Reduced Willingness to Expend Effort for Reward in Obesity: Link to Adherence to a 3-Month Weight Loss Intervention

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Objective: This study aimed to (1) compare the willingness to expend effort for rewards between young adults with healthy weight, overweight, and obesity; and (2) to examine how individual differences in the willingness to expend effort for rewards predict adherence to weight loss treatment.

Methods: Seventy-three participants completed the Effort Expenditure for Rewards Task (EEfRT). Of those 73 participants, 42 young adults with excess weight took part in a 3-month weight loss treatment after completing the EEfRT. Generalized estimating equation models were used to compare the groups with healthy weight, overweight, and obesity in the EEfRT. Logistic regression models, including the proportion of hard-task choices for each reward probability condition as predictors (12%, 50%, and 88%), were conducted to longitudinally predict adherence in the treatment.

Results: Young adults with obesity were significantly less willing to expend effort for high-magnitude rewards compared with participants with overweight ($P = 0.05$). The willingness to expend effort for uncertain rewards (50% probability) was distinguished between completers and dropouts in the weight loss treatment ($\chi^2 = 5.04$, $P < 0.02$).

Conclusions: Young adults with obesity, compared with their counterparts with overweight, have diminished motivation to expend effort for obtaining high-magnitude rewards. Less willingness to expend effort for the most uncertain rewards predicts poor adherence to weight loss treatment.

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Introduction

More than 30% of young adults (18-24 years old) in developed countries have overweight or obesity (1). Moreover, young adults gain weight at a higher rate than any other age group, and thus they are particularly vulnerable to develop obesity during this period (2). The importance of this link cannot be underestimated, given that, when obesity arises during young adulthood, there is a significantly higher risk of associated medical conditions and premature death from cardiovascular disease regardless of obesity status in middle adulthood (3). Furthermore, young adults with overweight and obesity are considered a particularly challenging patient group regarding adherence to weight loss treatment (4,5). Therefore, studies investigating predictors of adherence to weight loss treatment in young adults are needed.

Weight gain has been shown to have a dynamic course, in which the initially enhanced motivation to approach rewards shifts to diminished interest in these rewards as body mass index (BMI) increases (6). Thus, obesity is often associated with motivational deficits, as indicated by a less subjective engagement in and enjoyment of rewarding behaviors (7). In this context, it is important to examine effort-based decisions in which potential rewards are weighed against the effort required to achieve them (8). In the modern food environment, palatable energy-dense foods do not require much effort to be obtained given that these foods are readily available at a minimal cost for a large segment of the population (9). Conversely, the willingness to expend effort to lose weight is essential for adherence to weight loss interventions (10).

Effort-based decision-making varies as a function of the subjective value that individuals assign to reward (i.e., reward sensitivity) (11). According to an influential model of obesity proposed by Davis and colleagues, there is an inverted U-shaped relationship between levels of adiposity and reward sensitivity (6). Among individuals with healthy weight and overweight, this relationship is positive; i.e., a higher BMI relates to a higher reward sensitivity. However, the relationship becomes negative for individuals with obesity; i.e., a higher BMI relates to a lower reward sensitivity (12). This model has also been used to support a dynamic vulnerability account of the

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TABLE 1 Baseline characteristics of young adults with healthy weight, overweight, and obesity

	Healthy weight, mean (SD)	Overweight, mean (SD)	Obesity, mean (SD)	F/χ^2	P
Age	21.69 (2.11)	21.72 (1.7)	21.37 (1.53)	0.23	0.79
Gender (% male/female)	38/62	36/64	14/86	3.73	0.15
Full scale IQ	107.23 (12.43)	104.25 (11.92)	108.05 (10.48)	0.67	0.51
BMI	21.52 (1.96)	27.41 (1.41)	33.12 (2.16)	227.08	0.000

