Learned industriousness as a translational mechanism in anorexia nervosa

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Abstract

Researchers have long grappled to understand the persistence of behaviors that are non-hedonic and, ostensibly, aversive. At times, such behaviors are taken to excess in the form of psychopathology. Anorexia nervosa characterizes a prototype of a disorder in which behaviors that most people find unpleasant (e.g., restrictive eating, excessive exercise) are repeatedly performed, despite significant personal cost and risk of death. The learned industriousness theory, which originated from social psychology and behavioral neuroscience, provides a novel theoretical account for such serious, yet unexplained phenomena. Informed by human and animal data, this theory posits that effort (intense physical or mental activity) can be conditioned to acquire secondary rewarding properties through repeatedly pairing high-effort behavior with reward. Over time, effort sensations become less aversive and more appetitive because they signal impending reward, generalizing willingness to engage in effortful behavior. In this manuscript, we: 1) review behavioral and biological data supporting learned industriousness; 2) contrast learned industriousness with other conceptual models of effort persistence (e.g., goal-directed and habit learning); 3) highlight evidence that learned industriousness may account for the persistence of weight-control behaviors in anorexia nervosa; and 4) consider clinical and research implications of this model, including the translation to other psychological disorders.

Keywords: learned industriousness, reward, effort, eating disorder, anorexia nervosa, translational neuroscience

“The struggle itself towards the heights is enough to fill a man's heart. One must imagine Sisyphus happy.” -Albert Camus

A central unanswered question in the behavioral sciences is: why do some individuals persist in actions that cause harm and destruction to their lives? In attempting to resolve this unknown, it has been well recognized that disturbances of the reward system likely play a significant role in motivating many harmful behaviors.¹ Influential theories have suggested that an excessive drive towards short-term rewards (e.g., drug intoxication) without adequate consideration of long-term consequences (e.g., physical harm) are often responsible for destructive behavior patterns.^{2,3} In the context of temperamental or biological predispositions towards impulsivity or lessened inhibitory control, the ability to resist the inherently compelling nature of a particular set of primary rewards (e.g., drugs, food, sex) becomes overpowered. Although important research has developed from these ideas, this explanatory model cannot account for a set of phenomena that involve excess drive towards behaviors that are not obviously pleasurable.

It has long baffled behavioral economists and mental health professionals alike that some people tend to persistently engage in behaviors that are not rewarding in the traditional sense, or that are even ostensibly aversive. Loewenstein⁴ has utilized the illustrative example of mountaineering as prototype of this type of persistent behavior: a subset of individuals become strongly compelled to mountain-climb under extremely treacherous conditions, despite the fact that their momentary experience is one of unpleasantness and the potential costs are substantial (e.g., risk of death). Other examples of this type of persistent, non-hedonic behavior include overly abstemious financial practices⁵ or excess engagement in work pursuits.⁶ Critically, there are also corollaries within psychiatric illness. For instance, the eating disorder anorexia nervosa

(AN) is hallmarked by persistent weight-control behavior that overrides the basic biological drive to eat in service of the goal of weight loss.⁷ Thus, AN represents a remarkable (though pathological) prototype of excess goal pursuit through persistent engagement in behaviors that most individuals would find aversive and unrewarding. However, as we will discuss, we expect this phenotype to extend to a range of other psychiatric disorders.

AN is a Prototype of Pathological Non-Hedonic Persistence

AN is a serious mental illness characterized by extreme weight-control behaviors leading to a state of starvation.⁷ For some individuals with AN, weight-control behavior is characterized by continuous caloric restriction (i.e., restricting subtype [AN-R]) and, for others, extreme caloric restriction is punctuated by intermittent episodes of binge eating and/or purging (i.e., binge eating/purging subtype [AN-BP]). AN affects a substantial portion of the population, with lifetime prevalence rates similar to schizophrenia and other serious psychiatric disorders.^{8,9} Further, AN is associated with elevated physical and psychological morbidity and has one of the highest mortality rates of any mental disorder.^{10–12}

Some eating disorder behaviors, such as binge eating, are linked to heightened pursuit of primary reinforcers that are clearly rewarding (i.e., food).⁷ Indeed, it has been proposed that eating disorders primarily characterized by binge eating may share key similarities to other hedonically-driven disorders, such as substance use disorders.^{2,13} In contrast, individuals with AN engage *excessively* and *consistently* in a range of behaviors that most individuals find unpleasant (e.g., restrictive eating, intense exercise, self-induced vomiting). Although the average individual will attempt to alter their diet and exercise habits in order to lose weight at some point in their lifetime,¹⁴ most people find this experience unpleasant. Extended adherence to weight-control behaviors often limits access to the physical and social rewards associated with

consumption of palatable foods and requires enduring unpleasant side effects of caloric deficit (e.g., low energy, irritability).¹⁵ For this reason, it is extremely difficult for most people to sustain weight-control behaviors, even under conditions in which it may be beneficial for them to do so. In contrast, in AN, engagement in weight-control behaviors is *rigid* and *repetitive*, persisting beyond the point of severe negative consequences. For instance, individuals with AN continue to engage in weight-control behaviors after intensive treatment¹⁶ and even while acknowledging the potential for negative outcomes, including death.¹⁷ Although individuals with other eating disorder presentations engage in behaviors such as caloric restriction,¹⁸ here we focus on AN as a prototype of pathological non-hedonic persistence due to the pervasiveness of effortful weight-control behaviors hallmarking this diagnosis.

Although significant progress has been made to understand the mechanisms responsible for hedonically-driven eating disorder behaviors, such as binge eating,¹⁹ there is still limited understanding of the forces that maintain less classically rewarding eating disorder behaviors, such as restrictive eating.²⁰ The most common explanation for such behaviors is that they persist due to the heightened reward derived from weight loss.²¹ However, some individuals with AN report minimal or conflicting motivations for weight loss.²² Thus, desire for thinness appears to provide an incomplete account of the forces that maintain persistence of effortful weight-control.

