Cognitive Process Difference among Anorexia Nervosa, Bulimia Nervosa and Binge Eating Disorder

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Abstract. Eating disorder has created severe health problems for people different in gender, age and culture. The cognitive process varies depending on different types of the eating disorder. The current study of the cognitive process, including impulsivity (including motor response and decision domain), behavioral flexibility (including set shifting and goal-directed behavior), and attention bias are reviewed for eating disorders including Anorexia Nervosa (AN), Bulimia Nervosa (BN), and Binge Eating Disorder (BED). Then, the difference in decision-making is specifically discussed between AN, BN, and BED, indicating that decision impairment may reflect the trait of different types of the eating disorder. Besides, the decision-making process may reflect the different behavior of eating disorders. The article aims to categorize further subtypes of eating disorders and the conceptualization of AN-R (Restrictive type of Anorexia Nervosa), AN-B (Binging type of Anorexia Nervosa), BN, and BED. The result can bring more insights into neuroimaging to identify the underlying impairment, especially for the biological or cognitive endophenotypes that may attribute to impulsive and compulsive behavior for differentiating subtypes of obesity.

Keywords: Eating Disorder; Anorexia Nervosa; Bulimia Nervosa; Binge Eating Disorder; Decision Bias.

1. Introduction

Eating disorders (EDs) are mental health disorders with increased morbidity and all-cause mortality [1,2], characterized by persistent abnormal eating habits and eating-related behavior that will negatively impact a person's mental and physical health. The types of eating disorders include Anorexia Nervosa (AN), Bulimia Nervosa (BN), and Binge Eating Disorder (BED). The categorization is based on the difference in signs, symptoms and food-related behaviors, which need to diagnose differently with different treatments. AN is characterized by self-induced weight loss with body weight maintained at least 15% below expected or Body Mass Index (BMI) less than 7.5 and sustained by the patient disregard of the severe negative impact on health. The cause may be the distorted body image and anxiety resulting from low self-esteem. The subtype of AN is categorized by the difference in behavior/strategy in food consumption. The restrict type AN-R is figured by strict and limited food consumption without purging behavior, while the AN-BE involves purging behavior. The BN is characterized by repeated and persistent overeating and excessive preoccupation with control of weight through dreading of fatness or purging. BED is characterized by episodic excessive food consumption without purging behavior. Since the categorization of the phase instead of trait, for example, the BN is the early stage of AN, which means the cognitive process of different eating disorders is not only different. However, it may also have overlaps, which need to be explored further to understand the underlying mechanism for different types of behavior and the change from one behavior to the other. The cognitive impairment of impulsivity, compulsivity, and attentional bias are included to categorize different eating disorders and reflect the corresponding brain substrate and conceptualization of eating disorders.

2. Cognitive Process and Bias

2.1 Impulsivity

Impulsivity is actions taken without the foresight of risk or in an inappropriate situation. In addition, it is used to predict substance escalation and compulsive drug-seeking behavior. Impulsivity can be divided into motor response and decision domain, which have overlapping, discrete, neutral substrates [3].

2.1.1 Motor Response

The motor response-ability is the ability to switch to unconscious control while people are focused on another task, which involves motor response inhibition and waiting for impulsivity [3]. The former is the capacity to inhibit a preoccupied response, and the latter measures the anticipatory response to a cue that predicts reward [4]. Motor response inhibition is used for the measurement of cognitive impairment. For example, eating disorder participants may not be able to inhibit the food cues like the smell or visual exposure, which leads to actions like binging. As for the waiting response measurement, the eating disorder patients may not be able to wait to act before the scheduled task, and in addiction the task is usually expressed by the motivation to act and the inability to inhibit specific behavior. In motor response inhibition, the stop/no stop task measures the participants' ability to inhibit a response. Before the test, the participants learned about the item that indicated they to press a button and the item indicating not press (for example, yellow circle is pressing the button and blue is not pressed), then under limited time, the accuracy and time for response are measured, the lower accuracy and the longer response time indicating the lack of capability of an individual to inhibit dysfunctional thoughts and behaviors. Since the meta-analysis demonstrated the association between attention-hyperactivity and impulse control impairments [5], the task used to measure impulse control impairment in substance use disorders, particularly to stimulants, nicotine [6]. Moreover, the stop signal task is used for measurements of action cancellation, where the participants must respond to an arrow stimulus but only select one of two options depending on the direction of the arrow.

