Attentional Bias Towards Seasonal and Light Stimuli and Winter Depression Recurrence: An Ecological Momentary Assessment Study

ATTENTIONAL BIAS TOWARDS SEASONAL AND LIGHT STIMULI AND WINTER DEPRESSION RECURRENCE: AN ECOLOGICAL MOMENTARY ASSESSMENT STUDY

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ABSTRACT

Winter seasonal affective disorder (SAD) is a depression subtype in which episodes recur in the fall/winter months and remit in the spring/summer months. In laboratory studies, SAD patients show distinct emotional and psychophysiological responses to videos or photographs of light and seasonal stimuli. (e.g., winter scenes, overcast skies). Affective shifts upon exposure to such stimuli is consistent with learning theory, positing that greater attention is allocated to cues with predictable outcomes, i.e., in the case of SAD, winter/low light cues signaling an impending depressive episode. This project tested a model positing that increased attention to seasonal and light cues leads to anticipatory anxiety about the upcoming winter, which is followed by depressive symptoms, particularly among those with a longer history of SAD. Attention to seasonal and light cues and depressed and anxious mood were prospectively tracked over 21-days using ecological momentary assessment in 41 adults with SAD. Participants were recruited in the fall/winter prior to development of a depressive episode to track a time of expected depression symptom growth. A multilevel confirmatory factor analysis operationalized the attention variable with two factors, Attention to Positive Cues (PA; indicators = sunshine, clear skies) and Attention to Negative Cues (NA; indicators = gray skies, cloud cover, rain). In multilevel structural equation models, the direct effect of NA was not significant at either the within- or between-person levels on either daily depression or daily anxiety. Anticipatory anxiety did not mediate the relationship between NA and depressed mood, and number of prior SAD episodes did not moderate the relationship between NA and anticipatory anxiety. When breaking up the sample by prior treatment status, there was a trend suggesting lower NA among participants with prior exposure to SAD treatment with cognitive-behavioral therapy or light therapy relative to treatment naïve participants. Results suggest greater attention to light than seasonal cues in this sample; however, attention towards light cues was not related to daily depression or anxiety. This study is limited by insufficient power. Future studies should examine attention to light cues in relation to SAD symptoms beyond mood (e.g., fatigue) and the interaction of attention with cognitive appraisals of these cues.

DEDICATION

To my family—Mami, Papi, Nancy, Gladys, Erica, Nadia, and Pablo. *Gracias por todo*.

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CHAPTER 1: INTRODUCTION

Background

Winter seasonal affective disorder (SAD) is a recurrent subtype of depression in which major depressive episode onset and remission follow a seasonal pattern with onset in the fall/winter and remission in the spring/summer (Rosenthal et al., 1984). Common SAD symptoms include fatigue, changes in appetite and weight, and changes in sleep (American Psychological Association, 2013). SAD prevalence is positively correlated with latitude, with prevalence estimates of approximately 5% to 10% in the mid-Atlantic to northeastern United States (Rosen et al., 1990). Further, SAD is a highly recurrent disorder. In a clinical trial of 1,042 SAD participants (M_{age} = 42 years), on average, first episode onset was at age 27, with 13 past seasonal depressive episodes prior to study enrollment (Modell et al., 2005). These data underscore the public health significance of the cumulative adverse effects of SAD on functioning across the lifetime and the need to prevent recurrent episodes.

Initial SAD research posited biological mechanisms of the disorder related to changes in photoperiod across the seasons, such as circadian rhythm phase delays and reduced serotonin (see review by Lee et al., 1997). More recent theories have integrated both biological and psychological vulnerabilities to SAD, such as Young's dual vulnerability hypothesis (Young et al., 1991). Young's theory posits that SAD involves a biological vulnerability to develop vegetative symptoms (e.g., changes in energy, sleeping, eating/appetite) in response to seasonal changes and a psychological vulnerability to develop cognitive/affective symptoms in response to the vegetative symptoms. Therefore, Young's model assumes that the biological vulnerability is activated first and triggers only vegetative symptoms, preceding activation of the psychological vulnerability that triggers only cognitive/affective symptoms.

Another model, the integrative, cognitive-behavioral model (Rohan et al., 2009) maintains an emphasis on separate biological and psychological vulnerabilities to SAD but specifies a content for each. The biological vulnerability includes circadian dysregulation (e.g., a circadian phase-shift or longer duration of nocturnal melatonin release) in response to short photoperiods. The psychological vulnerability includes negative cognitions (e.g., maladaptive seasonal beliefs, rumination), emotional reactivity to light and seasonal stimuli, and avoidance behavior. Rohan's model posits that SAD episode onset is triggered when either environmental changes (e.g., short photoperiod) activate the biological vulnerability or conditioned negative anticipation of fall/winter seasonal changes activate the psychological vulnerability. Unlike Young's model, Rohan's model does not link specific SAD symptoms to one vulnerability or the other. Instead, once either vulnerability is activated, that vulnerability activates the other and the two vulnerabilities propagate each other in a reverberating cycle until the environment changes (e.g., photoperiod lengthens) or conditioned positive anticipation of spring/summer interrupts it.

The current study focuses on the integrative model's assertion that negative anticipatory thoughts about the impending winter trigger the psychological vulnerability, contributing to hypervigilance towards low light and fall/winter seasonal cues and emotion dysregulation when attending to such cues. The recurrent nature of SAD may facilitate learned associations between seasonal and light cues (e.g., fall foliage, shortening photoperiod, calendar dates such as end of daylight savings time, snow) and depressive symptoms over time. Indeed, studies have shown that depressed mood is exacerbated in people with SAD after being shown photographs or videos of season-or light-relevant stimuli (e.g., Sigmon et al., 2007; Rohan et al., 2003; Lindsey et al., 2011). In addition, seasonal beliefs (i.e., maladaptive beliefs about the seasons, light availability, and weather; Rohan et al., 2019) may represent a cognitive vulnerability to depression that is specific to SAD as opposed to nonseasonal Major Depressive Disorder (Rohan et al., in press). However, no prior study has prospectively tracked attention to season- and light-relevant cues in the natural environment and mood in SAD patients in the fall or winter, as the current study intends to do. Preliminary evidence for the role of light and season cues in SAD is reviewed below.

Evidence for Light and Seasonal Cues in SAD

One experimental laboratory study compared 20 women with a history of SAD to 20 never-depressed control women matched for age and education on emotional responses to outdoor photographs depicting sunny, overcast, and light-ambiguous (i.e., where the sky was not included) conditions (Rohan et al., 2003). The same participants were assessed in the fall, winter, and summer. SAD history participants reported greater improvement in baseline depressed mood after viewing the sunny photographs than never-depressed controls. In contrast, controls showed no significant differences in their mood responses to the different lighting conditions depicted. All participants rated the overcast images as significantly less pleasant than the sunny or overcast images, so this group difference in mood reactivity to the images cannot be attributed to the likeability of the images. Importantly, these within and between-group differences in mood responses to the light-relevant stimuli were observed across assessments in the fall, winter, and summer. In addition to transient shifts in self-reported depressed mood, psychophysiological reactions to the images were examined using skin conductance, a measure of general autonomic arousal. There were no between- or within-group differences on significant skin conductance responses (SCR) or SCR magnitude in response to the images. Therefore, the SAD history group showed distinct emotional reactivity to the different lighting conditions displayed in the images when measured using self-reported affect, but not in terms of autonomic arousal. These results are consistent with this proposal's argument that emotional reactivity to light-relevant stimuli is learned in SAD (i.e., an overcast sky is a conditioned stimulus for depressed affect and a sunny sky is a conditioned stimulus for positive affect).

Another study examined emotional responses to light and seasonal cues, including surface facial EMG, skin conductance, and self-rated mood, in 24 currently depressed individuals with SAD and 24 never-depressed controls, matched on race, sex, and age, at a single testing session in the winter (Lindsey et al., 2011). When shown photographs of the same outdoor scenes under varying light intensities (i.e., with an overcast vs. sunny sky) and in different seasons (i.e., in summer with greenery, in fall with foliage, or in winter with bare branches), individuals with SAD reported greater depressed mood and demonstrated increased corrugator (i.e., brow-pursing) facial EMG, more frequent significant skin conductance responses, and greater skin conductance response magnitude in reaction to overcast than to sunny scenes regardless of which season was represented (Lindsey et al., 2011). In contrast, controls did not differ in their emotional responses to these stimuli. Further, individuals with SAD responded with less corrugator activity, lower skin conductance response magnitude, and lower ratings of depressed mood to sunny scenes than the control group. These findings demonstrate a unique emotional reactivity to light cues that distinguished individuals with SAD from individuals with no history of depression and may represent a marker of a current SAD episode. The light cues in the images were more salient than the seasonal cues with regard to their effects on emotional responding among SAD participants. Without a nonseasonally depressed group in the design, it remains unknown if increased emotional responses to light cues is potentially a marker of SAD or of depression, in general, regardless of whether it follows a seasonal course.

