

Developing a Game-Based Intervention to Promote HPV Vaccination among Adolescents

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Authors' contributions

This work was carried out in collaboration among all authors. Author ACCC designed the study, collected data, performed the analysis and wrote the manuscript. Authors LO and AMB performed the analysis and contributed to writing the manuscript. Author AA contributed to design and writing. All authors read and approved the final manuscript.

Article Information

Editor(s):

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Complete Peer review History: <https://www.sdiarticle4.com/review-history/71027>

Original Research Article

Received 10 May 2021

Accepted 15 July 2021

Published 23 July 2021

ABSTRACT

Aims: To develop a developmentally and gender appropriate game-based intervention to promote Human Papillomavirus (HPV) vaccination in adolescents.

Study Design: Qualitative interview.

Place and Duration of Study: Participants were recruited from communities in Arizona, United States in 2019.

Methodology: Sample: eight parent-child dyads representing different adolescent's gender (4 boys, 4 girls aged 11-14) and racial/ethnic groups in the U.S. were recruited through purposive sampling. After receiving consents and assents, we conducted semi-structured interviews (60-90 minutes each) with each dyad at a quiet and private room. Each dyad received \$50 for their time and effort. The interview questions consisted of two parts: (a) questions related to game design, functioning, and feasibility of implementation; (b) questions related to theoretical constructs of the

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Health Belief Model and the Theory of Planned Behavior. The interviews were audio recorded with permission, transcribed into textual data, and analyzed using NVivo 12. We organized data and developed themes based on the theories and game design/development categories. Three researchers reviewed the results and discussed the discrepancies until reaching a consensus.

Results: Our findings suggested that the most common motivating factors for adolescents' HPV vaccination were vaccine effectiveness, benefits, convenience, affordable cost, provider's recommendation, and reminder for the 2nd shot. Recommendations for the game content and design: (1) *Content:* information about HPV and vaccine (e.g., consequences if infected, side effects of the vaccine), who, when and where to receive the vaccine. (2) *Game design:* 15 minutes or shorter, fighting/action storyline, option to choose characters/avatars, reward mechanism, and delivered by portable device (e.g., tablet).

Conclusion: Our findings inform a game-based intervention that incorporates key concepts of HPV and vaccine, and desired game features for adolescents and their parents. The long-term goal is to promote HPV vaccination in adolescents to prevent cancers.

Keywords: Cancer prevention; family; game-based intervention; HPV; vaccination.

1. INTRODUCTION

Human papillomavirus (HPV) is the most common sexually transmitted infection in the United States. It is approximately 80 million Americans are currently infected by HPV, and this number is projected to increase by 14 million new cases each year [1]. HPV is a family of viruses that infect both male and female epithelial tissue. Certain strains of HPV are significantly associated with various cancers and diseases including, cervical, vaginal, and vulvar cancers in females; penile cancers in males; and oropharyngeal and anal cancers in both males and females [1].

HPV vaccines are effective and safe in preventing HPV-related cancers and diseases [2]. Specifically, HPV cancers and genital warts have dropped 86 percent for adolescent girls and 71 percent for young women since HPV vaccine was available in the United States [3]. With these promising results, vigorous prevention efforts including recommended HPV vaccination for boys and girls at age 11 or 12, are essential to address this health issue [1,3].

Despite HPV vaccination being one of the most effective methods in preventing its related cancers and disease, vaccination rates for HPV remain suboptimal [4]. Before the COVID-19 pandemic, HPV vaccination rates in the U.S. for youth 13-17 years (48.9% for females and 47.1% for males) [5] were substantially below the Healthy People 2030 goal of 80% completion [6]. The suboptimal HPV vaccination rates have become even worse during the pandemic [7]. Evidence shows that HPV vaccine ordering and billing significantly dropped by at least 70% in

March 2020 and remained down by 25-50% in June 2020 [8]. It is critical to bring HPV vaccination back on track for cancer prevention.

