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Development and Testing of an Interpretational Bias Measure of Dental Anxiety

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Objectives: We hypothesized that individuals with dental care-related anxiety and fear would interpret ambiguous dental situations more negatively than non-anxious individuals. The objectives of these studies were to develop and test a Measure of Dental Anxiety Interpretational Bias (MoDAIB).

Methods: In the development phase, participants completing an online survey provided qualitative and quantitative assessments of dental scenarios that could be interpreted in either positive or negative ways. Scenarios producing the greatest difference in visual analog (VAS) scores between individuals with high vs. low dental anxiety as measured by the Modified Dental Anxiety Scale (MDAS) were included in the MoDAIB. In the testing phase, participants completed an online survey including the newly developed MoDAIB and dental anxiety measures.

Results: In the development phase, participants ($N = 355$; 65.6% female) high in dental anxiety (MDAS $\geq$ 19) gave significantly higher (i.e., more negative) VAS scores to all the dental scenarios than did those low in dental anxiety (p's < 0.05). In the testing phase, the MoDAIB was significantly and positively correlated with the MDAS ($r = 0.68$, $p < 0.001$), meaning that those who were high in dental anxiety selected negative interpretations of ambiguous dental scenarios significantly more often than did individuals low in dental anxiety (p's < 0.05). The MoDAIB showed good content validity and test-retest reliability.

Conclusions: Individuals high in dental anxiety interpret ambiguous dental situations more negatively than do less anxious individuals. Understanding individuals' interpretational styles may help dental providers avoid miscommunications. Interventions that train dentally anxious patients to consider more positive interpretations may reduce dental anxiety and should be investigated.

Keywords: dental anxiety, dental fear, interpretational bias, cognitive behavioral therapy, reliability – reproducibility of results, validity

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INTRODUCTION

Dental care-related anxiety and fear is well-established as a significant barrier to receiving dental treatment, leading 5–10% of adults in the United States to avoid necessary dental care (1). As described by McNeil and Randall (2), dental care-related *fear* occurs in response to treatment-related stimuli, often in the form of physiological reactivity, apprehension, and avoidance of the

feared stimuli. Dental care-related *anxiety*, meanwhile, is described as "a more cognitively-involved emotional response to stimuli or experiences associated with dental treatment." Much of the discussion of this paper will focus on "cognitively-involved emotional response(s)" (2), particularly related to negative thoughts and worries. Thus, the term "dental anxiety" will be used as shorthand for the concept of dental care-related anxiety and fear throughout this article, while acknowledging the complexity of the latter as a more precise and inclusive construct across individuals.

A commonly-cited model of the development and maintenance of dental anxiety is the "cycle of avoidance," in which the development of dental anxiety is predicated on a negative dental experience (3, 4). Fear of re-experiencing this experience leads to avoiding dental treatment, setting up the need for more invasive dental treatment, further reinforcing the perception of dental treatment as traumatic and painful (3, 4). Yet, the existence of a traumatic event is not required for the establishment or maintenance of dental anxiety. De Jongh et al. found no difference in the severity of dental anxiety between individuals with or without a history of a traumatic dental experience (5). A similar study found no difference in the number of self-reported "horrific" dental experiences recalled between individuals seeking treatment in a specialized dental anxiety clinic vs. a general dental clinic (6).

Anxious individuals are more likely than non-anxious control subjects "to interpret…ambiguous sentences in a threatening fashion" (7). This *interpretational bias* has been shown to exist in individuals with: (1) social anxiety disorder (8), (2) generalized trait anxiety (9), and (3) chronic pain (10). Steinman and Teachman, for example, developed a four-factor measure to assess "height fear-relevant interpretation bias" in individuals with acrophobia (fear of heights) (11). The Heights Interpretation Questionnaire (HIQ) presents various height-relevant scenarios and asks individuals to imagine themselves in such scenarios then indicate the likelihood of interpretations of each scenario (e.g., "you will fall"). The authors found that the HIQ strongly predicted fear and avoidance related to heights above that provided by a previous measure of acrophobia symptoms (11).

Could interpretational bias help explain why dentally anxious individuals maintain their dental anxiety, even without traumatic dental experiences? In a qualitative study of 20 adults seeking treatment in a dental sedation clinic in the United Kingdom, one participant described racing thoughts in anticipation of dental treatment: *"…my brain goes at a thousand miles an hour, everything from…what's he gonna say, is, I cannot even begin to describe the number of thoughts that go through my head."* (12). On the self-help website "Dental Fear Central" (www.dentalfearcentral.org), one commenter notes, "*If you suffer with dental phobia, it is possible that you'll interpret remarks which others might simply regard as helpful advice or fair commentary as negative – and pretty devastating."* (13).

Research has suggested training anxious individuals to endorse neutral or positive interpretation of an ambiguous stimulus can counteract the individual's bias toward making negative, anxiety-inducing interpretations and result in reductions in self-reported anxiety (14, 15). The first step in developing this treatment is to identify how individuals high and low in dental anxiety interpret ambiguous dental situations. To do this, we asked people high and low in dental anxiety to assess ambiguous dental scenarios both qualitatively and quantitatively. Our goal was to develop a measure of interpretational bias [Measure of Dental Anxiety Interpretational Bias (MoDAIB)] and determine if it can reliably assess whether a dentally anxious individual has a negative interpretational bias toward dental situations.

