ABSTRACT

DARRAH, JENNA ROSE. Brush Up on Knowledge: Oral Health Behavior is More Important Than You Think (Under the direction of Dr. Douglas J. Gillan).

The goal of this study was to determine the structure of participants' oral health knowledge by developing Pathfinder networks from their relatedness judgments of oral health concepts. Participants rated the relatedness of thirteen common dental terms in all possible pairs, which was compared to their responses made on an oral health behavior questionnaire. The results from the Pathfinder network analysis revealed a connection between oral health knowledge and positive oral health behaviors, including flossing and brushing as recommended by dentists. Previous work shows there is a large gap in recommendations by dentists and actual compliance of these behaviors, but the reasoning behind this gap is unclear. This study shows that individuals who have more dental knowledge appear to perform preventative oral health behaviors more regularly, so promoting the importance of regular dental behavior performance to the public may be effective in improving behavior.

Brush Up on Knowledge: Oral Health Behavior is More Important Than You Think

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BIOGRAPHY

Jenna Rose Darrah was born in Pittsburgh, Pennsylvania where she was the youngest of three to Douglas C. and Cynthia L. Darrah. Jenna earned her B.S. in Psychology in 2015 from Clemson University, and enrolled in the Human Factors and Applied Cognition program the following fall, working under the direction of Dr. Douglas Gillan.

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INTRODUCTION

Research on health-relevant behaviors indicate that people fail to comply with health directives at a high rate -- approximately 40% overall, with a rate as high as 70% when the behavior involves changing a person's lifestyle or modifying existing habits (Martin, Williams, Haskard, & DiMatteo, 2005). Failure to comply creates unintended risks for the well-being of the individual, as well as a massive financial burden on the individual and society as a whole. Avoidable healthcare costs of between $100 to $300 billion have been attributed to nonadherence in the U.S. annually, equal to 3 - 10% of the total costs for health care in the U.S. (Iuga & McGuire, 2014).

Very high noncompliance rates can also be observed with dental health. Noncompliance rates worsen markedly with symptom-free patients (Jimmy & Jose, 2011). With regard to preventive dental health, college-age students typically fall into this symptom-free category for gum disease and other oral health issues that do not reveal damage until later on in life. College-age students are a population who runs a high risk of developing gum disease, but do not currently show any symptoms (Becker & Maiman, 1980). Three key attributes influence patient compliance: (1) patients believe they are susceptible to the oral disease, (2) patients believe the risk poses severe consequences to their health, and (3) patients believe treatment will be beneficial (Yu, 2013). During the teenage and young adult years, many individuals may believe that none of these three attributes are true -- an "it won't happen to me" attitude. A study of college-aged students revealed that approximately one-quarter of these students were not brushing the recommended twice daily, and only 28.1% of students reported flossing daily (Luebke & Driskell, 2010). Additionally, in 2013, only 42% of the U.S. population reported having a dental visit (Meyerhoefer, Panovska, & Manski, 2016). These results show strikingly

low compliance rates, and, therefore, demonstrate that Americans are not practicing preventive behaviors to the degree that they should be. An article in the U.S. News (2016) explains the importance of flossing, because it removes food particles that promote bacteria growth that leads to inflammation and gum disease. These bacteria can build-up, producing plaque, which hardens into tartar. Tartar wears away at gums and bone, and can eventually cause tooth loss. The effects of plaque build-up during a crucial period of developmental growth can result in negative consequences for those who neglect to perform regular brushing and flossing. Duong Nguyen, a member of the CDC's Epidemic Intelligence Service (EIS), expresses in this article that his study shows that flossing education needs to be increased, and the long run benefits of flossing can prevent tooth decay and loss (U.S. News, 2016). Many studies have demonstrated the importance of complying with periodontal maintenance to improve oral hygiene, reduce the progression of periodontitis, and the enhance the integrity of teeth (Lee, Huang, Sun, & Karimbux, 2015).

Essentially, the take-home message is that practicing preventive behavior now will have a significant impact on future oral health. However, a critical issue in health behavior is getting people to understand and comply with that notion. This statement, taken together with the information presented above, begs the question: Why are there such low adherence rates related to performing simple preventive dental behaviors? Is there a lack of knowledge among the public concerning these oral health behaviors? The previous literature clearly highlights the current lack of adherence rates that starkly contrast with the data on the importance of these behaviors, particularly flossing and brushing.