Under the go/no go task, the study showed BED obesity group made more errors under food-related cues than the non-BED obesity group [7], and another study showed BED participants made more errors under food cues compared with non-food cues [8,9]. The study for BN also illustrated impairment under similar tasks and especially for the food-related cues [10]. The result illustrated the lack of capability to inhibit, especially food-related items for BED and BN, which reflected in their binging behavior and not in general impairment in cognitive inhibition ability, and the incapability of inhibition in food may result in a higher probability for them to exert the behavior, which is binging to relieve the craving. As for waiting impulsivity, no sufficient study has been found for AN and BN, but for BED patients, the study shows no difference between BED and non-BED patients [11,12].

2.1.2 Decision Bias

Decision bias is the tendency to make decisions or take actions unknowingly and irrationally. The result in the decision domain can reflect further the categorization of the subtypes of the eating disorder. The delay discounting and risk decision-making are discussed.

2.1.2.1 Delay Discounting

The delay discounting task is used to measure decisional impulsivity since the participants need to choose between the immediate but less reward and the long-term, but more reward, the ability to delay gratification indicates the capability to cope with the impulsivity under decision.

Under multiple cues, both BED and non-BED have common impairment in delay discounting for mild to moderate obesity. However, for morbid obesity, BED patients discounted at a greater value than non-BED. Also, the degree of obesity affects delay discounting among both BED and non-BED, figured by a higher degree of discounting under a more significant degree of obesity [13]. Since the impairment is under multiple cues not only focused on the food-related cues, the wider impairment in cognitive function should be considered. Moreover, whether the impairment reflects the phase of

obesity can be further understood through neuroimaging. Since the higher degree of obesity shows a difference in impairment between BED and non-BED patients, it could be the difference in self-control for BED patients in a risk situation. Regardless of high obesity, the BED still has binging behavior which may reflect their lack of self-control in long-term physical health and more focus on the short-term food reward. For non-BED patients, the delay discounting, even though the decision-making ability was impaired to a greater extent when the obesity degree increased but did not have risky behavior like binging. But for BED, the decision-making is impaired to a greater extent, so the binging behavior is acted regardless of the risk in behavior itself or the risk of obesity. No difference under the low degree of obesity, which may be due to the individual difference among BED in decision-making. Further studies need to determine if the BED patients with decision bias are more likely to shift from moderate to a high degree of obesity compared to the BED patients without decision bias, so it resulted in the sample bias. Alternatively, it may be due to the lower subjective value of the negative impact compared to the actual impact for high-degree obesity BED patients than the moderate-degree obesity BED patient, resulting in their higher discounting rate in delay in gratification. However, both results suggested a difference in decision-making bias among BED patients.

Moreover, AN patients illustrated a stronger ability to delay discounting compared to health-controlled individuals, and after weight restoration, AN has no difference from the health-controlled (HC) individuals [14]. The stronger self-control for AN may reflect their purging/restricting behavior, and the result after weight restoration may indicate the decision bias for AN to be a phase instead of a trait, suggesting the decision-making behavior can be altered. The correlation of self-controlled ability and weight for BED and AN patients may reflect the cognitive bias of decision-making under all eating disorder spectrums and indicate the decision impairment of obese participants. The weight may reflect the different behavior used to control the calories, like AN, and neglect the effect of the calories, like BED.

2.1.2.2 Risk-Taking Bias

Further investigating the risk-taking decision domain, the Iowa Gambling Task (IGT) measures the preference for risky and disadvantageous choices under uncertainty. Participants are told to pick from four decks with unknown loss or gain during the task. The decks are figured by overall gain or overall loss, and the ability of the participant to judge from the average outcome of each desk to determine their choice and win the most scores are used to measure the judgment for risk-taking under uncertainty. The game of dice task is also used to reflect the risk-taking for probabilistic risk. In the task, the participant was asked to bet on the results of a dice which was separated into four possible risk levels. The risk will be a possible gain (if the bet is correct) and loss (if the bet is wrong). For example, the level can be £1000, £500, £100, £50 loss or gain. The task is used to value the participants' tolerance towards probabilistic risk.

