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Money or funny: Effective connectivity during service recovery with a DCM-PEB approach

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ABSTRACT

While monetary compensation is considered the most effective service recovery strategy, relief theory claims that humor may also be useful in service recovery situations. This study investigated the effects of humor in service recovery using dynamic causal modeling and parametric empirical Bayes analysis to identify effective connectivity (EC) patterns in the dopaminergic reward system across four conditions representing different service recovery strategies: monetary compensation and humor (MH), monetary compensation and an apology (MA), non-monetary compensation using humor (H), and non-monetary compensation using an apology (CON, the control condition). The findings support the importance of the nucleus accumbens (NAc) in the monetary compensation (MH and MA) conditions and the amygdala in the non-monetary compensation (H and CON) conditions. Monetary compensation (MH and MA) resulted in right substantia nigra (rSN) to NAc EC, suggesting the processing of recovery satisfaction associated with perceived outcome fairness. Conversely, non-monetary compensation strategies (H and CON) resulted in left substantia nigra (lSN) to amygdala EC, suggesting the processing of satisfaction related to perceived interactional fairness. The use of humor for service recovery resulted in VTA-to-lSN-to-amygdala EC during humor appreciation, while the use of apologies (CON and MA) resulted in lSN-to-amygdala and lSN-to-VTA connectivity. Surprisingly, processing satisfaction in the MH condition did not activate the amygdala during humor appreciation. Coping humor could be norm-violating for service recovery, and its effectiveness depends on multiple factors. The results suggest that monetary compensation, humorous responses, and apologies play key roles in neurological responses to service recovery strategies.

1. Introduction

Humor can serve various social functions (Goel & Dolan, 2001; Janes & Olson, 2015; Martineau, 1972). For example, the coping functions of humor may relieve tension while also providing amusement during social interactions (Ford et al., 2017; Martin & Lefcourt, 1983; McGhee, 2010; Ruch et al., 2018). Previous research has found that people can and do use humor to cope with stress and adversity (Nezlek & Derks, 2001). Nevertheless, humor is something of a double-edged sword in interpersonal communications, with the potential to be either a social lubricant or an abrasive. This complicates its potential use in service failure situations and little is currently known about its effectiveness in such settings (Kobel & Groeppel-Klein, 2021). This study intends to expand the current understanding of coping humor as a service recovery strategy by examining the effective connectivity of the dopaminergic reward network resulting from tangible compensation (monetary) and intangible, interactional responses (coping humor and sincere apologies).

Numerous studies have shown that the superior frontal gyrus (SFG), inferior frontal gyrus (IFG), temporo-parietal junction (TPJ), and superior temporal gyrus play key roles during humor processing (Campbell et al., 2015; Chan & Lavallee, 2015; Yankovitz & Mashal, 2020). In addition, a large body of research shows that humor comprehension is associated with increased activation in the SFG, TPJ, and IFG regions, while humor appreciation is associated with increased activation in the amygdala, nucleus accumbens (NAc), and midbrain (Chan, 2016a,

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2016b; Chan & Lavallee, 2015; Chan et al., 2016; Chan et al., 2018b; Mobbs et al., 2003). Within the midbrain, the ventral tegmental area (VTA) and substantia nigra (SN) are the sources of the primary dopaminergic projections for functions ranging from attention and learning to emotion (Berridge, 2007). Previous studies of humor appreciation using verbal humor as stimuli have also revealed increased VTA activation (e.g., Bekinschtein et al., 2011) and the SN (e.g., Chan 2016a). In particular, studies of humor appreciation have also indicated a vital role for the amygdala in amusement experiences (Chan et al., 2012, 2013; Farkas et al., 2021; Mobbs et al., 2003; Vrticka et al., 2013).

Most previous studies have focused on monetary rewards (Knutson et al., 2001; Sescousse et al., 2010), but our recent studies have examined the neural correlates of humor as a social reward (Chan et al., 2018a, 2022). The findings of these studies showed the role of dopaminergic mechanisms in response to hedonic pleasure during humor rewards, especially in the *amygdala* (Chan et al., 2018a, 2022). Previous studies of monetary rewards have widely presented a core role for the *NAc* during both the reward anticipation phase (e.g., Chan et al., 2018a, 2022; Knutson et al., 2001; Sescousse et al., 2010, 2015) and the reward consumption phase (Chan et al., 2018a; Haber & Knutson, 2010; Sescousse et al., 2013).

The midbrain dopaminergic reward system (comprising the VTA and SN) is crucial in developing appropriate goal-directed behaviors, including motivation and information integration for obtaining specific feedback or outcomes (Sesack & Grace, 2010). The mesolimbic pathway is a core reward center that includes the midbrain (VTA), NAc, and amygdala (Berridge, 2007; Schultz, 2000; Taber et al., 2007; Wise, 2002). The mesolimbic dopaminergic system in the VTA projects to the ventral striatum (occupied mainly by the NAc) and limbic system (especially the amygdala) (Sesack & Grace, 2010; Wise, 2009). Monetary and humor rewards regulate reward consumption through the mesolimbic dopaminergic pathway (Chan et al., 2018a, 2022). Our previous studies of humor rewards have implicated the role of the VTA and SN of the midbrain during the consumption of humor (Chan et al., 2022). In particular, these psychophysiological interaction (PPI) analyses revealed functional connectivity in *NAc-midbrain* coupling for monetary rewards and *amygdala-midbrain* coupling for humor rewards (Chan et al., 2018a, 2022). The SN of the nigrostriatal dopaminergic system is essential to habit formation and motor execution (Haber, 2003). However, it is unclear to what extent the dopaminergic system in SN influences service failure recovery. The present study investigated the midbrain dopamine system (both VTA and SN), focusing on their affective functions after service recovery to determine the extent to which left SN (lSN) and right SN (rSN) affect such functions.

Service failure recovery may serve as a means of providing stress or pain relief when a company aims to rebuild its relationships with its customers (Smith & Bolton, 2002). Classifications of service recovery strategies typically include monetary/tangible compensation versus non-monetary/intangible compensation (Roschk & Gelbrich, 2014). Monetary compensation seems to be an effective strategy for service recovery (Khamitov et al., 2020), and it appears to operate by increasing satisfaction related to perceived distributive or outcome justice (Wirtz & Mattila, 2004). However, monetary compensation is not suitable for all situations, particularly when customers have been badly treated by employees and have suffered some form of psychological loss (Roschk & Gelbrich, 2014). Thus, service recovery strategies also traditionally include a social interactional response in the strategy of a sincere apology. The presence of an apology from service employees as part of service recovery is strongly linked to customers' perceptions of interactional treatment and fairness (Smith et al., 1999).

Most studies on the effects of compensation and apologies on service recovery have been based on justice theory (Tax & Brown, 2000; Wirtz & Mattila, 2004). The few studies dealing with the effects of humor in service interactions have typically addressed humor in the context of regular sales conversations without considering service failure situations (Kobel & Groeppel-Klein, 2021). Unlike tangible monetary compensation, coping humor from frontline service employees provides a social interactional response to reverse an emotional state. Humor is a mood booster and a mechanism for emotional coping (Chan et al., 2018b). Research on service failure recovery has rarely considered the use of humor. However, the psychological functions of humor highlighted by relief theory (Freud, 1905/1960), reversal theory (Apter, 1982), research on social functions of humor (Janes & Olson, 2015; Martineau, 1972), and coping humor with adversity (Ford et al., 2017; Martin & Lefcourt, 1983, McGhee, 2010, Ruch et al., 2018) provide a theoretical foundation for using humor in service recovery situations. Relief theories focus on the relief of tension (physiological arousal) (Freud, 1905/1960) or the relief of nervous energy associated with anxiety, fear, or stress (Spencer, 1860).

Dynamic causal modeling (DCM) seeks to identify effective (directional) connectivity between brain regions during tasks (Friston et al., 2003). As opposed to classical DCM (Stephan et al., 2010), the present study used DCM with a parametric empirical Bayes (PEB) method of Bayesian model reduction (BMR) to examine the bidirectional modulatory changes in intrinsic and extrinsic effective connectivity to model context-sensitive changes in information flow (Friston et al., 2016). This study included four conditions, each representing a strategic response in a service recovery situation: monetary compensation and humor (MH; monetary and humor), monetary compensation and an apology (MA; monetary and apology), humor only with non-monetary compensation (H; humor), and an apology only with non-monetary compensation (CON; the control/baseline/neutral condition) using a DCM-PEB approach. This study focuses on affective influence (e.g., dopaminergic reward network) rather than cognitive processing (e.g., SFG and IFG) in instances when service recovery strategies are implemented after service failure situations. Therefore, the present study focuses on the dopaminergic reward network, which comprises the midbrain (VTA and SN), NAc, and amygdala.