Nudelman & Ivanova (2018) determined that frequency of performance of health behaviors is positively correlated with perceived importance. In light of these considerations, the present exploratory study investigated the relation between people's oral health knowledge, both

declarative and procedural, and their rates of compliance with regard to general dental behaviors, such as flossing and brushing. Perhaps there is something about a person's knowledge and perceived importance of performing dental behaviors that correlates to a better performance rate. Mental models of participants oral health beliefs were constructed using Pathfinder networks to create a representation of individual's knowledge of dental terms. The advantage of using Pathfinder networks is that prominent relationships between concepts are extracted (Chen, 1998). These Pathfinder networks were then used to compare to the responses from participants regarding their perceived importance and overall compliance of the main crucial dental behaviors: Brushing, flossing, using mouthwash, and receiving regular check-ups. The hypothesis underlying this research was that greater knowledge would result in a more highly structured network, because specific concepts would be perceived appropriately as interconnected, whereas others would only be distantly connected (e.g., Furlough & Gillan, 2018). Dental health is largely influenced by an individual's personal performance habits, so understanding how to improve those habits is crucial for increasing compliance rates. This understanding of an individual's knowledge and perceived importance of these behaviors may provide insight about the reasoning behind why some individuals more regularly perform dental behaviors.

METHOD

Design

This study was conducted as a single experiment in a laboratory setting, beginning with a demographics questionnaire and dental knowledge survey, followed by a computer-based knowledge assessment task. All participants received the same questionnaire/survey and task set. Accordingly, participants' oral health behaviors were measured through the survey, and their

dental knowledge was measured by ratings of relatedness between different pairs of dental terms (see Table 1). Accordingly, the present study was a quasi-experiment in that variables were not manipulated to produce different oral health knowledge, but their existing knowledge was measured. This helped to determine the connections between different dental terms that may indicate relationships that users associate with good dental behaviors and compliance.

Demographic Variables

Participants were asked to respond to a demographics questionnaire, responding as they felt comfortable. The variables collected were age, gender, ethnicity, and how many years of college they have completed.

Self-Reported Dental Behaviors

In addition to the demographics questions, participants were asked to self-report the incidence of various dental behaviors that they perform. This included brushing frequency, flossing frequency, and mouthwash frequency, all gauged on a scale from never to twice per day. Additional questions asked were number of cavities the individual has had, which, if any, dental devices that used to have or currently have, how regularly they receive check-ups, and whether there is a history of gum disease in their family. These questions can be found in Appendix A.

Concept Ratings

The participants performed a relatedness rating task that involved a trial presenting two dental terms from a pre-generated list of thirteen words (see Table 1). These terms were selected using the ADA's glossary of dental terms (2012), by picking out common terms and behaviors that would be generally understood. Two of the terms were randomly generated from the list and presented together, until all combinations were exhausted, for a total of 78 relatedness

judgments. In order to perform a rating, participants were presented a numerical scale from one, which was "not at all related", to seven, or "extremely related".

Table 1. List of Dental Terms Used in Relatedness Ratings

Dental Terms
Brushing
Flossing
Cavities
Gum Disease
Dentist
Orthodontist
Fluoride
Root canal
Tooth cleaning
Plaque
Tooth Decay
Pulp
Mouthwash

Participants

Participants were 50 North Carolina State University students ranging in age from 17 to 29 years old, who were recruited from the North Carolina State University SONA System. This participant pool was recruited from students taking introduction to Psychology courses, and received course research credit for participating. There were no restrictions with regard to ethnicity or race for this study. A G*Power analysis was performed under the assumption of a regression analysis because one of the major analyses is the prediction of oral health behaviors from aspects of the Pathfinder networks. Assuming a medium effect (Cohen's F=.30), and the α=.05 significance level, it was determined that a sample size of 46 participants were required for this study to achieve appropriate statistical power (power= .95). Accordingly, the collected sample size exceeded the required participant number.

Procedure

Upon arrival in the laboratory, participants were instructed to sit in front of a 27-inch, 2015 model Apple desktop computer, where the entire duration of the experiment took place. They first read and verbally consented to the informed consent form. Participants were then asked to direct their attention to the computer screen, which displayed the questionnaire regarding their demographic information, as well as the survey questions regarding their dental health behaviors. Once they completed the questionnaire/survey, they continued to the second part of the experiment, in which they were shown two dental-related terms on the computer screen, and were asked to rate the similarity of the two terms on the seven-point scale described above. The pairs of terms for each participant were generated in a random order, so no participant saw the same sequence of pairs. Once the participant entered the appropriate relatedness rating, the program automatically moved to the next comparison in which two more terms were generated for comparison. This process was repeated until the program had generated every combination of two terms once, for a total of 78 relatedness ratings.

