findings in older adults, who had similar fMRI activation when anticipating gain as younger adults but less activation when anticipating loss[10].

As has previously been observed using this task[5], patients were slower during social than monetary conditions. This could reflect the potency of the cues. Social feedback through on-screen images might not be as salient as money, which participants correctly understood they would receive upon completion. Prior studies with this task have demonstrated fMRI activation of the same reward processing structures with feedback in the form of faces as with money[5].

Study limitations included small sample size and the potential for subjects' impairment to impact performance. Disease-related emotional face processing deficits may affect bvFTD and AD subject performance on social conditions and are an important consideration for explaining social behavior changes and apparent sensitivity to social reward in each illness. If emotional face recognition influenced findings, bvFTD performance differed from expectations based on the inconsistently-reported impaired recognition of negative affect in the illness.

Further directions will include validating these findings using other decision-making measures, separating reward oversensitivity from punishment insensitivity in bvFTD, and elucidating the anatomic mechanisms behind these behaviors. This study suggests that the processing of monetary and social rewards differs between bvFTD and AD, reflecting their differing patterns of neurodegeneration.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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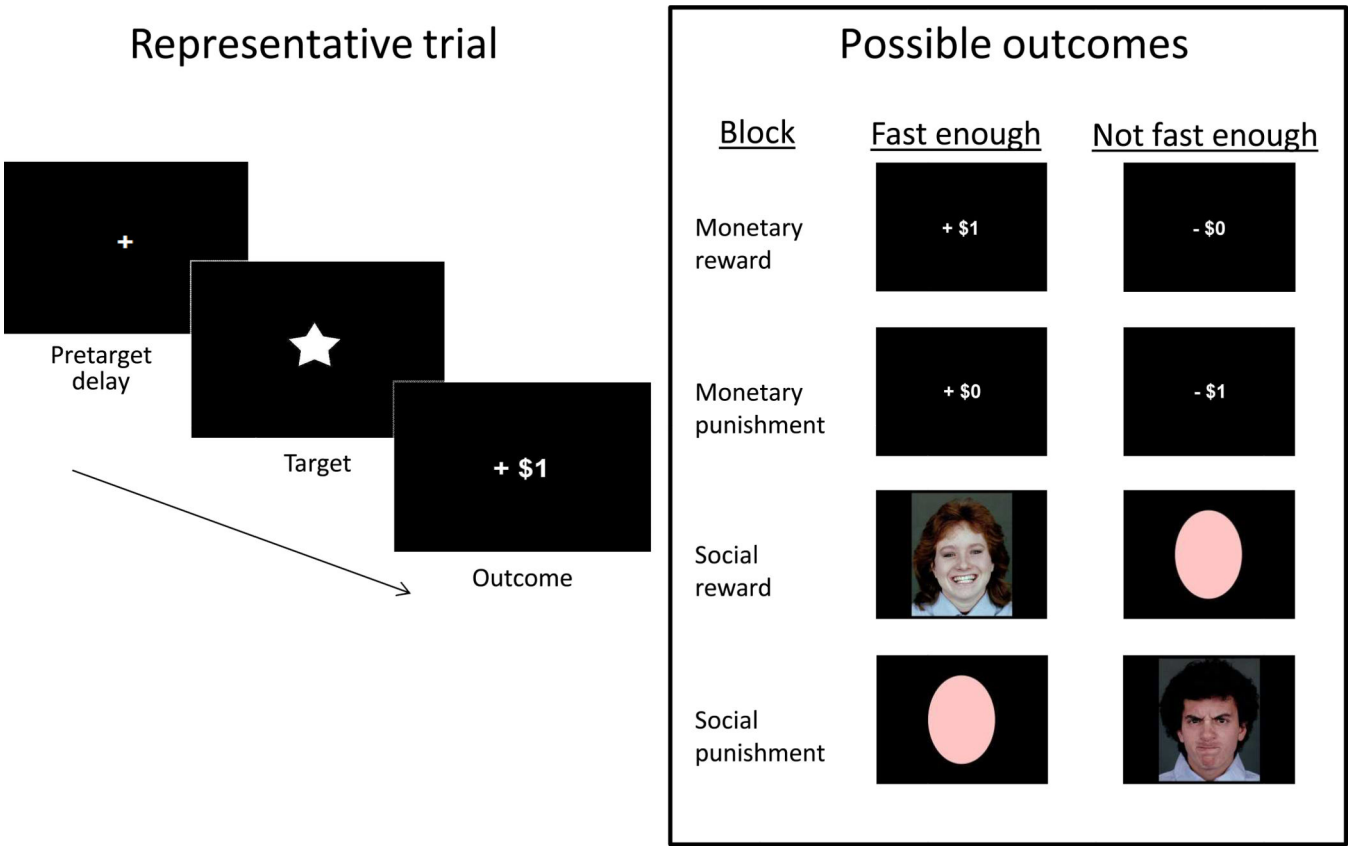

Figure 1.

