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The effect of brief mindfulness training on momentary impulsivity

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ABSTRACT

Delay discounting describes the tendency to select smaller-sooner rewards over larger-later rewards, which has been proposed as a behavior analytic model of impulsivity. Framed in this way, impulsivity is problematic because it results in the sub-optimization of rewards and is related to several addictive behaviors. The present study evaluated the efficacy of a brief, 5-min mindfulness exercise on participants' momentary state impulsivity using a monetary delay discounting questionnaire. Twenty-three participants were randomly assigned to either an experimental ($n = 11$) or control group ($n = 12$). Both groups completed delay discounting surveys before and after their respective interventions, where the experimental group watched a brief mindful breathing video and the control group watched a contemporary music video of approximately the same duration. Decreases in impulsive responding were seen in the experimental group and no significant changes were observed in the randomized control group. These results have implications for applying brief mindfulness-based strategies that can reduce the probability of impulsive choice behavior.

1. Introduction

The construct of impulsivity has been conceptualized by Critchfield and Kollins (2001) as a preference for a smaller more immediate reward over a larger delayed reward. Impulsivity is often measured using a standard delay discounting questionnaire in which participants choose between several concurrent hypothetical monetary choices. The first choice is a smaller monetary amount offered immediately, and the second choice is a larger monetary amount offered after a specified time. For instance, participants may be asked to choose between $700 dollars immediately or $1000 available after a delay. As choices are analyzed across various delays (ex., 1-week, 2-weeks, 1-month, 6-months, 1-year, 3-years, and 10-years), consistent trends emerge in decision making. Individuals who are more likely to choose the smaller-sooner rewards are said to discount the value of delayed rewards, which is often characterized as a measure of impulsivity. Performance on this or similar delay discounting tasks has been demonstrated as a reliable predictor of several maladaptive behaviors, including pathological gambling (Dixon, Marley, & Jacobs, 2003), smoking (Odum, Madden, & Bickel, 2002), alcohol consumption (Moore & Cusens, 2010), and obesity (Weller, Cook, Avsar, & Cox, 2008), among a myriad of other clinically relevant addictive behavior disorders (see Amlung, Vedelago, Acker, Balodis, & MacKillop, 2017 for a recent review).

A primary focus of discounting research has been in the prediction of clinically relevant maladaptive behavior patterns, such as those mentioned immediately above. Some research, however, has begun to demonstrate that impulsivity may not operate exclusively as a fixed character trait (see Odum, 2011 for a detailed description of potential trait and state characteristics of discounting); rather, momentary state variables may additionally participate in impulsive behavior, captured through discounted responding, that can be influenced in tightly controlled experimental arrangements (Bickel, MacKillop, Madden, Odum, & Yi, 2015). Dixon, Jacobs, and Sanders (2006) found that pathological gamblers demonstrated more impulsivity when presented with a discounting questionnaire in a casino when compared to a neutral community location, suggesting that impulsivity can be momentarily influenced by contextual features in the environment. In another demonstration, Dixon and Holton (2009) altered the magnitude of delay discounting in pathological gamblers using a conditional discrimination training procedure. The contextual cues of "better than" and "worse than" were trained to color contextual cues. The colored contextual cue of "better than" appeared with the larger-later and the colored cue of "worse than" appeared with the smaller-sooner option. Discounting rates decreased for all participants following training. Several additional interventions and environmental manipulations have additionally been shown to influence momentary impulsivity within a discounting framework, including among them therapeutic interventions that may be implemented by contextual behavior scientists (see

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Koffarnus, Jarmolowicz, Mueller, & Bickel, 2013 for a detailed overview of neurobehavioral events that may influence discounting in the literature).