Based on our previous studies of monetary and humor rewards in the NAc-midbrain and amygdala-midbrain (Chan et al., 2018a, 2022), the NAc was expected to play a central role in the reward network in responding to monetary compensation and that the amygdala plays a central role in responding to humor in service recovery situations. Based on previous studies on humor appreciation in the VTA or SN within the midbrain of the dopaminergic reward system (Bekinschtein et al., 2011; Chan, 2016a; Chan et al., 2022), midbrain (VTA) projections were expected to primarily reach the NAc and amygdala. Shared and distinct effective connectivity (EC) patterns were also expected to be observed across the four conditions representing service recovery strategies (MH, MA, H, CON). For the monetary compensation conditions (MH and MA), modulatory changes in EC between the midbrain (VTA/SN) and the NAc were expected to be observed. In non-monetary compensation conditions (H and CON), modulatory changes of EC between the midbrain (VTA/SN) and the amygdala were expected. The amygdala was also expected to be active in responding to the monetary compensation and humor (MH) condition.

2. Materials and methods

2.1. Participants

Forty-two healthy, right-handed volunteers (Oldfield, 1971) with no history of psychiatric or neurological diseases participated in this study (21 men and 21 women; 20–34 years old, with a mean age of 23.02 ± 2.65). All protocols aligned with relevant guidelines and regulations and were approved by the Research Ethics Committee of National Tsing Hua University. The participants provided written informed consent before the experiment.

2.2. Experimental design

The present study used an event-related functional magnetic resonance imaging(fMRI) paradigm. This study employed a two-way repeated-measures factorial design representing responses in a service recovery situation. A 2 (compensation: monetary compensation versus non-monetary compensation) × 2 (interactional response: humor versus non-humor/apology) design was used. The four resulting conditions were monetary compensation and humor response (MH), monetary compensation and non-humor (apology) response (MA), non-monetary compensation using humor response (H), and non-monetary compensation using non-humor (apology) response (CON). The CON condition was the baseline condition and consisted simply of an apology. The humor response was designed to elicit emotional reversal and relief, while the non-humor (apology) response was designed to induce a sense of satisfaction from the perception of fairness.

2.3. Stimuli

This study utilized a unique two-stage structure developed in our Cognition, Humor and Affect Neuroscience (CHAN) Lab based on earlier humor research (Chan et al., 2012, 2013) to investigate service failure recovery situations. Verbal jokes typically use a two-stage structure: a setup and a punch line. The setup involves the introduction of a scenario that elicits a set of conventional expectations, and the punch line involves a violation of these expectations that can be resolved in an amusing manner (Suls, 1972). This structure was adapted in the present study to create service failure recovery situations in which the service failure is introduced in the *setup* stage and the service recovery response is presented in the *punch line* stage. Depending on the condition, the service recovery strategy employed in the punch line consisted of compensation (monetary compensation versus non-monetary compensation) and a social interactional response (humor or apology). Coping humor, a type of humor used to manage stress or adversity, was used to construct the interactional responses in the conditions involving humor.

Previous research has indicated that humor has positive effects on customers when they find it particularly funny; however, otherwise, it is less effective than conventional service recovery methods such as monetary compensation or sincere apologies (Kobel & Groeppel-Klein, 2021). Two behavioral studies were conducted before the fMRI experiment to ensure that the verbal jokes were appropriate and valid as stimuli, thereby making sure that the participants found the jokes sufficiently amusing for their use as valid stimuli. A detailed description of the stimulus selection of two behavioral studies is provided in Part I of the Supplementary material file.

Sixty-four stimulus pairs for service failure and recovery scenarios in Mandarin Chinese were selected based on the results from the two behavioral studies. Sixteen stimuli were provided for each of four different conditions: monetary compensation and humor response (MH), monetary compensation and non-humor (apology) response (MA), non-monetary compensation using just humor response (H), and non-monetary compensation using just non-humor (apology) response (CON; control or baseline).

The present study was not able to make exact length and punctuation matches across all four response conditions (MH, MA, H, and CON) in the punch line, to control for the number of Mandarin Chinese words and the position of punctuation. Because the MH condition had more monetary compensation responses than the H condition, it was difficult to completely match the length and punctuation used in the stimuli in the MH and H conditions. Nonetheless, the setup and punch line stages of the monetary compensation conditions (MH and MA) were matched in terms of stimuli length and punctuation, as were the setup and punch line stages of the non-monetary compensation conditions (H and CON).

The stimuli were grouped such that there were 32 monetary compensation stimulus pairs for each of the two conditions involving tangible monetary compensation (MH and MA) and 32 non-monetary compensation stimulus pairs for each of the two conditions with intangible interactional compensation (H and CON). Thus, there was a total of 128 stimuli. The two types (monetary and non-monetary compensation) within each stimulus pair used the same setup but ended with a different punch line. Specifically, the punch line for the MH condition included monetary compensation with a humorous response, while the punch line for the MA condition included monetary compensation and an apology. Likewise, each non-monetary compensation pair shared a setup, but the punch line for the H condition was a joke, while the punch line for the CON condition was an apology. Examples are shown in Table 1. The two punch lines within each stimulus pair had the same length and punctuation in the original Mandarin Chinese version (see Supplementary Table S1).

Based on the incongruity-resolution theory (Suls, 1972) and comprehension-elaboration theory (Wyer & Collins, 1992), the present study used different humor techniques, such as bridging-inference (i.e., filling the gap), exaggeration (e.g., absurd, impossible, ironic, against nature and/or exaggerated situations), and ambiguity (e.g., jokes involving lexical, semantic, or phonological ambiguity) (Chan & Lavallee, 2015; Hempelmann & Ruch, 2005; Samson et al., 2009; Ruch, 1992; Ruch & Hehl, 2007). The coping humor stimuli included different verbal tones, such as witty and kind responses and mocking and sarcastic responses, in both the MH and H stimuli. In sum, the coping humor stimuli used in the study included different humor techniques (structure) and verbal tones (content) to provide variation.

2.4. Experimental procedure

The present study used an event-related fMRI paradigm. The experiment was presented using E-Prime 3, and all stimuli were presented in black and white. In each trial, a fixation of 500 ms was presented. The setup was delivered for 12 s, followed by a jittered interstimulus interval (ISI) of 1625–2375 ms (mean = 2000 ms). The punch line was shown for 9 s, after which a jittered ISI was shown, which lasted for a mean of 1000 ms. Participants provided a subjective

Table 1
Samples of monetary compensation and non-monetary compensation verbal jokes using humor response and corresponding non-humor (apology) response stimuli during the punch line stage.

Compensation	Humor structure		
	Setup	Punch line	
		Humor response (coping humor)	*Non-humor response (apology)*
Monetary compensation	I bought a patrol dog online. Days later, I received it and found it quite weak, which is completely different from the image and descriptions in the ad. I made an angry call to the seller and asked, “What kind of patrol dog is this?”	(*MH condition*) Seller: It is an undercover patrol dog and good at disguising itself. I will give you a full refund.	(*MA condition*) Seller: We’re very sorry to hear that this dog did not meet your expectations. I will give you a full refund.
Non-monetary compensation	A salesman came to my door to sell books. The salesman said, “Hi, ma’am. Here is a book titled ‘500 Excuses for a Husband to Return Home Late.” You seem to need it badly. I replied, “I have no need for this. I have a happy family. Please leave immediately.”	(*H condition*) The salesman: “I just sold a copy to your husband five minutes ago.	(*CON condition*) The salesman: "I am very sorry. I understand. I will pack up my things and leave.”

Note: The setup stage introduces the service failure scenario, and the punch line provides the service recovery response.

funniness rating by pressing one of four buttons on a keypad under their right hand to indicate how funny they found the stimuli (1 = “not funny at all” to 4 = “very funny”), lasting for a mean of 4000 ms. Finally, the jittered inter-trail interval (ITI) was shown and lasted for a mean of 2500 ms (Fig. 1).

Each participant was presented with 64 verbally constructed service failure and recovery scenarios (16 scenarios within each condition). There were four runs in total, and the order of the four runs was counterbalanced across participants. Each run included four trials for each condition (HM, MA, H, CON), and each run of the four conditions was randomized. Each run lasted 8 min and 16 s, with a 1-min break between runs. The total duration of the experiment was approximately 36 min 40 s per participant.