Under IGT, both BED and AN illustrated impairment in risk judgment [4], which can reflect their risky food consumption behavior through binging or restricting regardless of the potential risk. Under the game of dice task, in BED subjects with lower BMIs compared to the non-BED group, greater risk seeking under explicit probabilistic risk is observed to monetary rewards, whereas this shifts to risk aversion in BED subjects with higher BMIs [4]. The relation of BMI in risk-seeking behavior for BED obesity patients may reflect the different stages of binging. As at an earlier stage, the binging may be more tolerated regardless of the health risk. When shifting to a higher BMI, the risk is less tolerated. A similar study illustrated that the BED made a riskier choice which is figured by their subjective belief that the probabilistic reward is more likely to occur than the objective probability [15]. The study investigated the risk choice between certain and risky choice (e.g., the choice between a certain or risky choice with known probability, which may reflect their subjective belief of the higher 'gain' in binging, the in-control feeling expressed by large consumption of food or the relieve of anxiety or reward of high-calorie food (depends on the individual trigger), and lower value of 'loss', which is the subjective judgement of health consequence, compared to the reality. The study also observed binge eating severity scores positively correlated with probability weighting to reward

anticipation and negatively correlated with lose anticipation [15], which further consolidated the result of their subjective belief of a higher probability of gain and lower probability of loss compared to objective reality. The BED patients also illustrated impaired sensitivity, illustrated by greater risk preference to low-risk losses, while the non-BED obese group has more risk averse to high-risk loss [4]. For AN patients, the IGT score was significantly different between symptomatic AN patients and HCs, but not between recovered AN patients and HCs [16]. Given that during the experiment, there is no indication of the relation between starvation or depression or mean age with the impairment of risk-taking [16], those variables can be ruled out of the compound variables. However, the result of decision-making after recovery needs to be measured to indicate whether risk-taking is a trait for AN or a phase. Moreover, Garrido & Subirá (2013) also found a correlation between decision-making and impulsivity only in purging EDs [17].

For the difference between the decision-making between AN and BN, decision-making in AN would be characterized by impaired learning/memory functions, whereas decision-making in BN would be characterized by heightened sensitivity to reward as opposed to punishment [17]. The further study illustrated the lack of long-term alteration in strategy or improvement for the same task [18] for AN patients, which reflects the impairment in memory. Because in the long-term, AN can learn from the previous disks to make next better judgement. And also, the impairment in learning ability as the strategy isn't improved, given the tracking record of their choice for each game in the study. This can also reflect in their behavior. For AN, the previous negative impact of purging/restricting cannot be retrieved, so similar behavior persists constantly, and the impairment in learning may result in the incapability to change the behavior. And BN has attenuated brain activations in the reward circuitry in response to food rewards, which is believed to drive increased reward-seeking behavior [17]. For BN, the higher sensitivity of reward compared to punishment illustrates their subjective bias of overvaluing the reward of purging, which may be the temporary relief of anxiety and undervaluing the long-term impact on health, compared with objective reality.

For the subtype of AN: AN-R and AN-BE, since the result showed the loss aversion in the restrictive subtype was greater than that in the binge-purge subtype in both subsamples [17, 19], this may explain the different strategies AN-R and AN-BE utilized for food consumption. Since they both have higher anxiety towards potential weight gain for food, both AN-R and AN-BE value food negatively. But AN-R expresses in a more averse way through restricting, and AN-BE expresses in a less averse way which is binge-purging. Since poor nutritional status, the severity of symptoms, and general cognitive impairment in AN subjects do not appear to be responsible for their deficit on the GT [17], which means the decision-making difference among the subtype of AN is a trait instead of a phase. In fact, the long-term AN-R's result of GT illustrated their persistency in preference for disadvantageous dicks [18], which may indicate their impairment in learning since the persistence of behavior is unchanged regardless of negative impact. However, AN-BE did not have a significant advantageous or disadvantageous strategy [17]. Therefore, preference and persistence can illustrate their food consumption strategy. For AN-R, the view of food will be relatively more negative since restricting food may reflect a more negative view of food than binge-purging food, as reflected by the preference for disadvantageous strategy. Moreover, persistence illustrates that the learning ability of AN-R is also more impaired, so it is difficult for them to realize the negativity and change the behavior.

