Integrating multi-survey data into an ontological model of dental-care related fear and anxiety

Elena Milivinti[1,*], Finn Wilson[1,2], Ram A. N. R. Challa[3,4], Olga S. Ensz[2], Brenda Heaton[5], Astha Singhal[2], Michelle Cooper[2], Jiahang Yu[2], Emily Sardzinski[6], Daniel W. McNeil[2], William D. Duncan[2], and Alexander D. Diehl[3]

1 *Department of Philosophy, University at Buffalo, NY, USA.*
2 *Department of Community Dentistry and Behavioral Science, University of Florida, Gainesville, FL, USA*
3 *Department of Biomedical Informatics, University at Buffalo, Buffalo, NY, USA*
4 *Department of Family Medicine and Community Health, University of Wisconsin-Madison, Madison, WI, USA*
5 *School of Dentistry, University of Utah, Salt Lake City, UT, USA*
6 *University of South Florida Sarasota-Manatee, Sarasota, FL, USA*

Abstract

Dental care-related fear and anxiety (DFA) affects a significant proportion of people worldwide, leading to treatment avoidance, delayed care, and poor oral health outcomes. However, current assessment tools and clinical practices conflate fear and anxiety as interchangeable constructs, despite their distinct psychological and temporal characteristics. We extend the Oral Health and Disease Ontology (OHD) to represent dental-care related fear and anxiety, structured around the behavioral, physiological, and temporal dimensions of DFA. The ontology integrates data from multiple DFA studies such as the ADA Oral Health and Well-Being study, the Center for Oral Health Research in Appalachia (COHRA) studies, and the Black Women's Health Study. We analyze the questions from multiple DFA surveys by whether their answers are about dental care-related fear or anxiety occurring before a dental encounter, encompassing pre-appointment anxiety and anticipatory concerns, during a dental encounter, including in-office experiences (waiting room, examination, procedures), or after a dental encounter, covering post-treatment recovery and lingering anxieties. This temporal framework allows for a more nuanced understanding of how DFA evolves throughout the patient journey. We rely on temporal relationships such as '*precedes*', '*occurs during*', or '*follows*' to specify the relation of emotional and cognitive responses to the dental visit. Determining whether a survey item corresponds to dental care-related fear or anxiety involves mapping each item and determining whether the dental stimulus is distal or proximal to the dental encounter. The ontology will enable clinicians and researchers to identify specific triggering factors for individual patients and implement personalized interventions, moving to evidence-based, targeted treatment strategies that improve patient outcomes and reduce dental care avoidance.

Keywords

Dental Fear, Dental Anxiety, Dental Care-Related Fear and Anxiety, DFA, Ontology, Oral Health

1. Introduction

Dental care-related fear and anxiety (DFA) represents one of the most significant barriers to oral healthcare access and quality [1]. It results in delayed preventive care, avoidance of treatment, and deteriorating oral health outcomes [2]. Despite the research into dental-related psychological distress, current clinical assessment and intervention approaches remain constrained by fundamental conceptual ambiguities [3]. This conceptual murkiness arises in part from the insufficient differentiation between two related but often distinct phenomena. While dental fear and dental anxiety represent distinct

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* Corresponding author.
emilivin@buffalo.edu (E. Milivinti)
0009-0008-1739-5105 (E. Milivinti)

psychological responses [4], researchers and clinicians use the terms loosely and frequently consider them to be overlapping phenomena [5,6], thereby obscuring their distinct characteristics and clinical implications [7].

Fear represents an immediate emotional response to present or imminent threats, characterized by acute physiological activation and behavioral responses to specific, identifiable stimuli [8]. Anxiety involves anticipatory apprehension about future events, manifesting as persistent worry and tension about potential threats that may or may not materialize [9]. In the dental context, dental care-related fear manifests as an immediate negative emotional and physiological response to present dental care-related stimuli [10]. Patients experiencing it typically exhibit activation of the central amygdala [11, 12] and various physiological responses [7] in response to specific triggers such as the sight or sound [13] of dental equipment, physical sensations during procedures [14], or the clinical environment itself. These responses are temporally bound to the presence of triggering stimuli [15] and generally subside when stimuli are removed [16]. These stimulus-response patterns include reactions to several categories of dental and other fear-evoking stimuli [17]. Auditory triggers include drill-related sound stimuli [13], specifically the high-pitched noise of dental drills and dental suction sounds. Visual stimuli encompass drill-related visual stimuli, like the sight of the dental drill, and injection-related stimuli, such as the sight of the needle. Tactile stimuli include injection-related sensations [18] and the tactile sensation of instruments in the mouth. Additional stimuli include bright procedural lighting and olfactory triggers such as the distinctive smell of dental materials and antiseptics that create characteristic dental environments.