MATERIALS AND METHODS

Development Phase

Based on five factors of dental anxiety (16–18), we developed six scenarios for each of the five factors resulting in 30 ambiguous dental scenarios (**Table 1** for examples). The five factors of dental anxiety reflect those determined in previous research (16–18) as well as unpublished data from the authors that mirror this prior work. For each of the five factors (named Interpersonal, Fear of Pain, Anticipation, Worry, and Medical Catastrophe), the Principal Investigator (PI; LJH) developed several ambiguous dental scenarios based on her clinical experience treating dentally anxious individuals. The research team (LJH, BGL, and DSR) then discussed, revised, and ultimately selected 6 scenarios for each of the 5 factors to create a 30-item subset of questions for the survey.

Between March 7, 2019, and July 5, 2019, we recruited participants (adults aged $\geq$ 18) through Craigslist advertisements across 55 major cities across the United States to provide quantitative and qualitative evaluations of 5 scenarios each. Two similar advertisements were developed to target both individuals high in dental anxiety ("Are you afraid of the dentist?") and individuals with less dental anxiety ("Tell us how you feel about going to the dentist!") to recruit individuals with various levels of dental anxiety and oversample for high dental anxiety. These two advertisements did not run in the same city simultaneously and were rotated across randomly selected local Craigslist sites every 3 days during the study period.

Participants completed a randomly selected subset of five scenarios (one from each factor) online through SurveyMonkey. Participants could enter their email addresses for a random drawing to win one of several Amazon.com electronic gift cards.

Measures

In addition to questions related to the scenarios (see below) and demographic variables, participants completed the Modified Dental Anxiety Scale (MDAS) (19). The MDAS is a 5-item scale assessing anticipatory anxiety related to different aspects of dental care. Scores range from 5 to 25, with higher scores indicating higher levels of dental anxiety. The MDAS has high internal consistency and good construct validity (20). Demographic variables included questions regarding age in years; gender (male, female, prefer not to say, prefer to self-identify with an open-ended text box); state of primary residence in the United States (selected from a pull-down menu); highest level of education achieved (less than high school; high school/General Education

TABLE 1 | Development phase categories, selected ambiguous dental scenarios, interpretations, and qualitative comments.

Category	Example ambiguous scenario	Interpretations	Select qualitative comments from participants
Interpersonal	The dentist comes into the room, sits down, and looks at your x-rays. While looking at your x-rays, the dentist sighs heavily.	**Positive**: You think the dentist has had a long day and is tired. **Negative**: You think the dentist has seen something concerning on your x-ray.	• "That there [sic] tired and overworked. I work in health care so I know the feeling and I don't read into things to [sic] deeply until the doctor tells me whats [sic] going on." • "I do not understand how to read the xray [sic], so I am concerned." • "I would be highly alerted as to what he may say next. My anxiety would be definitely spike as I await the next sentence to either affirm my worry or concern."
Fear of pain	You are having a cavity filled, and you feel a slight twinge of pain while the dentist is drilling on your tooth.	**Positive**: You think the pain is not that bad; if you feel more pain, the dentist will stop. **Negative**: You think the pain will only get worse until you can't stand it anymore.	• "I don't think that a slight twinge of pain would bother [me] that much, especially if I'm informed by the dentist ahead of time that pain would be normal." • "I would wonder if the dentist screwed up. I would want the pain to go away." • "How do I hold back my fear and anxiety, even though the pain is minimal, it still excites the phobia of more dental pain to come."
Anticipation	You're sitting in the dentist's waiting room before your appointment.	**Positive**: You are thinking about your plans for the day after your appointment is over. **Negative**: You are thinking about how nervous you are about what will happen during the appointment.	• "Usually, I play games on my phone when I am waiting in a doctor's office. I am very calm by the time I am called back to one of the chairs." • "I would think about the procedure. I would hope it goes well." • "I would be extremely nervous and fear would grow. I usually have a lump in my throat and hope that I throw up so I dont [sic] have to go back to see him/her."
Worry	You have noticed a darker spot on one of your back teeth recently, and you bring it up with your dentist. Your dentist says, "I'm sure it's just a stain, I wouldn't worry about it."	**Positive**: You feel reassured; you're glad there's nothing to worry about. **Negative**: You feel dismissed; what if it's actually a serious problem?	• "I would be so relieved. That means nothing is wrong." • "The dentist is probably right. They have a financial incentive to fix issues as they arise." • "Shouldn't this guy be checking the tooth out thoroughly before he/she makes such a brash statement - Does he/she know what he's talking about?"
Medical Catastrophe	Your dentist gives you an injection to make your tooth numb, and you feel your heart rate speed up a little bit.	**Positive**: You think this is a normal feeling that people sometimes have when they are a little nervous, and it will pass. **Negative**: You think you are having an allergic reaction to the numbing solution that will keep getting worse.	• "I start to slowly breathe in and breathe out so that I can slow my heart rate down a bit." • "I've had those shots before and I hate them so I know that they make me anxious and that's what I would assume it was, anxiety." • "I may have been given a large dose, help!"