development of obesity, by which hypersensitivity to reward initially fosters weight gain and then is detrimentally impacted by fat accumulation (13). Therefore, it is relevant to examine effort-based decision-making across the three BMI categories (healthy weight, overweight, and obesity). However, few studies to date have examined effort-based decisions in individuals with excess weight, and these studies have not differentiated between overweight and obesity. Among the available studies, two have used concurrent schedules of reinforcement tasks, adapted from the animal literature, in which button presses were used as a measure of relative effort. Participants were required to choose between earning points for high-calorie snacks or sedentary activities. Findings have shown that adults with excess weight were more willing to expend greater effort to obtain high-caloric food than individuals with healthy weight (14,15). In another study, physical effort was measured by handgrip force. Participants had to make a decision about whether they wanted to exert effort to receive both food and nonfood rewards. Contrary to the above-described findings, individuals with obesity were less willing to exert effort for high-caloric food than their counterparts with healthy weight (16). It is thus important to further evaluate effort-based decision-making by using better validated tasks and different BMI ranges to clarify its link to obesity. Among the available measures of this construct, the Effort Expenditure for Rewards Task (EEfRT) has been shown to reliably assess the weight of both reward magnitude and probability and to correlate with the relevant trait of reward sensitivity (17). This trait has been shown to play a major role in the consumption of energy-dense foods and the hampering of weight loss efforts in young adults (18,19).

Effort-based decision-making may also be relevant to predict the clinical outcome of weight loss treatments. Recent studies have examined whether variation in reward sensitivity and motivation, and their related influences on decision-making under uncertainty, is associated with both the adherence to and the outcome of weight loss interventions (20,21). These studies have suggested that individuals who are more sensitive to reward during decision-making, and who assign higher weights to gains (rewards) versus losses in the evaluation of alternatives, are more likely to drop out of a weight loss intervention (20). It has been proposed that heightened sensitivity to reward is associated with more difficulty to withdraw from very drive-gratifying behavior, such as the consumption of palatable energy-dense yet unhealthy food (20). As such, intact sensitivity to reward and motivation may be necessary prerequisites to advantageous decision-making in the long term and successful treatment completion. To our knowledge, no study has focused on the prognostic utility of more cost/benefit aspects of decision-making, such as those related to the willingness to expend effort for rewards. This lack of research is striking given the link between anhedonia, which is characterized by an inability to feel pleasure in rewarding activities, obesity, and poor treatment outcomes (22). There is evidence indicating that only a minority of participants in behavioral weight loss interventions lose a significant amount of weight (5% or more of the original weight) (23). Consistent with this, a systematic review assessing weight loss treatment outcomes in young adults showed that behavioral interventions and combination interventions are associated with modest weight loss (5). Critically, it has been shown that young adults show poorer attendance and are less likely to be retained for follow-up assessments than older adults (4). Therefore, the likelihood that the benefit of losing a significant amount of weight will be accomplished even if the diet is completed is uncertain, and dieters may be willing to expend effort for uncertain benefits to successfully complete a weight loss intervention. However, despite the intuitive appeal of such a relationship, it is yet unclear whether the willingness to expend effort for uncertain rewards predicts adherence in weight loss interventions.

The aims of this study were (1) to compare the willingness to expend effort for rewards between young adults with healthy weight, overweight, and obesity, and (2) to examine how individual differences in the willingness to expend effort for rewards predict the adherence to weight loss treatment. The EEfRT (24) was used as a measure of the willingness to expend effort for rewards. We hypothesized that (1) the group with obesity would be less willing to expend effort for rewards than the group with overweight, and the group with overweight would in turn be more willing to expend effort for rewards than the group with healthy weight; and (2) the willingness to expend effort for the most uncertain rewards (50% probability) would distinguish between weight loss intervention completers and dropouts.

Methods

Participants

The baseline assessment was completed by 73 young adults (26 with healthy weight, 26 with overweight, and 21 with obesity). Participants' baseline characteristics are displayed in Table 1.

Participants with overweight and obesity were offered the opportunity to take part in a 12-week weight loss intervention. Of the 47 participants with overweight and obesity, 42 (89.3%) took part in the weight loss intervention. There was no baseline difference between those participants who took part in the weight loss intervention and those who did not.

Participants were recruited via community advertisements posted at the Monash University campus and clinics. The selection criteria for participants were defined as follows: (1) aged between 18 and 24 years; (2) BMI between 18 kg/m^2 and 24.9 kg/m^2 (group with healthy weight), 25 kg/m^2 and 29.9 kg/m^2 (group with overweight), and 30 kg/m^2 and 40 kg/m^2 (group with obesity); (3) no history or current evidence of neurological and psychiatric disorders, assessed via survey reports based on *Diagnostic and Statistical Manual of Mental Disorders* (Fifth Edition) criteria; (4) no comorbid medical conditions associated with excess weight; (5) no weight loss surgery; and (6) no medications for weight loss. Ethics approval for the present study was obtained from the Monash University Human Research Ethics Committee before commencement of this study.