Outline of the Current Manuscript

We propose that a theory borne from social psychology, *learned industriousness*,²³ may account for some of the processes that maintain AN and other psychiatric disorders characterized by continued engagement in effortful behaviors that are not clearly pleasurable. Although this model was developed approximately 20 years ago, it has not yet been applied to accounts of psychiatric disorders. In this manuscript, we will: (1) present the conceptual and empirical

underpinnings of learned industriousness, including how these compare and contrast to other learning theories; (2) review the psychological literatures supporting this model in healthy populations; (3) consider the evidence suggesting that this model may apply to AN and other psychiatric disorders involving effortful and ostensibly unpleasant actions; and (4) suggest a program of research designed to test the applicability of this theory to furthering the field's understanding of serious and persistent psychopathology.

The Learned Industrious Model: Theory and Evidence

Effort is the intensification of physical or mental activity in the service of meeting a goal.²⁴ The most clearly defined forms of effort are physical effort (e.g., exercise, repetitive motor actions) and cognitive effort (e.g., solving challenging mental problems). Both forms of effort expenditure are usually considered inherently aversive and frequently avoided by humans and other animals alike.²⁵ As such, in behavioral economics, effort is typically modeled as costly to organisms.⁵ Indeed, there is clear evidence that rewarding outcomes are typically devalued as the effort necessary to obtain them increases.²⁶ However, it has also been noted that effort can paradoxically be valued and become less aversive or even enjoyable under certain conditions or for certain people.²⁴ Learned industriousness describes a process by which high effort can become conditioned as a secondary reinforcer (i.e., rewarding in and of itself) when routinely paired with a more natural or primary reward (e.g., money, social praise).²³ This model posits that, over time, the sensation of effort becomes pleasurable because organisms have learned that this feeling signals that such rewards are imminent; therefore, they will begin to engage in effortful behavior as a means of experiencing the internal physical or self-signaled rewards associated with effort, regardless of the external outcomes from the effort.²³

Behavioral Evidence for Learned Industriousness

The learned industriousness hypothesis was originally informed by robust human and non-human animal behavioral data showing that repeatedly rewarding high-effort behaviors increased an organism's willingness to perform other demanding tasks, even when this effort was no longer necessary to obtain a reward. In a series of studies, researchers found that rats required to exert high effort for reward in one training task (e.g., repeatedly travel a runway to receive food) engaged in more frequent and vigorous effort in a subsequent unrelated transfer task (e.g., bar pressing for food), more often chose high-effort over low-effort subsequent activities (i.e., more bar presses for a greater amount of food versus fewer bar presses for less food), and were more resistant to effort extinction compared to rats not required to engage in effort during training.^{27–31} These results held true even when the amount and rate of reward delivered during initial training was the same for both high-effort and no-effort groups, and if a high effort was not required in the secondary transfer task (i.e., food was delivered after every bar press, regardless of effort).^{28,30} Effort-conditioned rats also continued to show willingness to engage in effortful actions in transfer tasks even when they required tolerance of clearly aversive outcomes (e.g., electric shock).³⁰ Similar patterns were found in humans. Rewarding high-effort expenditure on difficult tasks (e.g., completion of challenging math problems) increased effort expenditure and persistence on subsequent tasks that were not associated with an obvious reward (e.g., repeatedly pressing a computer button) and even reduced cheating on difficult tasks.^{32–34}

Subsequent behavioral and self-report studies have provided corroborating evidence for the learned industriousness theory. A comprehensive review by Inzlicht and colleagues²⁴ outlines several lines of research that suggest that effort itself can be considered valued and desirable. For instance, in their natural environment, animals have been observed to choose to work for rewards such as food, even when they can obtain these rewards without exerting effort.^{29,35} Further, a

wealth of data suggest that outcomes become more rewarding as the level of effort necessary to achieve the outcome increases.^{24,36} There is also evidence of trait-level differences in the degree to which people are willing to seek out effort across contexts, with some individuals demonstrating elevated motivation for engaging in challenging activities.³⁷

Together, these studies clearly highlight that training an organism to engage in high effort to obtain a reward makes them more willing to voluntarily engage in high effort in future unrelated tasks. Further, there is evidence that effort is valued by humans and non-human animals under some circumstances. Though the mechanisms of effort valuation and generalization are not fully established, learned industriousness posits that conditioning effects reduce the aversion and increase positive experiencing related to effort itself.

Neurobiological Evidence for Learned Industriousness

The neurobiology of effort-based decision-making has not been fully elucidated. However, neuroimaging studies provide emerging support for a biological basis that may support learned industriousness. Effort-based activities engage a broad neural network. In line with traditional conceptualizations of effort as aversive, several brain regions track the potential costs of effort expenditure. Activity in both the anterior cingulate and the anterior insula have been shown to correspond with effort discounting,^{38,39} tracking the costs of the energy demands required from effort.⁴⁰ These regions potentially mediate the aversive subjective experience of effort⁴¹ and the tendency to avoid high-effort activity.³⁸

However, other regions, notably those situated within the reward network, actively monitor the potential benefits of effort expenditure and invigorate effortful actions. Both the ventral and dorsal striatum are activated in anticipation of effort and predict a willingness to engage in high-effort activities.^{42,43} There is some evidence that the dorsomedial ventral striatum

is particularly responsible for tracking rewards related to effortful behavior.⁴⁴ During effort expectation, the striatum interfaces with regions of the prefrontal cortex, most notably the ventromedial prefrontal cortex (vmPFC), which tracks the value of the expected rewards from an effortful task³⁸ and willingness to seek high-effort rewards.⁴⁵ There is evidence that these brain-behavior connections are mediated through the dopaminergic system, as dopamine release in both the striatum and vmPFC mediates the willingness and tolerance for high-effort activity.^{46,47}