Development (GED) diploma; Associate's (2-year) degree; some college/university; Bachelor's (4-year) degree; some graduate work; Master's Degree; Doctoral Degree (e.g., PhD, MD, JD or other professional degree); other with an open-ended text box); time since last visit to a dentist (<6 months ago; 6–12 months ago; 1–2 years ago; 2–5 years ago; 5–10 years ago; more than 10 years ago); and reason for most recent dental visit (routine/scheduled treatment (cleaning, examination, filling); emergency (treatment due to pain or injury); other with an open-ended text box).

Participants rated 5 ambiguous scenarios (one for each factor) using several qualitative and quantitative methods, as described below and in the following order.

Qualitative Interpretation

Participants were given a description of a neutral dental scenario and then asked, *"In the following [text] box, and in a sentence or two, please describe what you would think if you were the patient in this situation."* Participants were asked to provide their own interpretation prior to reading any other interpretations to get their unbiased description of the scenario. The qualitative results were used primarily to provide guidance in selecting scenarios for the Testing Phase and are not presented in this article.

Likelihood Likert-Type Rating

Participants were then shown, one at a time, two potential interpretations of the situation, namely one positive and one negative (half of the participants saw the positive interpretation first, the other half had the negative interpretation first). They were asked to indicate how likely they thought each of the two interpretations was on a 4-point Likert-type scale, from 1 = Very Likely to 4 = Very Unlikely.

Likelihood Visual Analog Scale (VAS) Rating

Participants were shown a 100-milimeter horizontal VAS scale with the positive and negative interpretations anchoring either end (see **Table 1** for interpretations), along which they moved a slider to indicate how positive or negative they rated each scenario. The presentation of the positive and negative interpretations on the left side of the VAS (i.e., seen first when reading left-to-right) was counterbalanced across participants.

Prior Experience

For each of the 5 scenarios they read, each participant was asked, "*How often has this situation happened to you in any dental office*?" Responses ranged from 1 (Every Time) to 5 (Never).

Emotional Valence

For each of the 5 scenarios they read, each participant was asked, "*How positive or negative do you feel this situation is*?" Responses ranged from 1 (Very Positive) to 5 (Very Negative).

Testing Phase

Based on the results of the first study, the MoDAIB was reduced from 30 to 20 scenarios; the scenarios that showed the greatest difference in VAS scores between individuals high in dental anxiety (MDAS $\geq$ 19) and the rest of the sample (MDAS $\leq$ 19) were used in the MoDAIB in the Testing Phase. Between November 15, 2019, and April 25, 2020, we recruited participants (adults aged $\geq$ 18) through local Craigslist advertisements using the same recruitment and incentive strategy as in the Development Phase.

The test-retest reliability of the MoDAIB was assessed by giving participants the opportunity to enter their email addresses to be invited to take the survey a second time 2 weeks after completing the survey the first time. Individuals participating twice were given a second opportunity to win one of the gift cards.

Measures

Participants completed 20 items reflecting 20 scenarios (6 Medical Catastrophe, 5 Fear of Pain, 4 Anticipation, 3 Interpersonal, 2 Worry), the MDAS, and a 25-item, 5-factor Comprehensive Dental Anxiety Questionnaire (CDAQ) (16, 18–20). The CDAQ, developed by the authors, contains 25 items taken from other dental anxiety and general anxiety measures across the same five factors (subscales) as the MoDAIB (19, 21–26). Based on unpublished data by the authors, the CDAQ has a strong correlation with the MDAS (r = 0.81). The MDAS and CDAQ were included to assess the content validity of the MoDAIB. Participants were randomized to complete either the MoDAIB first or the MDAS and CDAQ first.

For each MoDAIB item, participants were asked to select which of two interpretations (1 = positive or 2 = negative) they thought was the most likely explanation of the scenario. Scores ranged from 20 to 40, with a higher score indicating more negative interpretations. The presentation order of positive and negative interpretations was counterbalanced across participants.

Statistical Analyses

Development Phase

Demographic data were assessed using descriptive statistics (means, frequencies), correlation coefficients, and chi-square analyses. Independent sample t-tests were used to test differences in means between participants high in dental anxiety (MDAS $\geq$ 19) and those with less dental anxiety (MDAS $\leq$ 18) on their likelihood Likert-type ratings and likelihood VAS ratings. Independent t-tests were also used to test differences in likelihood Likert-type ratings and likelihood VAS ratings for positive and negative scenarios.

Testing Phase

Demographic data were assessed using descriptive statistics (means, frequencies), correlation coefficients, and chi-squared analyses. Independent sample t-tests were used to test differences in means between participants high in dental anxiety and the rest of the sample on the overall MoDAIB. Correlations were computed between the MoDAIB, MDAS, and CDAQ.

Test-Retest Phase

Demographic data were assessed using descriptive statistics (means, frequencies). Correlations were calculated for the MoDAIB, the MDAS, and the CDAQ, comparing scores at Time 1 and Time 2, which were ∼2 weeks apart.

This study and all its phases were reviewed in February 2019 and determined to be exempt from Human Subjects review by the University of Washington Institutional Review Board.