Nevertheless, whether the difference in strategy is a phase or trait needs to be further discussed. The different impairment and biases may be due to the different process of cognitive processing, but whether the AN-R is a phase of AN-BE or a distinct type need to be differentiated. Moreover, the similarity between AN and OCD needs to be further explored [20], driven by the same cognitive process and the behavior overlap of AN and OCD. Relevant research evaluated that there is no decision-making difference for AN patients before or after treatment [20], indicating that the different strategies are a trait instead of a phase. Further exploration of biological or cognitive endophenotypes that may contribute to impulsive and compulsive behavior for differentiating subtypes can be investigated in the future.

2.2 Attention Bias

The study also showed that the PVL model deconstructs IGT performance into learning/memory, feedback sensitivity, and response consistency parameters [18]. The result showed the impairment in learning as the persistency in underperformance and no improvement under the same IGT task [18]. Since attentional impulsivity was significantly and negatively correlated with learning in AN [18], learning incapability may result from attentional bias. The AN patient may focus too much on the negativity of gaining weight and refuse or be incapable of learning from the negative physical impact of restriction. As for BED, the study illustrated susceptibility of impairment in working memory and attentional bias, which can reflect in the impaired self-regulation behavior under food cues for BED [4]. This could also reflect in their focus on food and exert compulsive binging behaviour for their strong attention.

2.3 Behavioral Inflexibility

When it comes to the behavioral flexibility, set-shifting is measured. Set-shifting is the ability to shift from different tasks or mental sets for flexibility measurements. Individuals with rigid thinking styles and strict values or behavior will illustrate inflexibility in set-shifting tasks. In the article, the Wisconsin Card method is used. Where the participant must choose from four cards matched to one question card, the pattern can be color, shape, or number based on specific rules but change over time. Must match cards to 1 of 4 cards, which differ by specific dimensions (color, shape, or number). For example, if the rule a shift from matching in number instead of matching in color, but the participant can not identify the change, then the set-shifting may be impaired after several additional tests with similar results.

The study shows that the set-shifting impairment is more significant for BED patients than non-BED patients with moderate obesity, but no difference for more severe obesity [4]. The result showed the behavior inflexibility in set-shifting may at a moderate level, reflect the compulsive behavior of BED and explain their behavior which may harm the physical and mental health, is difficult to stop or alter and eventually turn into binging. Since the severe obesity group has a similar result for set-shifting, the result illustrated that the severe obesity patient might have a similar behavioral inflexibility related to food consumption, even though the binging behavior is not observed. The cognitive impairment of severe obesity and BED may suggest that additional cognitive treatment should be used to support severely obese patients' mental processes. For the AN and BN patients, the difficulties shifting set seemed to be particularly marked in those with mixed symptoms of restriction and binging and/or purging and lesser degrees of set-shifting difficulties in those recovered from AN. However, in general, the AN and BN have impaired set-shifting [21]. Since the mixed symptoms illustrate that the impairment may reflect both AN and BN binging/restricting behavior and be signified or amplified by previous illness (previously binging or restricting), but it is a phase instead of a trait. Because after the recovery, the cognitive process showed improvement.

Regarding the goal-directed behavior impairment for BED and shift toward model-free habitual behaviors, the two-step task is used for assessment. During the task, two types of reinforcement learning (RL) are assessed: model-free and model-based RL. The participant needs to make two sequential decisions with different stimuli. For the first stage, the choices are associated with one of the two-second stages, and one first stage is associated with the second stage with different probability (e.g. 2a is 30% and 2b is 70%). Moreover, each second stage is associated with some probability of winning the reward, which may change during the task. In order to succeed in the task, the goal of the subject is to maximize the rewards in the second stage. Ideal performance would entail identifying the most rewarding second stage (e.g., 2b) and making first-stage choices that make this result more likely (e.g., the first-stage choice that results in 2b 70% of the time. The task can be used to test for model-based goal-directed behavior or model-free habitual behavior since the participant needs to discover and adapt the particular model underlying the probability of reward in each stage of the task to succeed in the test. According to the study, BED illustrated a tendency towards habitual behavior. The model-free preference is also reflected in other compulsive disorders like substance addiction

[18]. The result can also reflect the failure of BED in adapting healthier behavior due to the lack of goal-directed cognitive modelling ability to gain the maximum 'reward' in different situations. The neuroimaging result also shows the lower medial or frontal cortex and ventral striatal volume, similar to the compulsive disorder patients [18]. Furthermore, the perseverance of behavior reflected by choosing the same stimulus irrespective of the outcome made the BED patients less likely to change their behavior and easier to adapt to the habitual behavior of binging.