At a single assessment in the winter, Sigmon et al. (2007) examined emotional and psychophysiological reactivity to videos of outdoor scenes depicting winter vs. summer seasons in 15 currently depressed individuals with SAD, 15 currently depressed individuals with nonseasonal major depression, and 15 never-depressed controls. All groups were matched on age and education. In comparison to the nonseasonal major depression group and never-depressed controls, individuals with SAD demonstrated greater psychophysiological reactivity to the winter scenes, as evidenced by more frequent significant skin conductance responses and greater skin conductance response magnitude. In addition, individuals with SAD and nonseasonal depression reported a greater increase in depressed mood after exposure to the winter scenes relative to controls. The same study also examined attentional biases via a Stroop task presenting light- and dark-relevant (e.g., sunshine and dim, respectively), depressive (e.g., empty), and neutral (e.g., average) words. In response to the Stroop task, the nonseasonal depression group took longer than controls to respond to all words, suggesting a generalized interference for this group. In contrast, the SAD group took longer than the control group to respond to only the depressive and dark words. Due to the inclusion of a nonseasonal depression group, the Sigmon et al. (2007) study informs whether SAD and nonseasonal depression can be differentiated based on responses to environmental stimuli in the lab. Sigmon et al.'s results support that depressed individuals with SAD are distinct from those with nonseasonal depression based on emotional (i.e., psychophysiological) responding to winter stimuli. However, further research is needed to examine if this translates to an attentional bias towards dark and winter cues in the naturalistic environment in SAD and if this is relevant to episode onset.

An early study by Bouhuys and colleagues (1994) compared 29 individuals with remitted SAD and 29 individuals without a history of depression (with the groups matched for age and sex) on their judgements of line drawings of faces with varying expressions embedded in either light or dark backgrounds. Participants completed the faces task early in the fall and the SAD group was then followed into the winter. The task presented 12 line face drawings that varied in configurations of the eyebrows (4 variations: upward-turning, straight/close to the eyes, straight/further from the eyes, or downward-turning) and mouth (3 variations: upward-turning, straight, or downward-turning), with one consistent representation of eyes and nose. Each of the 12 faces were presented embedded in a white background with an illuminated light bulb in the corner or a black background with a non-illuminated light bulb in the corner (24 total drawings). Perceived emotional expression of the face drawings was measured to investigate a potential negative bias in judgment of emotional expressions linked with depressed mood and interpersonal processes in depression. The participants were asked to rate the face drawings on several adjectives (invitation, rejection, activation, sleepiness, elation, and sadness) on a 5-point scale from not applicable to highly applicable. SAD participants rated faces with ambiguous expressions shown in darkness as less activated than controls. The larger the difference in perceived invitation between ambiguous faces shown in light vs. dark backgrounds, the earlier the onset of SAD symptoms in the following fall/winter months. Only those with early onset SAD (i.e., those who developed a depressive episode before the winter solstice) differed from the control group in how inviting they perceived the faces depending on light vs. dark background (Bouhuys et al., 1994). Importantly, these results suggest an association between attention to light stimuli and timing of SAD episode onset, even at the level of symbolically represented light cues.

A related construct to attention towards light and seasonal cues, seasonal beliefs, has been posited as a cognitive vulnerability to SAD (Rohan et al., 2019). Seasonal beliefs represent maladaptive thoughts about the seasons, weather, and light. The Seasonal Beliefs Questionnaire (SBQ; Rohan et al., 2019) is a self-report measure of seasonal beliefs, consisting of 26 items rated on a 7-point Likert scale (totally agree/7 to totally disagree/1) reflecting “how you generally think.” This measure yields 5 subscale scores, including Personal Deficiency Related to Winter (8 items, e.g., “There’s something wrong with me in the winter.”); Global Summer Positivism (3 items, e.g., “I’m always happier when it’s warmer.”); Global Winter Negativity (5 items, e.g., “I’m not a winter person.”); Effects from Lack of Light (6 items, e.g., “It’s difficult to feel good on dark, dreary days.”); and Lack of Perceived Seasonal or Weather Effect (4 items, e.g., “The weather is irrelevant to how I feel.”).

Rohan and colleagues (2019) administered measures of generic depressogenic beliefs (i.e., dysfunctional attitudes) and seasonal beliefs (the SBQ) to a sample of 86

SAD patients, 30 nonseasonal depression patients, and 110 never-depressed controls. Results supported their hypothesis that seasonal beliefs distinguished SAD patients, as the SAD group had significantly higher SBQ scores than both the nonseasonal depression group and the control group. For total SBQ scores and all the SBQ subscales except the Global Summer Positivism, the SAD group had significantly higher scores than the nonseasonal depression group, and the nonseasonal depression group had significantly higher scores than the control group. On the Global Summer Positivism subscale, the SAD group had significantly higher scores than both the nonseasonal depression and control groups, but the nonseasonal depression group did not differ from controls. In contrast, the nonseasonal depression group had higher scores on the Dysfunctional Attitudes Scale than both the SAD and control groups, and the SAD group had significantly higher scores than controls.

In a secondary analysis using the same sample from Rohan et al.'s (2019) known-groups comparison, receiver operator characteristic (ROC) curve analyses were conducted to determine a cutpoint SBQ score (maximizing specificity and sensitivity) to differentiate between the seasonal depression and nonseasonal depression groups, the SAD and the control groups, and the nonseasonal depression and the control groups (Rohan et al., 2021). Results supported adequate predictive validity for total SBQ score, with a cutpoint of 132, in distinguishing between seasonal and nonseasonal depression, with good sensitivity (.798; i.e., 79.8% true SAD cases correctly classified) and acceptable specificity (.794; i.e., 79.4% true nonseasonal depression cases correctly classified). In contrast, Dysfunctional Attitudes Scale scores had poor predictive validity for distinguishing between the two depressed groups. Total SBQ score discriminated extremely well between the SAD group and the control group with a cutpoint of 121 (sensitivity = .939 and specificity = .873) but was poor in differentiating the nonseasonal depression group from the control group. These findings highlight that SBQ is a unique cognitive vulnerability to SAD and the utility of the SBQ as an initial screen for probable SAD in clinical practice settings.

There is also evidence that improved seasonal beliefs is a potential mechanism of the acute antidepressant and enduring effects of cognitive-behavioral therapy for SAD (CBT-SAD; Rohan, 2008). CBT-SAD is a cognitive-behavioral treatment tailored at increasing behavioral activation during the winter, restructuring negative automatic thoughts (including those related to winter, weather, and light availability), and relapse prevention. The manualized CBT-SAD treatment consists of 12 90-minute group sessions conducted twice weekly over the course of 6 weeks. In a large (N = 177) clinical trial comparing CBT-SAD and light therapy (LT), SBQ scores improved twice as much during the 6-weeks of CBT-SAD relative to LT, and a larger change in SBQ score during treatment was associated with lower risk of recurrence two winters after CBT-SAD, which was not the case in LT (Rohan et al., 2019). This provides preliminary evidence that offsetting seasonal beliefs in CBT-SAD may be mechanistic of CBT-SAD's enduring advantage over LT for depression recurrences two winters later (Rohan et al., 2016).

In a secondary analysis of the former clinical trial, the experimental therapeutics approach was applied to examine potential mediators of treatment outcomes during the 6-week course of CBT-SAD and LT (Rohan et al., 2020). CBT-SAD and LT are hypothesized to have distinct mechanisms for improving CBT-SAD symptoms, namely cognitive mechanisms for the former and chronobiological mechanisms for the latter treatment. Two cognitive vulnerability measures to capture the assumed cognitive mediators of CBT-SAD, the Dysfunctional Attitudes Scale (DAS) and the SBQ, and one chronotype measure to capture the assumed chronobiological mediator of LT, the Morningness-Eveningness Questionnaire (MEQ), were administered at pre-, mid-, and post-treatment. There were two measures of depression symptoms, the Structured Interview Guide for the Hamilton Rating Scale for Depression-SAD Version (SIGH-SAD), administered weekly, and the Beck Depression Inventory-Second Edition (BDI-II), administered at pre-, mid-, and post-treatment. Across both outcomes, results showed that change in seasonal beliefs mediated change in depression symptoms during CBT-SAD, even after accounting for antidepressant medication use, comorbidity status, and timing of treatment initiation. Further, the more general depressogenic construct, dysfunctional attitudes, did not mediate acute CBT-SAD outcomes. While greater changes in eveningness were associated with LT, results showed that eveningness did not mediate treatment outcomes in LT. These results suggest that CBT-SAD may exert its acute antidepressant effects by changing seasonal beliefs. Although this mediation effect emphasizes the importance of seasonal beliefs in CBT-SAD treatment, research is needed to elucidate how attention towards and mood reactivity to light, winter, and weather cues are associated with SAD episode recurrence.

Relevance of Learning Theory

Seminal models of attention and associative learning have informed this project, including Mackintosh's predictiveness principle. Mackintosh (1975) states that greater attention is allocated to cues that have predictive consequences than to cues that are nonpredictive. Mackintosh proposes a parameter, α, of a stimulus that partially determines the rate of learning and is subject to change according to how reinforcement correlates with the stimulus. More specifically, the learning rate for a given stimulus increases when it accurately predicts the reinforcer and decreases when it does not. Mackintosh rebutted Thomas' (1970) "inverse hypothesis," the assumption that as attention increases towards one stimulus, attention must decrease towards other stimuli. Rather, Mackintosh argued that subjects learn to ignore other stimuli that signal a reinforcer already signaled by another learned stimulus. In other words, attention is not allocated to stimuli that are providing the same information as a conditioned stimulus.