Dental care-related anxiety is characterized by its future-oriented nature [9] and its occurrence in advance of, and sometimes following, dental encounters. Patients experiencing it may begin worrying days, weeks, or even months before a scheduled appointment, engaging in rumination about possible negative outcomes, pain, or loss of control. This anticipatory cognitive pattern manifests in survey questions that assess appointment cancellation behaviors, postponement of necessary dental care, and avoidance of scheduling dental visits entirely.

Dental care-related anxiety can also manifest in post-appointment phases [19], particularly following negative dental experiences [20], where patients worry about treatment outcomes, potential complications, or future dental needs. These post-treatment anxieties often reinforce anticipatory patterns, creating a cycle where negative experiences fuel future pre-appointment anxiety and avoidance behaviors. Research [21] has further established connections between dental anxiety and broader traumatic experiences, suggesting that patients with histories of potentially traumatic events may be particularly susceptible to developing persistent post-treatment anxieties and outcome-focused worry patterns. The temporal extension of anxiety beyond the immediate dental encounter distinguishes it from stimulus-response fear and suggests the need for a different intervention approach [22]. However, current dental anxiety assessment tools predominantly focus on pre-appointment and procedural fears, with limited attention to post-treatment anxiety patterns. The absence of standardized survey questions specifically addressing outcome-focused worries, treatment efficacy concerns, and post-visit rumination represents a significant gap.

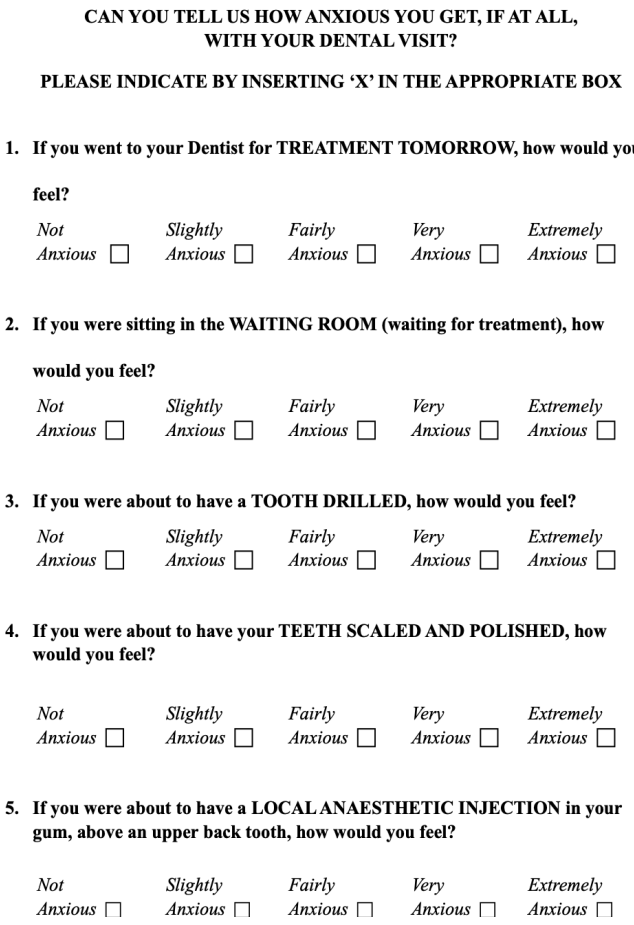
Our goal in this work is to create an ontology for representing dental-care related fear and anxiety, structured around its behavioral, physiological, cognitive, and temporal dimensions. Our work thus far has integrated data from the Center for Oral Health Research in Appalachia (COHRA) [23], ADA Oral Health and Well-Being in the United States [24], and the Black Women's Health study [25]. Except for the ADA Oral Health and Well-Being study, these studies use well-established DFA assessment instruments, including the Dental Anxiety Scale (DAS) [26], the Dental Fear Survey (DFS) [28], the Modified Dental Anxiety Scale (MDAS) [29], and the Index of Dental Anxiety and Fear (IDAF-4C+) [30].