RESULTS

Development Phase

Four hundred and two participants (mean age = 40.0, sd = 14.4, range = 18–85, 65.2% female) completed the survey for the first phase (see **Table 2**). The average MDAS score was 16.6 (sd = 5.6, range 5–25); 171 participants (42.5%) reported high dental anxiety (MDAS ≥ 19). Dental anxiety was not significantly associated with age ($r = -0.005$, $p = 0.93$), gender ($t = 1.77$, $p = 0.08$), or education (F = 1.9, $p = 0.06$). Participants high in dental anxiety were less likely to have seen a dentist within the previous 12 months and more likely to have last seen a dentist for emergency treatment than less anxious participants (p's < *0.05*, see **Table 2**).

Except for one question, there were no significant differences between counterbalanced forms. That is, participants answered all but one question the same whether they were presented with a positive or negative explanation first. Participants only differed in their rating of emotional valence on one scenario based on order effects. Participants were asked how positive or negative they felt the following scenario was: *"The dentist comes into the room, sits down, and looks at your x-rays. While looking at your x-rays, the dentist sighs heavily."* Participants who saw the positive explanation first ("*You think the dentist has had a long day and is tired*") rated this scenario more negatively, that is, higher on the 5-point Likert scale (1 = Very Positive, 5 = Very Negative), than those who saw the negative explanation first ("*You think the dentist has seen something concerning on your x-ray*"; 4.42 (sd = 0.65) vs. 2.43 (sd = 1.12); $t = 7.44$, $p < 0.001$).

TABLE 2 | Characteristics of participants in development phase, testing phase, and test-retest testing sub-sample.

	Development phase	Testing phase	Test-Retest phase
Sample size	402	394	139
Mean (sd) age	40.0 (14.4)	43.2 (14.7)	44.8 (14.1)
Gender (% female)	65.2	57.9	61.7
% with 4-year Bachelor's degree or more	50.3	53.8	55.0
Mean (sd) dental anxiety (MDAS) score	16.6 (5.6)	15.9 (5.6)	13.9 (5.7)
% with high dental anxiety (MDAS ≥ 19)	42.5	38.7	24.6
% with a dental appointment within the previous 12 months	67.6	64.7	69.5
MDAS ≤ 18	75	75.6	72.8
MDAS ≥ 19	58	51	58.8
% whose last dental appointment was emergency	19.5	18.6	15.6
MDAS ≤ 18	14	12.7	15.4
MDAS ≥ 19	25.7	28.5	17.6

Qualitative

Table 1 provides examples of interpretations participants gave before they were given positive or negative interpretations to rate for each scenario. As noted above, the qualitative results were used primarily to provide guidance in selecting scenarios for the Testing Phase, and analyses related to these data are not presented in this article.

Likelihood Likert-Type Rating

The mean likelihood rating for positive interpretations overall was 2.1 (sd = 0.1), while the mean likelihood rating for negative interpretations overall was 2.4 (sd = 0.3; see **Table 3**), suggesting that participants thought the positive interpretations were slightly more likely than the negative interpretations. **Table 3** provides mean ratings by factor.

Except for the Interpersonal scenarios ($t = 0.121$, $p = 0.243$), individuals with high dental anxiety rated positive explanations for the ambiguous scenarios as being significantly *less* likely (p's < 0.05) and negative explanations for the ambiguous scenarios as being significantly *more* likely than participants lower in dental anxiety (p's < 0.05).

VAS Ratings

The mean VAS rating across all factors was 44.0 (sd = 8.0). Individuals high in dental anxiety rated negative scenarios as more likely across all types of scenarios significantly more often than individuals lower in dental anxiety as evidenced by significantly higher VAS ratings between those high in dental anxiety and lower in dental anxiety (p's < 0.01; see **Figure 1** for VAS ratings).

Prior Experience

Across all scenarios, individuals high in dental anxiety were less likely to report the scenario had happened to them in any dental office compared to participants lower in dental anxiety (p's < 0.01).

Emotional Valence

Except for the Worry scenarios ($t = 1.7$, $p = 0.09$), participants high in dental anxiety rated all other scenarios as significantly more negative compared to those lower in dental anxiety (p's < 0.05).

Testing Phase

In the Testing Phase (data from the test-retest subsample are presented separately below), 394 adults (mean age = 43.2 years, sd = 14.7, range = 18–78; 57.9% female) completed the survey (see **Tables 2**, **4**). Results of the Testing Phase do not include

TABLE 3 | Development phase mean values for 5 scenarios included in each factor.

	Positive likely Likert ***(1 = Very Likely to 4 = Very Unlikely)***	**Negative likely Likert** ***(1 = Very Likely to 4 = Very Unlikely)***	**Likelihood VAS** ***(1–100; Higher score = negative interpretation more likely)***	**Experience** ***(1 = Every Time to 5 = Never)***	**Valence** ***(1 = Very Positive to 5 = Very Negative)***
	Mean (sd)	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**	**Mean (sd)**
Overall	**2.1 (0.1)**	**2.4 (0.3)**	**44.0 (8.0)**	**3.3 (0.5)**	**3.5 (0.2)**
Interpersonal	2.3 (0.5)	2.3 (0.6)	51.1 (17.4)	3.8 (0.4)	3.6 (0.4)
Fear of Pain	2.0 (0.6)	2.1 (0.3)	49.8 (8.3)	2.9 (0.3)	3.5 (0.4)
Anticipation	2.0 (0.4)	2.5 (0.5)	41.5 (16.4)	2.7 (0.8)	3.2 (0.4)
Worry	2.0 (0.5)	2.3 (0.3)	46.3 (10.2)	3.8 (0.6)	3.6 (0.3)
Medical Catastrophe	2.0 (0.2)	3.0 (0.1)	31.4 (5.7)	3.4 (0.6)	3.5 (0.2)

The bold values indicate the correlations between the corresponding subscales on the MoDAIB and the CDAQ (e.g., the correlation between the CDAQ Interpersonal and MoDAIB Interpersonal scales is 0.37).

