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# Parent Engagement with a Self-Tailored Cancer Prevention Digital Behavior Change Intervention: Exploratory Application of Affiliation Network Analysis

# Elisabeth R.B. Becker<sup>a</sup>, Sahiti Myneni<sup>a</sup>, Ross Shegog<sup>a</sup>, Kayo Fujimoto<sup>a</sup>, Lara S. Savas<sup>a</sup>, Erica L. Frost<sup>a</sup>, C. Mary Healy<sup>b</sup>, Stanley Spinner<sup>b</sup>, Sally W. Vernon<sup>a</sup>

<sup>a</sup> University of Texas Health Science Center at Houston, Texas, USA <sup>b</sup> Baylor College of Medicine, Houston, Texas, USA

# Abstract

Evaluating digital behavior change intervention engagement is complex and requires multidimensional and novel approaches that are emerging. The relationship and interdependence between engagement with the technology and engagement with the psychosocial or behavior change process often presents conceptual and evaluative challenges. Large objective data sets detailing technology use are plentiful but meaningful interpretation can be challenging at granular levels. Affiliation network analysis which describes two-mode network data may provide a novel approach to evaluate engagement of digital behavior change interventions. The purpose of this paper is to use affiliation network analysis as an exploratory method to describe, assess and visualize content-specific patterns underlying psychosocial characteristics related to HPV vaccine safety concerns of parents using the HPVcancerFree intervention. Results indicate that affiliation network analysis shows promise in supplementing existing methods to assess engagement of digital interventions.

# Keywords:

Health behavior, mobile applications, human papillomavirus

### Introduction

Digital technology is an increasingly popular delivery channel for health interventions and an emerging literature base is evolving around conceptualizing and measuring engagement for digital behavior change interventions (DBCIs) [1-7]. Conceptual frameworks have highlighted the distinction, yet interdependence, between engagement with the technology and engagement with the psychosocial or behavior change process [1,3,5]. Microlevel engagement includes the moment-to-moment engagement with the technology while macrolevel engagement involves the depth of involvement with the psychosocial or behavior change process linked to the behavior change goal [1].

A wide range of methods to evaluate both levels of engagement have been described including qualitative measures, self-report questionnaires, ecological momentary assessments, system usage data, sensor data, social media data and psychophysiological measures [8,9,10]. However, evaluations of DBCIs often fail to investigate how microlevel engagement impacts macrolevel engagement [11]. Additionally, DBCI system usage data is often reported for broad patterns across the whole sample, missing the opportunity to investigate how specific intervention content is used by subgroups [12]. Network analysis has traditionally been one-mode and based on social network data (social network analysis) in public health [13,14]. In contrast, affiliation network analysis allows for the visualization of patterns of ties formed between two distinct sets of nodes. Affiliation network analysis may provide a method for mediating existing gaps in the evaluation of multilevel engagement by achieving content-specific patterns underlying psychosocial characteristics.

The purpose of this study is to adapt methods of affiliation network analysis to achieve granular insights that can inform health education DBCI information architecture. This will be explored by evaluating content-specific patterns that underlie HPV vaccine safety psychosocial characteristics from parent users of the HPVcancerFree (HPVCF) DBCI.

#### **HPVcancerFree Digital Behavior Change Intervention**

HPVCF is an iOS and Android compatible smartphone app aimed at raising awareness of HPV and reducing barriers to HPV vaccination (Figure 1). HPVCF was designed for parents of patients aged 10-17 years who have not initiated HPV vaccination and belonged to a large urban pediatric clinic network in Texas. HPVCF contained four self-tailored components: 1) HPV A-Z, a compendium of nine content domains providing facts regarding the HPV vaccine; 2) Bust-A-Myth, seven educational modules including peer and provider testimonials addressing salient HPV vaccination barriers; 3) Notes4Doc, a medium to facilitate communication with providers; and 4) Get the Vax, a feature to schedule HPV vaccination appointments and receive tailored reminders. HPVCF was designed for self-guidance so did not prescribe an intended navigation path. HPVCF use was associated with improved parental knowledge and perceptions and HPV vaccination effectiveness [15].

#### Figure 1. Screen captures of HPVCF components



# Methods

**Study Design**: Study data was drawn from a group randomized control trial within a pediatric clinic network examining the effectiveness of HPVCF for modifying HPV vaccination attitudes and behavior [15]. The study occurred between September 2017 and March 2019 with the 51 clinics in the network randomized to either the HPVCF intervention (n=262 parents) or a comparison group providing usual care alone (n=297 parents). Parents in the intervention clinics were given instruction and links to download HPVCF from the Apple Store or Google Play. Parents were given a 'Personal ID' to enter the first time they launched the app for tracking purposes. Parents were enproved by the Institutional Review Board at the University of Texas Health Science Center at Houston (HSC-SPH-15-0202).