According to the World Health Organization [9], hesitancy to vaccinate is one of the top global health threats. This hesitancy may stem from limited knowledge of the vaccine's benefits, underestimation of the virus's risks, or difficulty in access or confidence in speaking with a healthcare provider [10]. Additionally, sex/gender, race/ethnicity, and geographic locations contribute to health disparities in HPV-related cancers [4]. Low HPV vaccination rates among adolescents are related to parents' lack of knowledge and awareness about the HPV vaccine, worries about its potential influence on their children's sexual behaviors, and gender-biased vaccine recommendations with only females being responsible for the disease and vaccination [11,12,13]. It is essential to develop tailored intervention for families to address these needs.

In the U.S., adolescents have already embraced the technology and used it widely in life and schools. In contrast to traditional learning approaches, adolescents favor game-based interventions as they make the learning process fun and interesting and increases motivation and emotional engagement [12,13,14,15]. Serious game-based intervention is an evolving, tailored education tool [10]. These digital games aimed to educate players have become a new and effective bridge to deliver health promotion education through the use of rewards, challenges, teamwork, avatars, and quizzes. Instead of learning through a pamphlet or presentation, serious game-based intervention

offers players the opportunity to learn through exploration and experimentation [14]. By increasing motivation and engagement through an interactive education tool, the effects on decreasing hesitancy of vaccination have exemplified promising results [10,16]. A key aspect of positive health outcomes is parent-adolescent involvement in health education [17].

As evidence suggests that clinical setting serves as a supportive environment for engaging families in health education [12,13] and the urgent need to involve both parents and adolescents in innovative health education for adolescents' HPV vaccination, we collaborated with a Family Advisory Broad (FAB) to identify key elements of content and design of a serious game for families to promote HPV vaccination in adolescents aged 11-14. Based on CDC recommendation [3], we target children of this age as prevention is more effective if done early, and only two doses of HPV vaccine are required.

2. MAERIAL AND METHODS

2.1 Framework

We use key theoretical constructs of the Health Belief Model (HBM) [18] and Theory of Planned Behavior (TPB) [19] to guide this study. HBM illustrates the relationships among an individual's perceived severity and susceptibility to the disease, benefits and barriers to a behavior, cues to action in changing a behavior, and the self-efficacy or confidence in one's ability to perform a behavior. These constructs provide a baseline to predict behavior change. TPB similarly explains and predicts health behavioral intentions based on behavioral, normative, and control beliefs [20]. Within these beliefs, an individual's attitude toward a behavior, subjective norm, and perceived behavior and control are highly associated with intention and behavior. Empirical evidence suggested self-efficacy a key element to facilitate communication about HPV vaccination between adolescent, parent, or healthcare provider [14]. A game-based intervention also found that children's have increased awareness of HPV vaccine and decreased vaccine hesitancy and related stigma through the communication with their parents [14]. Guided by HBM and TPB, Darville conducted interviews to inform development of a serious game for HPV promotion in young males [21]. The findings suggested that increased self-efficacy and higher perception of risk in young males were strongly associated with their vaccination intent.

2.2 Sample, Sampling, and Setting

We used purposeful sampling to recruit a FAB consisting of eight adolescent-parent dyads representing different child's sex (4 boys, 4 girls) and racial/ethnic groups (4 non-Hispanic White, 2 Hispanic/Latino, 1 non-Hispanic Black, 1 non-Hispanic Asian) in the United States. The inclusion criteria for the dyads were: (1) a child aged 11-14 years and one of his/her caregivers, defined as a family member who regularly takes care of the target child, (2) ability to speak, read, write, and understand English, (3) agree to be audio recorded, and (4) provide parental consent and child assent for participation. Participants were recruited through flyers distributed to our community and clinical collaborators, and snowballing. After eligible families consented to their participation, we conducted semi-structured interviews with each dyad in a quiet and private room.

2.3 Procedure

We received approval from the University Institutional Review Board (IRB). Ethical considerations were implemented throughout the process of conducting and analyzing research. Adolescent-parent dyad participants provided written consent and assent before participating in the study. Study materials were uploaded and saved in a secured drive protected by passwords and could be accessed only by the research team.

One researcher with extensive experience working with the target population for HPV vaccination led the interview and one research assistant (RA) took notes. Participants first filled out a brief survey for sociodemographic information (e.g., birth year, sex/gender, race/ethnicity, education level) and HPV-related questions (e.g., "Have you received HPV vaccine education from other sources, such as getting the information from your doctor or nurse?"). Next, participants answered questions about a) education content related to theoretical constructs of the HBM and the TPB, and (b) questions related to game design, functionality, and feasibility of implementation. Each adolescent-parent dyad interview lasted about 60-90 minutes and were audio recorded. Each dyad received \$50.00 to acknowledge their time and effort.