Measures

EEfRT. The EEfRT is a measure of the willingness to expend effort to obtain a monetary reward under different conditions of reward probability and reward magnitude (24). In each trial, participants were given an opportunity to choose between two tasks with different levels of difficulty: a "hard task" and an "easy task." Participants were told that successful trial completion did not guarantee winning money. Before making a choice, participants were provided with information that varied from trial to trial regarding (1) the reward probability (12%, 50%, and 88%) of winning the money and (2) the reward magnitude of the hard task for successfully completed winning trials. The reward magnitude was $1.00 for easy tasks and higher amounts that varied per trial within a range of $1.24 to $4.30 for hard tasks. Successful completion of hard task trials required 100 button presses using the nondominant little finger within 21 seconds, while successful completion of easy task trials required 30 button presses using the dominant index finger within 7 seconds. Participants were given 20 minutes to perform the task; thus, the number of trials varied across the participants.

Wechsler Abbreviated Scale of Intelligence. The Full Scale IQ-2 subtest is a measure of general cognitive ability (25). It consists of a vocabulary task and a matrix reasoning task.

Body mass index

Height and weight were measured using a Holtain stadiometer and an electronic scale (SECA Group, Hamburg, Germany), respectively, as part of the first phase of the study. BMI was calculated for each participant as the ratio of weight in kilograms divided by the square of height in meters.

Weight loss intervention

The weight loss intervention consisted of individual counseling and was implemented for 12 consecutive weeks between the baseline and second assessments. The intervention included two modules: (1) a nutrition module and (2) a physical activity module. The nutrition module involved a modified version of the intermittent fasting dietary strategy (5:2 diet protocol, 5 "feed" days and 2 "fast days"). Slight modifications were made to the 5:2 diet protocol to align the intervention more closely with the Australian Dietary Guidelines, with the provision of protein supplements and an emphasis on increasing vegetable and fruit intake on both feed and fast days. There is increasing evidence for the use of intermittent fasting for weight loss in adults with overweight and obesity, as it appears to have comparable effects on daily energy restriction (26). The nutrition module consisted of tailored dietary advice on 5 days of the week, with a focus on optimizing intake from the five core food groups and an overall reduction in energy intake. On the other 2 days of the week, supplementary milk-based protein shakes were provided for these fasting days. Participants were also advised to consume a preprepared meal, vegetables, and fruit on the fasting days. The total energy intake for each fasting day was approximately 800 to 1,000 calories per day. The nutritional module was supported by six face-to-face sessions with an accredited practicing dietitian, which were scheduled at baseline, week 1, week 2, week 4, week 8, and week 12. Monitoring of weight and dietary compliance, via 24-hour dietary intake recalls, was conducted during these sessions. The physical activity module involved encouraging participants to undertake light to moderate physical activity at least 5 days a week, with a duration of 30 to 60 minutes a day. Each participant was provided with a pedometer and a pedometer log to increase motivation for physical activity, and it was recommended to aim for 10,000 steps or more each day. Participants were monitored on their weight progress and routine clinical signs and symptoms, such as appetite, nausea, and bowel actions.

Several evidence-based behavioral strategies were used during the weight management program to promote adherence. At the first session, all participants set tailored weight loss goals with the dietitian, based on their expectations and the dietitian's advice of sustainable weight loss targets of 0.5 kg to 1 kg per week. In addition, participants routinely set lifestyle behavioral goals with the dietitian to assist with achieving their weight loss or health behavior goals. A variety of supplementary behavioral strategies were used as required with different participants. These included strategies such as problem solving, utilizing social support, graded tasks, prompts or cues, and self-monitoring of diet and weight. Dietary self-monitoring with food diaries was not used in this program, as it was believed to be too burdensome on a sample of young adults and also because of the difficulty associated with undergoing the modified intermittent fasting regimen. In line with dietetic practice guidelines, participants were recommended to check their weight weekly and not daily. As participants were attending face-to-face sessions weekly during the first month, the weekly weights were conducted at the face-to-face sessions and no self-weighing was required. During the last two months of the program, participants were recommended to self-weigh weekly, in between face-to-face sessions, although they were not asked to record this information.