While this literature suggests that reward-seeking and effort are intrinsically related, it does not necessarily suggest that effortful behavior can be intrinsically rewarding. However, other findings suggest that high-effort activity itself may generate activity within the dopaminergic system. For instance, activity in the striatum increases following a high-effort decision in anticipation of effort engagement, which may reflect reward anticipation of effort in addition to invigoration of activity.^{43,48} Further, the ventral striatum is activated to a greater extent when receiving and evaluating a reward that required greater effort to achieve.^{49,50} As a result, rewards resulting from greater effort tend to be more highly preferred.⁵¹ Additionally, greater dopamine receptor density is associated with greater achievement and effort motivation.⁵² These findings are consistent with a model in which dopaminergic activity may condition preference and subjective value for cognitive or physical exertion through the process of motivating effortful activity. In clinical investigations, individuals with psychotic and mood disorders show deficient striatal activity during effort decisions,^{53,54} which corresponds with the inactivity and effort discounting characteristic of these disorders.⁵⁵

As highlighted in **Figure 1**, these data suggest a working model in which learned industriousness would be reflected in the following patterns of neural activation during effort-based decision-making and activity: (1) increases in regions associated with the effort rewards

and associated behavioral correlates (e.g., effort willingness, subjective pleasure); and (2) decreases in activation in regions associated with effort costs and behavioral correlates (e.g., effort discounting, subjective aversion). Although this model and the research supporting it are consistent with a biological basis for learned industriousness, the neural correlates of individual-level differences in effort willingness and enjoyment have not yet been systematically tested and warrant further research. This growing literature on the neurobiological substrates of effort-based decision-making has the potential to enhance understanding of the mechanisms involved in effort-seeking.

Comparing Learned Industriousness to Other Theories of Effort Engagement

Other theoretical accounts have been generated to explain engagement in effortful behavior. From a *goal-directed* learning perspective, an organism may engage in high levels of effort because the outcome is so rewarding that the cost of the effort is considered worthwhile. There is strong evidence that increasing the value of the outcome (e.g., increasing a monetary reward) strengthens effort motivation towards that outcome.⁵⁶ A large volume of human and non-human animal studies have shown that organisms will exert high levels of effort to obtain especially potent reinforcers, such as high-fat foods, nicotine, and other drugs.^{57–61} Further, the degree to which individuals will exert effort towards certain problematic behaviors has been associated with negative psychological and health outcomes (e.g., effort for nicotine is higher in heavy smokers, effort for food is higher for binge eating).^{62,63} These findings correspond with the clinical phenomenon that some individuals will go to great lengths to engage in addictive behaviors because of the strong reward derived from those behaviors.

Another account of effortful behavior can be derived from *habit* learning. Habit learning is a process by which a behavior that is originally rewarded gets over-trained to the point that it

is automatically executed in certain situations irrespective of the anticipated appetitive or aversive outcomes.⁶⁴ Several human and non-human animal studies⁶⁴⁻⁶⁶ have demonstrated that organisms that have been repeatedly rewarded for engaging in a particular behavior will continue to execute this behavior even once the reward is removed. The habit model posits that certain cognitively or physically taxing behaviors persist in psychopathology (e.g., mental preoccupations in obsessive-compulsive disorder) because these behaviors have become cue-driven automatic responses, and therefore divorced from the actual cost or value of performing these actions.^{67,68}

To understand the varied factors motivating effort, it is important to distinguish between learned industriousness and these alternate theories. The first difference between these perspectives pertains to what and how an organism learns. For instance, consider the situation outlined in **Figure 2** in which the effortful behavior being trained in a rat is traversing a runway and the reward is food. In a learned industriousness paradigm, the rodent would typically be rewarded on a fixed ratio following the completion of a certain high number of runway traversals. Thereby, the rodent would learn that *effort* is rewarded. In a habit paradigm, on the other hand, the rodent would be repeatedly rewarded for the behavior of running, usually on an intermittent schedule, in a manner that is not dependent on the number of runway traversals. In this case, the rodent would learn that *the behavior of running* is rewarded. In the goal-directed paradigm, the difference would pertain to the salience of reward, such that the rodent would learn that in order to receive a highly salient reward (e.g., a palatable high-fat food), it would have to perform a number of runs. In this case, the rodent would focus on the outcome more than the learned behavior, learning that running or effort is *necessary to get something valuable*.

The nuances of these models become clear when considering how the organism will next behave in different situations. If returned to the same context in which runway running is no longer rewarded, the goal-directed rodent would stop running relatively quickly because this behavior was simply a means for obtaining the food reward. In contrast, both the habit-learning and learned industriousness rodents would continue to repeatedly traverse the runway. In the case of the habit-trained rodent, this would be because running had become an automatic, nonconscious habit. In the case of learned industriousness, it would be because the effort itself had become rewarding to the rodent. Consider the situation in which these two rodents were next given access to a new effortful behavior (e.g., bar pressing) that was not rewarded with food. According to these theories, the habit-trained rodent would not be particularly likely to engage in bar pressing because it was running, not bar pressing, that was over-trained. However, the learned industriousness rodent, recognizing this as a novel effort context, would engage in repetitive lever pressing, presumably because the sensation of effort held appeal. In the case of human behavior, the learned industriousness model could explain how learning one effortful behavior (e.g., endurance sports) could motivate a completely different effortful behavior (e.g., challenging mental work). This highlights one unique aspect of the learned industriousness theory: it can explain not only the persistence of effort, but also the generalization of effort. However, it is likely that each of these processes contributes to the motivation to engage in effort and that individuals transition between these processes, depending on contextual and learning variables.⁶⁷

Applying the Learned Industriousness Model to AN

The learned industriousness model has not yet been applied to understand psychiatric disorders characterized by excess effortful behavior. Indeed, the vast majority of the psychiatric

literature on effort-based decision-making has examined and identified deficits in effort motivation^{53,55,69–71} Using the example of AN, we will describe how the learned industriousness model may enhance the understanding of the opposite end of the effort spectrum, in which *heightened* effort leads to negative psychological consequences. Although AN is presented as a prototype of learned industriousness, we expect this presentation may extend to several other psychiatric presentations.