2.5. Image acquisition

The fMRI functional images were acquired using a 3 Tesla Siemens Magnetom Prisma scanner (Erlangen, Germany) equipped for echo-planar imaging (EPI) sequences based on blood oxygenation level-dependent (BOLD) contrast with a standard 20-channel head coil. This process was carried out by the Imaging Center for Integrated Body, Mind and Culture Research at the National Taiwan University. The visual stimuli were presented via MRI-compatible three-dimensional goggles (Resonance Technology, Inc.). T2*-weighted functional images, varying across the brain and BOLD contrast, were acquired parallel to the anterior-posterior commissure (AC-PC) plane and covered the whole brain using multiband accelerated EPI (acceleration factor = 3). The EPI parameters for the images were as follows: repetition time (TR) = 1000 ms, echo time (TE) = 30 ms, flip angle (FA) = 60º, field of view (FOV) = 220 × 220 mm^2, a 64 × 64 matrix, 39 slices with a 3.40-mm slice thickness with no gap, and voxel size = 3.43 × 3.43 × 3.40 mm^3. During each run, the first seven volumes (dummy scans) were discarded to achieve steady-state, and a series of 498 volumes was obtained that lasted approximately 8 min. Also, high-resolution structural T1-weighted anatomical images of the whole brain were acquired using a three-dimensional gradient-echo pulse sequence (Siemens MPRAGE sequence): TR = 1900 ms, TE = 2.28 ms, FA = 9º, FOV = 256 × 256 mm^2, a 256 × 256 matrix, 192 slices of a 1-mm thickness, and voxel size = 1 × 1 × 1 mm^3.

2.6. Image analysis

2.6.1. Preprocessing

The fMRI data were preprocessed and analyzed using SPM12 (revision 7771, Statistical Parametric Mapping, Wellcome Department of Imaging Neuroscience, London, UK) and implemented with MATLAB (MathWorks, Natick, MA, USA). The preprocessing steps of the functional EPI images included (1) slice-timing correction, (2) motion correction through the realignment of the mean image, (3) co-registration of the mean functional image to the T1, (4) segmentation scan (volume) to extract a gray matter image, (5) normalization of the functional acquisition to the standard Montreal Neurological Institute (MNI) template, and (6) smoothing with an 8-mm full-width at half-maximum (FWHM) Gaussian kernel to increase the signal-to-noise ratio (SNR) or decrease spatial noise.

2.6.2. General linear model

A general linear model (GLM) with an event-related design was used to analyze the functional images from each participant at the single-subject level. Regressors were created for compensation type (monetary and non-monetary compensation) and interactional response type (humor and non-humor [apology] response), including four conditions (MH, MA, H, and CON) by the convolution of the canonical hemodynamic response function (HRF), with the functions modeled by event onset for each trial. Six realignment parameters were included in the design matrix as covariates of no interest to account for head motion variance.

For group statistics, the single-subject contrast images were analyzed. Region of interest (ROI) analysis was performed. A ROI analysis used an a priori hypothesis based on previous imaging studies (Poldrack et al., 2008). Previous studies have revealed that the NAc is involved in the anticipation and consumption of monetary rewards (e.g., Chan et al., 2018a). Earlier studies have also shown that the amygdala plays a role in humor appreciation (Chan et al., 2012, 2013, 2022; Mobbs et al., 2003). The present study included the NAc as an ROI for monetary compensation and the amygdala as an ROI during humor appreciation. In addition, the midbrain VTA and SN were selected as ROIs for monetary and humor types. The mask for compensation and response was associated with five brain regions in the predefined ROIs. The WFU PickAtlas Tool (http://www.fmri.wfubmc.edu) was utilized to generate the ROI masks. This study used the boundaries of the NAc ROI based on Cauda et al. (2011). Also, the boundaries of the VTA ROI (x = −8 to 6; y = −26 to −14; z = −20 to −12) were defined based on Klein-Flügge et al. (2011).

A flexible factorial analysis was performed using a two-way repeated measures ANOVA, with the factors compensation (monetary and non-monetary) and response (humor and non-humor response). A threshold of family-wide error (FWE)-corrected $p < 0.05$ was applied at a peak level with a minimum of 10 voxels for multiple comparisons.

2.6.3. Dynamic causal modeling (DCM)

This study used dynamic causal modeling (DCM) to infer the effective connectivity (EC) between the brain regions involved in the dopaminergic reward network (VTA, lSN, rSN, NAc, and amygdala). A model with five nodes was constructed to assess the parameters of effective connectivity within the dopaminergic reward circuity (Friston et al., 2003) during service recovery with and without monetary compensation and with and without a humor response. This study adopted an event-related fMRI design with a 2 × 2 factorial design, including two levels for compensation (monetary and non-monetary) and two levels

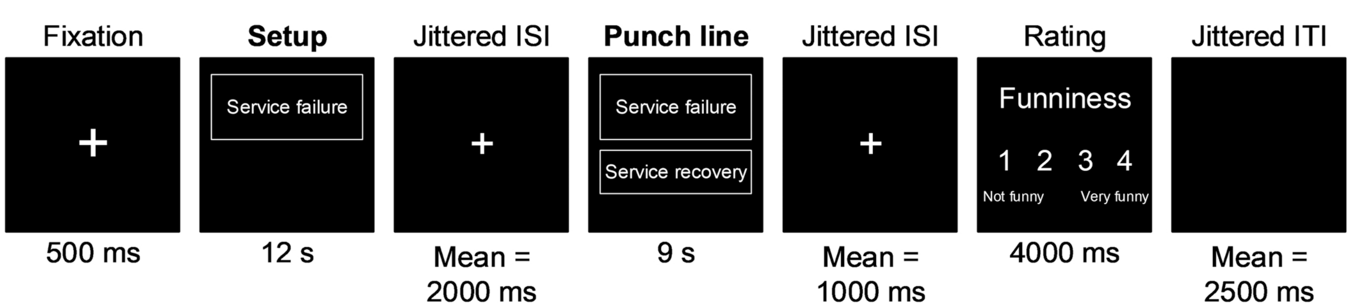

Fig. 1. Experimental procedure for a single trial. Each trial started with a fixation. Each trial included a single service failure recovery scenario, consisting of a setup stage and a punch line stage. The stimulus for the setup stage was presented, introducing a service failure situation, followed by a jittered inter-stimulus interval (ISI). An employee’s recovery response was then presented in the punch line stage, followed by another jittered ISI. A funniness rating prompt was shown (1 = “not funny at all” to 4 = “very funny”) and lasted for a mean of 4000 ms, followed by a jittered inter-trial interval (ITI).

for the interactional response (humor and non-humor/apology), for a total of four conditions (MH, MA, H, and CON). Effective connectivity matrices for the four conditions were estimated.

DCM (r12.5) was implemented using SPM12 to estimate the effective connectivity between the five selected nodes: the NAc, amygdala, lSN, rSN, and VTA. To quantify the effects of stimulus type (MH, MA, H, and CON) on effective connectivity between the nodes, DCM was employed to assess the causal inference between neuronal responses and infer distinct connectivity (Friston et al., 2003). The parameters of effective connections of a DCM model can be described by the following three matrices. The A matrix describes endogenous connectivity between nodes regardless of external experimental manipulations (i.e., the average connectivity across experimental conditions). The B matrix describes the changes in connectivity under each experimental manipulation. The C matrix describes the direct influence of each experimental driving input to the nodes (Friston et al., 2003; Zeidman et al., 2019a). The diagonal of the A and B matrices represents the values of $-0.5 \times \exp(\alpha)$ of the self-inhibition connections, which are unitless log scaling parameters scaled up or down the default value of -0.5 Hz (Zeidman et al., 2019a). The non-diagonal of the matrix represents the values resulting from the rate of change (in units of Hz). DCM analysis allows the quantification of the associated modulatory changes in effective connectivity (Friston et al., 2016) in a dopaminergic reward network of brain regions involved in service recovery.

2.6.4. Volume of interest (VOI) extraction

For DCM analysis, individual volumes of interest (VOI) were extracted based on the second-level GLM analysis. The anatomic masks of the NAc, amygdala, lSN, rSN, and VTA were determined based on the conjunction analysis of the contrasts (Friston et al., 2005) in the monetary compensation (MH versus MA) and non-monetary compensation (H versus CON) conditions of the GLM analysis. For each participant, the time series of each node (i.e., the BOLD signal over time in that node) was extracted within each ROI based on their first principal component (eigenvariate) (Zeidman et al., 2019a).

2.6.5. Specification of DCMs

The DCM analysis was performed by specifying a DCM per participant in the first-level (i.e., subject level) analysis. A bilinear DCM model was specified for each participant. The prior models for compensation type (monetary and non-monetary compensation) and response type (humor and non-humor/apology) were specified (driving inputs and modulation of connectivity) as a full model with the following settings: (1) the driving input entered all nodes (C matrix); (2) all the between-region intrinsic connections were set to "on"; (3) the compensation type and response type experimental manipulations modulated all connections. The full models were performed in a MATLAB cell array of DCM structures (i.e., Group DCM or GCM array). These full models were then estimated to find the optimal parameters providing the best model evidence (i.e., the best trade-off between model accuracy and complexity).