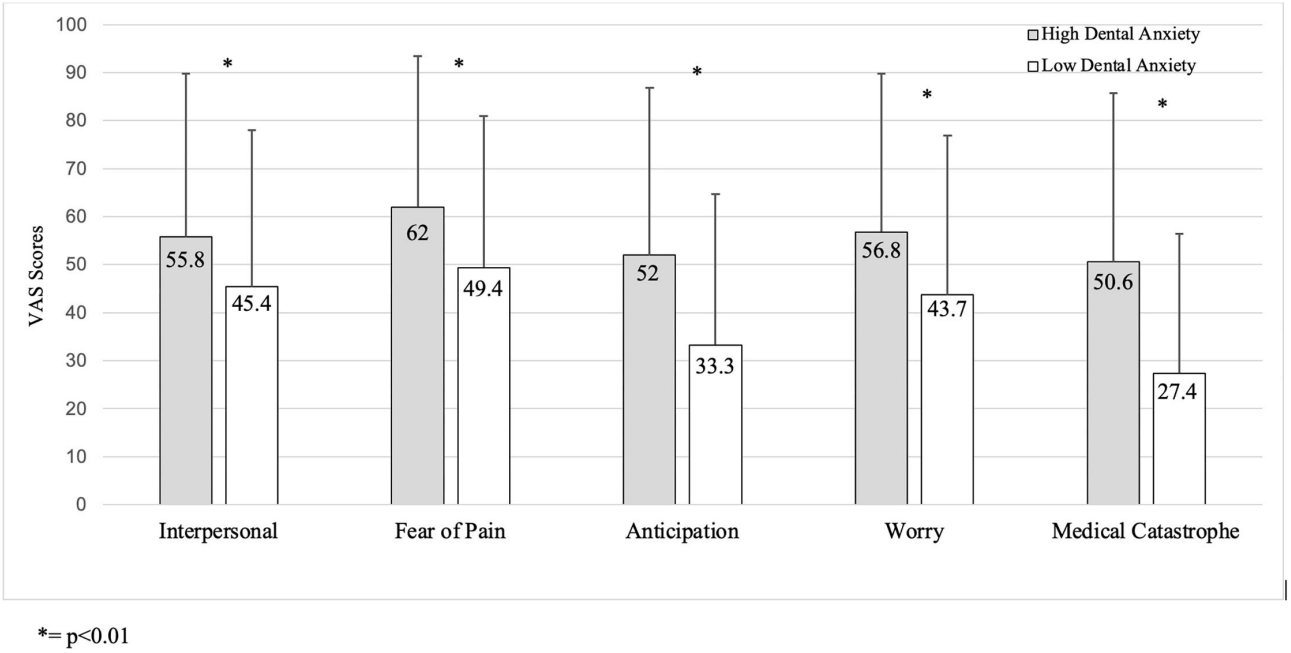

FIGURE 1 | VAS ratings by MDAS dental anxiety scores from Development Phase (higher scores indicate more negative interpretation).

those for the Test-Retest Phase ($N = 139$), presented below. The average MDAS score was 15.9 (sd = 5.6, range 5–25). One hundred and forty-four participants (38.7%) reported high dental anxiety (MDAS $\geq$ 19). Participants identifying as female reported higher MDAS scores (mean = 16.6, sd = 5.4) than those identifying as male (mean = 14.8, sd = 6.1; $t = 2.8$, $p < 0.01$). There was no correlation between dental anxiety and age ($r = 0.024$, $p = 0.647$). Participants high in dental anxiety were less likely to have seen a dentist within the previous 12 months and more likely to have last seen a dentist for emergency treatment than less anxious participants (p's < 0.001, see **Table 2**).

The mean MoDAIB score was 27.1 (sd = 5.1, range 20–40). Participants high in dental anxiety scored significantly higher on the MoDAIB (mean = 31.1, sd = 4.5) than the rest of the sample (mean = 24.8, sd = 3.8; $t = 14.0$, $p < 0.001$) (**Figure 2**). The MoDAIB was significantly and positively correlated with the MDAS ($r = 0.68$, $p < 0.001$) and the CDAQ ($r = 0.80$, $p < 0.001$). The MoDAIB factors and corresponding CDAQ factors were significantly and positively correlated with one another (p's < 0.001; see **Table 5**).

Test-Retest Phase

One hundred and thirty-nine participants (mean age = 44.8, sd = 14.1, range = 21–78; see **Table 2**) completed two administrations of the survey, an average of 14.1 days apart (sd = 6.6, range = 14–35 days). Those who completed the survey twice were 54.5%

TABLE 4 | The Measure of Dental Anxiety Interpretational Bias (MoDAIB).