**Participant Inclusion Criteria and Recruitment**: Eligibility for the study included: (1) Having a 10 -17-year-old child who was a patient in the clinic network (2) having a child that had not initiated HPV vaccination and (3) the ability to speak and write English. Parents were invited to participate in the study via patient health record portal invitations, flyers in the clinic waiting rooms and posts on the clinic network Facebook page. Recruitment for the study took place on a rolling basis from September 2017- September 2018.

# Measures

Participants completed a pre-and-post-intervention survey spaced five months apart. The surveys captured parental attitudes and beliefs about HPV and the HPV vaccine.

**Microlevel Engagement**: Microlevel engagement was measured as app page views per parent user. There were 77 app pages and links that a parent had unlimited access too over the course of their five-month intervention. These data were generated from logs collected and stored in the Matomo analytics platform [16]. Each time a parent clicked on an app button the corresponding page was recorded. Parents were tracked via their study ID.

Macrolevel Engagement: Macrolevel engagement was measured as longitudinal psychosocial change related to HPV vaccine safety concern. HPV vaccine safety concern was measured using a single survey item ("I am concerned about the safety of the HPV vaccine") adapted from the Carolina HPV Immunization Attitudes and Beliefs Scale [17] with a four-point Likert scale response format (Strongly Agree, Somewhat Agree, Somewhat Disagree, Strongly Disagree). Response options were collapsed into binary classes of agree or disagree for preand-post-intervention time points resulting in two states of valence (positive and negative) and two states of movement (change and no change). Parents were then categorized into one of four mutually exclusive groups based on their valence and movement (Table 1).

Table 1. Macrolevel engagement: parent groups by longitudinal HPV vaccine safety concern

"I am concerned about the safety of the HPV vaccine."					
Group Pre-test Post-test			Description		
1	Agree	Disagree	Reduced safety concerns		
2	Disagree	Disagree	Never had safety concerns		
3	Agree	Agree	Consistent safety concerns		
4	Disagree	Agree	Developed safety concerns		

#### **Affiliation Network Analysis**

Affiliation network analysis is based on two-mode networks consisting of two distinct set of nodes (N and V). The first set of nodes in our affiliation network represented parents (N) within a specific group (N; Groups 1-4). The second set of nodes represented the app pages (V) viewed by parents (V = 54 of 77 pages). Parents could not see each other or interact with one another on the app and hence were not influenced by one another's behavior. The affiliation networks were analyzed using UCINET version 6.698 [18] and the visualizations were created in Netdraw version 2.168 [19].

A parent-by-app page two-mode matrix representing affiliation ties between parents and app pages was created for each parent group. Each entry in the two-mode affiliation matrix recorded the existence or non-existence of an affiliation tie between a row (parent) and a column (app page), coded as one if a parent viewed the page and zero if a parent did not. We calculated descriptive statistics for each of the networks, including minimum, maximum, mean and median raw page degree centrality, an integer score that represents how many direct ties a page node has to parent nodes. To calculate the page normalized degree centrality scores (degree divided by the maximum possible degree in the network), we used the two-mode matrix [20]. A visual representation of the affiliation networks between parents and app pages was generated where the nodes of the distinct sets were connected via edges.

# Results

Ninety-eight parents were included in the study sample. Parents had a mean age of 41 ( $\pm$ 5.7) years, were majority female (96%), college graduates (56%), white, non-Hispanic (56%) and had private health insurance for their children (77%). Most parents had one child between the ages of 10 to 17 years old, with a range of one to four in that age group. At baseline 12% of parents did not intend to vaccinate their child for HPV, 41% definitely planned to and 46% of parents were unsure.

Parents visited HPVCF a total of 197 times during the study period (Table 2). Most parents used HPVCF once (46%) or twice (29%) with the range spanning from one to eight visits. During a single visit two to 84 actions occurred with a mode of three actions. The mode visit duration was 24 seconds with a range from three seconds to just under 27 minutes.