These surveys and assessment instruments capture diverse aspects of DFA from various population groups, and the multifaceted nature of fear and anxiety. We analyze the survey questions to determine whether their answers are about dental fear or anxiety occurring before a dental encounter (encompassing pre-appointment anxiety and anticipatory concerns), during a dental encounter (including in-office experiences such as in the waiting room, during an examination or procedures), or after a dental encounter (covering post-treatment recovery and lingering anxieties).

2. Methods

We build upon the Oral Health and Disease Ontology (OHD) to provide standardized representation of dental fear and anxiety self-report assessment instruments. The OHD is a domain-level ontology for representing the diagnosis and treatment of dental maladies [27]. We expand it by supplementing it with terms related to dental fear and anxiety, along with instruments used to measure these phenomena and stimuli that can instigate them.

The established DFA instruments we analyzed include the DFS, a comprehensive 20-item instrument assessing multiple dimensions including avoidance behaviors, physiological arousal, and dental stimuli and situations. We also examined the MDAS, a 5-item scale measuring anxiety levels associated with different aspects of dental treatment, from appointment scheduling to specific procedures. Figure 1 displays some questions appearing in MDAS. The IDAF-4C+ provided a multidimensional instrument reflecting some cognitive, emotional, physiological, and behavioral components of dental anxiety and fear. Figure 2 displays some IDAF-4C+ questions. Additionally, we analyzed the DAS, a 4-item instrument assessing general anxiety levels.



CAN YOU TELL US HOW ANXIOUS YOU GET, IF AT ALL, WITH YOUR DENTAL VISIT?

PLEASE INDICATE BY INSERTING 'X' IN THE APPROPRIATE BOX

1. **If you went to your Dentist for TREATMENT TOMORROW, how would you feel?**

   Not Anxious ☐ *Slightly Anxious* ☐ *Fairly Anxious* ☐ *Very Anxious* ☐ *Extremely Anxious* ☐

2. **If you were sitting in the WAITING ROOM (waiting for treatment), how would you feel?**

   Not Anxious ☐ *Slightly Anxious* ☐ *Fairly Anxious* ☐ *Very Anxious* ☐ *Extremely Anxious* ☐

3. **If you were about to have a TOOTH DRILLED, how would you feel?**

   Not Anxious ☐ *Slightly Anxious* ☐ *Fairly Anxious* ☐ *Very Anxious* ☐ *Extremely Anxious* ☐

4. **If you were about to have your TEETH SCALED AND POLISHED, how would you feel?**

   Not Anxious ☐ *Slightly Anxious* ☐ *Fairly Anxious* ☐ *Very Anxious* ☐ *Extremely Anxious* ☐

5. **If you were about to have a LOCAL ANAESTHETIC INJECTION in your gum, above an upper back tooth, how would you feel?**

   Not Anxious ☐ *Slightly Anxious* ☐ *Fairly Anxious* ☐ *Very Anxious* ☐ *Extremely Anxious* ☐

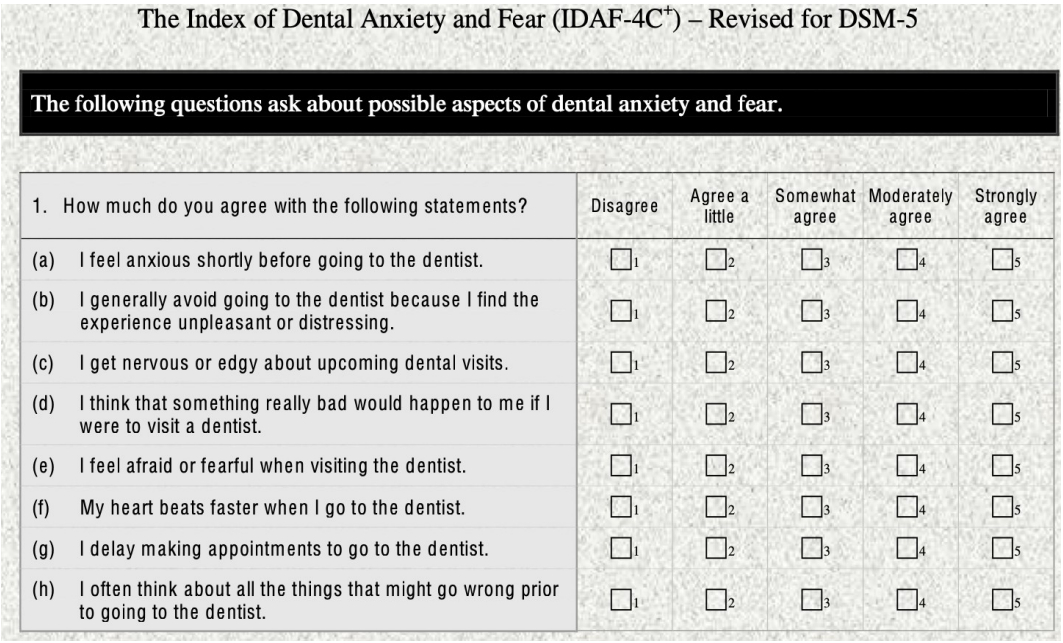
Figure 1. Sample items from the Modified Dental Anxiety Scale (MDAS)