In a study by Le Pelley and McLaren (2003), participants were asked to perform as an allergist predicting allergic reactions for theoretical patients in a computer task. In two respective phases, participants were presented with two patients, Mr. X. and Mr. Y, who had different allergic reactions (outcomes) to different foods (cues). Each trial consisted of presenting a combination of two different foods. After predicting the allergic reaction of the patient, participants received immediate feedback on the actual outcome. In the first phase, patient Mr. X had two different allergic reactions (e.g., dizziness or sweating). Certain foods (e.g., apples) served as good predictors that reliably predicted a specific allergic reaction, such as sweating. Other foods (e.g., bananas) served as poor predictors that were presented an equal amount with sweating and dizziness. Then in the second phase, a new patient, Mr. Y, was introduced. Mr. Y ate the same foods as Mr. X but had different allergic reactions (e.g., nausea or itching). In this phase, foods that previously predicted an allergic reaction for Mr. X, such as apples, were paired with foods that had not been predictive before, such as bananas. The second phase presented all cues equally with nausea and itching. Thus, previously good predictors and previously poor predictors were paired an equal amount with Mr. Y's allergic reactions in this phase. Results showed that participants learned about previously good predictors of allergic reactions, like apples, more rapidly than they learned about previously poor predictors of allergic reactions, like bananas (Le Pelley & McLaren, 2003). These results suggest that first phase learning carried over to the second phase with participants paying more attention to the cues with previously reliable outcomes, thus supporting Mackintosh's predictiveness principle.

Mackintosh's theory may apply to SAD because as individuals learn that changes in the environment (changing leaf color, shortened daylight, etc.) predictably precede negative changes in their mood and vegetative symptoms, learned associations may occur and thus greater attention may be directed towards these cues. For example, early in the course of the disorder, a person with SAD may observe early fall stimuli, such as shortened daylength, dropping temperatures, overcast skies, and changing leaf colors, and appraise such stimuli as neutral or may not direct much attention to them. If this person had recurrent depressive episodes that generally started in late November with symptoms of fatigue (the US), she might direct more attention to the changing leaf colors in early fall (the conditioned stimulus; CS) with each passing year she develops SAD as it becomes a stronger and stronger signal of her upcoming symptom onset. As reliable predictors of SAD symptoms, stimuli such as snowfall, overcast skies, and autumnal foliage may gain attention and learned associations, particularly for those with a longer history of SAD for whom the CS/US pairing has been more ingrained.

In an opposing model to Mackintosh's, Pearce and Hall's (1980) theory of attention offers an explanation of instances in which a strong association between a stimulus and reinforcer does not predict learning. This theory was informed by experiments conducted by Hall and Pearce (1979) in which rodents were presented with a tone followed by a weak shock, then presented with a tone followed by a strong shock. The results contradicted what Mackintosh's theory (1975) would predict, namely that attention towards the tone and a quick rate of learning with the large shock would occur. Instead, results showed that the learning rate was slow for the large shock-tone pairing (Hall & Pearce, 1979). Subsequently, Pearce and Hall (1980) proposed a theory that greater attention is allotted to stimuli that are *poor* predictors of their consequences. The authors argue that attention towards a predictable cue is not necessary since the consequence is already known. Rather, it may be more fruitful for animals to attend to that which is unknown. Thus, as a stimulus reliably predicts a consequence over time and learning is achieved, attention towards that stimulus may decrease. In contrast, when a stimulus is first paired with a consequence and thus is an inaccurate predictor, attention towards that stimulus may be high. The Pearce and Hall (1980) model of attention also predicts strong attention to the CS if the US is presented inconsistently from trial to trial and is thus always "surprising" (e.g., Kaye & Pearce, 1984; Pearce & Hall, 1980). Thus, if changing leaf color (the CS) was followed by anxious mood (US) sometimes, but sometimes not, this model would suggest that individuals with SAD would pay more attention to changing leaf color than if anxious mood consistently followed changing leaf color.

A review by Le Pelley and colleagues (2016) reveals that both models have accumulated support in the literature. However, Mackintosh's (1975) attention theory, which states that greater attention is given to cues with predictable consequences, has accumulated more support in research conducted on humans than Pearce and Hall's (1980) theory, which has received mixed support or failed to be replicated in the literature (Le Pelley et al., 2016). Further, while the two theories of Mackintosh and Pearce and Hall are seemingly opposing, more recent research has posited hybrid models incorporating rules of both (Le Pelley, 2004; Pearce & Mackintosh, 2010). Indeed, while the two theories often predict different outcomes, they function via different mechanisms and thus could represent two attentional processes that could coexist. As such, both Mackintosh's predictiveness principle and Pearce and Hall's uncertainty principle may play a role in the attentional and conditional processes relevant to SAD episode recurrence.

Study Purpose

Although laboratory studies support a relationship between exposure to light and seasonal stimuli and affective shifts in individuals with SAD, it is unclear whether this generalizes to an attentional bias in their daily experience of appraising these environmental cues and their mood reactions. The proposed study fills a gap in the literature by elucidating the role attention towards seasonal and light cues plays in SAD symptom development. This project explores a pathway whereby attention to low light and fall/winter season cues, assumed to be conditioned stimuli for depressive affect by virtue of repeated pairing over previous SAD episodes, increases anticipatory anxiety about the upcoming winter, which in turn prompts SAD symptoms to increase. The role anticipatory anxiety in SAD was referenced in the first academic article on SAD by Rosenthal and colleagues (1984), citing patients who "experienced anticipatory anxiety as early as July or August, months before the onset of a stable state of low mood and energy set in." (pg. 73). Despite this, anticipatory anxiety's role in SAD has yet to be further explored, and the first aim addresses the gap in the literature.

The current study capitalizes on an active NIMH-funded clinical trial (R01MH112819; PI: Rohan) to examine the relationship between light and seasonal cues and SAD symptom development. The clinical trial randomizes adults with winter SAD to 6 weeks of light therapy (LT) or cognitive-behavioral therapy tailored to SAD (CBT-SAD), with follow-up visits one and two winters later. This proposed project leveraged this clinical trial to recruit subjects from its incoming cohort of participants (target = 30) as well as existing participants who have completed treatment (target = 20, 10 in each arm). Over the course of 3 weeks, participants completed daily assessments of cues and mood state and weekly assessments of depressive and anxiety symptoms via their smartphone. It is hypothesized that increased attention to seasonal and light cues will lead to increased anticipatory anxiety, which will then lead to increased depressed mood. It is also hypothesized that as attention and number of prior SAD episodes increase, anticipatory anxiety will increase.

To our knowledge, this is the first study to prospectively track both SAD symptoms and attention to light and seasonal cues using ecological momentary assessment (EMA). EMA provides a feasible, ecologically valid method to collect data and extend prior findings assessed via laboratory paradigms such as presenting photographs/videos that vary in these cues. In another novel approach, this study is rooted in important tenants of learning theory, specifically the research conducted in humans supporting that people allocate attention to stimuli that have high predictive value (Mackintosh, 1975). Further, a second (exploratory) aim that compares subsamples of individuals with SAD formerly treated with CBT-SAD vs. LT to treatment-naïve subjects on EMA-assessed attention to cues will provide preliminary data on whether prior treatment history influences this construct. If, as hypothesized, CBT-SAD subjects show less attention to seasonal and light cues than LT and treatment-naïve subjects, this would converge with prior work on seasonal beliefs (Rohan et al., 2019, 2020). The current study sets the stage for future work to explore whether attentional bias to light and seasonal cues represents a prescriptive factor (e.g., predicts better outcome in CBT-SAD vs. LT) to improve precision medicine for SAD. It also sets the stage for future work applying the experimental therapeutics approach to examine attentional bias to light and season stimuli as a potential mechanism of CBT-SAD vs. LT.

Specific aims are: Aim 1a examines the relationship between attentional bias to seasonal and light cues and depressed and anxious mood**.** Hypothesis 1a: Increased attention to seasonal and light cues will lead to increased anticipatory anxiety, which will then lead to increased depressed mood. Aim 1b tests whether the strength of the relationship between attention to cues and anticipatory anxiety is moderated by number of prior SAD episodes**.** Hypothesis 1b: As attention and number of prior SAD episodes increase, anticipatory anxiety will increase. Aim 2 explores whether attention towards seasonal and light cues differs by treatment status**.** This preliminary aim compares individuals with SAD previously treated with LT or CBT-SAD to each other and to treatment-naïve individuals. Hypothesis 2: Subjects treated with CBT-SAD will demonstrate less attentional bias towards seasonal and light cues than both LT subjects and treatment-naïve individuals.

CHAPTER 2: METHODS

Recruitment Strategy and Timeline

Forty-one participants from the clinical trial's recruitment pipeline were recruited to participate in this project, which was separate from the parent R01 study (participants opted in or not). In addition, people who did not qualify for the R01 study (e.g., had a contraindication to LT, such as retinal disease) were still eligible for this study. Individuals who met criteria for SAD, whether or not they were included in the R01 sample, were offered the opportunity to participate in this study.

To maximize sample size and feasibility, this project recruited from the trial's participants who had completed treatment in addition to the incoming cohorts. The option of participating in this project was presented to these participants after a diagnostic interview visit but before treatment, enabling subjects who opt into this study to complete the study prior to randomization. After diagnostic interview in the trial, there is a medical screen, bimonthly mood monitoring until a threshold score is obtained, and a pre-treatment biomarker assessment—all of which takes approximately four to six weeks to complete.