The study concluded once the participant completed all sets of comparison ratings. The participants were offered to view the matrix representation of their relatedness ratings if they desired. The entire study lasted approximately 20 to 30 minutes.

Collecting Data

SurveyMonkey (January 2, 2018) was used in the laboratory for participants to answer survey questions to collect their self-reported oral health behaviors; traditional demographic questions were also evaluated during this time (Appendix A). In order to assess dental knowledge for each participant, participants' relatedness ratings were analyzed using the Pathfinder network algorithm, which produced a network in which the oral health concepts are

represented as nodes, with and relatedness ratings used to determine the links that connect the nodes (Chen, 1998). This collection of nodes and links represent how individuals gauge relationships between concepts (Harary, 1969). The Pathfinder algorithm is based on mathematical graph theory; the algorithm eliminates links that are not on the shortest path between all pairs of nodes in a network consisting of the shortest paths between nodes (see Dearholt & Schvaneveldt, 1990). The algorithm uses two parameters: (1) q, which limits the number of indirect relatedness ratings used in producing a network and varies from 2 to n – 1 (where n is the number of nodes) and (2) r which determines the metric used in computing the path lengths, and varies from 1 to infinity. The minimum span network is produced with $q = n - 1$ and $r =$ infinity. Pathfinder networks based on concepts have been shown to predict cognitive performance (Cooke, Durso, & Schvaneveldt 1986; Cooke, 1992), to be related to amount of experience with on-line games (Furlough & Gillan, 2018), to aid in the construction of hypertext systems (McDonald, Paap, & McDonald, 1990), to investigate cognitive changes produced by metaphors (Gilman & Gillan, 2001), and to relate to student performance in classes (Goldsmith, Johnson, and Acton, 1991) among a wide variety of other applications of the method.

Statistical Analyses

Relatedness ratings for the Pathfinder network were carried out in JRate (2006), a Java program that collects pairwise relatedness ratings. The JPathfinder (Interlink Inc., 2017) program was utilized for the analysis of this data, which was used for statistical computing and graphing, and created visual output representations of the data. The JPathfinder program takes all of the individual judgment ratings and uses the Pathfinder algorithm to determine relationships from the individual's knowledge organization and present them in visual and statistical form

(Stevenson, Shah, & Bish, 2016). An example of a Pathfinder network visual output model can be found in Figure 1.
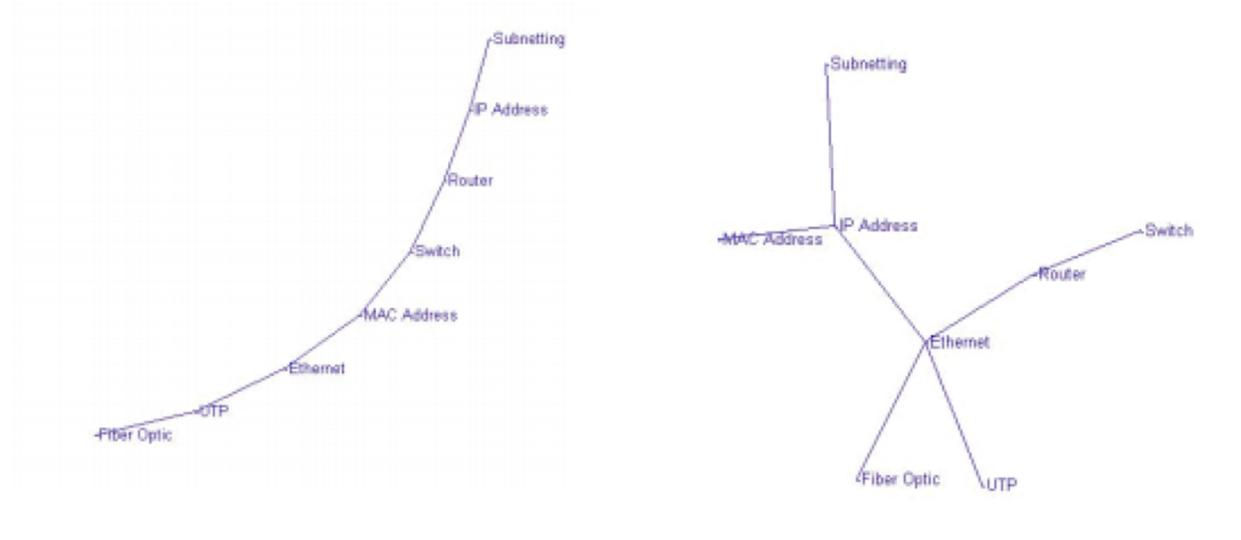

Figure 1. Example Pathfinder network analysis (DiCerbo, 2007).