Our ontology development has been informed by real-world datasets, including COHRA data [23], which provide rich contextual information about dental anxiety and fear patterns in underserved populations, and ADA clinical datasets that offer standardized dental procedural and diagnostic codes [24]. These datasets present a unique challenge for semantic integration due to their heterogeneous data structures, varying terminologies, and population-specific characteristics. The COHRA dataset's focus on Appalachian communities revealed culturally-specific expressions of dental anxiety, while the ADA datasets needed integration with psychological assessment terminologies.

This multi-instrument and multi-dataset approach is necessary to develop an ontology that can capture the full spectrum of how dental fear and anxiety is conceptualized, measured, and documented across different clinical and research contexts. The instruments' varying focus areas, spanning general concerns versus specific procedural stimuli and physiological versus behavioral responses, as well as their diverse data characteristics, informed our decisions about class hierarchies, property relationships, and the granularity needed for representing different dental care-related fear and anxiety subtypes within the ontological framework.

Several key ontological modeling decisions drove the selection and analysis of these specific assessment instruments. The temporal factor emerged as critically important from survey questions such as "If you went to your Dentist for treatment TOMORROW, how would you feel?" (Question 1, MDAS) This indicated that dental care-related anxiety is not a static trait but a dynamic state that varies

with temporal proximity to treatment.



The Index of Dental Anxiety and Fear (IDAF-4C+) – Revised for DSM-5

The following questions ask about possible aspects of dental anxiety and fear.

1. How much do you agree with the following statements?	Disagree	Agree a little	Somewhat agree	Moderately agree	Strongly agree
(a) I feel anxious shortly before going to the dentist.	☐1	☐2	☐3	☐4	☐5
(b) I generally avoid going to the dentist because I find the experience unpleasant or distressing.	☐1	☐2	☐3	☐4	☐5
(c) I get nervous or edgy about upcoming dental visits.	☐1	☐2	☐3	☐4	☐5
(d) I think that something really bad would happen to me if I were to visit a dentist.	☐1	☐2	☐3	☐4	☐5
(e) I feel afraid or fearful when visiting the dentist.	☐1	☐2	☐3	☐4	☐5
(f) My heart beats faster when I go to the dentist.	☐1	☐2	☐3	☐4	☐5
(g) I delay making appointments to go to the dentist.	☐1	☐2	☐3	☐4	☐5
(h) I often think about all the things that might go wrong prior to going to the dentist.	☐1	☐2	☐3	☐4	☐5

Figure 2. Sample of IDAF-4C+ dental fear and anxiety questions.

Our ontology building process followed standard methodologies, utilizing spreadsheets for initial conceptual mapping and Protégé [31] for formal ontology construction and validation. We employed a systematic approach to identify and import relevant existing ontologies through established repositories including the Ontology Lookup Service (OLS) [32] , Bioportal [33] , and Ontobee [34] . These platforms enabled comprehensive searches across biomedical and health-related ontologies to identify potentially relevant terminologies and conceptual frameworks.

The ontology development incorporated both top-down and bottom-up approaches to ensure comprehensive coverage of the dental fear and anxiety domain. The top-down methodology involved importing established terms and conceptual hierarchies from existing ontologies [35] that contained relevant dental, psychological, or health-related terminology. This approach provided foundational structure and ensured alignment with established biomedical vocabularies and classification systems.