Table 2. HPVcancerFree retention	and	use
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Total number of separate visits	
(all momenta)	107
(all parents)	197
Number of visits per parent	
mean (SD); range; mode	2 (1.25); 1-8; 1
Distribution of parent visits	
(%)	
1 visit	46
2 visits	29
3 visits	13
4 visits	10
5 visits	2
8 visits	1
Actions <sup>a</sup> per visit	
mean (SD); range; mode	11 (10); 2- 84; 3
Visit duration (seconds)	
mean (SD); range; mode	207 (249); 3- 1601; 24
<sup>a</sup> Viewing an app page or link	

Parent Groups: The largest group contained parents that consistently had safety concerns about the HPV vaccine despite using HPVCF (Group 3, 42%), followed by parents who never felt concerned over HPV vaccine safety (Group 2, 32%), then parents who had reduced safety concerns after using HPVCF (Group 1, 21%) and finally parents developing safety concerns after using HPVCF (Group 4, 5%) (Table 3). The parent groups were not statistically significant across any demographic variable. However, the parent groups were statistically significant for baseline HPV vaccination intent ( $x^2$  (12) = 39.51, p<0.001) with the majority of those that definitely intend to get the HPV vaccine for their child belonging to Group 2 (63%) and the majority of those that don't intend to get the HPV vaccine for their child belonging to Group 3 (83%).

Table 3. Parer	t group size a	nd raw degree	centrality (page)	)
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Group	N (%)	Raw Degree Centrality (Page)				
		Min	Max	Mean (SD)	Median	
1	21 (21.4)	0	12	3.37 (2.55)	3	
2	31 (31.6)	0	16	2.81 (3.34)	2	
3	41 (41.8)	0	25	6.28 (5.39)	5	
4	5 (5.10)	0	3	0.46 (0.75)	0	
A Kruskal-Wallis rank test revealed that the median degree centrality across the four user groups was not the same ( $X^2 = 75.244$ , p = 0.0001).						
Further, the dunn post-hoc tests showed statistically significant results						
between each pairwise comparison.						

Raw Degree Centrality (Page): Parent groups that had safety concerns at the start of HPVCF (Groups 1 and 3), had higher median and mean degree centrality scores than parent groups that did not have safety concerns at the start of HPVCF (Groups 2 and 4) indicating that parents with initial safety concerns tended to view more app pages (Table 3). Group 3 had the largest range for degree centrality scores indicating greater variability in app views among parents that were consistently concerned about the safety of the HPV vaccine. A Kruskal-Wallis rank test revealed that the median degree centralities across the four groups were different ( $X^2 = 75.244$ , p = 0.0001). Further, the dunn post-hoc tests showed statistically significant results between each pairwise comparison.

Normalized Degree Centrality (Page): Table 4 highlights the median normalized degree centrality and the normalized degree centrality of app pages exceeding the median threshold for each group. There were nine pages out of 77 that exceeded threshold for all parent groups. Five of these pages were in the HPV A-Z component and included information about HPV and the vaccine, dosing schedule and recommendations and safety.

There were five pages in HPVCF (one in HPV A-Z and four in Bust-a-myth) with titles that explicitly referred to HPV vaccine safety. The median threshold of the five safety-focused pages was exceeded by Group 3 for all five pages, by Groups 1 and 4 for four pages and by Group 2 for two pages. However, views of these pages never reached more than 44% of parents per group indicating that most parents were not viewing safety pages. Different patterns of use were seen between parents who reduced their safety concerns (Group 1) and parents that did not (Group 3). Group 1 exceeded threshold for all pages addressing the myth that the HPV vaccine is not necessary (Myth 1) and all pages addressing the myth that their child is not at risk for contracting HPV (Myth 5) while Group 3 exceeded threshold for all the pages directly referencing the myth that the HPV vaccine is new (Myth 4) and the myth that their child is too young for the HPV vaccine (Myth 7). Distinct patterns of use were also seen among parent groups who reported not having safety concerns at post-survey (Groups 1 and 2) compared to parent groups who reported safety concerns at post-survey (Groups 3 and 4). Groups 1 and 2 exceeded threshold for viewing the 'Getting the HPV Vaccine' page (29% and 10% respectively) while Groups 3 and 4 exceeded threshold for the 'Talking to the Doctor' page (17% and 20% respectively).