			Interpretation	
Item	**Factor**	**Stem**	**Positive (score = 1)**	**Negative (score = 2)**
1	Fear of Pain	You're having a cavity filled, and you feel a slight twinge of pain while the dentist is drilling on your tooth. You think the pain…	…is not that bad; if you feel more pain, the dentist will stop.	...will only get worse until you can't stand it anymore.
2	Anticipation	You're sitting in the dentist's waiting room before your appointment. You are thinking about...	…your plans for the day after your appointment is over.	…how nervous you are about what will happen during the appointment.
3	Medical Catastrophe	Your dentist gives you an injection to make your tooth numb, and you feel your heart rate speed up a little bit. You think...	...this is a normal feeling that people sometimes have when they are a little nervous, and it will pass.	...you are having an allergic reaction to the numbing solution that will keep getting worse.
4	Fear of Pain	Before sitting in the dental chair, you see an injection needle on a tray that will be used to get your tooth numb before the procedure. You think...	...you will be glad to be numb and not feel anything during the procedure.	...you are afraid that the injection will hurt.
5	Anticipation	You walk into the room with the dental chair and see a tray with a napkin draped over it. You think...	...the tray is being kept clean by the napkin so the instruments don't get dirty.	...the tray is full of scary-looking instruments the dentist doesn't want you to see.
6	Medical Catastrophe	You are sitting in the dental chair, waiting for the procedure to start. You feel a slight sensation of "butterflies" in your stomach. You think...	...you are feeling a little nervous, which is very normal. The feeling will pass soon enough.	...you will keep feeling more and more nauseated until you become sick during treatment.
7	Interpersonal	You are having a dental procedure done, and the dentist says something to the assistant that you couldn't quite hear. The assistant asks, "Could you repeat that?" You think...	...the assistant also couldn't hear what was said and was asking the dentist to repeat what was said.	...the assistant was questioning what the dentist wanted to do during your procedure.
8	Medical Catastrophe	When examining your teeth, your dentist gently touches the back of your throat, causing you to gag briefly. You think...	...this is a normal reaction that sometimes happens to you.	...you will not be able to tolerate any treatment because you gag easily during dental treatment.
9	Interpersonal	You are running late for your dental appointment and call the front desk to let them know you're on your way. The receptionist says, "We'll see you soon" and quickly hangs up the phone. You think...	...the receptionist is busy with many calls and needs to get off the phone quickly.	...the receptionist is annoyed that you'll be late and may tell the dental staff to rush through your treatment.
10	Fear of Pain	Your dentist tells you your tooth will be numbed before the procedure starts. You think...	...you will be glad to be numb and not feel anything during the procedure.	...the numbing will not work and you will feel the entire procedure.
11	Anticipation	After cleaning your teeth, the hygienist steps out of the room to get the dentist to examine your teeth. While waiting for the dentist to come in, you think…	...that the appointment is almost over and you'll be leaving soon.	...about all of the problems the dentist might find in your mouth.
12	Medical Catastrophe	Your dentist is getting ready to fix your tooth, and says they would like to use a rubber dam ("raincoat") during the procedure. You think...	...using the rubber dam will keep your tooth dry and help the procedure go faster.	...using the rubber dam will make it so you can't breathe during the procedure.
13	Fear of Pain	You're having your teeth cleaned, and it seems that the hygienist is having to scrape your teeth more than usual to get them clean. You think that...	...after the appointment, your teeth will feel nice and clean.	...after the appointment, your mouth will be very sore.
14	Anticipation	You are sitting in the dental chair, waiting for the dentist to come in and start fixing your tooth. You think...	...about all of the things that could go wrong during the procedure.	...you will be glad when your tooth is fixed and you don't have to think about it anymore.

(Continued)

TABLE 4 | Continued

			Interpretation	
Item	**Factor**	**Stem**	**Positive (score = 1)**	**Negative (score = 2)**
15	Worry	You are standing at the front desk, scheduling your next dental appointment. The front desk staff member pulls up your record on the computer and looks surprised. You think...	...the front office member heard someone else in the office say something unexpected.	...the front office member knows something terrible about your record that you should be worried about.
16	Medical Catastrophe	The hygienist is using an instrument to clean your teeth that sprays water. You can feel some water building up at the back of your throat. You think...	...you can raise your hand to signal to the hygienist that you need to swallow.	...you will not be able to stop the procedure to swallow and will end up choking on the water.
17	Interpersonal	You are having your regular dental cleaning, when the hygienist introduces you to a new dentist in the practice who will examine your teeth today. You think...	...you will probably like this dentist as much as the one you've been seeing.	...you are not being given any choice as to which dentist you see.
18	Fear of Pain	During your dental treatment, you need to keep your mouth open for a longer time than you have for other dental appointments. You think...	...you will be glad to rest your jaw when the appointment is over.	...your jaw will be very sore after the appointment.
19	Worry	Your dentist is giving you an injection to numb your tooth, and you swallow a bit of the bitter-tasting anesthetic. You think...	...this is such a small amount of solution, it won't make a difference.	...this solution tastes really bitter, and will definitely make you sick.
20	Medical Catastrophe	During your dental appointment, you feel yourself breathing more quickly than usual. You think...	...you need to focus on slowing your breathing down, and you'll be fine.	...your breathing will continue to get faster until you have a panic attack.

of those invited to retake the survey (139 of 255), and 35.3% of the 394 who participated in the first administration of the survey.