Complementing this top-down approach, we implemented a bottom-up methodology that extracted concepts directly from the survey questions and data dictionaries of our selected datasets. This bottom-up analysis was essential for capturing domain-specific nuances and terminology that emerged from the actual measurement instruments and research contexts. By analyzing the specific language, constructs, and conceptual relationships present in the Dental Fear Survey (DFS), Modified Dental Anxiety Scale (MDAS), Index of Dental Anxiety and Fear (IDAF-4C+), and the Dental Anxiety Scale (DAS) we ensured that our ontology accurately represented how dental fear and anxiety are operationalized and measured in clinical and research practice.

3. Results

Our framework addresses the distinction between dental fear and anxiety, building on Park et al. [32] characterization of their distinct temporal characteristics and clinical manifestations through a formal approach. This differentiation provides a foundation for targeted intervention strategies and improved

outcome prediction by establishing clear criteria for identifying when patients experience immediate fear responses versus anticipatory anxiety patterns.

The framework aims to resolve three critical gaps in current research: the widespread conflation of fear and anxiety, the absence of systematic categorization for dental stimuli, and the lack of formal semantic representation for diverse assessment methodologies. Our framework provides formal definitions, hierarchical stimulus taxonomies, temporal relationship modeling, and standardized assessment instrument representation within a unified ontological structure.

Clinical research [8] in both animals and humans has distinguished fear as a phasic response to specific, imminent stimuli and anxiety as a more sustained state elicited by less predictable, distant, or potential threats. The APA defines anxiety as a future-oriented, long-acting response broadly focused on diffuse threats, while fear represents a present-oriented, short-lived response to clearly identifiable and specific threats [37]. Based on this established distinction, we operationalize fear and anxiety as temporally distinct constructs, potentially with different intervention implications.

Fear: An emotion process responding to present or imminent stimuli, characterized by physiological arousal and behavioral activation in response to a currently perceived threat.

Anxiety: An emotion process consisting of anticipatory apprehension about future events or situations, characterized by persistent worry, catastrophizing, and uneasiness about potential future threats.

Terms like ‘emotion process’, ‘fear’, and ‘anxiety’ appear in the Emotion Ontology (MFOEM) [38]. We are considering using MFOEM classes for these more general, non-dental-specific classes, though there is a risk in adopting some of its more controversial theoretical stances, such as its commitment to the appraisal theory of emotion.

Building upon these two foundational definitions, we provide formal definitions for dental fear and dental anxiety that capture the domain-specific manifestations of these emotional responses:

Dental Care-Related Fear: Fear triggered by stimuli in the immediate dental care environment, including behavioral responses such as avoidance and physiological responses such as muscle tension and increased heart rate.

Dental Care-Related Anxiety: Anxiety experienced in relation to future dental encounters, characterized by cognitive responses such as worry.

3.1 Dental Visit Stimulus Hierarchy

Dental fear and anxiety can be instigated by various stimuli, and questionnaires frequently ask about these stimuli, making them important to model in our ontology. However, there is also a risk of potential redundancy in modelling both stimuli and perceptions, despite these being different phenomena. This is because the same fear response can be represented as being the result of some stimulus or the perception of that stimulus. For example, a patient's elevated heart rate could be triggered either by the actual sound of a dental drill or by their perception that the drill sound indicates impending pain. Due to this, we continue to iterate on our stimulus hierarchy in the ontology to avoid this redundancy in usage. Using a systematic approach, we categorize the stimuli present in dental encounters that serve as potential triggers for fear or anxiety responses [9-13], as displayed in Table 1. These stimuli maintain a hierarchical structure reflecting the taxonomic relationships in our ontological framework, enabling precise identification of specific triggers and their relationships to broader stimulus categories.

Table 1
Stimulus categories and associated survey questions

Stimulus Category	Examples	Survey Questions Mapped
Instrument	Dental tools and equipment	Needles or injections (IDAF-4C+ 3.h)
Auditory	Drill sounds, suction noises	Hearing the drill (DFS 17)
Visual	Needle sight, dental instruments	Seeing the dentist walk in (DFS 13) Seeing the anesthetic needle (DFS 14) Seeing the drill (DFS 16)
Tactile	Injection sensation, instrument contact	Feeling the needle injected (DFS 15)
		Feeling the vibrations of the drill (DFS 18)
		Having your teeth cleaned (DFS 19)
Olfactory	Dental material odors, antiseptics	The smell of the dentist's office (DFS 12)
Environmental	Clinical Setting, Lighting	Being seated in the dental chair (DFS 11)

The survey questions were adapted from the Dental Fear Survey (DFS) and the Index of Dental Anxiety and Fear (IDAF-4C+), which served as starting points for developing our hierarchy. Although the Modified Dental Anxiety Scale (MDAS) also includes items addressing specific stimuli - such as "If you were about to have a TOOTH DRILLED, how would you feel?"- we chose to prioritize items from the DFS and IDAF-4C+ for clarity and consistency in our hierarchical design.