2.4 Interview Questions

Education content. The HBM guided a portion of the interview discussions by questioning about

perceived susceptibility and severity of HPV (e.g., “What are the health outcomes you would expect with and without vaccination?”), perceived benefits and barriers related to HPV vaccination (e.g., “What would make you want to get the HPV vaccine?”), cues to action (stimulus needed to accept vaccination), and self-efficacy (level of his/her confidence in the ability to be vaccinated). General questions were asked regarding the participant’s knowledge and awareness of HPV and HPV vaccine (e.g., “What information would you like to know about HPV and vaccines?”), source of knowledge and awareness (e.g., “Tell me more about how you became aware of the HPV vaccine.”), the preferred source of knowledge (e.g., “If you wanted more information about HPV and vaccines, where or whom would you go to?”), and confidence and comfort in communication with the provider were asked (e.g., “How comfortable would you feel talking to a provider about the HPV vaccine?”). Additionally, we asked questions addressing participant’s general attitudes towards HPV and HPV vaccine (e.g., “Tell me more about your thoughts on HPV and HPV vaccine.”), subjective norms (e.g., “If your friend got a vaccine, will you get one too?”), perceived behavioral control (assessed by the ease or difficulty of the behavior), and vaccination intent (e.g., “If you/your child can get HPV vaccine when you/your child go to doctor’s office for an annual checkup, would you/your child get it?”).

Game development. Game development categories included the gaming interests and practices, views on games with educational messages to promote health, and storyline creation. Specifically, we asked questions relating to the participant’s desired knowledge to acquire from the game (e.g., “If you would develop a game to teach your friends about HPV and vaccines, what needs to be included in the game to help them understand?”), game design (e.g., “If you were to develop a game for adolescents and their parents, what would you put in the game?”), and storyline (e.g., “What type of stories would be interesting to you regarding HPV and vaccines?”).

2.5 Data Analysis

The audio-recorded interviews were transcribed into textual data by one researcher. Two other researchers confirmed the verbatim transcription. The transcripts were downloaded and analyzed using NVivo 12.0 software to develop codes by three researchers [22]. Pre-developed codes were used to identify each participant’s

responses, organize data, and develop themes based on the HBM and TPB constructs. Notable quotes and recurring topics were classified into the HBM, TPB, and game development categories. We conducted inductive thematic analysis using the following steps [23]: become familiar with data, create initial codes, identify themes, review/refine themes, define and name themes, and produce the report. Disagreements were discussed until reaching a consensus.

3. RESULTS AND DISCUSSION

3.1 Sample Characteristics

Our FAB consists of eight parent-adolescent dyads representing different child’s biological sex (boy vs. girl), racial/ethnicity, and economic status (reduced/free lunch vs. regular). Half of the participating children were boys and the other half were girls. In the families, four (50%) identified themselves as Non-Hispanic White, two (25%) were Hispanic/Latino, one (12.5%) was Asian, and one (12.5%) was Black. The child’s age ranged from 11 to 14 ($M = 12$); caregiver’s aged ranged from 31 to 55 ($M = 40$). The caregivers included five mothers, one grandmother, and three fathers. All caregivers were working. Half (50%) of the children were eligible for reduce-priced or free lunch at school, an indicator of family’s economic status.

3.2 Conceptual Content of the Game

Game content is the critical HPV-related content needed to be included in the game intervention. Participants expressed their interests in learning about HPV etiology, HPV vaccine, and other preventative strategies against HPV. The adolescents’ desired game content included what HPV was, the effects if infected with HPV, the purpose of the HPV vaccine, and other preventative measures to take to avoid contracting HPV. The parents’ desired game content included the consequences of HPV infection, the side effects of the HPV vaccine, when their child should receive the vaccine, and education regarding additional strategies to protect against sexually transmitted infections. A parent participant inquired, “If you’re infected, what happens?”.