The exploratory is also measured for both BED and non-BED. In the task, subjects chose the time to stop a clock, resulting in either random wins or losses. In addition, the tendency to stay and exploit the same time choice or explore alternate times were assessed. The results showed that BED is more exploratory in the loss domain than non-BED [15]. Since the BED has less avoidance of uncertainty and is more exploratory in the losses, that may explain their binging behavior, which values less uncertainty in the damage to health and more aggressive food consumption in terms of the exploratory in the losses.

3. Discussion

In summary, for the different cognitive processes, the different types of eating disorders illustrated different biases. For impulsivity, both BN and BED illustrated motor inhibition impairment under the food cues, which may result in binging behavior as an active response due to the incapability of inhibiting food cues. And, the decision-making for BED is impaired at a high degree of obesity, not a low degree, whether only the decision-biased BED patients are more likely to shift from moderate to high degree obesity which is driven by individual difference, or it is the subjective difference value of the food reward between high and moderate obese BED patients need to be further explored. For AN, the decision-making was reflected by stronger self-control but altered to no difference between HC after weight restoration, which suggested the bias is a phase and can be altered through the change in behavior. Both BED and AN have impaired risk judgment. For BED patients, the impairment is figured by a higher subjective belief in a positive outcome than reality and a lower subject belief in a negative outcome than reality, which may reflect their binging behavior. More specifically, they value more about the 'gain' in food consumption but value less about the 'loss' in health. Moreover, AN's impairment is reversible after recovery, which illustrates as a phase, not a trait for AN. AN's decision impairment reflected impairment in learning and memory. In contrast, BN's decision impairment was reflected by higher sensitivity to reward compared to losses, which illustrated a similar response with the BED patients. This can be further reflected in the subtype of AN as AN-BE illustrated a similar response by lower loss aversion than AN-R, and AN-R illustrated more severe impairment in learning and memory. Both relationships between binging behavior and risk-taking need to be further understood through neuroimaging as it is reflected in behavior involving binging across all eating disorder spectrums. The attention bias of AN and BED is reflected through the impairment in learning, and BED will be higher under food cues. As for behavioral inflexibility, for BED, the moderate obese degree illustrated a difference with the non-BED obese group, but at a higher degree, the obese group illustrated similar impairment in set-shifting. The set-shifting among the high-degree obese group needs to be further explored for a more comprehensive treatment of obesity. For AN and BN, the set-shifting is both impaired but more significant for mixed symptoms and can be altered after recovery, which implies that the behavior change may change the cognitive bias in set-shifting as it is not a trait for the patients. As for the goal-directed behavior impairment, the BED has more tendency and higher perseverance towards habitual behavior and more exploration in the loss domain.

4. Summary

In conclusion, the different cognitive impairments reflected different behavior of different types of eating disorders, which suggested that therapy can reflect more on the behavior to make a judgement of the cognitive impairment in treatment. Moreover, the categorization of different eating

disorders showed overlaps in cognitive processes and behavior. However, whether one type of eating disorder is the phase of the other type or is a distinct trait need to be further explored. Furthermore, the similarity in behavior and cognitive process of eating disorders with other types of mental disorders like OCD needs to be further explored for insights into comorbidity. Moreover, in future research, the highly obese BED patients can be investigated more through neuroimaging compared to low obese BED as they reflect different cognitive biases in decision-making and the set-shifting, and whether the decision-making bias and risk-taking bias and set-shifting can be a measurement of the success in recovery for AN need to be taken into consideration. Also, the relationship between risk-taking and binging behavior can be further understood as the binging behavior patients, regardless of the type of eating disorder, illustrate the degree of overvalue reward in risk-taking compared to restricting type of eating disorder. The mental treatment for obesity was also suggested as studies showed various cognitive impairments for the group. Furthermore, the restricting type's impairment in learning and memory can be further explored, as its correlation with attention bias may be the cognitive bias for the behavior. The behavioral inflexibility in adapting a new model for BED and more exploration in the loss domain can be further focused on during the CBT treatment.

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