At Time 2, the mean MoDAIB score was 25.9 (sd = 5.0, range 20–40). As in Time 1, participants high in dental anxiety scored significantly higher (mean = 31.3, sd = 4.1) on the MoDAIB than those low in dental anxiety (mean = 24.0, sd = 3.8; $t = 9.5$, $p < 0.001$). The test-retest reliability of the MoDAIB (e.g., the correlation between the Time 1 and Time 2 administrations) was 0.89 ($p < 0.0001$). This was similar to the test-retest reliability indices of the MDAS (0.88, $p < 0.0001$) and the CDAQ (0.95, $p < 0.0001$). The MoDAIB was significantly correlated with both other measures both at Time 1 (r's between 0.68 and 0.88, p's < 0.0001) and Time 2 (r's between 0.75 and 0.81, p's < 0.0001), suggesting a high level of content validity for the MoDAIB.

DISCUSSION

To our knowledge, this is the first set of studies to investigate interpretational bias in dental anxiety and to develop a measure of this bias. We found that individuals high in dental anxiety interpreted ambiguous dental scenarios more negatively than individuals low in dental anxiety. We also found that this dental interpretational bias can be reliably assessed using a 20-item measure, and that this measure correlates highly with previously validated measures of dental anxiety.

While some evidence exists that dental anxiety can be caused by aversive dental experiences (3, 4), there is also evidence that a person's cognitions play a key role in maintaining dental anxiety (27, 28). The dental setting presents ambiguous and uncertain situations for many patients, and patients can easily differ from one another in how they interpret the same situation. In the Development phase, we determined which scenarios produced the greatest difference in positive/negative VAS ratings between those with high dental anxiety and the rest of the sample for inclusion in the MoDAIB. We began with six scenarios in each of the five factors. Interestingly, while most or all the Medical Catastrophe (6 of 6), Fear of Pain (5), and Anticipation (4) scenarios were retained, only 3 Interpersonal and 2 Worry scenarios were kept for the MoDAIB. Scenarios related to Medical Catastrophe and Fear of Pain address physical sensations, both painful and non-painful, experienced during dental treatment. Similarly, Anticipation scenarios reflect looking ahead to such physical and possibly painful sensations, such as sitting in the waiting room or in the dental chair before dental treatment begins. Meanwhile, Interpersonal and Worry scenarios may reflect less imminent or less threatening issues, such as the front office staff member being annoyed at a patient arriving late.

Individuals with high levels of dental anxiety anticipate dental treatment to be more painful than those low in dental anxiety (29, 30), and there is evidence that individuals are more anxious about dental procedures they have not yet experienced (31, 32). In

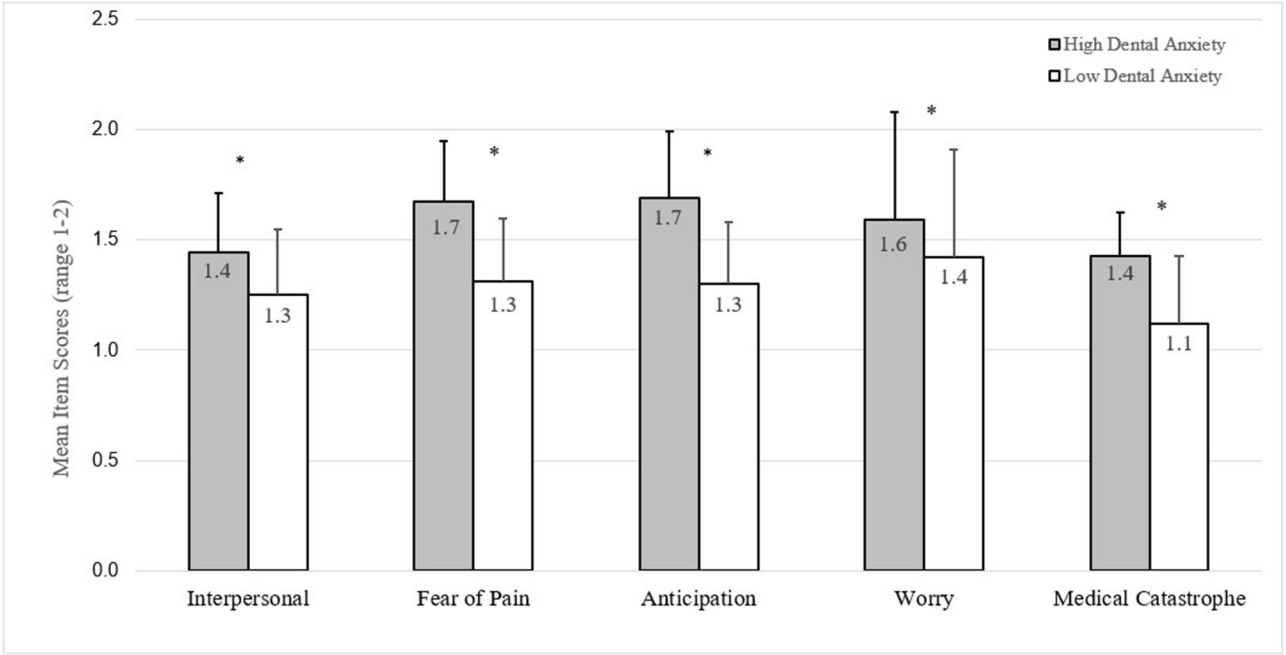

FIGURE 2 | MoDAIB scenario type mean scores by high and low dental anxiety (Testing Phase).