From the adolescent-parent dyad interviews, we identified eight main thematic groups related to the content of the HPV Game: (1) knowledge and awareness, (2) perceived benefits of vaccination, (3) perceived barriers of vaccination, (4) perceived facilitators of vaccination, (5)

perceived susceptibility of getting HPV, (6) perceived severity of getting HPV, (7) cues to action, and (8) subjective norm. Three sub-themes: HPV and vaccine, Source of knowledge, and Communication with provider were further developed under the “Knowledge and awareness” theme. Example quotes are presented in Table 1.

3.2.1 Knowledge and awareness

3.2.1.1 HPV and vaccine

Knowledge and awareness of HPV and HPV vaccination is the participant’s understanding of HPV and the HPV vaccine. More than half (62.5%) of the participants were not aware of HPV and the vaccine. Those that were aware of HPV and the vaccine knew the virus could cause cancer and genital warts. Those that were not aware of HPV and the HPV vaccine desired to know the overall basics about HPV and the HPV vaccination, the transmission of HPV, the effects of the virus if infected, and preventative measures to avoid the virus. Overall, the adolescent’s knowledge and awareness of HPV and the HPV vaccine were vague and deficient.

3.2.1.2 Source of knowledge

This question asked the source where participants learned about HPV and the vaccine if they had heard or know about it. Adolescents reported learning about HPV and the vaccine from healthcare providers or the internet. An adolescent participant stated, “The doctor told me like what shot it was, I was like okay” and another participant acknowledged, “I googled it.” The sources of awareness for parents were healthcare providers, family member, church, media, or the internet.

Adolescents’ preferred sources of knowledge included teachers, school nurses, healthcare providers, family members, and media. Parents’ preferred sources of knowledge were healthcare providers, family members, and media. Overall, the greatest preference for the adolescent-parent dyads was from a healthcare provider. As an adolescent participant stated, “I would probably go to a doctor because they would know more about it than your parents and anybody in your family.”

3.2.1.3 Communication with provider

When assessing the level of comfort in communicating with the healthcare provider, the adolescent-parent dyads overall felt comfortable

asking questions. The adolescents indicated no preference in the healthcare provider’s sex/gender when communicating about HPV and the HPV vaccination.

3.2.2 Perceived benefits of vaccination

Perceived benefits are the participant’s perception of the effectiveness of HPV vaccination to reduce the threat of its related illnesses. The greatest perceived benefit of vaccination for adolescent-parent dyads was cancer prevention. They acknowledged the HPV vaccination as a protection not only for the teen years but also for a lifetime. A parent addressed the benefit of protecting their child by stating, “You’re not just protecting for the teenager, you’re protecting for a lifetime.”

3.2.3 Perceived barriers of vaccination

Perceived barriers are a person’s feelings on the obstacles to getting the HPV vaccine. For adolescents, the perceived barriers of vaccination were the efficacy of the HPV vaccine, side effect concerns, and the pain that comes with receiving a vaccination. For caregivers, perceived barriers of vaccination included safety concerns of the vaccine including side effects, the vaccine cost, and unfamiliarity of where to receive the vaccine. A parent participant expressed, “Is that vaccine safe? That’s what always comes to my mind.”

3.2.4 Perceived facilitators of vaccination

Perceived facilitators are factors that promote HPV vaccination. Adolescents identified the effectiveness of the HPV vaccine and if a healthcare provider recommended the HPV vaccination as main facilitators. For caregivers, facilitators were cultural/language accommodations, cost and affordability, convenience in location and time, effective education, and feelings of parental responsibility. A caregiver urged how a resource, such as the educational game, “...is going to help grandmas like me because we are so busy working still and do everything else, we don’t sit down and read a magazine or read about it or google or research.”

3.2.5 Perceived susceptibility of getting HPV

Perceived susceptibility is the participant’s subjective perception of the risk of acquiring HPV or HPV-related cancer. Parents acknowledged that the adolescent will eventually become sexually active and therefore become at risk for

HPV-related cancers. Additionally, a parent mentioned that family cancer history increased the perceived susceptibility.

3.2.6 Perceived severity of getting HPV

Perceived severity of getting HPV is the participant's feelings on the seriousness of contracting HPV. The participants considered medical consequences when evaluating the severity. One adolescent stated, "They can probably die." One caregiver shared the worries about an increased risk for cancers if infected.