2.6.6. Parametric empirical Bayes (PEB) analysis

After the GCM estimation was completed, parametric empirical Bayes (PEB) analysis was used to generate the connectivity parameters for the second level (i.e., group level) (Friston et al., 2016). In this analysis, group effects and subject-specific (group level) connectivity parameters in the dopaminergic reward neurocircuitry (NAc, amygdala, lSN, rSN, and VTA) for service failure recovery responses were evaluated (Friston et al., 2015, 2016). The PEB models demonstrate different relative influences in terms of connection strengths (in Hz) or their modulation (Zeidman et al., 2019b). That is, all participants share the same architecture but demonstrate varying magnitudes of condition-specific effects.

The primary purpose of the DCM-PEB analysis was to examine the modulatory effects of experimental manipulation on the effective connectivity among the five nodes. The Bayesian modeling enabled estimations of the condition and group means in this study's 2×2 design. The PEB approach implemented in SPM12 was used to conduct the following group-level effective connectivity analyses: (1) testing the group effects for each DCM parameter and (2) estimating the model after including all the covariates. In the study, the covariates matrix of the PEB model included the following regressors: (1) "mean" (ones for all participants) and (2) mean-centered "satisfaction ratings" (satisfaction rating for each participant during the scanning, mean-centered).

After PEB model estimation, Bayesian model reduction (BMR) was performed to efficiently prune out parameters that did not contribute to the model evidence (Friston & Penny, 2011; Friston et al., 2016). BMR was utilized to perform an automatic search over reduced PEB models as an exploratory approach, a particularly efficient form of model comparison. A Bayesian model average (BMA) analysis was then calculated to average the parameters weighted by the posterior probability (Pp) across all models searched by the BMR. The PEB method uses Bayesian posterior inference (Friston et al., 2003, 2016). The threshold of the posterior probability for the PEB analysis was set at $Pp > 0.99$.

2.6.7. Leave-one-out (LOO) cross-validation

A leave-one-out (LOO) cross-validation (CV) was performed to see if we could predict participants' satisfaction ratings by their neural activity (Friston et al., 2016; Zeidman et al., 2019b). In this procedure, a PEB model was estimated using the data from all participants except one, then the covariates of interest of the left-out (test) participant were predicted by the model. The process was repeated with each participant left out to assess the accuracy of each model's prediction. In our study, the LOO-CV was conducted with each participant in the test dataset. The remaining 41 participants were in the training dataset. The calculation or prediction was repeated 42 times. We then tested the correlation between the estimated and actual values of the satisfaction ratings of the left-out participants to see if it was sufficiently large to ensure predictability.

3. Results

3.1. In-scan and post-scan behavioral results

Participants rated funniness on a four-point Likert scale (1 = "not funny at all" to 4 = "very funny") during the in-scan phase. The funniness ratings were 3.31 ± 0.27 for the MH condition, 1.47 ± 0.31 for the MA condition, 3.29 ± 0.29 for the H condition, and 1.47 ± 0.29 for the CON baseline condition. A one-way repeated-measures ANOVA on funniness presented a significant difference, $F(3, 123) = 928.25$, $p < 0.001$, $\eta2 = 0.958$. Bonferroni post hoc tests revealed that the funniness ratings in the humor conditions (MH and H) were significantly higher than those in the non-humor (apology) conditions (MA and CON).

Participants rated the degree of service failure, comprehensibility, funniness, and recovery satisfaction on a seven-point Likert scale (1 = "very low" to 7 = "very high") during the post-scan phase (Table 2). A one-way repeated-measures ANOVA of the degree of service failure showed no significant differences across the four conditions, $F(3, 123) = 1.875$, $p = 0.138$, $\eta^2 = 0.018$, indicating that the participants perceived all stimuli as service failures. A one-way repeated-measures ANOVA of the degree of comprehensibility showed no significant differences across the four conditions, $F(3, 123) = 1.854$, $p = 0.141$, $\eta^2 = 0.191$, indicating that the participants comprehended all stimuli. A one-way repeated-measures ANOVA on funniness showed a significant difference, $F(3, 123) = 690.47$, $p < 0.001$, $\eta^2 = 0.944$. Bonferroni post hoc tests revealed that the ratings in the humor conditions (MH and H) were significantly higher than those in the non-humor conditions (MA and CON). Finally, a one-way repeated-measures ANOVA on satisfaction indicated a significant difference, $F(3, 123) = 33.21$, $p < 0.001$, $\eta^2 = 0.779$. Bonferroni post hoc tests revealed that the ratings in the

Table 2
Means and standard deviations for the degree of service failure, comprehensibility, funniness, and satisfaction across four conditions of service failure recovery.

Service recovery	Service failure		Comprehensibility		Funniness		Satisfaction	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
MH	4.67	0.97	6.58	0.52	5.41	0.44	4.98	0.73
MA	4.77	1.03	6.49	0.53	2.07	0.59	5.07	0.60
H	4.59	0.81	6.45	1.12	5.39	0.56	4.02	0.79
CON	4.55	0.89	6.27	1.10	2.11	0.64	4.22	0.69

Note: M = mean; SD = standard deviation; post-scan ratings on a seven-point Likert scale; MH = monetary compensation and humor; MA = monetary compensation and an apology; H = non-monetary compensation using humor; CON = non-monetary compensation using an apology (i.e., control/baseline/neutral condition).

monetary compensation conditions (MH and MA) were significantly higher than those in the non-monetary comprehension conditions (H and CON). The detailed results of the in-scan and post-scan ratings are provided in Part II of the Supplementary material file.

3.2. fMRI results

There was an interaction between compensation (monetary or non-monetary compensation) and interactional response (humor or apology). The post hoc tests demonstrated significant simple main effects for monetary compensation (MH and MA) and non-monetary compensation (H and CON). In terms of monetary compensation, the contrast between MH and MA conditions (MH > MA) showed increased activation in the right NAc, left amygdala, bilateral SN, and left VTA. Regarding non-monetary compensation, the contrast between the H and CON conditions demonstrated activation in the same brain regions, including the right NAc, left amygdala, bilateral SN, and left VTA (Table 3 and Fig. 2).

Table 3
Four conditions and simple main effects for compensation and responses in the MH, MA, H, and CON conditions in the dopaminergic reward system during service recovery.

Brain region	L/R	Voxel	Z value	MNI coordinates		
				x	*y*	*z*
Monetary compensation and humor (MH)						
Nucleus accumbens (NAc)	R	19	9.76	12	8	0
Substantia nigra (lSN)	L	14	11.43	-10	-20	-12
Substantia nigra (rSN)	R	13	7.15	10	-20	-10
Ventral tegmental area (VTA)	L	28	10.76	-8	-22	-12
Monetary compensation and an apology (MA)						
Nucleus accumbens	R	15	3.05	12	10	2
Non-monetary compensation using humor (H)						
Nucleus accumbens	R	16	11.25	12	4	0
Amygdala	L	14	3.76	-20	-10	-10
Substantia nigra (lSN)	L	261	12.94	-10	-18	-10
Substantia nigra (rSN)	R	247	9.51	12	-18	-10
Ventral tegmental area	L	106	10.34	-8	-22	-14
Non-monetary compensation using an apology (CON)						
Nucleus accumbens	R	56	5.43	12	10	2
Monetary compensation (MH > MA)						
Nucleus accumbens	R	210	4.90	10	6	0
Amygdala	L	29	4.87	-24	-6	-14
Substantia nigra (lSN)	L	282	7.03	-10	-20	-10
Substantia nigra (rSN)	R	15	5.31	10	-20	-10
Ventral tegmental area	L	178	6.80	-8	-22	-12
Non-monetary compensation (H > CON)						
Nucleus accumbens	R	15	4.87	12	2	0
Amygdala	L	15	5.15	-24	-6	-14
Substantia nigra (lSN)	L	56	6.80	-8	-18	-10
Substantia nigra (rSN)	R	15	4.49	10	-18	-10
Ventral tegmental area	L	28	6.10	-8	-22	-12

Note: A threshold at the peak level was set to $p < 0.05$ with family-wise error (FWE) corrections for multiple comparisons and activation clusters that involved more than 10 voxels.

The present study used additional conjunction analysis to define the selection of DCM nodes (Friston et al., 2005) for service recovery after GLM analysis. Based on their roles in processing revealed by the monetary compensation contrast (MH > MA) and the non-monetary compensation contrast (H > CON), five ROIs were chosen for the conjunction analysis: the NAc, amygdala, lSN, rSN, and VTA. The conjunction analysis revealed common activation in the right NAc (MNI [x, y, z] = 12, 6, 0; Z = 9.76), left amygdala (−24, −6, −14; Z = 4.87), lSN (−10, −20, −10; Z = 7.03), rSN (12, −20, −10; Z = 4.86), and left VTA (−8, −22, −12 and −8, −18, −10, Z = 10.76). Coordinates stand for MNI space and represent the group peak coordinates (center of the sphere).