The symptoms of AN certainly require substantial physical and mental effort. For instance, restrictive eating and excessive exercise require tolerating physical effort (e.g., hunger, fatigue, physical discomfort) and cognitive effort (e.g., tracking intake and activity) for lengthy periods of time before achieving the presumed desired outcome (e.g., weight loss). Other eating disorder behaviors, such as self-induced vomiting or fasting, require the ability to tolerate shorter-term, but more intense physical effort. Yet, unlike most individuals without an eating disorder, evidence suggests that many individuals with AN find these behaviors appetitive or relieving, rather than aversive.^{72–74} In line with the learned industriousness model, we propose that effortful eating disorder behaviors may yield short-term reward in AN because they fall within a class of effortful behaviors requiring persistence or intensity that an individual may have been conditioned to find reinforcing.²³

According to learned industriousness theory, individuals with AN may be discriminately rewarded (e.g., through social praise or positive achievement outcomes) for engaging in effortful behavior, either in the form of eating disorder behavior and/or effortful non-eating disorder behavior (e.g., school, work, or athletic performance). Indeed, such behaviors are often socially rewarded in societal and familial cultures that value individualism, self-control, and achievement.^{75,76} Individuals with AN also may be genetically or temperamentally predisposed

to engage in high-effort behavior^{77,78} and respond to rewards for effort.⁷⁹ As such, they would incur more opportunities for effort to be rewarded and may be more inclined to attend to the rewards from effort. Through this process, individuals with AN may ultimately internalize self-reinforcement for effort and seek out novel effortful experiences, eating disorder-related or otherwise.²³

This model explicitly accounts for problematic effort generalization. Even if a person was not originally reinforced for eating disorder behaviors, but rather for other forms of industrious behavior (e.g., athletics in the absence of weight loss), the class of effortful behavior could expand to include eating disorder behaviors (e.g., restrictive eating, excessive exercise) through cue generalization. Similarly, the positive effort sensations associated with eating disorder behaviors may generalize to other problematic effortful behaviors, such as excess studying, working, or cleaning and organizing. Additionally, in the learned industriousness account, multiple levels of reinforcement could surround weight-control behaviors, making them more difficult to change. For example, exercise could be reinforcing both because it leads to a desired outcome (i.e., weight loss) and because it is classified as effortful. Thus, even if clinical interventions shifted the desire for thinness, a drive towards weight loss could persist, driven by the rewarding quality of the effort required to engage in weight-control behaviors. Thus, this model can identify novel targets that surround the maintenance of eating disorder symptoms in AN and other potentially maladaptive effort-oriented patterns.

Distinction between Learned Industriousness and Other Theories of AN

Goal-directed and habit-learning accounts of AN, informed by the preclinical models outlined previously, have similarly posited a role of aberrant reward learning in the development of weight-control behaviors in AN. Goal-directed reward models of AN suggest that weight-

control behaviors in AN are driven by heightened salience of the rewards derived from weight loss, like thinness.⁸⁰ There is strong evidence to support this hypothesis, as cues for thinness and weight loss have been shown to be highly rewarding to individuals with AN.⁸¹ However, in parallel to the processes outlined in **Figure 2**, this model would only account for excess drive towards illness-compatible behaviors and situations. Further, it would be expected that any effortful behaviors that do not lead to weight change would ultimately extinguish.

Habit theories of AN suggest that weight-control behaviors in AN are initially driven by heightened reward derived from weight loss, but through overtraining become cue-driven habits that are automatically performed without conscious consideration of the rewards from weight loss.^{20,82} There is evidence that weight-control behaviors in AN share qualities of habit behavior;⁸³ however, it remains unclear if individuals with AN have a generalized tendency towards habit dysfunction, or if this process may be specifically applied to eating disorder behaviors in this population.^{83–85} Either way, habit processes localize to a specific behavior or behavioral sequence. Thus, these would account for the persistence of specific highly practiced weight-control behaviors, but not a general tendency to engage in effort.

A learned industriousness model of AN differs from the above theories in critical ways. First, according to learned industriousness, the rewards derived from effortful eating disorder behaviors would not be presumed to relate solely to resultant weight loss or thinness. In fact, effortful weight-control behavior would not even need to be the first instance in which effort is conditioned as reinforcing. Second, in learned industriousness, effort would be subjectively and consciously experienced as positive, rather than an aversive to be overcome to achieve weight loss (goal-directed theory) or value agnostic (habit theory). Third, effort generalization across behaviors (e.g., academic achievement to restrictive eating) could occur without ever directly

contacting positive outcomes of the new behavior (e.g., weight loss), due to the shared associative effort qualities between the behaviors. Finally, although much of the same neural circuitry is hypothesized as involved in each of these learning theories,^{38,80,82} the timing and pattern of neural activation or dopaminergic engagement may differ. For instance, in learned industriousness, striatal activation and dopamine release would correspond with cues signaling effort, rather than the rewards to be obtained through effort per se. Additionally there is evidence that steady dopaminergic ramping (rather than phasic release) may correspond with outcomes requiring delay or effort,⁸⁶ further distinguishing the reward signaling associated with effort conditioning. Because AN is a complex, multifaceted illness, it is likely that each of these mechanistic models describes some component of the learning processes that maintain the clinical symptoms in this disorder.