Mindfulness-based strategies include several therapeutic approaches that may specifically influence momentary state impulsivity (Ashe, Newman, & Wilson, 2015). Mindfulness, which has been practiced for centuries, is a major component of contemporary functional contextual therapies such as Acceptance and Commitment Therapy (ACT: Hayes, Strosahl, & Wilson, 2012). Mindfulness practices originated from eastern Buddhist philosophies (Hayes, 2002) and may take several forms, such as guided meditation, mindful breathing, progressive relaxation, etc. These techniques increase the salience of internal and external experiences as they occur in the present environment (Luoma, Hayes, & Walser, 2007), and have demonstrated effectiveness in reducing medical and psychological symptoms (Carmody & Baer, 2008), anxiety and depressive symptoms (Vøllestad, Nielsen, & Nielsen, 2012), and stress (Chiesa & Serretti, 2009). In addition to this growing body of research on the clinical utility of mindfulness-based strategies, at least three studies have been published recently that suggest that mindfulness techniques may influence impulsivity.

Hendrickson and Rasmussen (2013) conducted an examination the effects of mindful eating on delay and probability discounting for food and money. Their findings indicated that participants in a mindful eating group discounted food less than their baseline measures, whereas individuals in the control group did not, however neither group demonstrated a change in monetary discounting, suggesting that the intervention targeted only food stimuli. Morrison, Madden, Odum, Friedel, and Twohig (2014), conversely, did see a change in participant responding to a standard monetary delay discounting task when undergraduate students were assigned to a 60–90-min acceptance-based training, and compared against a waitlist control group. Finally, Yao et al. (2017) evaluated reality therapy combined with mindful meditation conducted over the course of 6-weeks, where meditation was conducted for the final 10-min of weekly sessions. Again, results supported a decrease in delay discounting following the intervention.

Taken together, these results suggest that encouraging participants to act mindfully, through a combination acceptance-based training, goal-directed problem solving, and mindful meditation and engagement, can lead to momentary decreases in impulsive choices. Although these results are promising, each requires considerable time and effort. A benefit of many mindfulness-based strategies is that engaging mindfully with the environment can be low-effort, and conducted within only a few minutes. Mindful breathing in a stressful situation, for example, can be completed in a short time with immediate psychological effects (see Keng, Smoski, & Robins, 2011 for a review). When an individual seeks to minimize impulsive state decision making momentarily, rather than to influence impulsivity as a longer-term trait variable, taking part in a 60–90-min training or enrolling in a 6-week therapeutic intervention is not tenable. Further, in contemporary society, individuals are continuously subject to stimuli that may encourage impulsivity, such as in corporate advertising, and therefore there is utility in researching approaches that may immediately counteract impulsive responding, that can be implemented with minimal response effort and time required of the participant.

Therefore, the purpose of the study was to evaluate the influence of a brief, 5-min guided mindful meditation exercise on the momentary impulsivity demonstrated by participants on a monetary discounting task. The specific mindfulness task was a publicly available resource, to simulate an actual activity that a person may engage in to momentarily improve mindful interaction with the environment. We compared participant responses following the mindfulness exercise to responses exhibited by participants in a randomized control group, who instead watched a music video by Biggie Smalls. This video was selected to simulate a stimulus condition that is readily and publicly available in the natural environment, that may have served to momentarily increase impulsive responding given the content of the music video.

2. Methods

2.1. Participants and setting

Participants were 24 graduate students attending a course at a Midwestern American university; the researchers recruited participants during class, and all students provided consent to partake in the experiment. The recruiting researcher was not affiliated in any capacity with the class. No extra credit was offered to the students for participating, and all students in the class agreed to participate in the study. The participants were quasi-randomly assigned to two groups, using an online random number generator, ensuring that an equal number of participants were placed into each group. Once randomly assigned, participants did not interact with one another for the duration of the study. Participants were familiar with the research assistants conducting the study (the research assistants were not blind to the study), but participants were blind to the purpose of the study. Because the assistants were not blind, they were instructed to follow the scripts below verbatim during the experiment.