3.3. DCM results

Fig. 3 shows the PEB analysis results for the A matrix and B matrices. In Fig. 3(A), the A matrix (i.e., baseline connectivity) represents the intrinsic connectivity between nodes. The results for the A matrix showed all negative self-connections (the diagonal), suggesting decreased inhibition in these regions and increased responsivity to the inputs from the network. The B matrices in Fig. 3(B) represent the modulatory effects exerted by each of the four conditions (i.e., MH, MA, H, and CON) on the effective connectivity between the modeled nodes. Connection strengths of the parameters whose posterior probability was higher than 0.99 (Pp > 0.99) are reported. In Fig. 3(a), the figure corresponds with the figure in the A matrix above. In Fig. 3(b), the figures correspond with the B matrices directly above.

The modulatory effects of the MH condition showed that the rSN of the midbrain sends multiple excitatory influences on the NAc, the VTA of the midbrain, and the lSN. The modulatory effects of the MH and MA conditions showed some similarities in the NAc across the monetary compensation strategies for service failure recovery. The NAc receives multiple excitatory sources from the bilateral SN (lSN and rSN) during monetary compensation and an apology (MA). The present study revealed increased effective connectivity (EC) from the lSN to the amygdala (lSN → amygdala) during humor appreciation (H). Interestingly, EC from the lSN to the amygdala (lSN → amygdala) also increased during MA, H, and the non-monetary compensation using an apology (CON) condition, suggesting that all of these elicited positive emotions. However, the CON baseline condition showed a positive forward connection from the lSN to the amygdala (lSN → amygdala), as well as a negative inverse connection (amygdala ⇢lSN). Importantly, the positive modulatory effects of amusement from humor appreciation (H) resulted in a stronger connection from the lSN to the amygdala (connection strength = 1.34 Hz) than those from the MA and CON conditions (Fig. 3).

The present study used a DCM-PEB approach and showed the importance of the NAc in processing monetary compensation and the amygdala in processing non-monetary compensation. The NAc and amygdala are major dopaminergic targets in the mesolimbic reward system. In the monetary compensation conditions, the processing of monetary compensation and humor (MH) was associated with effective connectivity from the rSN to the NAc. Likewise, experiencing satisfaction from monetary compensation and an apology (MA) was associated with effective connectivity from the bilateral SN to the NAc. In the non-monetary compensation conditions, processing humor appreciation (H) and an apology (CON) were associated with effective connectivity from the lSN to the amygdala (Fig. 4).

The predicted service recovery strategy (MH, MA, H, and CON) of each participant was evaluated by a leave-one-out (LOO) cross-validation (CV) model to determine whether the model parameters that differed across conditions predict the classification of new participants. The results of the LOO cross-validation showed that the lSN had a positive influence on the NAc (lSN → NAc) in the monetary compensation and an apology (MA) condition when including the satisfaction

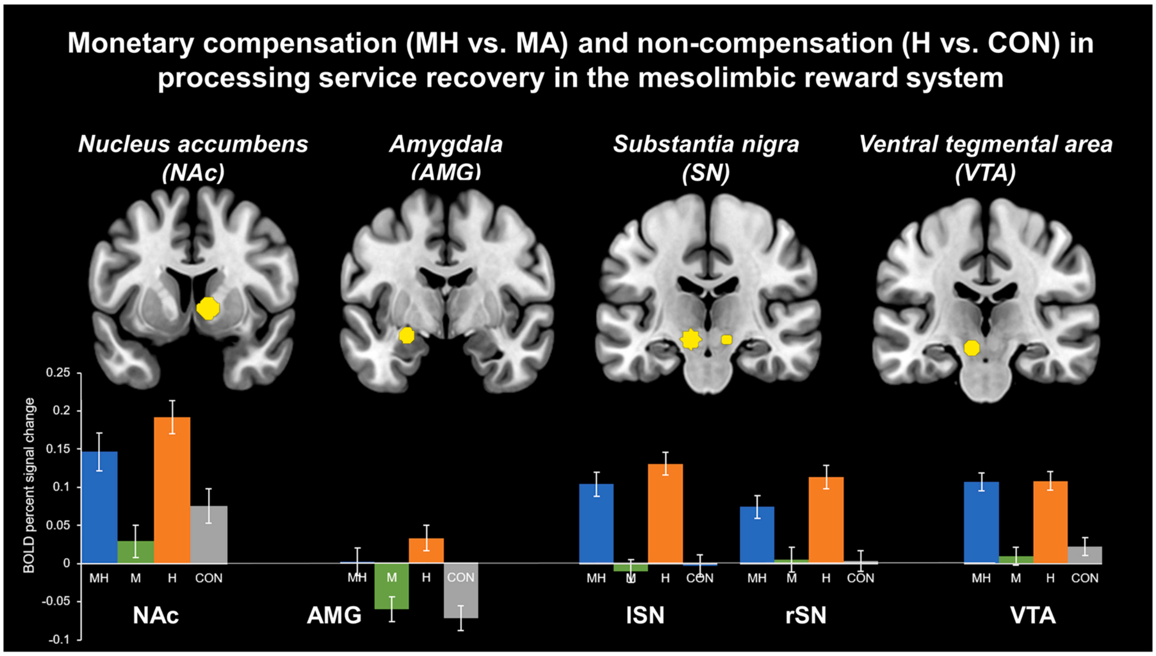

Fig. 2. Processing service recovery after experiencing service failure in the dopaminergic reward brain regions. (Top) Contrasts between monetary compensation (MH versus MA) and non-monetary compensation (H versus CON) showed increased activation in the NAc, amygdala, bilateral SN, and VTA. (Bottom) On the bottom are bar graphs displaying the BOLD percent signal change (PSC) of the peak voxels for each of the four recovery conditions (MH, MA, H, and CON). The error bars represent the standard error of the mean (SEM). MH = monetary compensation and humor response; MA = monetary compensation and an apology response; H = non-monetary compensation using humor response; CON = non-monetary compensation using an apology response (baseline). lSN = left SN; rSN = right SN.