Building upon the stimulus-related questions in the surveys, we developed a hierarchical categorization of the different stimuli that can trigger fear or anxiety in patients during a dental encounter, as displayed in Table 2. These stimuli are subclasses of what we refer to as 'sensory inputs', which are distinct from more subjective, first-person experiences. Instead, this class describes more objective phenomena, processes which instigate experiences but are not themselves the experiences.

Table 2
Stimulus categorization

Stimulus	Definition
Dental Visit Stimulus	A sensory input experienced by a patient during a dental encounter.
Dental Instrument-Related Stimulus	A sensory input experienced by a patient that is caused by instruments used during a dental procedure. Examples include drill, dental scaler, dental probe, and dental suction-related stimuli.
Dental Visit Visual Visual	A visual input experienced by a patient during a healthcare encounter. Examples include observation of blood, bright lights, and needles.

Dental Visit Sound Stimulus	An auditory input experienced during a dental procedure. Examples include the sound of equipment, such as a drill.
Dental Visit Smell Stimulus	An olfactory input experienced by a patient during a dental procedure. Examples include the smell of dental materials and cleaning products.
Dental Visit Smell Stimulus	A gustatory input experienced by a patient during a dental procedure. Examples include the taste of mouthwash, blood, and tooth polish.
Dental Visit Tactile Stimulus	A touch-related sensory input experienced by a patient during a dental procedure. Examples include the feeling of a needle injection, drilling, or scraping.

By distinguishing between general categories (e.g., "dental instrument-related stimulus") and specific instances (e.g., "drill-related sound stimulus"), we provide a foundation for evidence-based interventions by establishing a standardized vocabulary for identifying, measuring, and targeting specific triggers. Once the triggering factor has been identified, it becomes possible to offer patients tailored solutions that directly address their specific concerns, moving from generic anxiety management to personalized interventions that enable successful dental treatment completion.

3.2 Axiomatization of Survey Question Relationships

Our ontological framework formalizes the relationships between survey questions and their underlying psychological constructs through a system of axioms that specify temporal relationships, behavioral manifestations, and measurement targets. This axiomatization enables a precise mapping of assessment items to their corresponding fear or anxiety dimensions.

We use temporal relationships to establish the relationship between patient behaviors/responses and their distance from dental care processes. Fear responses are characterized by proximal temporal relationships (occurring during or immediately adjacent to dental procedures), while anxiety responses are characterized by distal temporal relationships (occurring at temporal distance from dental procedures). Classes are bolded, relations are italicized, and quantifiers are in Roboto font.

(Pre-Visit Anxiety Manifestation Axioms):

dental appointment delay *precedes* some **dental encounter**

dental appointment delay *is marker for* some **dental anxiety**

These axioms establish that dental appointment delay behaviors occur before a dental encounter and indicate the presence of dental anxiety rather than immediate fear responses.

(During-Visit Fear Response General Class Axiom):

physiological arousal and *occurs during* some **dental encounter** and *triggered by* some **dental stimulus** SubClassOf *is marker for* some **dental fear**

Physiological arousal occurring during dental care processes in response to specific stimuli indicates fear rather than anxiety.

3.3 Behavioral Classification Pattern

Our ontological framework establishes a comprehensive classification system that differentiates dental anxiety from fear through an integrated behavioral and physiological pattern. This approach combines temporal relationships, physiological responses, and diagnostic indicators within a single conceptual framework that supports consistent interpretation across different assessment instruments and clinical contexts. The framework operates on the principle that the timing, nature and manifestation of patient responses provide diagnostic indicators for distinguishing between dental care-related fear and anxiety.