The result from randomization was 12 participants in each group. The control group included 8 females and 4 males, within an age range of 22–37 ($M = 24.83$) and a reported annual income range from $0-$16,800 ($M = \$11,074.18$). Of the participants, 8 were Caucasian, 2 were Hispanic, 1 was Asian, and 1 was Biracial. The experimental group included 8 females and 4 males, within an age range of 22–40 ($M = 26.83$) and a reported annual income range from $7500-$25,000 ($M = \$13,791.67$). Of the participants, 9 were Caucasian, 2 were African American, and 1 was Biracial. Participants were retained in all subsequent analyses if they (a) answered all questions contained in the surveys and (b) demonstrated only a single indifference point at each delay value in the surveys. For example, if a participant switched on more than one occasion from taking the larger-later to the smaller-sooner reward, the participant was excluded from subsequent analyses. Only a single participant met the exclusion criteria from the experimental group, and no participants withdrew from the study. Therefore, only 11 participants were retained in the experimental group, and 12 in the control group. The study received approval from the human subjects committee at Southern Illinois University. The experiment occurred within two classrooms on the university campus, and was approximately 30 min in duration for both groups.

2.2. Procedures

After participants completed a consent form, the researcher administered a demographic survey and an initial delay discounting survey to all of the participants in the same room. In regard to the delay discounting survey, participants were provided with the following verbal instructions:

> *"You will now be provided with a survey. The survey will ask you to make several hypothetical choices between two different dollar amounts. The first column will offer a dollar amount that is available immediately, while the second will offer an amount after a delay. For example, the first question asks whether you would like to receive $70 now or that same amount in a week. Your task is to complete the survey choosing the option that is most appealing to you. Please make your selections as if they are real dollar amounts that will be given to you."*

Once these prerequisite materials were submitted, the researcher randomly assigned participants to either the control group or the experimental group. The groups were then separated into two rooms, to complete the remainder of the study concurrently. Therefore, the study was completed in two separate groups / rooms. The participants viewed the videos with their respective groups, and completed the second discounting survey in the respective rooms. The researcher delivered the following instructions to the experimental (Mindfulness) group:

"You are about to watch a video, please pay attention to the whole video and refrain from using technological devices or attending to any other materials that may potentially distract you from the video."

The participants were not provided with any rationale regarding the purpose of either video or the subsequent discounting task. Following the instructions, the experimental group viewed a video online that required them to engage in a "mindful breathing meditation" exercise (5:12 min in length) (Stop, Breath, & Think, 2016). The video guided participants through a breathing exercise via auditory instructions with no visuals aside from an undulating circular pattern displayed on the screen. The video provided a series of prompts to the listeners: first, to complete brief body scan, then engage in muscle relaxation, and finally, to practice awareness of breath and breathing processes. When the video ended, the researcher immediately delivered a second delay discounting survey to the experimental group. After the surveys were submitted, the experimental group was debriefed and dismissed from the room. In a second room, the control group was provided with verbal instructions identical to those given to the experimental group, after which they viewed a music video by Biggie Smalls entitled, "Hypnotize" (5:38 min in length) (Wallace, 2011). This video was chosen for the control condition because researchers did not believe that it had any relevancy to the topics of discounting, impulsivity, or mindfulness. Again, when the video ended, the researcher immediately delivered a second delay discounting survey to the control group. After the surveys were submitted, the control group was debriefed and dismissed from the room. No distraction tasks were provided between the video and surveys in the study.

2.3. Measures

2.3.1. Delay discounting survey

The delay discounting survey utilized in this study was adapted from the procedure used by Dixon et al. (2003). Two columns were displayed on the survey, with each row presenting a choice between an immediate monetary reward and a fixed delayed monetary reward. The fixed delayed monetary reward, presented in the second column, was $70 for every choice, with varying delays of 1 day, 30 days, 90 days, 180 days, 365 days, 548 days, and 730 days. The immediate monetary values, presented in the first column, were $70, $60, $50, $40, $30, $20, and $10 for each delay set.

2.4. Statistical analyses

Several visual and statistical analyses were conducted for the purposes of this study. First, the indifference point in each delay condition was determined for all participants. This was completed by finding the point at which the participant switched preference from the immediate reward to the larger delayed reward in each set. After the indifference points across all delay sets were determined for each participant, averages for the experimental group and the control group were calculated for both pre- and post-test measures. Subsequently, mean indifference points were calculated at each delay value across groups, and we fit both hyperbolic (Mazur, 1987) and hyperboloid curves (Green, Fry, & Myerson, 1994; see also Green & Myerson, 2004 for an overview of the hyperboloid model and comparison to other hyperbola equations) to the obtained means for all groups to describe consistencies in the data, using the hyperbolic Eq. (1):