Evidence for Learned Industriousness in AN

Although the above learned industriousness model of AN has not been tested directly, there is significant indirect evidence in the extant literature that supports the hypotheses that generalized valuation of effort may maintain eating disorder behaviors in this population.

Animal Models

The activity-based anorexia rodent model is the most common animal model of AN.⁸⁷ This model yields results that correspond with the learned industriousness perspective. In activity-based anorexia paradigms, rodents are food-restricted and provided free access to a running wheel. Within this environment, some rodents engage in excess wheel running and restricted food intake that results in substantial weight loss. This behavior persists even when food becomes freely-available, such that some rodents run themselves to the point of death. Importantly, some rodents are resistant to the development of activity-based anorexia behavior,

likely due to individual differences in dopaminergic functioning.⁸⁸ For those rodents that develop activity-based anorexia, researchers have hypothesized that hyperactivity may be an evolutionarily-imprinted foraging behavior elicited by food shortage to help the animal find a food-rich environment;⁸⁹ yet, a limitation of evolutionary hypotheses is that they cannot be tested. Further, such explanations would not clarify the momentary motivators driving this behavior. To date, the mechanisms underlying the activity-based anorexia model have not been fully understood.⁹⁰ Yet, it is clear that these rodents demonstrate a tendency towards multiple effortful behaviors. Learned industriousness could provide a framework for testing the hypothesis that the effort of food restriction could motivate foraging hyperactivity, or vice versa. However, it should be acknowledged that there are limitations to the translation of the activity-based anorexia model to the human clinical phenomenon of AN.⁹¹

Qualitative and Self-Report Data

Considerable qualitative and self-report data suggest that some individuals with AN find the effortful quality of eating disorder symptoms to be rewarding. Individuals with AN and other eating disorders have described that behaviors such as restrictive eating, exercise, and purging yield feelings of enjoyment, pride, self-confidence, or uniqueness.⁹²⁻⁹⁶ In fact, in one survey study, nearly 75% of individuals with AN endorsed engaging in restrictive eating to feel strong, powerful, or proud of themselves.⁷² This finding corresponds with naturalistic ecological momentary assessment research, which has found pride to significantly increase following restrictive eating for individuals with AN-R.⁷³ Further, in one qualitative survey, individuals with AN were asked to describe the degree to which their values corresponded with their eating disorder.⁹⁷ One commonly identified theme was that individuals valued the focus on hard work, achievement, and control that maintained their eating disorder symptoms. For instance, one

respondent indicated, ““When I don’t eat and when I do those things it’s kind of like a buzz, in the sense that all the positive aspects that I think about myself – that I have willpower, I’m strong, I’m independent, I feel attractive, I feel confident – when I do those things like that it feeds into those things,”” p. 6.⁹⁷ Thus, eating disorder symptoms could serve as an extension of a positive emphasis placed on difficult, effortful activity.

Temperament

Individuals with AN may possess long-standing patterns of behavior that are aligned with preference for effort-based rewards. Persistence is a temperamental construct that reflects the tendency to work towards longer-term rewards in the face of momentary aversives or non-reward.⁹⁸ A recent meta-analysis found evidence of elevated persistence across eating disorder presentations, including AN, with the highest effect sizes reported for AN-R relative to healthy controls (Cohen’s $d = .52$).⁷⁷ Behavioral data support these self-reported findings, as individuals with AN have been found to persist longer on non-eating disorder laboratory tasks than individuals without an eating disorder.⁷⁹ While other temperamental propensities, such as harm avoidance and reward dependence, have been found to change as an individual recovers from AN, persistence has been found to remain stable even in recovery,⁷⁷ suggesting that this is a personality characteristic that persists beyond acute illness. Together, these data demonstrate evidence of inclination towards long-term effort-based rewards among individuals with AN.

Delay Discounting

Delay (or temporal) discounting is the devaluation of a reward as a function of delay in its receipt.⁹⁹ Delay discounting assessments typically present the participant with a binary choice between a smaller reward received sooner (e.g., \$5 today) or a larger reward received later (e.g., \$20 in a week). Participants are asked to indicate their preference for each binary choice

presented over several trials or items. Research has suggested a modest link between delay and effort discounting,¹⁰⁰ suggesting a potential association of delay discounting with learned industriousness. The ability to delay reward has been associated with many positive psychological and quality of life outcomes.¹⁰¹ Therefore, unsurprisingly, most psychiatric disorders are characterized by over-discounting delayed rewards, demonstrating difficulty delaying immediate gratification.¹⁰² In contrast, AN is one of the only psychiatric disorders associated with under-discounting of rewards, showing a preference bias for larger rewards available later versus smaller rewards available sooner.¹⁰² This pattern of delay discounting could suggest that individuals with AN also may be inclined to over-value effortful rewards. However, because effort and delay tolerance are related but distinct constructs, further research is needed on effort discounting in AN.