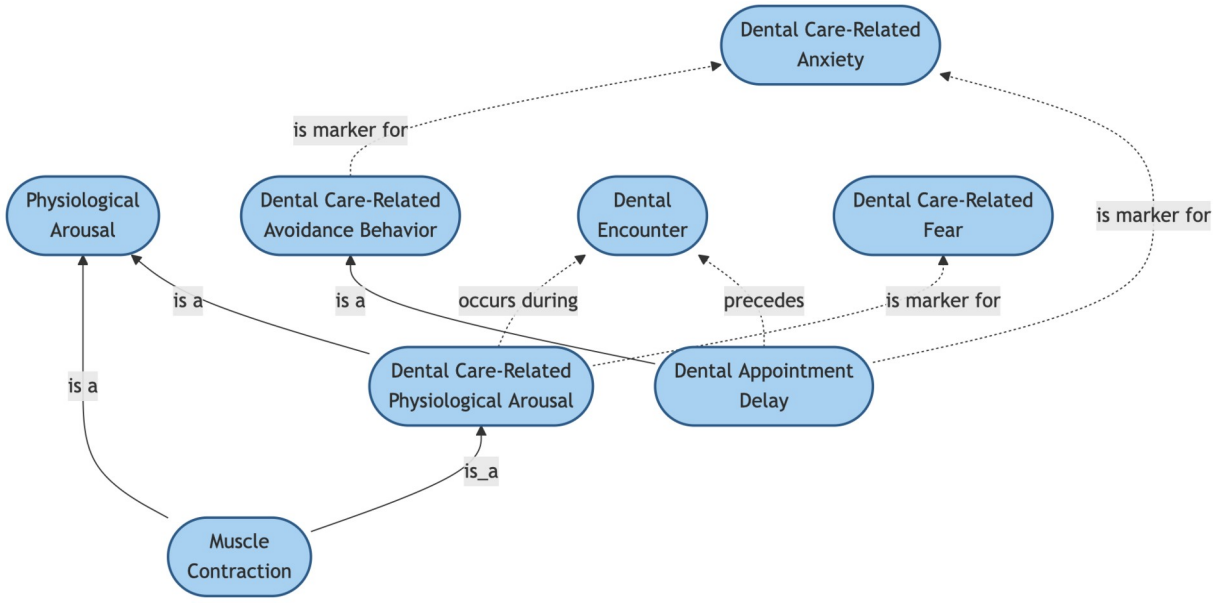


Figure 3: Ontology Pattern for representing relationship between dental care-related fear and physiological responses. The nodes represent instances to the type described by the node labels.

The pattern combines both distal avoidance behaviours and proximal physiological responses within a single ontological structure. The pattern differentiates between two primary response categories:

1. Distal Avoidance Behavior Component

   The pattern incorporates the temporal precedence relationship where dental encounters precede dental appointment delays and avoidance behaviors. This creates a diagnostic framework where prior negative dental experiences trigger future avoidance patterns. Consider Sarah, an adult who had a traumatic root canal experience six months ago. She now postpones routine cleaning appointments for months, citing "scheduling conflicts" when actually experiencing anticipatory dread. The avoidance behaviors serve as markers for dental care-related anxiety, establishing that:

   - Temporal precedence: Avoidance behaviors occur as anticipatory responses before future dental encounters, representing anxiety-driven attempts to prevent future distress..
   - Diagnostic indication: Pre-encounter avoidance behaviors indicate dental care-related

anxiety, supporting the theoretical distinction that anxiety involves anticipatory distress about future events.

2. Proximal Physiological Response Component

The pattern captures immediate physiological responses that occur during dental encounters. When Sarah finally attends her rescheduled appointment, she exhibits muscle contractions in her jaw and shoulders, perspiration, and tension upon entering the office. The physiological arousal component demonstrates:

- Temporal concurrence: dental care-related physiological arousal responses occur during the dental encounter, making them immediate reactions to present stimuli.
- Diagnostic indication: The physiological response indicates dental care-related fear, supporting the theoretical distinction that fear involves immediate emotional and physiological activation in response to present threats.

This unified pattern creates a comprehensive diagnostic framework that captures the full spectrum of dental care-related distress through temporal differentiation, multi-modal assessment capabilities, hierarchical classification, and predictive relationships. The framework distinguishes between anticipatory responses (anxiety-related) and concurrent responses (fear-related) based on their temporal relationship to dental encounters, while simultaneously integrating both behavioral and physiological indicators to provide multiple assessment pathways for clinicians to identify and classify patient distress.