$$V = A/(1+kD)$$

And the hyperboloid Eq. (2):

$$V = A/(1+kD)^s$$

Both equations were fit to proportional indifference and delay values for comparison. Proportional values were obtained for each indifference point by dividing the obtained indifference point by the maximum possible indifference point, and for the delay values by dividing each delay value by the maximum possible delay value. In both equations, k represents a theoretical estimate of discounting. In the hyperboloid function, s is a parameter that represents a nonlinear scaling of the influence of delay (i.e., the hyperbola is raised to the power s). We then compared the equations to determine if including the s parameter provided a significantly greater fit to the obtained data, and the obtained mean k and s parameters were compared across groups.

To further evaluate differences in discounting across the two groups, we calculated pre- and post-test area under the curve (AUC) for every participant's obtained proportional indifference point at each proportional delay, using the following equation developed by Myerson, Green, and Warusawitharana (2001):

$$\text{AUC} = \sum \quad (X_2 - X_1) \times \left[\frac{(Y^1 + Y^2)}{2}\right]$$

In this equation, higher AUC values represent less discounting, or less impulsivity (Myerson, Green, & Warusawitharan). We corrected for disproportionality in the length of delays in the AUC calculation by converting the delays to integers 1 through 7 to obtain the X (delay) values, as recommended by Borges, Kuang, Milhorn, and Yi (2016). Therefore, the scores presented in the results are AUC_{ord} values, which provide an unbiased and atheoretical measure of discounting that can be used in parametric statistical testing. In addition, an obtained significant difference in model fit by adding the s parameter in the hyperboloid function suggested that delay may have biased AUC differences, necessitating the use of AUC_{ord} for a more direct comparison. To determine if the differences between the two groups from pre- to post-assessment periods were statistically significant, we conducted a 2 × 2 mixed ANOVA to evaluate main effects and interactions.

3. Results

The results of the study are displayed in Figs. 1 and 2. Fig. 1 displays the mean values at which the experimental group and the control group switched preference to the delayed reward, both in pre- and post-test, with hyperboloid discounting curves fit to the data. The hyperboloid function provided a preferred fit for all curves and the difference was statistically significant (Control Pre: $F(1, 5) = 25.38$, $p < 0.05$; Control Post: $F(1, 5) = 10.86$, $p < 0.05$; Experimental Pre: $F(1, 5) = 13.4$, $p < 0.05$; Experimental Post: $F(1, 5) = 24.8$, $p < 0.05$). Because the hyperboloid model introduces an additional free parameter,

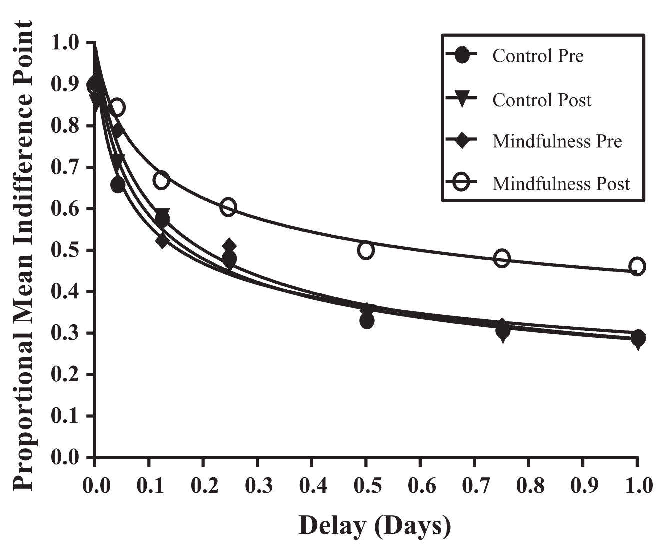

Fig. 1. Mean indifference points for the control and mindfulness groups at pre- and post-assessment periods. Lines indicate hyperboloid curve functions fit to the data.