Participants

The project enrolled adults who 1) had SAD at the parent trial screening (i.e., met DSM-5 criteria for a principal diagnosis of Major Depression, Recurrent, with Seasonal Pattern based on the course of depression in the past two years), 2) were not currently in a major depressive episode (i.e., endorsed fewer than five depressive symptoms over the past two weeks in a phone screen) at study entry to allow for anticipated growth in symptoms over the EMA study, and 3) had a mobile phone. Exclusion criteria included bipolar disorder, psychotic disorder, moderate/severe substance use disorder, and serious current suicidal intent. Inclusion criterion (1) and these exclusions were assessed via SCID for DSM-5 (APA, 2013) in the R01.

Procedures

After obtaining consent, inclusion criteria (2) and (3) were assessed via a phone screen. If eligible, the participants completed baseline self-report measures at an initial visit. The day after the initial visit, EMA data were collected every day for 21 days. Participants completed daily assessments of mood as well as light and seasonal cues and weekly assessments of anxiety and depressive symptoms via text message surveys. Mosio®, an EMA software, automatically sent the text message surveys at a scheduled time with two reminders, the first at 30-minutes and the second at 1-hour after the survey was initially sent. To maximize compliance, the investigator collaborated with individual participants to determine an optimal scheduled time in the evening (7 pm to 9 pm) to send surveys. For weekly assessments, which required more time to complete (~ 20 mins.), participants were compensated more than for the daily assessments (~ 10 mins.). To encourage continued compliance, compensation increased by $1 each week for each survey type. Namely, participants were compensated $2 per daily survey in Week 1, $3 per daily survey in Week 2, and $4 per daily survey in Week 3. Likewise, weekly compensation for weekly surveys increased from $4 in Week 1 to $6 in Week 3. If a participant achieved 75% compliance in a given week, they received a $7 weekly bonus. Thus, participants were compensated a maximum of $90 for this study. Participants were compensated via check at the end of their EMA completion.

Measures

These methods aim to test the hypotheses using an ecologically valid, innovative and feasible approach. Table 1 provides an overview of the assessment timeline and measures used.

Table 1

Overview of Measures and Assessment Timeline

Construct	Measure	Variable	Baseline	Daily	Weekly
Depressive symptoms	BDI-II	• BDI-II score			✓
Anxiety symptoms	BAI	• BAI score			✓
Mood state	POMS-SF	• Depression-Dejection • Tension-Anxiety		✓	
Attention to light and seasonal cues	Novel measure	• Latent factor		✓	
Seasonal beliefs	SBQ	• SBQ score	✓		

Note: BDI-II=Beck Depression Inventory-Second Edition. BAI = Beck Anxiety Inventory. POMS-SF = Profile of Mood States-Short Form. SBQ = Seasonal Beliefs Questionnaire. Daily and weekly refers to the 21 days of EMA assessment.

Seasonal Beliefs Questionnaire (SBQ). The Seasonal Beliefs Questionnaire (SBQ; Rohan et al., 2019) was used to help determine construct validity of this project's novel measure, i.e., the EMA-administered questions about attention towards and mood reactivity to light and season cues in the environment. The SBQ is a self-report measure of seasonal beliefs, consisting of 26 items rated on a 7-point Likert scale (totally agree/7 to totally disagree/1) reflecting "how you generally think." This measure yields 5 subscale scores, including Personal Deficiency Related to Winter (8 items, e.g., "There's something wrong with me in the winter."); Global Summer Positivism (3 items, e.g., "I'm always happier when it's warmer."); Global Winter Negativity (5 items, e.g., "I'm not a winter person."); Effects from Lack of Light (6 items, e.g., "It's difficult to feel good on dark, dreary days."); and Lack of Perceived Seasonal or Weather Effect (4 items, e.g., "The weather is irrelevant to how I feel.").

Beck Depression Inventory-Second Edition (BDI-II). The BDI-II is a 21-item self-report measure of depressive symptom severity (Beck, Steer, & Brown, 1996). The BDI-II consists of 21 items, each item is rated using a 4-point Likert scale (0 to 3), and the responses are summed to yield a total score. Higher scores indicate more severe depressive symptomatology. The BDI-II has demonstrated good psychometrics across studies and varying populations, including good convergent validity and good test-retest reliability (Beck et al., 1996). In this study the BDI-II was administered once weekly.

Beck Anxiety Inventory (BAI). The BAI is a self-report measure of anxiety. The 21-item measure is rated on a 4-point Likert scale (0/Not at all to 4/Severely), with higher scores indicating greater anxiety severity (Steer & Beck, 1997). Possible total scores range from 0 to 63. The BAI has demonstrated good discriminant validity, test-retest reliability, and high internal consistency. In this study, the BAI was administered once weekly.

Profile of Mood States—Short Form (POM-SF). The POMS-SF is a shortened version of the POMS (McNair et al., 1971), which assesses psychological distress (Curran et al., 1995). The POMS-SF contains 37 items of adjectives, which are rated on a 5-point Likert scale. It yields several subscales: Total Mood Disturbance, Tension-Anxiety, Anger-Hostility, Depression-Dejection, Vigor-Activity, Fatigue-Inertia, and Confusion-Bewilderment. Specifically, this project used the Tension-Anxiety and Depression-Dejection subscales (14 items). These items were administered daily throughout the 21 days of assessment. Internal consistency of the POMS-SF has been shown to be high and comparable to the original POMS (McNair, Lorr, & Droppleman, 1981).

Light and Seasonal Cues. SAD research has yet to examine attention to light and seasonal stimuli in a real-world context. Thus, a novel light/seasonal cue measure was used for this project. The measure presents a list of negative (e.g., gray skies, cold temperatures) and positive (e.g., bright sunshine, warm temperatures) light and seasonal cues, developed based on Drs. Rohan’s and Michael Young’s expertise with the population. Participants were asked to rate, “So far today, how often have you found your attention drawn to [cue]?” on a 5-point scale: 0 (Not at all), 1 (A little bit), 2 (A moderate amount), 3 (A lot), and 4 (An extreme amount). Specifically, participants were asked about 16 light and seasonal cues: cloud cover, gray skies, cold temperatures, frost, snow, rain, sunrise time, sunset time, daylength, soft shadows, bare trees, clear skies, bright sunshine, warm temperatures, hard shadows, and today’s date. To dilute the perceived intent behind this measure, cues directed towards non-seasonal environmental cues were included, such as surrounding people, animals, and noise level. Cues were counterbalanced for order. For each cue attended to (attention rating $\geq$ 1), the participant’s reactivity to the cue was measured (“Rate your reaction when you noticed [cue]”) using a 5-point scale: 1 (Very Negative), 2 (Negative), 3 (Neutral), 4 (Positive), 5 (Very Positive). The a priori plan was to operationalize the attention variable as a latent factor derived from a multilevel confirmatory factor analysis.

Power Considerations. A statistical power analysis for N = 50 was conducted using the ema.powercurve function in R, which is used for multi-level studies. Power estimates were determined at different EMA compliance rates and at an outcome variable intraclass correlation of .50 (ICC = 0.50). At a 100% compliance rate, the study is sufficiently powered to detect large effect sizes (*d* = 0.80; 1 – β = .80, *p* = .05). At a lower, more realistic ICC of .30 and 75% compliance rate, the study is also able to detect large effect sizes (*d* = 0.80; 1 – β = .80, *p* = .05). In considering the small sizes and power for exploratory Aim 2, data will be analyzed using effect sizes, such as β, rather than p-values. In this way, this exploratory and novel work will be interpretable and informative for future research.

CHAPTER THREE: RESULTS

Descriptive Statistics

Of 78 people screened, 47 were eligible. Sixteen participants were ineligible due to currently meeting criteria for a depressive episode. Of the remaining ineligible people screened, 1 had completed both CBT-SAD and LT, 1 did not own a mobile phone, 2 had experienced manic/manic episodes before, 4 had moved out of the area, and 7 were not interested. Of the 47 eligible participants, 5 were lost at the initial visit stage. One participant withdrew after starting EMA due to cell service issues.

The sample for these analyses included 41 participants (M_{age} = 48; SD = 16), consisting of 23 (56.1%) treatment completers (12 CBT-SAD, 11 LT), and 18 (43.9%) treatment-naïve individuals. Participants had experienced SAD for a self-reported average of 18 years (SD = 15.7). Approximately one-third of participants were taking medication for depression (*n* = 13; 31.7%) and two-thirds of participants were not (*n* = 28; 68.3%). Most participants identified as White (*n* = 35; 85.4%). One participant (2.4%) identified as Hispanic or Latino, one participant as Asian (2.4%), and 3 (7.3%) participants as other or mixed race. Most participants were women (*n* = 31; 75.6%), and seven (17.1%) participants were men. Most participants had completed college or beyond (*n* = 33; 80.5%) and were employed (*n* = 25; 61%). Table 2 presents descriptive statistics for baseline variables assessed at the initial visit. Variables that were assessed on a daily basis had a 93.2% compliance rate.