Incentive delay task design. The structure of a representative trial is shown on the left. On the right the possible outcomes are shown for each of the four task blocks depending on whether the subject pressed the spacebar fast enough or not.

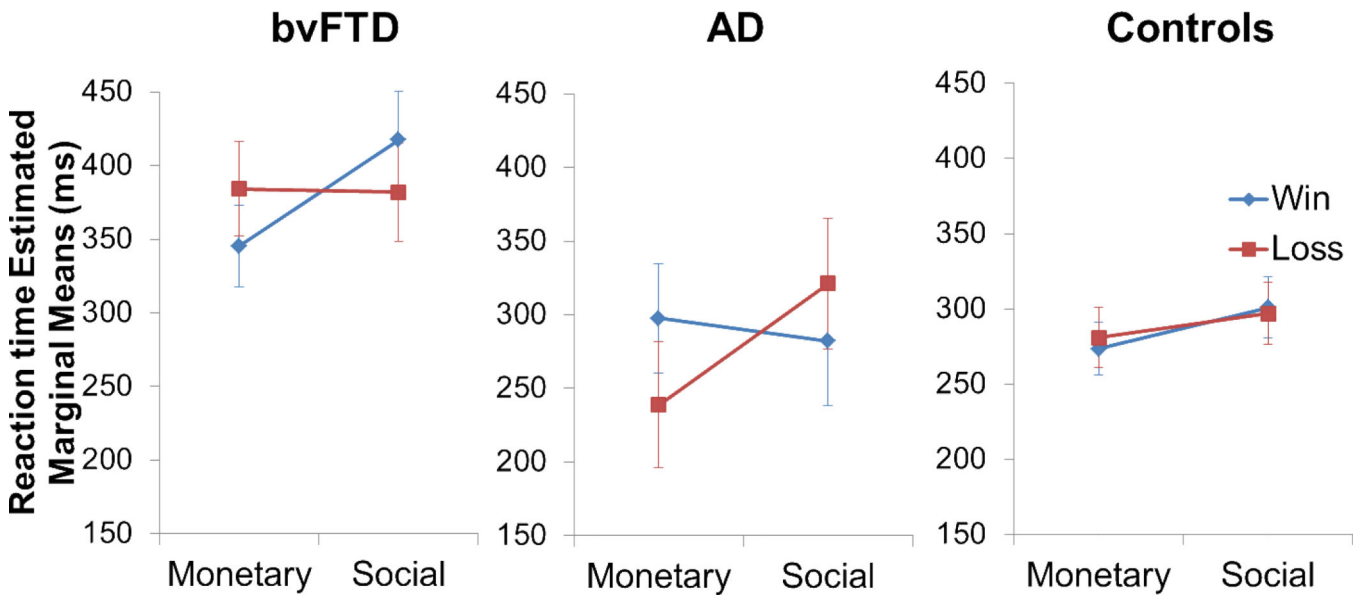

Figure 2.

Interaction effect. The mean reaction times for behavioral variant frontotemporal dementia (bvFTD) (*left*), Alzheimer's disease (AD) (*center*), and normal controls (*right*) are displayed for each of the four conditions. Bars indicate standard error. Results are displayed corrected for age, education, and Mini-Mental State Examination Score.

Table 1

Group Demographics

	bvFTD subjects	AD subjects	Normal controls	Statistical comparison	*p* value
N	14	11	41		
Male gender (%)	11 (78.6%)	7 (63.6%)	18 (43.9%)	χ^2=5.499	.064
Age	58.4 (8.84)	64.6 (8.62)	70.5 (5.14)	$F(2,63) = 18.054$	< .001
Education (years)	16.00 (2.54)	17.45 (2.25)	17.78 (2.06)	$F(2,63) = 3.446$	.038
MMSE (/30)	26.86 (1.56)	23.82 (3.09)	29.37 (0.94)	$F(2,63) = 55.43$	<.001

MMSE, Mini Mental State Examination

Data for age, education, and MMSE are shown as mean (standard deviation)