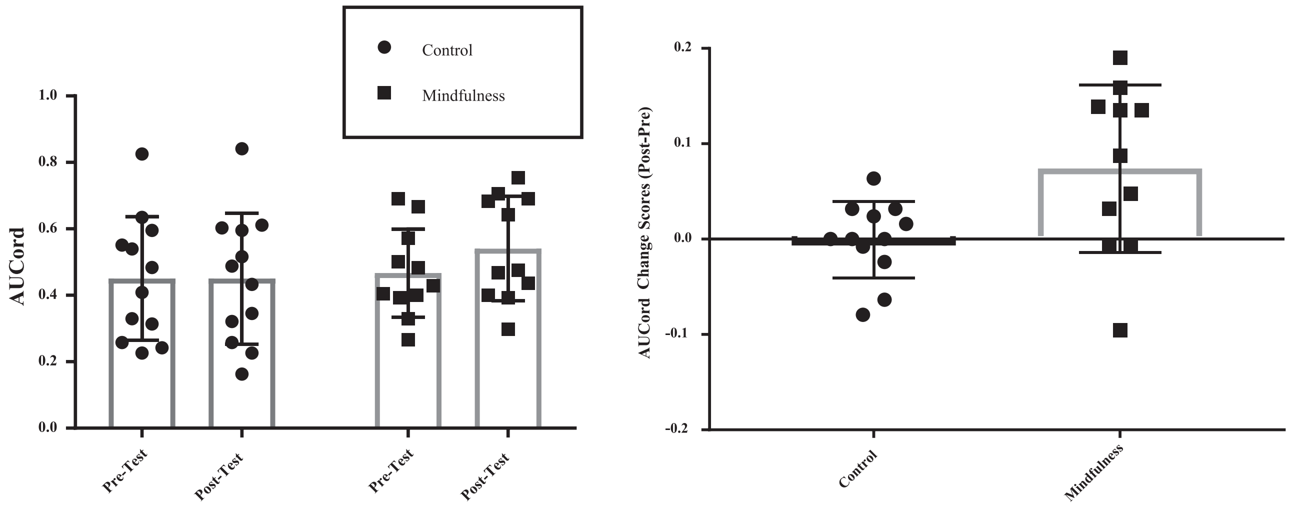

Fig. 2. Scatter dot plots of individual participant AUCord values at pre- and post-assessment periods (Left) and individual participant change scores from pre- to post-assessment periods (Right).

we compared the models using Akaike's Information Criteria (AICc) to determine which model was most likely to have produced the data. Results suggest that in all cases, the hyperboloid model was the preferred fit (probability correct range from 63% to 94%, compared to 6 to 37% for the hyperbolic model). The obtained *k* and *s* values, and model R^2 values are presented in Table 1. In general, the hyperboloid function provided a good fit for both the experimental group (R^2 = 0.96, R^2 = 0.94) and the control group (R^2 = 0.96, R^2 = 0.94) consistent with prior research on delay discounting. Comparison of the obtained *k* values from the hyperbolic equation that is most frequently used in delay discounting research suggests that this discounting parameter was similar for the control group at both pre- and post-test, as well as for the experimental group at pre-test (range, 4.1–4.5). The obtained *k* value for the experimental group at post-test was the lowest (1.9), and less than 50% of the other obtained *k* values. For the hyperboloid equation, *k* and *s* values are difficult to compare as these free parameters interact to provide a best fit equation (i.e., the denominator of the hyperbolic model is raised to the power of *s*). To allow for comparison, we calculated the denominator of the hyperboloid model: $(1 + kD)^s$, produced by the obtained best fit *k* and *s* values (assuming a median proportional delay value of D = 0.5), and results again show a similar obtained discounting value for the control group at both pre- and post-test and for the experimental group a pre-test (range, 2.72–2.79), and lower discounting for the experimental group at post-test (1.93). These results correspond with visual inspection of the discounting curves in Fig. 1, where the discounting curve for the experimental group at post-test appears to diverge considerably from the other three nearly overlapping discounting curves.