Weight loss intervention adherence was defined as attending all six face-to-face sessions (baseline, week 1, week 2, week 4, week 8, and week 12) during 12 consecutive weeks with a tolerance of + 2 weeks for the last session. Participants who did not attend all six face-to-face sessions during 14 consecutive weeks were considered dropouts.

Data reduction and statistical analysis

As per instructions, participants performed the EEfRT within 20 minutes, and the number of trials completed during that time varied among them (mean trials completed = 61.76, SD = 4.65, range = 52-73 trials). For consistency of analysis, only the first 50 trials were used, consistent with the original study using the EEfRT (24). There were significant group differences in total trials completed (F [2, 67] = 3.25, P = 0.045), with the group with obesity (mean trials completed = 63.86, SD = 5.28, range = 55-73 trials) completing more trials than the groups with healthy weight (mean trials completed = 60.81, SD = 4.05, range = 52-71 trials) and

TABLE 2 GEE models

				95% CI		
	χ	b	SE	Lower	Upper	*P*
Model 1						
Reward magnitude	18.10					0.00
Medium	6.58	0.41	0.16	0.09	0.73	0.01
High	15.24	0.84	0.21	0.41	1.26	0.00
Reward probability	12.41					0.00
Medium	2.05	0.31	0.21	−0.11	0.73	0.15
High	8.38	0.96	0.33	0.31	1.61	0.00
Expected value	22.10	0.78	0.16	0.45	1.11	0.00
Trial number	9.15	−0.01	0.00	−0.01	0.00	0.00
Group	4.42					0.10
Overweight	0.14	−0.08	0.22	−0.52	0.35	0.70
Obesity	3.97	−0.05	0.25	−1.00	0.00	0.04
Model 2						
Reward magnitude	18.27					0.00
Medium	3.91	0.52	0.26	0.00	1.04	0.04
High	5.11	0.67	0.29	0.09	1.26	0.02
Reward probability						0.00
Medium	2.07	0.31	0.22	−0.11	0.75	0.15
High	8.26	0.97	0.34	0.31	1.64	0.00
Expected value	21.34	0.78	0.16	0.44	1.11	0.00
Trial number	9.25	−0.01	0.00	−0.01	0.00	0.00
Group*reward magnitude	14.85					0.02
Model 3						
Reward magnitude	18.03					0.00
Medium	6.55	0.41	0.16	0.09	0.73	0.01
High	15.18	0.83	0.21	0.41	1.25	0.00
Reward probability	12.50					0.00
Medium	5.74	0.67	0.28	0.12	1.22	0.01
High	7.87	1.21	0.43	0.36	2.06	0.00
Expected value	22.65	0.79	0.16	0.46	1.11	0.00
Trial number	9.20	−0.1	0.00	−0.01	−0.00	0.00
Group*reward probability	7.75					0.25

All models included reward magnitude, reward probability, and trial number. Estimations computed in relation to low reward magnitude level, low reward probability level, and the group with healthy weight, the parameters for which are therefore redundant.
χ^2 = Wald; b = regression coefficients are linear predictors of the likelihood of choosing the hard task; CI = confidence interval; GEE = generalized estimating equations.

overweight (mean trials completed = 60.91, SD = 4.23, range = 53-69 trials).

Generalized estimating equation (GEE) models were performed to test the effects of group and the interactions between group, reward magnitude, and probability on the willingness to expend effort for rewards. We used an exchangeable matrix and a binary logistic distribution to model the dichotomous outcome of choosing the hard versus the easy task in the EEfRT. Wald χ^2 statistics were tested with a type III sums of squares approach. All GEE models included reward magnitude, reward probability, and expected value. Furthermore, each model included a trial number as a covariate to control for possible effects of fatigue over the course of the task. Reward magnitude was converted to a categorical variable with three levels: low (< \$2.30), medium (\$2.31-\$3.29), and high (> \$3.30).

We examined adherence in three separate logistic regression models, including the proportion of hard-task choices for each probability condition as predictors (12%, 50%, and 88%).