TABLE 5 | Correlations between MoDAIB and CDAQ factors.

		MoDAIB factors				
		Interpersonal	**Fear of Pain**	**Anticipation**	**Worry**	**Medical Catastrophe**
CDAQ factors	Interpersonal	**0.37****	0.42**	0.45**	0.39**	0.40**
	Fear of Pain	0.28**	**0.56****	0.54**	0.36**	0.44**
	Anticipation	0.40**	0.56**	**0.70****	0.41**	0.56**
	Worry	0.44**	0.59**	0.66**	**0.46****	0.69**
	Medical Catastrophe	0.32**	0.64**	0.57**	0.39**	**0.73****

***p < 0.001.*

our sample, individuals with high dental anxiety were less likely to report that they had experienced the scenarios than were other participants. MoDAIB scenarios representing painful and non-painful physical sensations may be at the same time less familiar but also more relevant to dentally anxious individuals.

Cognitive-behavioral interventions can be designed to modify a person's negative interpretations in the context of dentistry (the "cognitive" in "cognitive-behavioral") (33). The therapeutic strategy known as Cognitive Bias Modification (CBM), is a way of "modifying bias in information processing" (34), and aims to change a person's bias toward threatening situations, thereby reducing their anxiety. In a meta-analysis of CBM for social anxiety disorder, Liu and colleagues found a greater effect for interpretational bias than for attentional bias (35).

Findings from our study do not allow us to make generalized statements regarding the interpretation style of all individuals with high levels of dental anxiety, and interventions for dental anxiety should be tailored in each case to account for individual differences in the experience of dental anxiety. As a part of a screening, the MoDAIB can give the dental team important knowledge of how their particular patient interprets the dental setting. If a patient scores highly on the MoDAIB, it can tell the dentist that this patient is more likely than not to interpret ambiguous situations negatively, which may further exacerbate their dental anxiety and impede treatment progress. Patients with a more negative interpretational bias (as measured by a high MoDAIB score) may benefit from more explicit communication from the dental team about the proposed treatments and

what the patients can expect during procedures as far as physical sensations.

Limitations

Although individuals were recruited from across the United States using Craigslist and oversampled for individuals high in dental anxiety to have geographic diversity and a large range of participants with dental anxiety, this study relied on a self-selected sample of individuals whose responses may not represent a random national sample. Compared to the larger Testing sample, individuals who returned to complete the survey as part of the Test-Retest sample had lower mean MDAS scores, were less likely to be categorized to have high dental anxiety, were more likely to have had a dental appointment in the previous 12 months, and were less likely to have sought emergency care at their most recent dental appointment. These differences between the Testing and Test-Retest groups limit the generalizability of the results and call for more extensive validation of the MoDAIB. The Craigslist advertisements appeared in the sites based in large U.S. cities, which may not have reached as many individuals in more rural areas. Due to an unfortunate and unintentional omission during data collection, we did not collect data on race or ethnicity from our participants, so we are not able to determine how representative our sample is from that perspective. As there were fewer interpretational differences between dentally anxious and less anxious participants for Interpersonal and Worry scenarios than for other factors, it may be beneficial to develop different scenarios for these two factors that better discriminate between dentally anxious and less anxious individuals.

Future Directions

Our results clearly show that individuals in our study with high dental anxiety reported more negative interpretations of ambiguous dental situations than those with low or no dental anxiety. Additional validation work should be done with the MoDAIB with more diverse general and clinical samples. Going forward, the MoDAIB may be used as part of a larger intervention designed to modify the interpretations of individuals with high dental anxiety. CBM has been shown to reduce anxiety, at least in part by modifying individuals' negative interpretations of situations (34–36). If highly anxious individuals are able to change their negative interpretations of ambiguous dental situations, their overall dental anxiety may be reduced, and communication with the dental team may be improved.

CONCLUSIONS

Individuals who have high levels of dental anxiety are more likely to interpret ambiguous dental scenarios in a negative way compared to individuals with lower levels of dental anxiety. Prior therapeutic interventions for dental anxiety do not typically emphasize how individuals interpret commonly experienced dental situations, and evidence for this dental interpretational bias suggests potentially fruitful and exciting new avenues for therapeutic interventions for dental anxiety.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the University of Washington Institutional Review Board. Written proof of informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

LJH contributed to the conception and design of the study, performed data collection and interpretation, drafted, and revised the manuscript. BGL and DSR contributed to the conception and design of the study, data interpretation, critical review, and revision of the manuscript. All authors contributed to the article and approved the submitted version.

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