3.2.7 Cues to action

Cues to action are the strategies to activate "readiness," stimulating participants to get vaccinated. For adolescents, the cues included appointment reminder cards, text messages, and calls. Caregivers shared similar cues and included emails as a way to remind them about children's appointments. A caregiver declared, "I would say text and email, just because you check your phone all the time, you check your email all the time and it's always going to be there to remind you." Additionally, caregivers explained "child's puberty" as a cue to action. When children's puberty start, the need for the HPV vaccination becomes even more vital. One caregiver stated, "Parents may think ...12- or 13-year-olds do not need that (the shot) because that is not what they are doing (not engaging in sexual activities). But that's not accurate."

3.2.8 Subjective norm

Subjective norms are the degree of pressure the participant feels from significant people in their lives regarding the HPV vaccination. Subjective norms for adolescents included family members, such as parents who make the decision about vaccination. An adolescent revealed, "I don't really have a choice, cause my mom made me do it." Subjective norms for parents included friends, peers, or colleagues influencing others to become educated and receive the HPV vaccination.

3.3 Design Features of the Game

The emerging themes and example quotes from adolescents and their caregivers were compiled in the Table 2.

3.3.1 Features

Game design explains the desired elements in the game intervention, including communication,

music, length of the game, device, choice of characters/avatars, and motivating factors, such as rewards. Communication preferences included allowing more than one person to play in the same game environment simultaneously. When asked if multiplayer was used in the adolescent's regular gaming, adolescents stated that they played games with friends and families including parents. The adolescents preferred calming music, if any, as the consensus was music could cause distraction. A 15-minute educational game was considered to be appropriate as expressed by both adolescents and their caregivers. The preferred game devices were smartphone, computer, PS4, Nintendo Switch, or tablet. Tablets were specifically mentioned by the caregivers if used in the clinical settings as tablets are easy to carry while providing comfortable and appropriate visual effects.

Suggestions for the choice of characters/avatars included "...get to pick a girl or boy at the beginning." Adolescents liked to choose characters with different abilities and appearances, such as "There are two characters, they have both different abilities that can do different things for certain missions." Encouraging words in the game such as "keep going, vaccines never give up" would be helpful to engage adolescents. Motivating factors included reward by coins or points earned after answering questions correctly, new weapons when advancing through the game, and progressing to different levels. An adolescent stated, "I like the moving onto the next level thing. I could collect diamonds and points to buy stuff."

3.3.2 Story line

The storyline is comprised of the ideas that adolescent-parent dyads suggested would be entertaining and appropriate for an educational gaming experience. Recommended storylines included action or fighting, sports, role-playing, art or fashion, and puzzles. The two most highlighted storylines were action or fighting and sports. An example of how action or fighting could be implemented into an educational gaming experience was "HPV is like a zombie they combat you. And then you get it for shot as a weapon." An example of how sports could be implemented into an educational game was "if you choose wrong answer, the goalie stops the ball. If it is the right answer, you score the goal and get the rewards for it."

Table 1. Interview themes-content of HPV game

| Themes | Sub-themes | Example quotes (adolescent) | Example quotes (caregiver) |
|---------------------------------|---------------------|---|---|
| Knowledge & Awareness | HPV | "I'm still kind of confused I am like, why you like to get it, like what's it?" | "Just really get the basic thing, as far as the cancer for women, and for men the oral cancer stuff like that, the earlier the better, you get it, you get it, the better off you'll be." |
| | Vaccine | "Get the vaccine at the right age before you start doing anything." | "So, it is a prevention of sexually transmitted disease." |
| Source of Knowledge & Awareness | Teacher/school | "I have not learned about HPV in school." | |
| | Healthcare provider | "The doctor told me like what shot it was." | "When I takes the vaccine, then they would try to educate." |
| | Family | | "I remember [your] mom asking and I suggest you should do it, well...we never had conversation with you (child) about it." |
| | Church | | "I forgot what it was called, but it was like...little bit about puberty, abstinence...sexual like... health and preventive measures." |
| | Media | | "...saw an ad on a TV." |
| | Internet | "...I googled it." | "She (child) googled it and that's we did, so hum...that is all I know to this point." |
| Preferred Source of Knowledge | Teacher/school | "Probably, cause they're teachers. They have the education." | |
| | Healthcare provider | "I would probably go to a doctor because they would know more about it than parents and anybody in family." | "We should ask the doctor." |
| | Family | "My parents because I trust them." | "She comes to me (mother) a lot. All my kids do...they ask me questions." |
| | Friends | "I won't ask friends. I just kind of think it will be awkward." | |
| | Media | "I would probably not [google it], because it's just kind of weird to and also the | "That is a good way." |