Because R^2 may present a biased interpretation of the orderliness of data, we also utilized Johnson and Bickel (2008) algorithm to identify non-systematic data retained in our analysis, where data were considered non-systematic if (a) any indifference point was greater than the previous indifference point by $20 or greater,[1] and / or (b) if the last indifference point was not less than the first indifference point. Due to using a small sample size, a high rate of non-systematic data could significantly reduce confidence in our obtained results. The number of non-systematic data points for each condition / time are summarized in the table and shows that of the 46 completed discounting tasks (23 participants on 2 occasions), 2 would be considered non-systematic according to the algorithm (4% of the total obtained data). Therefore, we considered the data to be sufficiently systematic despite the small sample.

Fig. 2 (left panel) shows the obtained AUC_{ord} values for each of the participants, across both groups, and pre- and post-assessment periods. Because of clear differences of the effect of *s* on the obtained *k* values in the hyperboloid curve fit across groups, AUC_{ord} was considered a more appropriate measure to avoid bias due to quasi exponentiation of the delay parameter. The results indicate that the mean AUC_{ord} for the experimental group was 0.47 (*SD* = 0.13) at pre-test and 0.54 (*SD* = 0.16) at post-test, and the mean AUC_{ord} for the control group was 0.45 (*SD* = 0.19) at pre-test and remained at 0.45 (*SD* = 0.20) at post-test. Visual analysis of the data suggests a difference between the two groups in changes in AUC_{ord} from pre-test to post-test, where a change in mean was only observed for the experimental group. The results of the 2 × 2 mixed ANOVA suggest that there was a significant interaction between assessment time and group assignment ($F(1,21) = 7.07$, $p < 0.05$). Fig. 2 (right panel) was included to provide a visual analysis of the consistency of participant changes in AUC_{ord} values across the two groups. Visual inspection of this data indicates that, for the control group, five of twelve participants demonstrate an increase in AUC_{ord} (42%), four demonstrated a decrease in AUC_{ord} (33%), and three demonstrated no change in AUC_{ord} (25%); for the experimental group, eight of twelve participants reported an increase in AUC_{ord} (67%), and three reported a decrease in AUC_{ord} (33%). Closer examination of the data for the experimental groups suggest that, for the three participants who showed a decrease, the decrease was near 0. For the eight participants who demonstrated an increase in AUC_{ord}, there appeared to be a bimodal distribution, where 5 of the participants demonstrated relatively large changes, and three of the participants demonstrated small changes resembling the increases observed for some participants in the control group.

4. Discussion

The purpose of the present study was to evaluate the effect of a brief, 5-min guided mindfulness meditation on momentary delay discounting as a measure of impulsive choice behavior. Mindfulness-based therapies are designed to encourage participants to interact with the environment here and now, rather than the verbally constructed environment that governs much of complex human behavior (Hayes et al., 2012). Conceptually, several arguments could be made regarding the influence of mindfulness on impulsive choosing. For example, mindfulness may decrease impulsivity because participants are instructed to

[1] Johnson and Bickel (2008) selected a value of 20% to avoid being overly stringent. We translated this to $20 or greater in our study such that *any* increase in subjective value more than the difference between successive choice values (i.e., $10) would be considered non-systematic.

Table 1
Obtained best fit parameters for the hyperbolic and hyperboloid equations across conditions and measurement time. Non-systematic data in each condition / time are also provided.

	Hyperbolic	Hyperboloid				
Condition / Time	k	k	s	(1 + kD)ˆs	R^2 (Hyperbolic / Hyperboloid)	Non-systematic data
Control Pre-Test	4.54	66.93	0.28	2.74	0.78/0.94	0
Control Post-Test	4.55	37.68	0.34	2.79	0.81/0.96	1
Experimental Pre-Test	4.12	25.85	0.38	2.72	0.87/0.94	1
Experimental Post-Test	1.94	36.56	0.22	1.93	0.67/0.96	0

attend to relevant variables in the environment to make decisions that align with his or her larger, later values. These results extend previous research in this area (Morrison et al., 2014; Yao et al., 2017) by supporting the potential usefulness of a very brief intervention that a person could employ in the natural environment, to momentarily reduce impulsive choice behavior. The results even further add to a growing body of research (Bickel et al., 2015) suggesting that, although trait characteristics are evident in delay discounting research (Odum, 2011), several contextual environmental factors may serve as state variables that either increase or decrease the probability of impulsive choices. Where delay discounting has been implicated in the development of a broad range of clinical disorders, such as gambling addictions and obesity (Amlung et al., 2017), there is therefore a need to illuminate conditions that counteract impulsive behavior when its occurrence leads to psychological suffering. Our results suggest that brief mindfulness practices may serve as one such variable, among many (Bickel et al., 2015), that could counteract impulsive delay discounting.