Effort Valuation

Another facet of reward processing that may be relevant to learned industriousness is effort valuation, or the willingness to work for a rewarding commodity.¹⁰³ Effort valuation is often assessed with progressive ratio paradigms that require participants to expend motor energy (e.g., button presses) or cognitive energy (e.g., solving puzzles) to obtain a reward. Over the duration of the task, the effort required to obtain a reward substantially increases and, typically, willingness to work for the reward decreases. Individuals with eating disorders have consistently demonstrated that they will put forth substantial effort in these paradigms to engage in weight-control behaviors. For instance, individuals with restrictive eating pathology, such as AN, will expend great amounts of effort to earn exercise,^{104–107} caloric restriction,¹⁰⁸ and non-nutritive artificial sweetener.¹⁰⁹ It is unclear whether effort expenditure is heightened in these studies because an eating disorder-related reward is at stake, because the effort to obtain the reward is

rewarding in and of itself, or both. However, initial evidence suggests that generalized effort valuation may impact eating- and weight-related behaviors. For instance, elite athletes show higher physical effort valuation¹¹⁰ and an exercise intervention for sedentary adults was found to reduce sensitivity to effort costs,¹¹¹ suggesting a relation between one specific type of effortful behavior (i.e., physical activity) and general effort valuation. Additionally, one study found that general eating pathology was associated with less mental effort avoidance.¹¹²

Engagement in Other Effortful Activities

There is also evidence that individuals with AN engage in effortful activities independent of eating disorder behaviors. For instance, there is a robust link between competitive and elite athleticism and AN.^{113,114} These findings have often been attributed to the weight standards associated with sports with an appearance or weight focus (e.g., gymnastics, wrestling) or a bias towards leanness to meet performance standards (e.g., running). However, there is also evidence that rates of eating disorders increase with competitiveness or eliteness of sport independent of weight-focus,¹¹⁴ suggesting that there may be a shared mechanism between the effort required for elite athleticism and eating disorder behavior. In fact, one analysis argued that the qualities that coaches describe as essential to athletic achievement, such as willingness to engage in difficult tasks, are the same qualities that maintain AN.¹¹⁵ Other studies have found that persistence and “obsessive passion” among competitive athletes predicts exercise addiction and injury risk.^{116,117} Thus, excess drive towards and enjoyment of the effort of athletic activities in some cases may be linked to negative outcomes, and may constitute an uninvestigated shared mechanism for elite sports and AN.

Additionally, the association between high academic achievement and AN has been well established. There are genetic and familial links between higher educational attainment and

AN.^{78,118,119} Higher school performance has been found to serve as a risk factor for subsequently developing AN¹²⁰ and individuals who have already developed AN have been found to have elevated academic standards and performance.^{121,122} Although these associations have often been attributed to perfectionistic tendencies, it is possible that they could result from conditioned reinforcement of industrious activities, affecting a broad class of effortful behaviors.

Summary of Evidence

Several lines of inquiry converge to suggest that individuals with AN may have a temperamental or genetic propensity towards effort tolerance and may more highly value effortful and delayed outcomes. These qualities could lead individuals with AN to more readily engage in a range of effortful behaviors, including academic and athletic endeavors, as well as eating disorder behaviors. There has been less evaluation of the emotional experiences associated with effort among individuals with AN; however, qualitative data suggest that individuals with AN find the effortful quality of eating disorders to be gratifying in increasing pride and self-assurance. This research supports the learned industrious model of AN in suggesting that weight-control behaviors may be so compelling because they fall within a class of effortful activities, which affected individuals have been conditioned to associate with reward. Additional research directly testing this model is needed to determine the extent to which learned industriousness plays a role in AN.

Clinical Implications of the Learned Industriousness Model

Because effortful behavior has generally been considered to be aversive, there are no treatments specifically designed to reduce this class of behaviors. Indeed, it is far more common for interventions to attempt to increase effortful engagement.¹²³ However, prior approaches to altering other problematic but rewarding behaviors may provide insight into interventions

relevant to altering pathology of excess effort. Below we consider how focusing on excess industriousness as a treatment target could impact therapeutic approaches for AN, and perhaps other psychiatric disorders. It should be noted that all the described techniques are already routinely employed in psychological and psychiatric treatments; however, effortful behavior is not explicitly the target for any existing treatments for mental health concerns. Here, we consider how existing approaches could be adapted to specifically target this class of behaviors.

Extinguishing or Reducing Reward Derived from Effort

If excess effort characterizes a broad class of problematic behaviors for an individual (i.e., the tendency to push oneself too hard and ignore appropriate cues to decrease effort), taking steps to directly reduce the secondary rewarding qualities of effort may be indicated. This approach would involve conditioning a new relationship with effort, such that the aversive qualities of effort are highlighted and amplified, while the rewarding qualities of effort are minimized or ignored. Such aversive conditioning approaches have been used to alter the reinforcing properties of other problematic behaviors, such as substance use disorders and non-suicidal self-injury.^{124,125} Using this approach, aversive conditioning could be achieved through repeatedly pairing effortful behavior (e.g., exercise cues) with something negative (e.g., unpleasant pictures, an aversive auditory tone). Alternatively, mindful observation could be used to attend to the inherently unpleasant qualities of demanding cognitive and physical tasks in order to shift the cost-reward ratio of effort. Another approach would involve maximizing expectancy violations by providing and noticing opportunities in which high-effort activity did not yield the physical, emotional, or social reward expected.¹²⁶ However, it is important to note that this approach assumes that all forms of heightened industriousness are problematic. Therefore, such interventions would need to be implemented with care to avoid extinguishing

useful forms of elevated effort that are performed in the service of an individual's valued goals. The desired outcome would be for the individual to appropriately calculate the costs of effort, while moderating the influence of the rewards from effort, when deciding to engage in a behavior.

Reinforcing Alternate Non-Problematic Forms of Effort

In a somewhat contradictory approach, interventions could focus on leveraging the reward derived from effort to engage in alternate challenging activities that are more adaptive than eating disorder symptoms. The goal would be for individuals to learn to purposefully select demanding activities that fall more in line with their long-term goals and values and cause less harm than eating disorder behaviors.¹²⁷ Intervention approaches for other populations have found that reinforcing safe and socially-acceptable replacement behaviors with functional equivalence can reduce problematic behavior patterns (e.g., replacing self-harm with other vigorous physical exercise)¹²⁸. In the case of AN, the focus would be on pursuing other activities requiring physical or mental exertion (e.g., a long-term career goal, volunteer activity, or home improvement project) to fulfill the sense of purpose, pride, and satisfaction previously derived from the eating disorder behaviors. Further, such interventions could frame the work of recovery as effortful (which, indeed, it is for this population), enhancing pride derived from recovery, rather than symptom engagement.⁹⁴ However, this intervention carries the reverse risk associated with extinguishing effort rewards, such that it could result in reliance on a new form of excess effort for reward that similarly yields negative effects (e.g., work or study “addiction”, being a “perfect patient”).