3.4 Assessment Instrument Representation in the Oral Health and Disease Ontology

The OHD provides foundational classes for representing assessment methodologies through two primary components: the dental fear assessment instrument class (OHD_0008008) and the dental fear assessment instrument answer class (OHD_0008012). These classes establish the structural foundation for representing the diverse array of DFA measurement tools analyzed in our study, including the Kleinknecht Dental Fear Survey (DFS), Modified Dental Anxiety Scale (MDAS), Index of Dental Anxiety and Fear (IDAF-4C+), and Corah's Dental Anxiety Scale (DAS).

Questions in DFA studies are often drawn from questions in DFA assessment instruments. For example, the first question used in the COHRA2 study is taken from DFS question 1: "Has fear of dental work ever caused you to put off making an appointment?" This presents modelling questions about whether to include a specific study, such as COHRA2, into OHD. We decided that such studies were better shared to the research community as data schemas, since their primary purpose is to collect and analyze data. To accomplish this, we have employed a hybrid approach using Linked Data Modelling Language (LinkML) to describe the data model [39]. We defined the schemas of study questions in a yaml file, and using LinkML we generated the schema in other formats, such as OWL and JSON, along with documentation for the schema.

4. Discussion

A primary advantage of our ontology is its capacity to harmonize data from different research contexts. Dental fear and anxiety research has been constrained by heterogeneous assessment instruments and measurement approaches. By annotating data with ontological terms, researchers gain access to sophisticated querying capabilities that transcend the limitations of traditional databases.

Our work reveals significant gaps in the clinical treatment of dental care-related fear and anxiety. While we used existing survey instruments as a foundation for our ontological modeling, we found deficiencies such as a lack of questions addressing post-treatment anxiety [19]. We are confident that our approach can substantially improve upon current assessment methods and provide a comprehensive framework for understanding the full spectrum of patient experiences.

A philosophically interesting case we encountered involves how to temporally relate dental cancellations to future appointments, which might never occur. Intuitively, we might expect that dental appointment cancellations precede some dental appointments. However, a patient may cancel an appointment and never attend (or schedule) another one. This would result in an axiom asserting that dental appointment cancellations precede some dental appointments turning out to sometimes be false. We considered several approaches to address this modeling challenge.

One option would be to instantiate the cancelled dental appointment as an actual instance of dental appointment which the cancellation precedes. However, this would involve treating events that never happen as real events, a stance which is difficult to justify in any realist ontology [40].

Another potential option would involve instead treating the cancelled appointment as an Information Content Entity (ICE). The cancellation would be a process which takes this appointment information as an input, and its output would be a change of this information, say by removing it from a clinical calendar. This option would not temporally relate the cancellation to the appointment, rather it involves a change of information which is about some future commitment. The major downside of this option is that it adds another sense of 'appointment' to the ontology; they can either be events or information. This adds a layer of complexity which users would have to be mindful of, say when querying delayed appointments.

Yet another option might be to pun the dental encounter class so it can also be queried as an individual. This way, supposing a cancellation occurs and no true instance of appointment ever occurs, the class 'dental encounter' nonetheless exists in the ontology, and this class can be punned to be treated as an individual. We could then say the cancellation precedes the dental encounter class punned as an individual. This option would be overly complicated and difficult to understand for most users, though it may be a helpful option for savvy users who are familiar with punning.

Instead of referring to temporal relations at all, one might instead add an axiom which asserts that a dental appointment cancellation is marker for dental care-related anxiety. This axiom would work fine to relate appointment cancellations to anxiety, though it does not make use of any temporal semantics which might be helpful to users.

Given the unique clinical significance of appointment avoidance behaviors in dental anxiety, we adopted a hybrid approach that balances ontological rigor with clinical utility. We assert that dental appointment cancellation 'only' precedes some dental encounter. This axiom handles situations in which no future encounter occurs (trivially), since it does not assert that there is some future dental encounter that the cancellation precedes. This axiom restricts users to asserting temporal relationships only for dental cancellations, limiting them to preceding dental encounters rather than other event types. We also highlight that this option can be done in conjunction with the previous option. Users can simultaneously include this precedes relation for dental cancellations while also inferring they are markers for dental care-related anxiety. Our solution reflects the reality of dental care-related anxiety, where appointment delays and cancellations are not merely inconveniences but represent symptoms that require ontological modeling. We think that this option can accommodate this domain-specific challenge while maintaining philosophical consistency.

Declaration of Generative AI

The author(s) have not employed any Generative AI tools.

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