Table 2

Descriptive statistics for measures collected at baseline

	N	Mean	SD
Initial BDI-II	41	13.76	9.24
Initial BAI	41	8.22	7.20
SBQ	41	130.90	21.75

Notes. BDI-II: Beck Depression Inventory—Second Edition. BAI: Beck Anxiety Inventory. SBQ: Seasonal Beliefs Questionnaire.

Table 3

Intra-class correlations (ICCs) for variables assessed daily using EMA

Variable	M	SE	ICC
POMS[1] Depression Subscale	3.84	0.51	0.50
POMS Anxiety Subscale	3.77	0.47	0.57
Attention to… (0-4 scale)[2]			
Changing leaf colors	0.56	0.11	0.54
Gray skies	0.96	0.10	0.28
Cold weather	1.29	0.10	0.29
Cloud cover	0.95	0.10	0.31
Frost	0.13	0.05	0.15
Snow	0.74	0.10	0.31
Rain	0.67	0.08	0.16
Sunrise time	0.61	0.09	0.37
Sunset time	1.15	0.12	0.51
Daylength	1.16	0.12	0.53
Soft shadows	0.21	0.06	0.40

Bare trees	0.80	0.12	0.51
Clear skies	0.85	0.09	0.24
Bright sunshine	1.01	0.08	0.19
Warm weather	0.70	0.09	0.29
Today’s date	0.78	0.08	0.33
Animals	1.16	0.17	0.75
Noise	0.78	0.07	0.23
Surrounding people	1.15	0.10	0.35
Reaction to… (1-5 scale)[3]			
Changing leaf colors	2.79	0.15	0.57
Gray skies	3.79	0.07	0.40
Cold weather	3.81	0.08	0.45
Cloud cover	3.68	0.07	0.30
Frost	3.58	0.11	0.59
Snow	3.27	0.13	0.59
Rain	3.58	0.10	0.52
Sunrise time	3.02	0.12	0.57
Sunset time	3.48	0.11	0.54
Daylength	3.51	0.11	0.63
Soft shadows	3.06	0.14	0.41
Bare trees	3.48	0.12	0.67
Clear skies	1.92	0.05	0.18
Bright sunshine	1.77	0.07	0.38
Warm weather	2.08	0.09	0.46
Today’s date	3.07	0.08	0.38
Animals	1.93	0.09	0.46
Noise	3.33	0.07	0.25
Surrounding people	2.72	0.08	0.28

Notes.
[1] POMS: Profile of Mood States Short Form. [2]Frequency of noticing the cue in the past day, rated on a 4-point scale: 0 (Not at All), 1 (Occasionally), 2 (A Lot of Time Today), 3 (Most of the Time Today). [3]For each cue noticed ($\geq$ 1), reactivity as rated on a 5-point scale: 1 (Very Negative), 2 (Negative), 3 (Neutral), 4 (Positive), 5 (Very Positive).

Multilevel structural equation modeling, which allows for examination of within-person (Level 1; L1) effects, between-person (Level 2; L2) effects, and latent factors, was used to analyze the data. Level 1 examines daily effects of the independent variables on the daily outcome variables, whereas Level 2 examines the effects of independent variables on outcome variables averaged across all timepoints. Age, sex (self-identified as male or female), race (White/non-White, regardless of ethnicity), treatment status (treatment-naïve/treatment completer), antidepressant medication status (present/absent), timing of data collection (i.e., week number in the year), baseline anxiety scores, and baseline depression scores were included as potential covariates. Potential covariates not significantly associated with the outcome variable were dropped from the analyses in favor of a more parsimonious model. Missing data were addressed with maximum likelihood estimation.

To determine the data's suitability for multilevel modeling, intra-class correlations (see Table 3) were first calculated for the study variables, and they were all deemed to be suitable (i.e., > .10) for inclusion in the analyses. The intra-class correlations represent the proportion of variance explained by between-person differences.

Multilevel Confirmatory Factor Analysis of Novel Measure

To test the validity of the novel attention measure, a multilevel confirmatory factor analysis (MCFA) was conducted with the attention ratings for light and seasonal cues. A two-factor model, Attention to Seasonal Cues and Attention to Light Cues, was hypothesized. The model fit was evaluated using several model fit statistics [model chi-square, confirmatory factor index (CFI), root mean square error of approximation

(RMSEA), etc.]. If the fit statistics suggested poor model fit, the a priori plan was to re-run the CFA, dropping observed variable(s) that do not load significantly onto the latent factors from the analysis. Items with factor loadings below |0.4| ($\geq$ 0.4 or $\leq$ -0.4), at either level (in favor of a more parsimonious model) were dropped and the model was respecified.

When running the hypothesized Attention to Seasonal Cues (SA) and Attention to Light Cues (LA) MCFA model, a third factor, Attention to Distractor Cues (DA), with indicators noise, animals, and surrounding people, was added. The fit for the hypothesized model was poor: χ^2 (df =304) = 1574.81, p < .001; CFI = .53; TLI = .48; RMSEA = .07; and $SRMR_{Within}/SRMR_{Between}$ = .094/.179. For the LA factor, only gray skies, rain, cloud cover, clear skies, and bright sunshine had standardized factor loadings above |0.4| at both within- and between-person levels (see Table 4). For SA, cold weather was the only indicator with a sufficiently large enough factor loading. For DA, both animals and surrounding people had factors above |0.4| at both within- and between-person levels. After this initial model specification, DA was subsequently dropped from the factor analysis because of non-conceptual overlap with the remaining variables in the domain of interest (i.e., attention to light and seasonal cues). Given that SA only had one indicator, new potential factors were tested given the two indicators that emerged: Attention to Positive Cues (PA) and Attention to Negative Cues (NA). A new two-factor model was then specified, with PA including clear skies and sunshine and NA including gray skies, rain, cloud cover, and cold temperatures. Results of this respecified model showed cold temperatures with a small factor loading size (.07) at the within-person level. Thus, the cold temperatures indicator was dropped from the model, and the model was respecified to its finalized form. Figure 1 presents the final MCFA model and its results.

Table 4

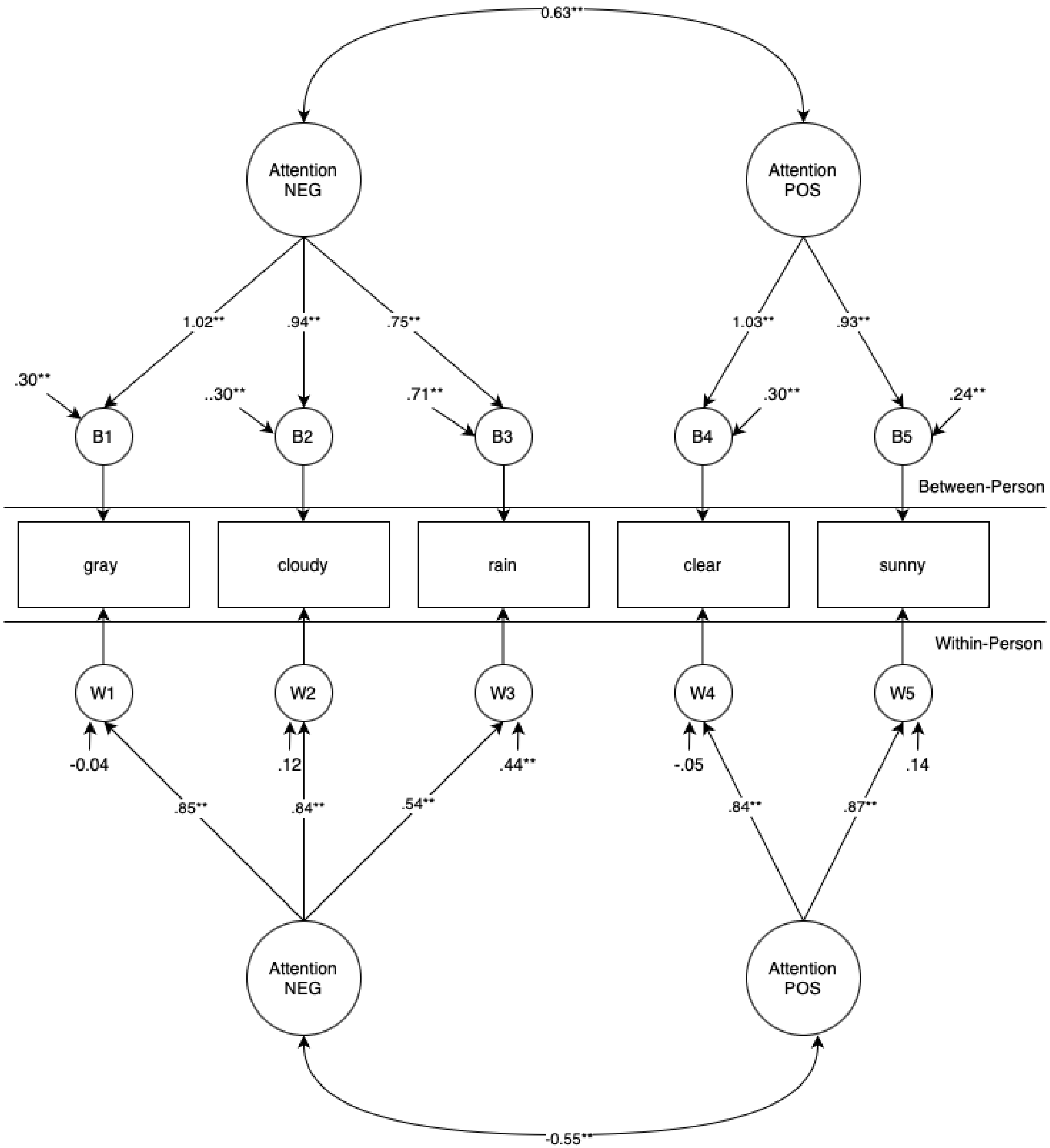
Multilevel Confirmatory Factor Analysis (MCFA) Parameters