Diversifying Reward Classes and Properties

An approach to reducing reward dependence on effort that can avoid pitfalls of the previously mentioned strategies is to increase the diversity of potentially rewarding behaviors. Certain activities that are typically considered rewarding, such as social interaction, are perceived as less rewarding and more aversive by individuals with AN.⁸¹ Additionally, individuals with AN tend to derive less reward from hedonic, high-novelty rewards.^{77,81} It may be that individuals who have been conditioned to overvalue effort may find low-effort recreation (e.g., self-soothing activities, such as taking a bath or watching a movie) less enjoyable. Thus, they may need support in enhancing the salience of behaviors that are incompatible with effort, or else not explicitly tied to effort. Expanding the diversity of rewarding activities may reduce the reliance on effortful behavior to generate a positive emotional experience. Indeed, such approaches have been successfully used to divert attention from other problematic rewards, such as drugs of abuse, at least in animal models.¹²⁹

Biological Interventions

Increased availability of and facility with a range of neuromodulation approaches (e.g., transcranial magnetic stimulation, transcranial direct current stimulation, EEG or fMRI neurofeedback) offers an alternate set of tools by which to accomplish the above clinical goals. For instance, excitatory neuromodulation of regions associated with effort discounting (e.g., anterior cingulate), especially during effort-based decision-making, could potentially increase attention to effort costs.¹³⁰ In terms of pharmacotherapy, there could also be a role for use of anti-craving medications to reduce drive towards effortful behavior.¹³¹ Additionally, if evidence supported the learned industriousness model of AN and other psychiatric disorders, this could influence decision-making surrounding prescribing medications associated with invigorated effort, such as stimulant medications, to such patients.¹³² However, research on the

neurobiological substrates of effort-based decision-making is in its early stages and more data in this area are needed to most accurately target biologically-oriented treatments for effort overvaluation.

Summary of Clinical Implications

If future research supports the contribution of the learned industriousness conditioning model to the maintenance of psychopathology, including AN, additional work will be needed to develop and test interventions for disrupting this problematic process. Although the above interventions target the novel process of effort-based decision-making, previous behavioral treatments for AN have demonstrated limited efficacy.¹³³ Therefore, testing the above interventions, as well as developing new intervention approaches, will be a critical future direction in this area of research.

Future Research Directions

Although there is clinical interest in persistence and effort (or perhaps lack thereof) in the behavioral sciences, the field of effort expenditure and learned industriousness is relatively nascent and research is sparse. Accordingly, researchers have yet to examine how the learned industrious framework may help to explain the clinical phenomenology of AN and other mental health concerns. In this section, we outline potential avenues of future investigation of learned industriousness in AN.

Behavioral and Cognitive Correlates of Learned Industriousness

Behavioral paradigms have been developed to measure physical effort decision-making and expenditure, such as the Effort-Expenditure for Rewards (EEfRT) task,¹³⁴ Effort-Based Decision-Making task,³⁸ and progressive ratio tasks.^{80,105,106,108,109} These tasks examine willingness to expend different amounts of motor effort for different magnitudes of primary

reinforcers (e.g., food) or conditioned rewards (e.g., money). The EEfRT task additionally manipulates the probability of receiving reward. Similar tasks, such as the Cognitive Effort Discounting Task¹³⁵ and Cognitive Effort-Expenditure for Rewards Task,¹³⁶ have been designed to examine cognitive effort expenditure (e.g., performing n-backs). These measures provide an important starting point for examining general tendencies to seek out effortful activity. To date, very few studies have examined effort-based decision-making in eating disorders, and none have examined this process in AN specifically.^{112,137} Therefore, initial data are needed to test whether this group demonstrates a tendency to overvalue effort.

Additionally, there are some areas in which these measures may need to be adapted or expanded to test the learned industriousness model. These tasks have been largely designed upon the assumption that effort is aversive and will decrease reward motivation. Therefore, it is less clear how intrinsic rewards derived from effort would be evaluated by these paradigms. Emerging computational models derived from these tasks may offer a way to probe dependence on magnitude of external reward in effort-based decision-making.^{24,138} In these models, less external reward dependence coupled with greater effort selection may be expected in the case of learned industriousness. Incorporating self-report of subjective experience into these paradigms may be additionally beneficial towards understanding the function of effort. Another potential issue is that these measures tend to demonstrate only small to moderate intercorrelations,¹³⁹ suggesting that they may tap into somewhat distinct constructs. Further work to determine the sources of task variability would assist in most precisely selecting tasks to test the tendency towards effort generalization.

Moreover, future work is needed to test the cognitions that precede and follow engagement in effortful activity for different individuals or groups. For instance, elucidating the

expectancies that individuals with AN hold about engaging in effort could deepen the understanding of motivations to engage in such behavior. Likewise, illuminating cognitions experienced following effort could facilitate understanding of the reinforcing properties of effort.

Neural Correlates of Learned Industriousness

To date, there is a dearth of research investigating the neural substrates of effort valuation in healthy persons and psychiatric disorders, leaving many unanswered questions about how the brain implements decisions to engage in effort. For instance, although the ventral striatum was previously considered the centralized “hub” for effort motivation, new work suggests dissociable profiles of effort valuation, effort discounting, and actual physical effort expenditure within this region.⁴⁴ Further, to our knowledge, there have not been studies examining the neurobiology of effort over-valuation or differences in neural activation to effort in persons with AN or other psychiatric disorders characterized by excess effort. As such, further research is needed to better characterize the neural underpinnings of effort in general, as well as in reference to anomalies in effort responding across psychiatric conditions.