Despite the outcomes of the present study, there are several limitations that constrain the inferences that can be generated from the data. A first limitation is the representativeness and size of the sample. All of the participants were graduate students from a Midwestern American university, which may not be representative of the population at large. In addition, only 23 subjects participated in the study, however, significant effects were observed between the groups, suggesting that mindfulness can affect the impulsivity of non-clinical populations. A second limitation is that the participants were not screened to assess levels of impulsivity before they were recruited for the study, therefore it is unknown whether any of the participants were predisposed to maladaptive behaviors associated with increased impulsivity, such as gambling, drug use, alcoholism, etc. Because of this, it is unknown whether the results of this study would be replicated with clinical populations. Additionally, although mindful breathing is an element of mindfulness practice, it cannot be certain that the effects of this treatment were necessarily the result of mindfulness. The participants were also exposed to certain stimuli, such as auditory instructions and an intended quiet, calm environment, that the control group were not. Finally, we used a monetary delay discounting survey that deviated from other research in the specific monetary increments and delay values, therefore further research is needed to support the validity of this measure. Our data do show that hyperboloid curves provided a strong fit for the data, suggesting that participant responses were similar to those obtained in other discounting tasks (Green & Myerson, 2004) that have utilized this curve fit.

In addition to reducing the limitations in the current study, future research may expand upon the results of the study in several ways. First, future research may continue to discover environmental manipulations that reduce impulsivity. The present study included a brief instruction in mindful breathing to reduce momentary discounting, but did not evaluate the effects of long-term mindfulness practices, or the durability of the changes over time. Carmody and Baer (2008) suggest several mindfulness activities that may be used to promote a general state of mindfulness, and the long term effects of these practices may be examined. Future researchers should not only consider using larger sample sizes and a more diverse pool of participants, including clinical populations, but should also consider the inclusion of follow-up measures to assess for maintenance of the effects. In addition, given a primary advantage of the present study is that the activity can be used in a variety of contexts, future research may evaluate how brief mindfulness may disrupt the influence of contexts that have historically lead to impulsive behavior. For example, casinos have been shown to increase the momentary impulsivity of disordered gamblers (Dixon, Jacobs, & Saunders, 2006), where a brief mindfulness activity may serve to reduce the influence of the casino context. As well, component analyses isolating the causal variables for the change in discounting apparent following mindful breathing would be important to the development of future therapeutic techniques. As the mindfulness revolution continues to unfold, the effects of this practice on impulsivity and other harmful behaviors must be examined to truly understand its influence.

4.1. Conclusion

The results of the present study demonstrate that a brief exposure to mindfulness can momentarily decrease discounting of rewards across delays as a measure of impulsivity. Discounting scores have been shown to be a reliable indicator of impulsive behavior patterns (Dixon et al., 2003; Moore & Cusens, 2010; Odum et al., 2002; Weller et al., 2008) and as such, interventions that may decrease discounting are of value. Mindfulness techniques have had demonstrated effects on stress reduction, psychological functioning, and overall well-being (Carmody & Baer, 2008). The current results suggest mindfulness exercises may have therapeutic benefits for those individuals whose maladaptive functioning is related to impulsive behavior patterns. The present study utilized a mindful breathing video that was freely available and accessible to the general public. Interventions such as these may be especially helpful for therapists and clinicians who assign take home exercises for clients to complete outside of the typical therapeutic setting. As more interventions become readily available to the public on internet platforms, more research is needed to examine the therapeutic benefits or supplementary benefits they may have for clients seeking intervention.

Conflicts of interest

All authors declare they have no conflicts of interest.

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Ethical approval

All procedures performed in this study which involved human participants was in accordance with the ethical standards of the institution and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained for participation in this research.

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