	Within-person		Between-person	
Parameter	Standardized	SE	Standardized	SE
Factor Loadings				
LA				
Gray skies	.83	.03	.95	.02
Rain	.55	.06	.58	.10
Cloud cover	.81	.04	.91	.08
Sunrise time	-.06	.04	.81	.08
Sunset time	.13	.04	.80	.08
Daylength	.17	.05	.79	.08
Clear skies	-.56	.07	.85	.25
Bright sunshine	-.58	.07	.83	.30
Soft shadows	.17	.05	.51	.12
SA				
Cold temperatures	.86	.08	.74	.12
Frost	.36	.06	.52	.17
Snow	.36	.06	-.00	.32
Bare trees	.10	.05	.94	.07
Today’s date	.03	.07	.78	.07
Changing leaf color	.02	.06	.74	.11
Warm temperatures	-.38	.05	.18	.19
Distractors				
Animals	.12	.09	.49	.11
Noise	.59	.11	1.04	.14
People	.63	.12	.67	.12
Factor Correlation				
SA WITH LA	.08	.07	.79	.15
DIS WITH LA	-.01	.06	.33	.19
DIS WITH SA	.26	.07	.39	.20

Notes. SA = Attention to Seasonal Cues. LA = Attention to Light Cues.

Figure 1

Confirmatory factor analysis model for novel measure of attention to cues



With these alterations made, the overall model fit of the MCFA was good: χ^2 (*df* =8) = 19.60, $p < .001$; CFI = .99; TLI = .97; RMSEA = .042; and $SRMR_{Within}/SRMR_{Between}$ = .034/.018. Standardized factor loadings for the Attention to Negative cues ranged from .54 to .87 at the within level and .75 to 1.02 at the between level, and all these factor loadings had p-values below .001. Results showed a statistically significant correlation between the factors at the within-person level ($\psi_{NA.PAw}$ = -0.55, *SE* = .05, *z* = -10.48, *p* < .001) and at the between-person level ($\psi_{NA.PAB}$ = 0.63, *SE* = .13, *z* = 4.67, *p* < .001).

Model saturation occurs when the number of parameters is equivalent to the number of data points, such that the degrees of freedom are zero. Saturation of the MCFA model was conducted via correlation estimation among indicators at each respective level to analyze potential level-specific issues with fit. Results of the saturation demonstrated good between-person fit, χ^2 (*df* = 4) = 2.98, *p* = .562; CFI = 1.00; TFI = 1.00; RMSEA = .000; and $SRMR_{Within}/SRMR_{Between}$ = .001/.017. Likewise, results of the saturation showed good within-level fit, χ^2 (*df* = 4) = 14.00, *p* = .007; CFI = .991; TLI = .953; RMSEA = .056; and $SRMR_{Within}/SRMR_{Between}$ = .034/.007.

The omega coefficient, which estimates the reliability of the model across time, was calculated at within- and between-persons level of the MCFA. Analogous to Cronbach's alpha, omega is generally recommended for multilevel analyses (Geldhof, Preacher, & Zyphur, 2014). The omegas were good for the within-person and between-person Attention to Positive Cues factor at .85 and .98, respectively. For the Attention to Negative Cues factor, the between-person omega was stronger at .95, with the within-person omega at .78.

To further test the construct validity of the novel measure, correlations between the attention variable and subscales from a relevant validated measure, the Seasonal Beliefs Questionnaire (SBQ), were examined. This included bivariate correlations between the Attention to Negative Cues factor and the Lack of Perceived Seasonal or Weather Effect subscale score from the SBQ; and the Attention to Negative Cues factor and Effects from Lack of Light SBQ subscale score. As the novel measure was developed in consultation with experts in SAD (Drs. Kelly Rohan and Michael Young), acceptable construct validity was expected.

Correlations between the SBQ Effects of Lack of Light (ELL) and Lack of Perceived Effects of Weather and Light (LPS) subscales, respectively, and the between-person level of the Attention to Negative Cues latent factor were generated. Results showed a statistically significant correlation between the ELL subscale and NA, r = 0.306, SE = .093, p < .001). Results showed that the Attention to Negative Cues latent factor was also correlated with the SBQ LPS subscale score, r = 0.871, SE = .039, p <.001. A correlation between NA and total SBQ score was significant but not as strong as correlations with these subscales, r = 0.141, SE = .067, p = .036.

For the purposes of the remaining analyses, only the Attention to Negative Cues factor was used (dropping the Attention to Positive Cues factor) as a predictor variable. This decision was made because only attention towards the *negative* cues is hypothesized to play a role in developing a recurrent SAD depressive episode. Further, this decision is bolstered by research suggesting that "bad" effects are generally stronger than "good" effects in psychology (Baumeister, et al., 2001).

Aim 1: Multilevel Latent Variable Mediation Model

Several potential covariates [i.e., baseline depression on the BDI-II, baseline anxiety on the BAI, timing of data collection (week number in the year), treatment status (treatment completer vs. treatment-naïve), age, sex, race (White vs. non-White, regardless of ethnicity)[1], and antidepressant medication status (present vs. absent) were examined

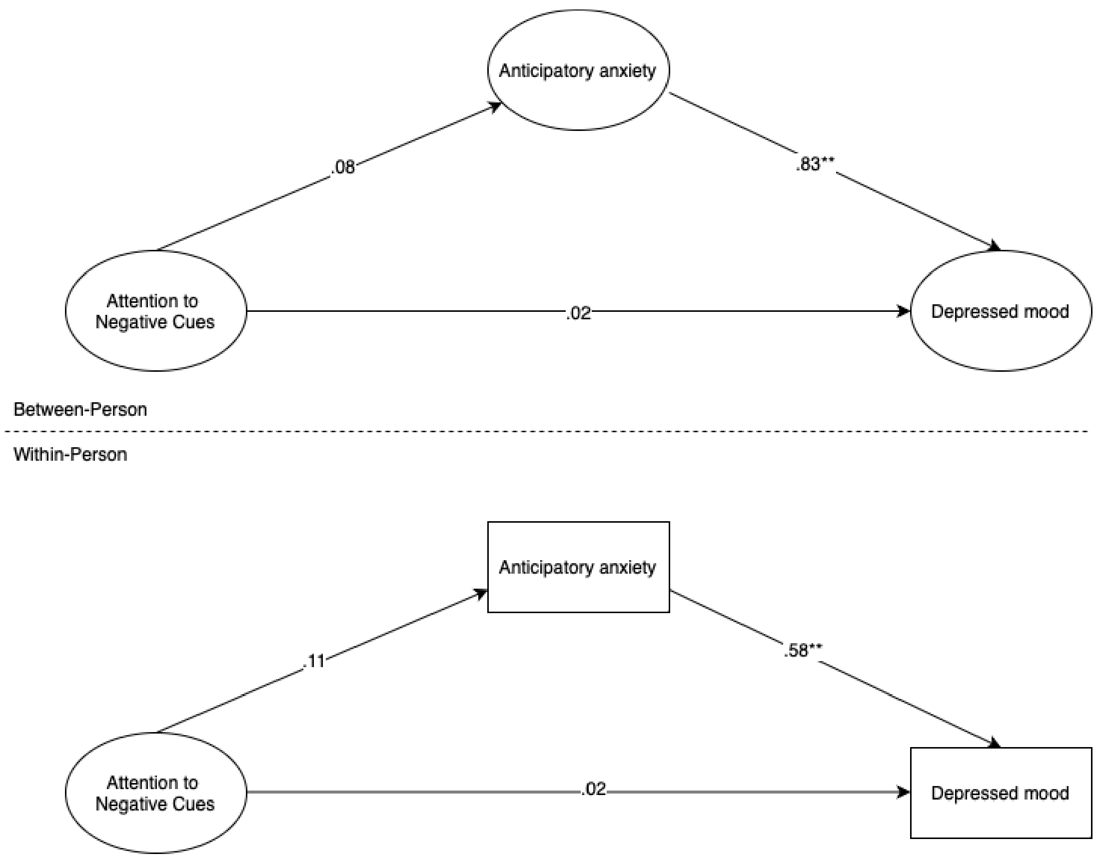
[1] The one participant who identified as Latinx also identified as non-White.

for association at the between level with the outcome variables, namely daily depression or daily anxiety. Only race and baseline depression (BDI-II scores) were significantly associated with daily anxiety and/or daily depression and were included as covariates in all models where daily anxiety and/or daily depressions were outcomes. At the between-person level of the project's mediation model, covariates race ($b = .37$, $SE = .07$, $p < .001$) and baseline depression scores ($b = .30$, $SE = .08$, $p < .001$) were significantly associated with daily depression, such that the participants who were White reported on average higher depression scores. Similarly, the participants who had higher baseline depression scores at baseline also reported higher depression scores on average. None of the proposed covariates were significantly associated with NA. A centered day of assessment (i.e., 1-21) was controlled for at the within-person level to account for any patterns in responses associated with timing. Non-significant covariates were dropped in favor of a more parsimonious model.