Learned Industriousness as a Transdiagnostic Process

A foundational step in testing the learned industriousness model will be to characterize effort expenditure in persons with AN, given the face-valid link between this disorder and effortful behaviors. At present, it remains unclear if effort expenditure is elevated among individuals with AN only in disease-specific contexts, or more generally. Relatedly, it will be important to compare the subjective experience of effort expenditure in persons with AN relative to other individuals. Beyond information derived from qualitative report, little is known about whether effort expenditure is rewarding, relieving, less aversive but still unpleasant, or aversive (but necessary to achieve weight-control goals) in AN. Further, distinct decision processes may

promote disordered eating for different individuals or stages of illness.^{140,141} Future research may also wish to examine disease status as a function of industriousness to garner information regarding whether aspects of effort-based decision-making are traits, risk factors, and/or maintaining factors related to eating pathology.

Finally, individuals with other eating disorders (e.g., bulimia nervosa) and other clinical populations (e.g., obsessive-compulsive spectrum disorders, autism spectrum disorders) engage in heightened goal-directed behavior that may result from the conditioning processes hypothesized in learned industriousness. Some research has found elevated persistence in bulimia nervosa and other eating disorders besides AN.^{77,142} Further, one study identified less mental effort avoidance among participants with eating disorder symptoms (not AN specifically), as well as individuals with obsessive-compulsive symptoms.¹¹² Another study found evidence of elevated effort expenditure among individuals with autism spectrum disorders.¹³⁸ Additionally, some studies have found individuals with bulimia nervosa, obsessive-compulsive personality disorder, and subsets of individuals with chronic depressive disorders to demonstrate similar shallow delay discounting as found in AN, suggesting the potential relevance of effort under-discounting in these populations.^{143,144} These data suggest that the learned industriousness model warrants investigation in other populations beyond AN, as over-valuation of effort may represent an under-investigated transdiagnostic psychiatric phenotype.

Individual Differences in Industriousness

It is also possible that effort willingness and enjoyment vary across eating disorder and other populations as a function of individual or situational variables. It is clear that willingness to exert effort exists on a continuum in healthy populations,²⁴ and the same is likely to be true among individuals with psychiatric disorders. In fact, one study identified different effort

decision-making computational subtypes among individuals with schizophrenia, which were associated with distinct clinical profiles.¹⁴⁵ Thus, it will be fruitful to inquire further regarding whether aspects of the learned industriousness model characterize all, or just a subset, of individuals within various diagnostic groups (e.g., AN). Additionally, it will be useful to determine how learned industriousness processes interact with other learning processes hypothesized to maintain AN.^{80,82} Further, an idiographic approach may be helpful in examining contextual factors involved in healthy versus unhealthy effort engagement within a particular individual. This approach could identify the situations under which an individual may be most inclined to engage in excess effort, clarify how or why a certain challenging activity (e.g., exercise) may be chosen over another (e.g., a difficult cognitive task), and identify sources of reinforcement for effortful behavior (e.g., social versus automatic).⁷² One such pathway to idiographic assessment may be through adapting effort paradigms to be administered via mobile device in concert with assessment of momentary contextual and affective variables.

The above-described future research directions will provide a foundation upon which to more definitively test the application of the learned industrious model to understand excess effort in AN and other pernicious psychiatric illnesses characterized by high levels of effort.

Conclusion

The learned industriousness model is built on a strong theory and preclinical data. Indirect evidence suggests that this model could explain how certain psychiatric populations, such as individuals with AN, develop the tendency to over-pursue effortful behaviors that most people find aversive. However, to our knowledge, this model has not been directly tested in any clinical disorder. Effortful goal pursuit is often considered positive and encouraged in both popular culture and in clinical interventions.¹²³ Data demonstrating that some psychiatric

disorders may be maintained by effort over-valuation could be paradigm-shifting, indicating that ostensibly positive behaviors could go too far to yield severe outcomes. Thus, further tests of this model are needed in clinical populations to better understand a subset of puzzling psychiatric phenomena (i.e., excess drive toward non-hedonic outcomes) that remain unexplained and undertreated.

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Declaration of Interests

None.

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Figure 1. Proposed Biobehavioral Correlates of Learned Industriousness. Brain regions and behavioral correlates in green represent structures and characteristics expected to increase (in activation, frequency, or intensity) in the case of learned industriousness. Brain regions and behavioral correlates in red represent structures and characteristics expected to decrease (in activation, frequency, or intensity) in the case of learned industriousness. aI = Anterior insula; AMG = Amygdala; dACC = Dorsal anterior cingulate cortex; DS = Dorsal striatum; vmPFC = Ventromedial prefrontal cortex; VS = Ventral striatum.

Figure 2. Comparison of Learned Industriousness and Other Reward Learning Models.

Comparison of learned industriousness, habit, and goal-directed learning theories on what is learned at training (initial learning opportunity) and whether effortful behavior would be expected at testing (return to same context without reward) or generalization (change to a new effortful context).

	Training	Testing	Generalization
	Reward learning occurs	Same context, no external reward	New context, no external reward
Rodent
Human
Model	What is learned?	Effort?	Effort?
Learned Industriousness	High effort is rewarded (independent of specific behavior)	✓	✓
Habit Learning	Specific behavior (e.g., running) is rewarded (independent of effort)	✓	✗
Goal-Directed Learning	Effort or specific behavior is exerted to obtain a high value reward (e.g., high-fat food)	✗	✗
No Learning	Reward is freely available (regardless of behavior or effort)	✗	✗