The networks from each participant's relatedness ratings were derived using JPathfinder with the parameters *q* and *r* set to n-1 and infinity, respectively, thereby producing the minimal Pathfinder network. In addition to a network for each individual participant, Pathfinder networks were derived that combined the results from participants grouped into different oral health compliance categories.

The Pathfinder networks were analyzed in several ways. The first method to analyze the data was to simply look at the way the networks were structured. If the resulting network is a chain structure, as seen as the left network in Figure 1, the network simply contains a single path from one term to the next term, with a single term directly linking another. In contrast, the network on the right in Figure 1 shows a branched web of connections, which is more complex to interpret. This branching network shows how the concepts are interconnected, with the central

node, "Ethernet", toward the center, which has several connections stemming from it. Looking within the network, there may be specific key terms that are at the central nodes, and therefore have more connections among the concepts that need to be present for other nodes to connect. Central nodes are important to determine because, as concepts with many links, they may represent an individual's perception of the most important concepts in the network.

Participant responses to the questionnaire were categorized into two groups, high and low compliance, for each behavioral question. These questions included frequency of brushing, flossing, and mouthwash. If the participant responded on the upper half of the response options, which included twice daily, once daily, every other day, or a few times per week; they were considered to be in the high compliance group. Responses of less frequency were placed into the low compliance category. For the check-ups questions, responses were placed into the high performance group if they reported regular check-ups every few months, every six months, or once per year. The remaining responses were regarded as low compliance. All participants reported brushing their teeth once or twice daily, and were therefore not classified into a high or low grouping. These splits were made to determine the various differences that existed between high and low compliance of these fundamental dental behaviors.

Coherence and similarity ratings were calculated for the networks derived for the high and low performance groups for each oral health behavior. Coherence measures the consistency of the data in the network (Dunlap & Grabinger, 2001) and relates to expertise in a topic area (e.g., Schvaneveldt, Durso, & Dearholt, 1988). For the coherence measure, a higher value indicates greater consistency between the rated relatedness and the relatedness in the network based on the relationship of the concepts. Similarity is a means for comparing different

Pathfinder networks and is based on the proportion of shared links between those two networks (Goldsmith & Davenport, 1990).

Responses from the oral health survey were further analyzed. For the floss, brush, and mouthwash frequency questions, responses were coded from 0 to 7, with 0 representing "never" and 7 representing "twice daily". The question regarding how often the individual received regular dental check-ups was numbered in a similar manner, from 0 to 4. The reasoning for this categorization was to display and quantify the results in a manner that participants responses could be directly compared. Each participant's values for the four oral health behaviors were summed producing a total maximum compliance score of 25. Once these values were totaled, participants were separated into quartiles by this overall compliance score, and a Pathfinder network was generated for each quartile. Participants in the low compliance category (n=14) had an overall score from 10 to 13, the next lowest grouping (n=14) was from 14 to 16, third grouping (n=10) was a score of 17 or 18, and the highest compliance group (n=12) had overall compliance scores ranging from 19 to 22.

RESULTS

The Pathfinder networks for the groupings based on oral health behaviors were used in interpreting the structure of participants' knowledge about oral health behavior. Because of the nature of this exploratory study, the results are generally presented in a qualitative fashion. The general structure of each individual participant's Pathfinder network was branched, as opposed to chained, and somewhat complicated, with anywhere from one to four central nodes that acted as the basis for each of the networks.