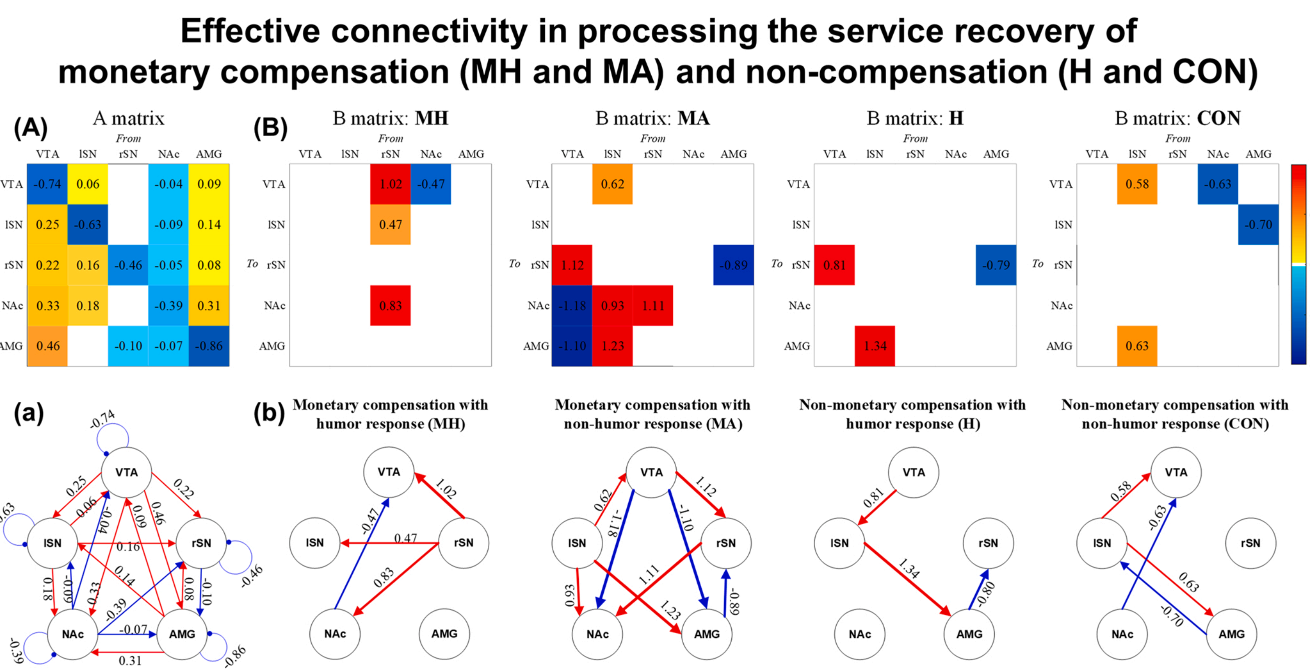

Fig. 3. Effective connectivity in processing the monetary compensation and humor (MH), monetary compensation and an apology (MA), non-monetary compensation using humor (H), and non-monetary compensation using an apology (CON; control/baseline) conditions. (Upper, A and B) Results of the DCM analysis are presented as connection weights given by the time constants (in Hz) for (a) the A matrix and (b) experimental modulatory effects (B matrices; MH, MA, H, and CON), for which the effects are significant (at 99% confidence). Effective connectivity strengths are presented in numbers and colors. Positive (excitatory modulatory effect) connectivity is represented by positive numbers and a scale from yellow to dark red; negative (inhibitory modulatory effect) connectivity is represented by minus signs and a scale from turquoise to dark blue. The numbers indicate the connection strength of directed connectivity (in Hz). (Lower, a and b) Significant modulatory effects of connections during the presentation of (monetary or non-monetary) compensation and interactional response (humor and apologies). (a) The figure shows the A matrix of the effective connectivity of the unmodelled baseline (Pp > 0.99). (b) Modulatory effects in the B matrices of four recovery strategies in the MH, MA, H, and CON conditions. The red lines represent positive modulatory effects, and the blue lines represent negative modulatory effects. The number represents connection strength (in Hz).

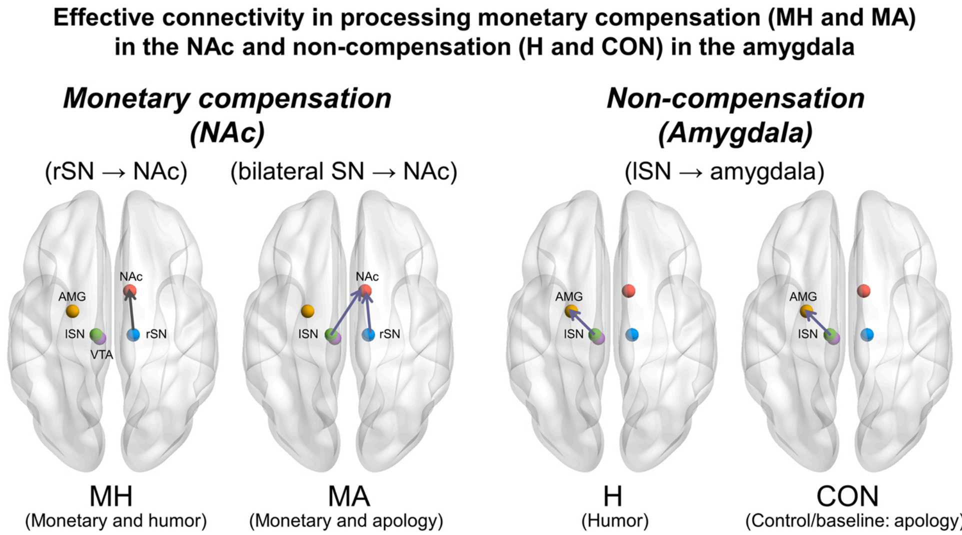

Fig. 4. The distinction between monetary compensation and non-monetary compensation: effective connectivity in the processing of monetary compensation in the *NAc* and the processing of non-monetary compensation in the *amygdala*. Experiencing satisfaction for monetary compensation (MH and MA) was associated with effective connectivity from the right substantia nigra (rSN) to the nucleus accumbens (NAc). Likewise, experiencing satisfaction for non-monetary compensation (H and CON) was associated with effective connectivity from the left substantia nigra (lSN) to the amygdala. MH = monetary compensation and humor; MA = monetary compensation and an apology; H = non-monetary compensation using humor; CON = non-monetary compensation using an apology (control/baseline).

ratings. The out-of-sample correlation between the model's predictions and observed data was significant, as revealed by LOO cross-validation ($r(40) = 0.29, p = 0.031$) in the current sample. Therefore, we conclude that the satisfaction ratings for monetary compensation and an apology (MA) can be predicted above the level of chance by the model, especially the lSN → NAc connection.

4. Discussion

Service failures are stressful and emotion-laden events that trigger coping processes. The present study examined the neural mechanisms underlying the processing of different service failure recovery strategies by combining the presence or absence of monetary compensation and either humor or an apology as a social interactional response. In particular, the present study employed humor as a service recovery strategy that is a rarely investigated interactional response in service failure situations.

The present study builds on earlier studies of monetary rewards in the *NAc* (Chan et al., 2018a, 2022; Haber & Knutson, 2010; Jauhar et al., 2021; Knutson et al., 2001; Knutson et al., 2003; Sescousse et al., 2010, 2013; Wilson et al., 2018) and humor rewards in the *amygdala* (Chan et al., 2018a, 2022). It also extends previous studies of functional connectivity (i.e., non-directional connectivity; e.g., PPI analysis) for monetary and humor rewards (Chan et al., 2018a, 2022). Notably, this study expands upon earlier research by examining the response of crucial dopaminergic reward neurocircuitry (midbrain, NAc, and amygdala) to different service recovery strategies (Bekinschtein et al., 2011; Chan, 2016a, 2018a, 2022). Finally, the study used a DCM-PEB approach to investigate the existence of functional connectivity in the *NAc-midbrain* during the consumption of monetary rewards and the *amygdala-midbrain* during the consumption of humor rewards (Chan et al., 2018a, 2022).

This study identified distinct core roles of the NAc in processing service recovery strategies that included monetary compensation and humor (MH) and monetary compensation and an apology (MA). This study also revealed a distinct core role of the amygdala in processing service recovery strategies involving non-monetary compensation, paired with either humor (H) or an apology (CON). These findings are consistent with earlier findings that the *NAc* is involved in the anticipation (Chan et al., 2018a, 2022; Knutson & Greer, 2008; Knutson et al., 2001, 2003) and pleasurable consumption of monetary gains (Chan et al., 2018a). These findings of this study are also consistent with earlier findings that the *amygdala* is essential to humor appreciation (Amir et al., 2015; Bartolo et al., 2006; Bekinschtein et al., 2011; Chan, in press; Chan, 2016a, 2016b; Chan & Lavallee, 2015; Chan et al., 2012, 2013, 2016, 2018a, 2018b, 2022; Farkas et al., 2021; Mobbs et al., 2003; Vrticka et al., 2013). Instead of cartoons, the present study employed verbal humor as a stimulus. One previous study showed that computing social error signals involved activity in the SN and VTA to support simple reward-based and social decision-making in an ultimatum game (Hétu et al., 2017). In the present study, the SN played a more critical role than the VTA across all four conditions. One possible explanation for these results in the SN (not in the VTA) is that service failure and recovery elicits emotion reversal from negative (e.g., anger) to positive emotion (e.g., relief) in response to both tangible and intangible compensation. In our previous studies (Chan et al., 2018a, 2022), humor rewards were found to elicit emotional shifts from neutral to positive emotion (amusement) during humor appreciation with activity in the amygdala-midbrain coupling, especially in the VTA within the midbrain.

Compensation is an important service failure recovery strategy used to dissipate anger and dissatisfaction. Effective recovery strategies turn angry and frustrated customers into loyal ones (Hart et al., 1990), and effective compensation-based recoveries can be essential in retaining customers. In this study, financial compensation was considered, as it is the most widely used means of compensation in service recoveries (Khamitov et al., 2020). These findings of the present study are consistent with previous results indicating that NAc-midbrain functional connectivity is vital to the hedonic pleasure experienced during the anticipation and consumption of monetary gains (Chan et al., 2018a). The present study used a DCM-PEB approach to further identify increased positive effective connectivity (EC) from the bilateral SN (BLSN) to the NAc (BLSN → NAc) during recovery satisfaction for the monetary compensation and an apology (MA) condition. The present study also employed a LOO cross-validation (CV) analysis to consider satisfaction ratings as covariates. The LOO-CV showed that the actual effect correlated significantly with the estimated effect of lSN → NAc connectivity on satisfaction ratings in the MA condition, suggesting that the connectivity strength reliably classified participants' satisfaction scores ($r = 0.29$, $p = 0.031$). The LOO-CV approach is an effective method for identifying neural circuits (Zeidman et al., 2019b), potentially leading to strategies for achieving greater levels of satisfaction in service recovery situations. In addition to the LOO-CV approach, the k-fold cross-validation and train-test holdout cross-validation methods should also be effective for confirming the robustness of results (Liu et al., 2022), especially when the dataset is large (e.g., 500 datasets). Future studies might also use the k-fold and holdout methods to establish predictive validity when the study is a larger dataset (e.g., 500 participants). The results also revealed an increased positive EC from the rSN to the NAc (rSN → NAc) in the monetary compensation and humor (MH) condition, representing excitatory influences after experiencing monetary compensation.