Results

Comparison of effort-based decision-making between young adults with healthy weight, overweight, and obesity

Three independent GEE models were tested (see Table 2). Model 1 tested for a main effect of group on preference for hard tasks but did not find any evidence for a significant main effect (χ^2 [2] = 4.42, $P = 0.10$). The three groups did not differ in the willingness to expend effort to obtain a monetary reward. Model 2 tested for the interaction between group and reward magnitude and found a significant interaction (χ^2 [6] = 14.85, $P = 0.02$). Post hoc pairwise comparisons indicated that within trials with a low and medium reward magnitude, the three groups showed similar preferences for hard and easy tasks (all $P > 0.05$). Within trials with a high reward magnitude, however, the group with obesity showed a lower probability of making hard-task choices compared with the group with overweight ($P = 0.05$). Nonetheless, neither the group with obesity nor the group with overweight was significantly different from the group with healthy weight ($P > 0.05$) in choosing the hard task in trials with a high reward magnitude. Model 3 tested for an interaction between group and reward probability but did not find evidence for the interaction (χ^2 [6] = 7.75, $P = 0.25$). Therefore, we did not find a difference between the three groups in their sensitivity to reward probability when choosing hard tasks.

Prediction of adherence in the weight loss intervention

There was a significant reduction in BMI ($t = 4.43$, $P < 0.001$, Cohen's $d = 0.33$) after treatment. Of the original 42 participants, 25 (59.5%) completed the intervention and 17 (40.5%) did not. This adherence rate is similar to those reported in the literature in this age group (27,28). No statistically significant difference was observed between completers and dropouts in sociodemographic

TABLE 3 BMIs and sociodemographic characteristics of weight loss intervention completers and dropouts

	Completers (*n* = 25)	Dropouts (*n* = 17)		
	n	*n*	χ2	*P*
Females/males	16/9	14/3	1.67	0.19
	Mean (SD)	Mean (SD)	*t*	*P*
BMI	30.12 (3.62)	30.27 (3.36)	−0.12	0.89
Age	22.12 (1.33)	21.59 (1.77)	1.11	0.27
IQ	104.38 (9.42)	104.94 (13.79)	−0.15	0.87

TABLE 4 Regression models predicting intervention attrition using the proportion of hard-task choices for each probability as the predictors

	Model 1[a]	Model 2[b]	Model 3[c]
Model χ^2	1.9 ($P < 0.16$)	5.04 ($P < 0.02$)	0.331 ($P < 0.56$)
Cox and Snell R Square	0.04	0.12	0.00
Nagelkerke R Square	0.06	0.16	0.01
Predictor (Wald statistic)	1.68 ($P < 0.19$)	4.18 ($P < 0.04$)	0.329 ($P < 0.56$)
Completers corrected classified	100%	69.6%	95.70%
Dropouts corrected classified	0%	50.0%	12.50%

[a]Proportion of hard-task choices for 12% probability.
[b]Proportion of hard-task choices for 50% probability.
[c]Proportion of hard-task choices for 88% probability.

characteristics, including gender, age, IQ, or baseline BMI (Table 3).

We examined adherence in three separate logistic regression models, including the proportion of hard-task choices for each probability condition as predictors (12%, 50%, and 88%). Only the logistic regression model for the 50% probability condition was statistically significant ($\chi^2 = 5.04$, $P < 0.02$), indicating that this model was able to distinguish between weight loss intervention completers and dropouts. The predictor (hard-task choices for 50% probability) was significant as well ($P < 0.04$). This model explained between 12.1% (Cox and Snell R Square) and 16.4% (Nagelkerke R Square) of the variance in dropout status and correctly classified 69.6% of completers and 50% of dropouts (Table 4).

Discussion

Consistent with our hypotheses, young adults with obesity displayed less willingness to expend effort for rewards than their counterparts with overweight. Specifically, compared with young adults with overweight, those with obesity were less willing to expend effort for the rewards with the highest magnitude. The willingness to expend effort for the most uncertain rewards reliably distinguished between weight loss intervention completers and dropouts. Weight loss intervention completers expended significantly more effort for uncertain rewards than dropouts. Our results suggested that the willingness to expend effort for uncertain rewards was relevant to characterize obesity and to predict adherence to weight loss interventions.