Central Nodes

Central nodes can be defined as any node that contains at least three links, and is not part of a subnetwork (Furlough & Gillan, 2018). The central nodes for each grouping of participants was extracted from the output data provided in JRate, as well as by looking at the resulting Pathfinder network. The participants placed into the low floss compliance group (n=27) had two central nodes, dentist and tooth cleaning. The complementary high floss compliance group (n=23) also contained the same two central nodes, dentist and tooth cleaning, with an additional central node for cavities. The high mouthwash compliance group (n= 21) had several more central nodes than its low counterpart (n=29). The high group's nodes included dentist, tooth cleaning, and cavities, while the low group only had two central nodes at dentist and tooth cleaning. There were no differences between the high and low check-up networks, both having two central nodes for the concepts dentist and tooth cleaning. Looking at the four overall dental compliance, or frequency of performance, categories, the high compliance group had the most central nodes. All four compliance groups shared three central nodes in common: brushing, dentist, and tooth cleaning. Both the low and high compliance groups also had cavities as a central node. The medium-high group had flossing as a fourth central node. The high compliance group uniquely had plaque as a fifth central node. The resulting network for each group can be found in Figures 2a through 2d, beginning with high compliance. The four networks all produced a branched configuration.
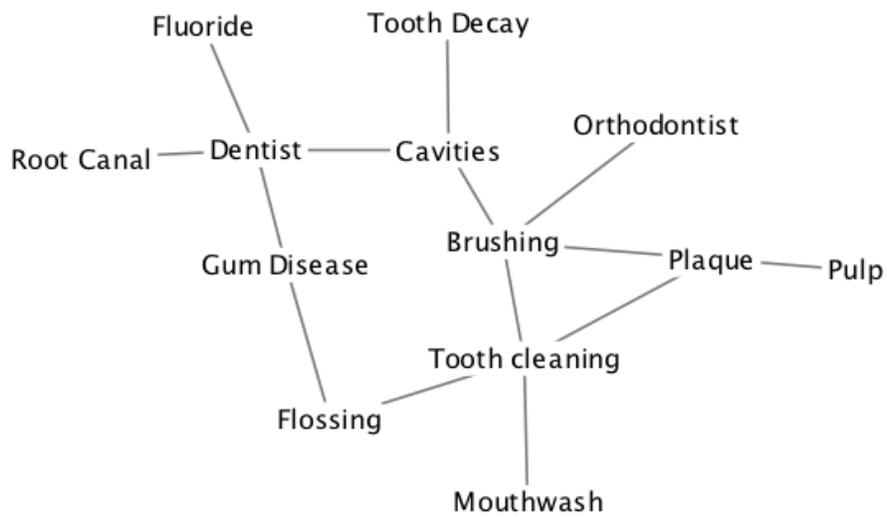
Figure 2a. Network representation of oral health concepts for the high overall oral health behaviors group.

Figure 2b. Network representation of oral health concepts for the medium-high overall oral health behaviors group.

Figure 2c. Network representation of oral health concepts for the medium-low overall

oral health behaviors group.

Figure 2d. Network representation of oral health concepts for the low overall oral health

behaviors group.

Coherence

A Mann-Whitney U test for coherence showed no significant difference across low and

high groups for any of the individual critical dental behaviors. The high floss group had a higher

coherence rate than its corresponding low compliance group, .672 and .488, respectively. Similar findings were shown for using mouthwash, with the high group showing a coherence rating of .692 and the low group at .432. The two check-up groups had very similar coherence ratings, .565 for high and .612 for low. Brushing was not considered due to the lack of variability in responses.

The overall compliance groups showed consistently increasing coherence with increasing performance. From low to high, the coherence values were .345, .585, .605, and .703, respectively (see Table 2). A Mann- Whitney U test reveals the high compliance group had a significantly higher coherence than the overall low compliance group ($U=39$, $p=.02$).There were no significant differences comparing any other combination of groups.

Table 2. Coherence Ratings Among Each Overall Compliance Behavior Group.

Group	Coherence
Low	0.345
Medium Low	0.585
Medium High	0.605
High	0.703

Similarity

Similarity was considered for each individual behavior between the low and high groups, and all comparisons showed moderate similarity. The similarity of the four overall compliance score groupings were also calculated. Individual similarities were compared between two groups at a time, and all comparisons revealed a similarity score at or below .5. There does not appear to be a consistent trend between lower and higher compliance groups with regard to their similarity between networks. The results can be summarized in Table 3.

Table 3. Similarity Ratings Among Each Overall Compliance Behavior Group.