Specific Aim 1a examined the relationship between attentional bias to seasonal and light cues and depressed and anxious mood. The project hypothesized that attention to seasonal and light cues has a mediating effect, such that attention to seasonal and light cues leads to increased anticipatory anxiety which leads to increased depressed mood. A multilevel structural equation model examined the direct and indirect effects of attention to seasonal and light cues on depressed mood (see Figure 2). At Level 2, the model examined averages across time in attention to seasonal and light cues and anxious and depressed mood. At Level 1, the model examined daily differences in attention to seasonal and light cues predicting daily differences in anticipatory anxiety (POMS-SF Tension/Anxiety subscale) and depressed mood (POMS-SF Depression/Dejection subscale). Attention to seasonal and light cues was operationalized as a latent factor derived from the MCFA. As seen in Figure 2, the model examined daily anxiety as a mediator between the latent attention variable and daily depression.

Figure 2

Multi-level mediation model of anticipatory anxiety



Note. ** p <.001

The overall fit of the mediation model was generally acceptable: χ^2 (df =36) = 95.12, p < .001; CFI = .97; TLI = .94; RMSEA = .047; and $SRMR_{Within}/SRMR_{Between}$ = .046/.093. Results showed nonsignificant within-person (b = .06, p = .138, 95% CI [-.004, .159]) and between-person (f) indirect effects of NA on depression via anticipatory anxiety. Similarly, the direct effect of Attention to Negative Cues on daily depression was not significant at the within-person (b =.02, SE = .05, p = .739) or the between-person (b = .02, SE = .08, p = .759) levels. The effect of Attention to Negative Cues on anticipatory anxiety was not statistically significant at the within-person (b = .11, SE = .05, p = .739) or the between-person (b = .08, SE = .14, p = .543) level. The standardized coefficients of daily anxiety on daily depression were significant at the within-level (b = .58, SE = .07, p < .001) and the between-level (b = .83, SE = .11, p < .001), indicating that those with higher daily anxiety were on average also reporting higher daily depression. At the within level, the standardized coefficient for day of data collection (which was centered such that 0 was the midpoint of EMA data collection) on Attention to Negative Cues was statistically significant (b = -.22, SE = .04, p < .001). Similarly, at the between-person level, covariates race (b = .37, SE = .07, p < .001) and baseline depression scores (b = .30, SE = .08, p < .001) were significantly associated with daily depression, such that participants who reported their race as White, on average, reported higher daily depression.

Specific Aim1b examined whether the relationship between attention to cues and anticipatory anxiety is moderated by number of prior SAD episodes. This was examined using a latent moderation analysis conducted at the between-level. Anticipatory anxiety (POMS-SF Tension-Anxiety subscale) served as the outcome variable and attention to cues (NA latent factor) and history of SAD (number of prior SAD episodes) served as predictors. To test the moderating effect of SAD history, an interaction term, number of self-reported prior SAD episodes ×Attention to Negative Cues, was added. This model thus tested whether attention to seasonal and light cues averaged across time was predictive of anticipatory anxiety averaged across time. The strength of the relationship between attention to cues and anticipatory anxiety was expected to be moderated by number of prior SAD episodes, such that as attention and number of prior SAD episodes increase, anticipatory anxiety increases. Results showed that neither number of prior SAD episodes (b = -.01, SE = .03, p = .613) nor the interaction term were predictive of daily anxiety (b = .002, SE = .03, p = .955). Thus, number of prior SAD episodes did not moderate the relationship between Attention to Negative Cues and anticipatory anxiety as predicted.

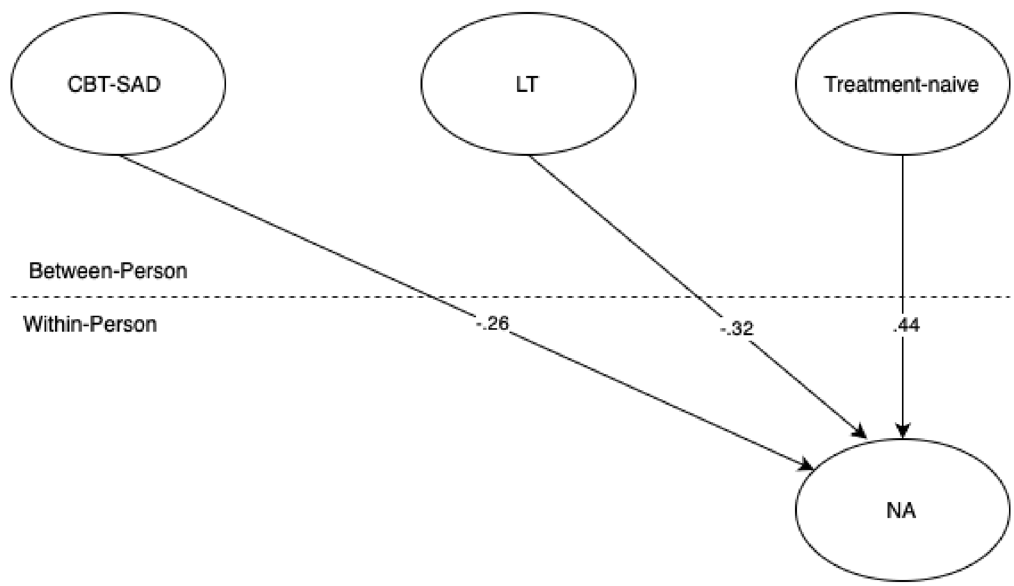
Aim 2: Multilevel Latent Variable Cross-Level Regression Model

Specific Aim 2 is an exploratory aim examining whether participants' treatment status group—namely whether they were treatment naïve, CBT-SAD completers, or LT completers—predicts attention to seasonal and light cues. Thus, a cross-level regression model was run with three dummy-coded categorical variables (treatment-naïve, CBT-SAD-completers, or LT completers) at the between-level predicting the latent factor, Attention to Negative Cues, at the within-level (see Figure 3). Potential covariates were not included in this model as none were significantly associated with the outcome variable, Attention to Negative Cues. Attention towards negative cues was expected to differ significantly by treatment status, with those previously treated with CBT-SAD demonstrating less attentional bias toward seasonal and light cues than those previously treated with LT or those who are treatment-naïve. Given the small cell sizes, results were interpreted with effect sizes.

Results showed nonsignificant relationships between the three treatment status groups and Attention to Negative Cues. The CBT-SAD group had a standardized coefficient of -.26 (SE = .40, p = .515), a small effect size, suggesting a small strength of the relationship between CBT-SAD completion and NA. Results showed medium effect sizes for the treatment-naïve group, coefficient of .44 (*SE* = .28, *p* = .120), and LT group, coefficient of -.32 (*SE* = .33, *p* = .333). Given the directionality of the coefficients, these patterns suggest a trend whereby SAD treatment completion (whether LT or CBT-SAD) was associated with less attention towards negative cues than treatment naïve status.

Figure 3

Multi-level model of treatment status predicting NA



CHAPTER 4: DISCUSSION

This study examined a hypothesized pathway in which attention to seasonal and light cues leads to anticipatory anxiety about the upcoming winter which leads to depressive symptoms in winter seasonal affective disorder (SAD). This project was informed by learning theory, clinical interactions with the SAD population, and extant research showing an established emotional reactivity and attentional bias towards these cues in this population. This project developed a novel measure to assess attention to seasonal and light cues and administered it daily, along with measures of depressed and anxious mood, via ecological momentary assessment (EMA) over 21 days in 41 adults with SAD. Participants entered the study before the onset of a full-threshold winter depressive episode to capture a window of expected growth in depression symptoms.

A multilevel confirmatory factor analysis (MCFA) included attention ratings towards all 16 light and seasonal cues presented daily: gray skies, cold temperatures, cloud cover, frost, snow, rain, sunrise time, sunset time, daylength, soft shadows, bare trees, clear skies, bright sunshine, warm temperatures, today's date, and hard shadows. The good-fitting model included two factors, labeled "Attention towards Positive Cues" (PA) and "Attention towards Negative Cues" (NA). NA consisted of three indicators (i.e., rain, cloud cover, and gray skies), and PA consisted of two indicators (i.e., clear skies and bright sunshine).

Results of the MCFA contrasted with the study's conceptualization around deployment of attention to both light and seasonal cues in people with SAD. All five of the indicators were light-related, suggesting that light-related cues are more frequent targets of attention to people with SAD than seasonal cues such as snow and bare trees, across both the assumed negative and positive targets of attention. Given that photoperiod (i.e., daylength from sunrise to sunset) is a more robust predictor of the timing of annual SAD episode onset than weather-related variables such as temperature and solar radiation (Young et al., 1997), it is surprising that the cues "daylength," "sunrise time," and "sunset time" did not emerge as indicators in the model.

The hypothesis of this project's primary model—that increased attention to seasonal and light cues leads to anticipatory anxiety about the upcoming winter which leads to depressive symptoms—was not supported by the results. Surprisingly, the direct effect of Attention to Negative Cues was not significant at either the within- or between-person levels on either daily depression or daily anxiety. This indicates that individual and between-subjects variability in attention towards rain, cloud cover, and gray skies was not related to variability in daily depression or anxiety on the POMS. A mediation model, in which anticipatory anxiety (POMS anxiety subscale score) mediated the relationship between the latent NA factor from the MCFA and depressed mood (POMS depression subscale score), was non-significant after controlling for race and baseline depression.