Conversely, the present study showed negative modulatory changes from the VTA to the NAc (VTA ⇢NAc) in the MA condition and from the NAc to the VTA (NAc ⇢VTA) during the MH condition, representing inhibitory influences. For many dopaminergic reward systems, the NAc integrates excitatory, inhibitory, and modulatory inputs to select an adaptive motivational and emotional behavior output. Moreover, the midbrain (specifically in the VTA) receives excitatory and inhibitory inputs to regulate goal-directed behavior (Sesack & Grace, 2010). In this study, service recovery in the monetary compensation (MH and MA) strategy that provides an expected reward or satisfaction increased the release of dopamine release in SN → NAc connectivity. Conversely, service recovery that fails to produce an expected reward or satisfaction of monetary compensation decreased the release of dopamine in VTA ⇢NAc and NAc ⇢VTA connections. Future studies could further explore the role of the midbrain VTA in processing service recovery responses involving monetary compensation and humor (MH) and non-humor (an apology; MA).

The SN dopaminergic neurons project to the NAc to elicit relief, satisfaction, or pleasure in response to monetary compensation (MH and MA) and project to the amygdala to elicit relief, amusement, or pleasure in response to non-monetary compensation (H and CON). The role of midbrain dopaminergic neurons involves both the VTA and the SN. The VTA primarily projects to multiple areas of both the limbic system (the mesolimbic system, especially the ventral striatum and amygdala) and prefrontal cortex (the mesocortical system), while the SN primarily projects to the dorsal striatum (e.g., caudate and putamen) (Berridge, 2007; Schultz, 2000; Taber et al., 2007; Wise, 2002). However, the present study showed that the ventral striatum (NAc) is a major target of SN dopaminergic neurons. Our previous research revealed activation in response to monetary rewards in the NAc-midbrain and especially in the midbrain VTA when using humorous cartoons as stimuli (Chan et al., 2018a, 2022) and activation in the midbrain SN when using verbal humor as a stimulus (Chan, 2016a). Future studies could further examine the processing of monetary compensation and humor using different humor stimuli (e.g., verbal humor and visual cartoons). Also, future studies could further investigate the processing of monetary compensation and coping humor for service recovery in different regions of the nigrostriatal reward circuity such as the region from the SN to the dorsal striatum.

In previous studies on monetary rewards, participants received real money after the experiment (e.g., an extra 20 US dollars) (Knutson et al., 2001, Chan et al., 2018a, 2022; Sescousse et al., 2010). However, this study did not give real cash refunds after the experiment. The monetary compensation (MH and MA) conditions resulted in increased modulatory changes in effective connectivity in the rSN to the NAc, while the non-monetary compensation (H and CON) conditions did not result in effective connectivity in the NAc. This result is consistent with the view that the NAc is vital in the anticipation (wanting and motivation) and consumption (liking and hedonic pleasure) of monetary gains (Chan et al., 2018a), especially in the monetary anticipation phase (Knutson et al., 2001). This study provides findings on NAc activity during the anticipation or consumption of monetary compensation following a service failure.

The GLM analysis results of monetary compensation (MH vs. MA) and non-monetary compensation (H vs. CON) showed increased activation in the midbrain, including the bilateral SN and the left VTA. Although it is believed that the SN is involved in the nigrostriatal pathway and the VTA is involved in the mesolimbic pathways (Haber & Fudge, 1997), the present study did not confirm the connectivity of the VTA to the ventral striatum (occupied mainly by the NAc). Conversely, the study did detect connectivity from the rSN to the ventral striatum (NAc) in the monetary compensation (MH and MA) conditions. The present findings suggest that distinct subregions of the SN and VTA of the midbrain are not recruited to create VTA-to-NAc pathways when processing monetary compensation combined with humor or apologies. One possible interpretation of these results is that the coordinates of the SN and VTA are close. Furthermore, the VTA coordinates were close to the boundaries ($x = -8$ and $z = -12$).

The processing of humor during service recovery also needs to be addressed. Many studies comparing humor to non-humor stimuli have demonstrated that different distinct regions are active during humor appreciation (e.g., Chan & Lavallee, 2015; Samson et al., 2008, 2009). Such findings are consistent with the view that amygdala-midbrain functional (non-directional) connectivity plays a vital role in the hedonic pleasure associated with amusement during the consumption of humor rewards (Chan et al., 2018a, 2022). The present study employed a DCM-PEB approach and revealed increased effective (directional) connectivity from the lSN to the amygdala when humor was used for service recovery. A previous study showed that the SN-amygdala pathway was critical to surprise-induced enhancements of attention (Lee et al., 2006). Human SN dopaminergic neurons are modulated by stimulus novelty in associative learning (Kamiński et al., 2018). The amygdala reflects amusement during humor appreciation (Chan et al., 2012, 2013; Farkas et al., 2021; Vrticka et al., 2013). The results of this study revealed information flow from the lSN to the amygdala. These results suggest that the lSN pathway is specifically required for eliciting emotion to incongruity (surprise) processing and the subsequent feeling of amusement associated with amygdala activation after the humorous resolution of the incongruity (Chan et al., 2012, 2013, 2018a, 2022).

Importantly, this study revealed increased modulatory changes in the effective connectivity from the lSN to the amygdala in the non-monetary compensation (H and CON) conditions. Activity in the humor response (H) showed strong modulatory changes in the same lSN → amygdala (1.34 Hz) pathway, while activity in the apology (CON) condition showed relatively few modulatory changes from the lSN to the amygdala (0.63 Hz). Notably, monetary compensation combined and an apology (MA) resulted in the same lSN → amygdala (1.23 Hz) effective connectivity, as did humor (H). Moreover, the apology (CON) condition and the monetary compensation and an apology (MA) conditions resulted in the same lSN → amygdala effective connectivity. Processing both humor and apology recovery responses involved lSN dopamine projections to the amygdala. Previous research indicates that the appetitive prediction error involves activation in the left amygdala and left substantia nigra to predict pain relief, thereby reflecting reward learning (Seymour et al., 2005). As compensation appears to be particularly successful in eliciting relief, it would be interesting to compare the processing of monetary compensation and an apology (MA), humor without monetary compensation (H), and an apology without monetary compensation (CON) while focusing on the lSN-to-amygdala pathway. While the use of an apology is widely accepted, it is possible that other social interactional responses could be effective as well. Future research could also investigate combinations of humor and conventional apologies (humor and apology) and combinations of humor and conventional methods (monetary and apology) in service recovery strategies.

This study also investigated whether humor triggers a positive recovery effect when combined with monetary compensation in a service failure recovery situation. Unexpectedly, the combination of monetary compensation and humor (MH) did not result in amygdala activation, although previous research found amygdala involvement (Chan et al., 2012, 2013). In other words, the present study revealed lSN-to-amygdala effective connectivity for humor responses (H), monetary compensation and apology responses (MA), and apology responses (CON) but not for the MH condition. One possible explanation for these results is that humor appreciation (H) does not have an additional effect on monetary compensation in the MH condition. Also, previous studies on monetary and humor rewards (Chan et al., 2018a) and monetary, sexual humor, and erotic rewards (Chan et al., 2022) showed that the pleasure ratings associated with monetary gains were significantly higher than those associated with other types of rewards (e.g., humor, sexual humor, and erotic rewards). People's satisfaction with and enjoyment of monetary gains were stronger when compared with humor appreciation. The monetary compensation and humor (MH) condition may have a ceiling effect on the feeling of satisfaction. Hence, humor may not have an additional effect.

Unexpectedly, we did not find shared patterns of effective connectivity between the MH and H conditions. Since monetary compensation is considered the gold standard method in service recovery, consumers may expect this recovery strategy from service firms, whereas humorous responses may be viewed as violations of service norms (Béal & Grégoire, 2022). In other words, compared to humorous responses, monetary compensation can lead to higher inferences of positive motives of service firms to remedy the service failure (Béal & Grégoire, 2022). Therefore, the MH condition showed increased effective connectivity in rSN → NAc connectivity for monetary compensation but not in lSN → amygdala connectivity for humor appreciation. Furthermore, customers' post-recovery satisfaction can be strongly influenced by the recovery process itself and the positive rewards that it may provide (De Matos et al. 2007). The use of humor has to be appropriate in contexts or particularly funny to have similar effects as traditional recovery methods such as monetary compensation or apologies (Kobel & Groeppel-Klein, 2021; Mathies et al., 2016). In other words, when resolving an instance of service failure, using humor could be norm-violating, and its effectiveness depends on multiple factors.