One reason why individuals with obesity, compared with their counterparts with overweight, may have expended less effort for the greatest rewards is that the participants with obesity did not increase their preference for the hard tasks during high rewards as the group with overweight did. This notion resonated with the findings of previous cross-sectional self-report studies that have shown that individuals with obesity are less sensitive to reward than individuals with overweight (6). Furthermore, individuals with obesity reported less engagement in rewarding activities (7) and were less willing to engage in physical effort for high-caloric food (16). One potential mechanism to explain less willingness to work for reward in obesity is the rewiring of the brain's reward system associated with the long-lasting consumption of food with high energy density (29,30). Prolonged overeating has been associated with alterations in the dopaminergic reward system, and these alterations have been shown to result in hyposensitivity to reward in obesity (30). In our study, however, performance of groups with overweight and obesity did not differ significantly from the healthy-weight group, although with the $P = 0.10$, the possibility exists that a larger sample may be needed to reveal such differences. Our findings, therefore, did not fully support a dynamic model for the relationship between reward sensitivity and BMI, which proposed that the motivation to approach rewards among individuals with healthy weight increases in individuals with overweight and shifts to diminished interest in these rewards in individuals with obesity.

Our weight loss adherence findings suggested that intervention completers may be willing to overcome the uncertainty and effort-related costs of desired rewards when making effort-based decisions. Despite the lack of guarantee of receiving the reward (successfully losing weight), intervention completers may have had more motivation than dropouts to comply with treatment requirements (effort costs), such as not consuming energy-dense food and coping with the discomfort that arises from reducing caloric intake and physical activity (e.g., food cravings and the physical discomfort that can accompany exercising). Therefore, the willingness to expend effort for uncertain rewards may reflect an adaptive mechanism that increases the likelihood of goal pursuit in situations in which rewards are uncertain and cannot stimulate appetitive responding (31). In contrast, for the participants who did not complete the weight loss intervention, the lower level of willingness to exert effort for the most uncertain rewards may have been associated with greater estimated effort costs in relation to the probability of attaining the reward. Based on this high estimated effort, dropouts may be less motivated to complete a weight loss intervention, where the lack of guarantee of reward (successfully losing weight) would be expected to tax motivation maximally. That is, intervention dropouts may have been more sensitive to effort costs, particularly under the circumstances of a reward that is not guaranteed, and were thus not willing to complete a weight loss intervention.

Our findings may have important clinical implications. First, they underlined the usefulness of cognitive measures to identify patients at risk of dropping out of a weight loss intervention. Second, they suggested that effort-based decision-making skills may be a promising target for interventions promoting better treatment outcomes in young adults. Treatments aimed at altering the value of rewards by manipulating the brain's reward system using dopaminergic modulation may promote a greater willingness to exert effort to achieve weight loss. Furthermore, our findings supported the importance of the clinical cutoff points of overweight versus obesity and the examination of the three BMI categories (healthy weight, overweight, and obesity). Frequently, individuals with overweight and obesity are examined as a whole (overweight/obesity vs. healthy weight), or only individuals with obesity are investigated.

The weight loss intervention conducted in this study required a higher level of effort from participants than standard interventions given that it was based on the intermittent fasting dietary strategy, including two fasting days. The findings of the present study may be generalizable to other weight loss interventions that require higher levels of effort, such as the very low-calorie diet, which restricts calories to very low amounts. However, future studies are warranted in order to investigate whether effort-based decision-making is linked to adherence in standard weight loss interventions. A second limitation to the present study is our small sample size, which may have affected the power to detect significant differences on the EEfRT between participants with excess weight and healthy weight. Furthermore, participants' willingness to exert effort for monetary rewards may have been influenced by financial security and extrinsic motivation (32). Finally, this study adopted a valid but also limited definition of adherence, i.e., completing all treatment sessions. Future studies should investigate how the willingness to expend effort for uncertain rewards is associated with additional measures of behavioral adherence, such as the adherence to dietary recommendations and physical activity.

We concluded that young adults with obesity, compared with their counterparts with overweight, demonstrated diminished motivation to expend effort for high-magnitude rewards. Furthermore, the willingness to work for uncertain rewards may be crucial to adhere to weight loss intervention and complete treatment objectives. O

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