Table 4. HPVCF pages exceed	'ing med	ian normal	lized degree
centrality threshold by comp	onent fo	r each par	ent group

	Parent group				
	1	2	3	4	
Median normalized degree	14.3	6.5	12.2	0	
centrality (%)					
Normalized degree centr	ality fo	r pages	exceedi	ng	
median thr	eshold	(%)			
Home					
About App	38.1	51.6	61.0	40.0	
HPV A-Z					
About HPV	28.6	29.0	31.7	20.0	
About HPV Vaccine	19.0	22.6	29.3	20.0	
Recommendations	23.8	19.4	29.3	20.0	
Dosing Schedule	57.1	41.9	41.5	60.0	
Getting the HPV Vaccine	28.6	9.7	/	/	
Safety & Side Effects	28.6	32.3	43.9	40.0	
Talking to the Doctor	/	/	17.1	20.0	
Bust-a-Myth					
Myth 1: Not Necessary	33.3	12.9	24.4	20.0	
Facts	23.8	9.7	19.5	/	
Parents	19.0	9.7	/	/	
Doctors	19.0	/	/	20.0	
Myth 3: Not Safe	28.6	9.7	36.6	40.0	
Facts	28.6	/	24.4	/	
Parents	19.0	/	29.3	20.0	
Doctors	/	/	31.7	40.0	
Myth 4: Vaccine is New	23.8	9.7	29.3	/	
Facts	/	/	26.8	/	
Parents	/	/	18.5	/	
Doctors	/	/	14.6	/	
Myth 5: Child Not at Risk	42.9	9.7	14.6	20.0	
Facts	19.0	/	/	20.0	
Parents	19.0	/	/	/	
Doctors	23.8	9.7	/	/	
Myth 7: Child is Too Young	28.6	22.6	29.3	/	
Facts	/	/	22.0	/	
Parents	/	12.9	17.1	/	
Doctors	19.0	19.4	19.5	/	
Notes 4 Doc					
Create Note	/	9.7	/	40.0	
Get the Vax					
Launch MyChart	/	16.1	/	/	
Set Appointment Reminder	/	19.4	/	20.0	
/ indicates below threshold					

Network Diagrams: Figure 2 visually represents the types and amount of content accessed by parent groups. The diagrams illustrate the comparative size of each group (number of circle nodes), the variability of app page views among parents within a group (size of circle nodes) and the popularity of app content (size of square nodes). The amount of content accessed varies the most for Group 3 (red circle nodes).



Figure 2. Parent group network diagrams



# Discussion

This study demonstrates the novel application of affiliation network analysis to understand DBCI engagement by describing content-specific patterns underlying parent psychosocial characteristics related to HPV vaccine safety. Fifty-three percent of parents completed HPVCF not concerned about HPV vaccine safety. However, the biggest group at 42% were parents that consistently had safety concerns despite HPVCF exposure (Group 3). The majority of parents who indicated they did not intend to get the HPV vaccine for their child at the start of the intervention belonged to this group.

The findings from this study inform HPVCF intervention design by highlighting granular differences in content views that might lead to better optimization, personalization, retention and attrition in future iterations and studies. Group 1 and 3, containing parents that had safety concerns at the start of the intervention, tended to view the most app pages overall. These groups also viewed the most safety related pages with Group 3 exceeding threshold for all of them and Group 1 exceeding threshold for all but one of them. Group 3 was more likely to view pages relating to the age appropriateness and newness of the HPV vaccine compared to Group 1 which viewed more pages relating to the necessity of the vaccine and likelihood of their child getting HPV. This may indicate the different concerns parents in the groups had related to HPV vaccine safety. For some parents it might be that passive education on HPV vaccine safety is not enough to change attitudes and beliefs and strategies that focus on adaption, tailoring and personalization are needed [21]. The five parents who developed safety concerns after using the intervention (Group 4),

may have acquired awareness about the HPV vaccine that increased their perception of seriousness resulting in their negative psychosocial movement.

# Limitations

Findings from this exploratory study should be interpreted in the context of limitations. Some parent groups were small and therefore may not adequately represent intervention use and page views. This analysis focused on app page views (binary yes/no) and app page content as a proxy for microlevel engagement. However, the dimensions of frequency, duration and depth of interaction with individual app pages should also be considered [22]. The analysis assumed a causal association between page views and knowledge uptake and retention among parents. This assumption was not explored in this study and future work can investigate if this is a valid assumption. Importantly, this study only utilized degree centrality measures and other individual and network level metrics may provide value for assessing context-specific patterns. Additional network measures can be explored in future work. Finally, macrolevel engagement (HPV vaccine safety concern) was measured using a single self-reported item and results may differ from other macrolevel engagement measures.

# Conclusions

Affiliation network analysis is a useful method for assessing and diagramming the association between technology use and psychosocial change in HPV vaccine safety. Affiliation network analysis shows promise in supplementing existing methods to assess engagement of DBCIs, providing insights often overlooked by summative statistics. Further research in this novel application of affiliation network analysis is indicated.

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#### Address for correspondence

Elisabeth Becker elisabeth.becker@uth.tmc.edu