In our service failure and recovery study, we found that another possible explanation for the finding that coping humor may not have an additional effect was that monetary compensation may exert a 'ceiling effect' in the MH condition. Most previous studies of humor have used emotional reversals moving from neutral to positive emotional states (Chan et al., 2012, 2013). However, in our study, service failure in the setup stage elicits negative emotion (e.g., anger) and the service recovery strategy in the punch line stage elicits positive emotion (e.g., satisfaction). The emotion reversal is thus from negative to positive emotion (Apter, 1982). Previous research on coping humor has indicated that it is difficult to shift from a negative emotional state to an extremely positive one (Chan, 2014) because of the psychological distance involved in this type of emotion regulation. This is a possible explanation for our finding that emotion reversal in the service failure and recovery situation did not result in effective connectivity in the lSN → amygdala pathway for humor appreciation in the MH condition. The direct monetary compensation effect is stronger than the coping humor effect and may have set a 'ceiling' on the feeling of satisfaction. Future studies might further examine the dissociation of effective connectivity for two-stage processing (setup and punch line) of service failure and recovery situations (Chan, in press). In other words, future studies might further examine emotional reversals that occur in service failure and recovery situations, with shifts from negative emotions in the setup to positive emotions in the punch line. Such research might focus on the interactions between cognitive and affective processes in the mesocorticolimbic (MCL) system. In the MCL system, evidence of such interaction might be found in cognitive processing in the IFG and SFG (Campbell et al., 2015; Chan et al., 2012, 2013; Yankovitz & Mashal, 2020) with affective processing in the mesolimbic system (Chan et al., 2018a, 2022).

We also found that another possible explanation for our finding that coping humor did not affect responses to monetary compensation (MH) was related to small differences in length in the stimulus pairs. It was difficult to match the lengths of the MH and H stimuli in the present study because the MH condition had more monetary compensation responses than the H condition (see Supplementary Table S1 and S2). In the present study, we were not able to make exact length and punctuation matches across all four conditions. However, length and punctuation in the setup and punch line stages were matched across the two monetary compensation conditions (MH and MA) and the two non-monetary conditions (H and CON). Future studies could attempt to match stimulus across both stages (i.e., setup and punch line) and then compare the MH and H conditions.

The only overlap in effective connectivity between the MH and MA conditions was observed for rSN → NAc connectivity, indicating that both conditions included monetary compensation. One possible explanation for these results is that there may be a ceiling effect for the feeling of satisfaction from the response to monetary compensation in the NAc. People's satisfaction with and enjoyment of tangible monetary compensation were stronger when combined with humor appreciation and apologies. Furthermore, regarding the effective connectivity between MA and CON, there were overlaps between lSN → amygdala and lSN → VTA connectivity, representing that both conditions involved an apology. However, activity in the MA condition showed more intense modulatory changes in the lSN → amygdala (1.23 Hz) than in the apology (CON) condition (0.63 Hz). An apology recovery (CON) strategy may have a joint effect on monetary compensation in the MA condition, meaning that an apology recovery strategy elicited positive emotional arousal via dopamine release to the amygdala.

The levels of subjective satisfaction indicated in the behavioral results show that humor was less effective than conventional monetary service recovery strategies (MH and MA; see Table 2). The present study also revealed that monetary compensation strategies (MH and MA) resulted in significantly higher satisfaction levels than non-monetary compensation strategies (H and CON). This result is consistent with previous studies showing that humor is less effective than conventional service recovery strategies when customers do not find the humor to be particularly amusing (Kobel & Groeppel-Klein, 2021). Such findings suggest that using humor as a recovery strategy is advisable only when customers are likely to perceive it as funny. Coping humor is similar to self-enhancing humor (Martin et al., 2003), benevolent humor (Ruch & Heintz, 2016; Ruch et al., 2018), and aggressive humor (Martin et al., 2003) to enhance the self or others. In both the MH and H conditions using different humor techniques, such as bridging-inference (e.g., filling the gap), exaggeration (e.g., absurd), and ambiguity (e.g., pun) structures, were used to form coping humor (Chan & Lavallee, 2015). The contents of coping humor (both MH and H) included different verbal tones, such as witty and kind responses or mocking and sarcastic responses. The present study's results provide initial insights into how humor is processed as a service recovery strategy. Future research may investigate how to increase the perceived funniness of verbal humor in service failure situations.

However, coping humor may not simply consider the degree of funniness during service failure situations (Heintz, 2020; Ruch, 1992; Ruch & Rath, 1993). Future studies could consider participants' perceptions of the use of humor's pro-sociality or offensiveness as covariates, especially for offensive, inappropriate, and annoying ratings of aversiveness (Ruch, 1992). Compared to the motivational model (e.g., a release function), the salience theory of humor (e.g., aggressive humor) can more easily be inferred by assessing participants' personalities for processing aggressive stimuli (Derks & Arora, 1993; Goldstein et al., 1972). Future studies could recruit and compare participants with high senses of humor (HH) and low senses of humor (LH) in service recovery situations. Future studies could also investigate how service recovery pleasure is impacted by monetary compensation combined with coping humor while considering variations in its perceived satisfaction, funniness, and aversiveness, as measured by subjective ratings. Future studies might recruit actual customer service employees as participants, to enhance the ecological validity of the research.

The present study was based on emotion reversals that occur as the intended outcome of service recovery strategies, with a focus on neural activity in the mesolimbic system in response to humor response strategies (Chan et al., 2018a, 2022; Mobbs et al., 2003). We note that the present study modeled the effective connectivity of the subcortical network (VTA, lSN, rSN, NAc, and amygdala) during service failure and recovery situations involving the service recovery strategies of monetary compensation, coping humor, and apologies (MH, MA, H, and CON), with subjective hedonic ratings included. Future studies could further examine the processing of monetary compensation and coping humor for service recovery in the cortico-subcortical networks of the reward circuitry, such as the mesolimbic and nigrostriatal system with the anterior cingulate cortex (ACC), orbitofrontal cortex (OFC), and ventromedial prefrontal cortex (vmPFC) (Chan et al., 2018a, 2022; Haber & Knutson, 2010; Sescousse et al., 2013).

5. Conclusion

In the present study, the *NAc* was revealed to play a key role in processing in the monetary compensation service failure recovery conditions (MH and MA). Likewise, the *amygdala* played a key role in processing in the non-monetary compensation (humor and apology) conditions (H and CON). The amygdala may also be involved in processing apologies, which constitute a conventional service recovery strategy. In the two monetary compensation conditions, monetary compensation and humor (MH) increased modulatory changes in the effective connectivity from the rSN to the NAc. In contrast, monetary compensation and an apology (MA) increased modulatory changes in the effective connectivity from the bilateral SN to the NAc. Furthermore, the LOO cross-validation confirmed lSN → NAc connectivity on satisfaction ratings in the MA condition.

Unexpectedly, the results did not indicate effective connectivity from the SN/VTA to the amygdala in response to monetary compensation and humor (MH). In the non-monetary compensation conditions, the processing of humor (H) strengthened the modulatory changes in effective connectivity from the VTA to the lSN (0.81 Hz) and from the lSN to the amygdala (1.34 Hz) (VTA → lSN → amygdala). Likewise, responses to an apology (CON and MA) resulted in smaller modulatory changes in the effective connectivity from the lSN to the amygdala (0.63/1.23 Hz) and from the lSN to the VTA (0.58/0.62 Hz).

The behavioral results showed that although humor has a positive effect on service recovery satisfaction, it is much less effective than monetary compensation. Monetary compensation and an apology should be preferred for service recovery (Kobel & Groeppel-Klein, 2021; Roschk & Gelbrich, 2014). However, humor may increase amusement-related arousal as effectively or more effectively than an apology (Kobel & Groeppel-Klein, 2021). Future studies could examine increases or decreases in recovery satisfaction, comparing conventional recovery strategies (monetary compensation or an apology) with service employees' humor responses based on different levels of participants' perceived funniness (as measured by subjective ratings). This study mainly investigated the dopaminergic reward circuitry (midbrain, NAc, and amygdala) for the service recovery strategies of monetary compensation, humor, and apologies, especially in mesolimbic reward neurocircuitry (e.g., midbrain → NAc and midbrain → amygdala).

Credit authorship contribution statement

Yu-Chen Chan: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Chen-Ya Wang:** Writing – review & editing, Project administration, Funding acquisition. **Tai-Li Chou:** Writing – review & editing, Validation.

Conflicts of interest

The authors declare no potential or actual conflicts of interest.

Data Availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.biopsycho.2022.108464.

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