	Low	Med Low	Med High
Medium Low	0.5		
Medium High	0.45	0.43	
High	0.5	0.4	0.36

DISCUSSION

The results reveal that although different performance groups of participants may have networks with almost equal complexity, their structures differ to a degree. For instance, the fact that all four overall compliance groups show three central nodes in common (dentist, brushing, tooth cleaning), reveals that there is some common baseline knowledge that all individuals are aware of regarding the importance of brushing their teeth and visiting the dentist for regular maintenance and prevention. It is interesting that both the low and high groups have cavities in a central position, whereas in the two medium groups, there is only a single link to cavities. The high compliance group had a fifth central node at plaque, which is a second negative health outcome in addition to cavities. Perhaps both high and low compliance individuals focus more on the negative outcomes of oral health than the intermediates, but the high group focuses on prevention through regular, positive oral health behaviors, while the low compliance group may understand the issues but are not directly affected, and therefore do not take proper action. In addition to this, more central nodes may explain the underlying reason for why the overall high compliance group had a more intricate mental model, which is in line with Bradley et al.'s (2006) explanation that experts have more highly constructed mental models than those with less experience. The higher complexity emphasizes more structure in their knowledge of various dental concepts, a finding supported by Furlough and Gillan (2018). Because the individual oral

health behavior compliance scores are all compiled into the overall compliance scores, only the overall groupings are discussed below.

The differences within the networks, as well as the differences in coherence among the networks suggest that the different groups based on the oral health behaviors may have different mental models concerning oral health. The coherence values reveal that the higher compliance groups had more uniformity in their relatedness of concepts. The relatively low similarity values determined between the four overall compliance groups uncovers that the groups differ with regard to their network structures, and therefore showed a low correspondence with neighboring networks. Further support for the higher intricacy of the higher compliance groups is shown by the overall mean number of links for each group. There is a clear trend that increasing overall compliance correlates with more links, and therefore a higher level of interconnectedness.

The results of this study show that individuals with more knowledge in the dental realm perform dental behaviors more regularly, and therefore may have a higher perceived importance of these behaviors. It is imperative to spread awareness of the importance of performing these preventative behaviors, to help decrease the incidence of dental issues later in life. This finding could have a successful impact if we utilize social media and other far-reaching platforms to promote good dental behaviors. Social media is quickly becoming a popular tool for health promotion due to its large reach and has been shown to correlate with behavior change (Korda & Itani, 2013). Perhaps the missing link between perceived importance of a concept and taking action is the motivational step, which could be promoted through social media outlets that engulf our everyday lives. If there is some relationship found, these results can help design a new elicitation method to promote flossing and brushing behaviors.

LIMITATIONS AND FUTURE DIRECTIONS

One pertinent limitation is that the population studied included a narrow age range. It may be the case that young adults do not fully value the importance of good oral health because they have yet to experience the effects of prolonged poor oral compliance, such as gum disease and tooth decay. Another limitation was the particular design of this study, because the focus was on conceptual knowledge as opposed to skilled behavior. Although some of the concepts used here are related to procedures (e.g., flossing), this type of analysis doesn't reveal a person's knowledge of the performance of that task. The Pathfinder networks derived in this study provided information about the set of relations among concepts, but not the specific nature of the relations or the directionality. In addition, the present results cannot reveal whether individuals who know more comply better, or if individuals comply better because they know more. With this in mind, future work could be directed at determining the causal relations between oral health behaviors and oral health knowledge. The present study aimed at observing mental models in the dental context, but future research could be aimed at generalizing the findings here to other areas, as well as other age groups.

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APPENDIX

Appendix A

Demographic Questionnaire and Dental Knowledge Survey

1. How often do you floss?
____ Twice daily
____ Once daily
____ Every other day
____ A few times per week
____ Once per week
____ Once per month
____ Almost never
____ Never

2. How often do you brush your teeth?
____ Twice daily
____ Once daily
____ Every other day
____ A few times per week
____ Once per week
____ Once per month
____ Almost never
____ Never

3. How often do you use mouthwash?
____ Twice daily
____ Once daily
____ Every other day
____ A few times per week
____ Once per week
____ Once per month
____ Almost never
____ Never

4. Do you have a history of cavities? If so, how many?
____ Yes
____ No
Enter number of cavities: _____

5. Have you ever had or do you currently have a dental device for your mouth (braces, mouth guard, retainer, etc.)? Please specify the device.
____ Used to have
____ Currently have
Enter name of device: _____

6. How often do you receive regular dental check-ups?

____ Once every few months
____ Once every 6 months
____ Once per year
____ Every other year
____ Do not receive regular check-ups

7. Do you or does someone in your family have a history of gum disease? Please specify on the line provided.

_____

8. What is your age in years?

_____

9. What is your gender?

____ Female
____ Male
____ Prefer not to answer

10. What is your ethnicity?

____ African American
____ Asian/ Pacific Islander
____ Caucasian
____ Hispanic or Latino
____ Other

11. How many years of college have you completed?

____ Zero
____ One
____ Two
____ Three
____ Four
____ Five
____ Six
____ More than six