The study's conceptual model was designed to test learned relationships between attention to light and seasonal cues and anxious mood as well as between attention to negative cues and depressed mood. These results suggest that attention to rain, cloud cover, and gray skies was not associated with depressed or anxious mood in this sample; however, it is possible that attention towards these cues is associated with a different SAD symptom, such as fatigue or anhedonia. Indeed, the items on POMS-SF Depression-Dejection subscale are largely mood states: unhappy, sad, blue, hopeless, discouraged, miserable, helpless, and worthless. In contrast, the Tension-Anxiety subscale is a mix of physiological and emotive anxiety: tense, on edge, uneasy, restless, nervous, and anxious. Fatigue is a prominent SAD symptom not captured by either of these subscales, but one that could be measured using the POMS Fatigue-Inertia subscale in future studies.

Another explanation for the surprising lack of support for the study's model is a possible difference between perceived and actual associations between environmental cues and mood for people with SAD. This project was inspired by clinical observations of the SAD population whereby CBT-SAD participants commonly report that the beginning of their SAD symptoms coincides with some external cue, such as the end of daylight savings time. However, it is possible that perceived associations between symptom onset and an environmental stimulus are not accurate, particularly because they tend to rely on retrospective recall in making such assertions. Alternatively, it is possible that the environmental cues most strongly associated with SAD symptom onset, like short daylength, for example, are not the ones to which people with SAD most frequently attend. This study found elevated attention to rain, cloud cover, and gray skies in the sample.

Power to detect effects represents an important consideration for these results. A priori power analyses were conducted with the recruitment goal of 50 participants, and results showed sufficient power to detect large effect sizes for that sample size. Ultimately, with a sample of 41 participants, the project was underpowered to detect even large effect sizes. Thus, it is possible that meaningful relationships between attention, anxiety, and depression are present but were undetected due to insufficient power.

Beyond insufficient power, there are several potential reasons for this study's failure to support the mediation model. The method of measuring the attention construct is one potential contributor. Given that attention to seasonal and light cues is a largely unexplored construct, this project utilized a novel measure to measure participants' attention to seasonal and light cues. Efforts were taken to construct a valid and reliable measure, including consultation with eminent SAD researchers and efforts to assess construct validity (i.e., correlations with the SBQ and its subscales). Indeed, results showed an MCFA model with good fit, and the negative attention factor was significantly correlated with overall SBQ score and specific subscales of the SBQ, Effects of Lack of

Light and Lack of Perceived Seasonal or Weather Effect. However, especially given the novelty and self-report nature of the measure, the novel measure is subject to fallibility. This project's results contrast with the results of relevant studies informing this work, such as the distinct emotional reactivity to light cues in SAD patients as compared to healthy controls (Rohan et al., 2003, Tierney Lindsey et al., 2011). It is possible that a more objective measure of attention, such as eye-tracking, would represent a better method of operationalizing attention to seasonal and light cues. Although eye-tracking is arguably a more objective measure of attention, the EMA method used in this project has greater ecological validity, as current eye-tracking devices are not ambulatory. Nevertheless, eye-tracking could supplement the existing literature on emotional reactivity and attentional bias to these cues in the SAD population.

Assuming insufficient power obscured a direct effect of Attention to Negative Cues on depressed mood, other potential mediators beyond anticipatory anxiety could be explored. Further, significant indirect paths could be explored without significant direct effects. For example, a cognitive mediator between attention and depression, rather than an anxiety mediator, is possible. In other words, attention to cues may not be sufficient to predict depression without taking negative cognitive appraisals of the cue into account. Recent research found that change towards more flexible seasonal beliefs, as measured by the Seasonal Beliefs Questionnaire, during CBT-SAD mediated improvement in depression during treatment (Rohan, Burt et al., 2020) and explained lower depression severity following CBT-SAD relative to light therapy (Rohan, Burt et al., in press). These findings provide compelling data to support seasonal beliefs as a mediator of CBT-SAD's outcomes. Thus, it is possible that inclusion of a variable to capture the individual's cognitive interpretation of light and seasonal cues would reveal relationships between attention and mood through cognitive appraisals. Previous research has examined the association between cognitions and momentary depressed mood in real time (Wenze et al., 2010). Such methods could potentially be applied to SAD patients in response to environmental cues.

Relationships between attention to environmental cues and mood in SAD should, in theory, be stronger in those with more experience with the disorder due to more ingrained learning. In this study, number of prior SAD episodes did not moderate the relationship between NA and anticipatory anxiety. The candidate moderator variable (i.e., number of prior SAD episodes) was measured via retrospective self-report. In a phone screen, number of prior SAD episodes was assessed by asking participants to report how many years they have experienced SAD. However, retrospective recall is fallible, and participants were not likely applying DSM-5 Major Depression criteria to their experiences. A more formal assessment of all prior major depressive episodes and their timing, such as with a semi-structured diagnostic interview, would have provided a more accurate operationalization of this moderator variable.

This project's potential covariates, both those with significant and non-significant effects on outcome, warrant further discussion. A randomized clinical trial found that non-white race was a negative prognostic indicator for CBT-SAD and light therapy outcomes at treatment endpoint (Rohan et al., 2015). Surprisingly, this project showed the opposite relationship whereby those who identified as White (regardless of ethnicity) had on average higher levels of daily depressed mood than those who did not identify as White. This finding could be explained by the vastly different cell sizes and the small number (around 7% of the sample) who identified as non-white, with another 7% not reporting their race. Cultural differences in endorsing mental health symptoms could offer another explanation for the finding. For example, it is possible that majority individuals may be more likely to endorse depressed mood, and minoritized individuals may under-report their depressed mood due to mental health stigma. Baseline depression, as measured by the Beck Depression Inventory-II scores, was another significant covariate in the mediation model predicting depression, such that on average those with higher baseline BDI-II scores had higher POMS-SF Depression-Dejection subscale scores over the 21 days of EMA. Other examined covariates, including age, self-reported sex, and antidepressant medication status, were not significantly associated with the outcome variables and thus were dropped from the analyses. It is possible that just as with the other results, potentially meaningful covariates were not detected due to insufficient power.

In the exploratory model, a cross-level regression between treatment status (CBT-SAD completer, LT completer, and treatment-naïve), CBT-SAD completion had a small effect size on NA, LT had a medium effect size on NA, and treatment naïve status had a medium effect size on NA. Though the associations were not significant, results trended towards expected directions, such that those who had completed treatment, whether CBT-SAD or LT, showed lower levels of attention towards negative cues, whereas treatment naïve participants showed higher levels of attention towards negative cues. Of course, this aim should be re-tested with larger cell sizes and adequate power. A natural hypothesis follows that SAD treatment, particularly with CBT-SAD, may weaken the CS:US learned association with these seasonal and light cues (CS) signaling depression

(UCS). For example, a CBT-SAD intervention like behavioral activation may create new associations with seasonal and light cues by pairing a cue like snow with a joy-evoking activity such as skiing. Even though light therapy does not directly target emotional responses to seasonal cues, less negative associations with these cues may be formed during light therapy as depression improves.

Indeed, several paths abound for future research, beginning with replication with a larger sample size. A replication study should also include refinement of the novel measure by examining new cues, such as the attentions towards the weather app, as well as an open-ended *other* option for participants to contribute to the non-exhaustive list of potential cues. Secondly, the self-report attention measure could be corroborated with another measure of attention, such as eye-tracking. This would incorporate multiple methods of measuring the attention variable. As mentioned, future research could examine other potential mediators, including cognitive mediators such as real-time thoughts about environmental stimuli. Following up on the project's exploratory aim, testing whether CBT-SAD or LT contributes to weakening a learned depressogenic association with seasonal and light cues, presents another avenue of research.

Like all studies, this project is not without its limitations. Investigators made efforts to capture an ephemeral, distinct period before a recurrent SAD episode develops by recruiting people previously diagnosed with SAD but ruling out those in current episode (i.e., meeting five or more criteria for current major depression). However, it is unknown how many participants developed a depressive episode after the study. Recruitment occurred on a rolling basis to facilitate accrual, whereas ideally participants would have been recruited at the same time. However, timing of data collection was not a significant covariate. As discussed above, the novel measure created for this study needs more refinement. While the MCFA results showed good fit, only five seasonal and light indicators of the sixteen cues tested had large enough factor loadings at both the between- and within- person level to be included in the model. Results of this study showed that baseline depression, as measured by BDI-II scores at an initial visit, was a significant covariate. However, BDI-II scores do not match how depressed mood was measured in the EMA data collection (POMS-SF depression subscale), and ideally the POMS subscale would have been assessed to ascertain baseline depression. Finally, as mentioned before, this project is also significantly limited by its power and its retrospective self-report for determining number of prior years with SAD.

In conclusion, this project marks the first study to prospectively examine attention to seasonal and light cues in adults with SAD. Although the study's primary hypothesis was not supported, the novel measure of attention to seasonal and light cues offers an interesting insight into environmental targets of attention among adults with SAD, namely light cues like cloud cover, rain and gray skies.

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