| Themes | Sub-themes | Example quotes (adolescent) | Example quotes (caregiver) |
|---------------------------------------|--|---|--|
| Communication with Provider | Comfort level | internet is not always correct." "I think so. Sometimes it feels a little awkward to ask those questions." | "Oh yeah... (feel comfortable asking HPV questions)" |
| | Preference of provider's gender | "It doesn't really matter" | |
| Perceived Benefits of Vaccination | Cancer prevention | "I want the vaccine especially if like the future has more to hold ...you don't want to get cancer or anything, especially since we don't have any cures yet." | "It helps prevent from getting those nine cancers." "Definitely, so you're not just protecting for teenager, you're protecting for a lifetime." |
| Perceived Barriers of Vaccination | Efficacy | "I would most likely be scared if it doesn't work on me." | |
| | Safety concern/ side effects | "...the side effects, I mean like after you take the shots, if there's any like illness or cancer. So that right there like a line border or like a lot anything like that. I'd take it, but I'd be very cautious about my body after." | "...the safety issues. I think more about it is preventive of people don't want to do it because I don't have family members have cancers." |
| | Painful | "I have like a bruise... Like, the soreness of it." | "She (child) gets shots and gets swelling and reacts a little bit. So, she doesn't like this." |
| | Cost/insurance | "I worry about the cost." | "That is a lot (\$200 per shot) if there is no insurance coverage." |
| | Where to get it Provider not recommending | | "Can you tell me where to get free vaccination?" "This one is just another one to add to it, that is for whatever reasons, always sort of not as much of priority (for providers) I guess." |
| Perceived Facilitators of Vaccination | Cultural/ language | | "...like a monitor to translate (the language)." |
| | Effective | "I don't really mind shots at all as long as it can help me in the future." | |
| | Affordable | | "If they can get it at free places." |
| | Convenience (time, location) | "I wouldn't feel comfortable getting my shots at school, | "That (HPV shot) should be mandated. Maybe putting in another title on that, but then you do not really get |

| Themes | Sub-themes | Example quotes (adolescent) | Example quotes (caregiver) |
|---|---|---|--|
| | | cause it's just kind of weird for me think about it." | into the truth this candy coating." "I would just rather it would be done at the doctor's office or comes to the clinic I take them to. I like to keep everything in one place." |
| | Education/ intervention | | ".... this is going to help grandmas like me because we are so busy working still and do everything else, we don't sit down and read a magazine or read about it or google or research, you know." |
| | Provider recommendation | "I think the nurse usually says you should get the vaccine. I would most likely say yeah." | |
| | Parental responsibility | | "I think it is parent thing, because you really can't give them something accountable, only the fact you going to have a healthy child." |
| Perceived Susceptibility of Getting HPV | | | "It doesn't necessarily have anything to do with this, even when I first heard about it, like my, you know, my kids are going to be sexually active in some time." |
| Perceived Severity of Getting HPV | | "They can probably die?" | "...cancers." |
| Cues to Action | Reminder card, text messaging, email, phone call, mail | "When we went to the dentist, they like call the confirm...make sure we can make it, or we have to schedule." | "I think text is better, cause I'm checking it constantly." |
| | Puberty | | "Parents may think ...12- or 13-year-olds do not need that (the shot) because that is not what they are doing (not engaging in sexual activities). But that's not accurate." |
| Subjective Norm | Family/relative | "My mom made me do it." | "Recommend it." |
| | Friend/peer/ colleague | "It depends." | "The one got the shot would tell her friends about it." |

Table 2. Interview themes-game format and technology

| Themes | Sub-themes | Example quotes (adolescent) | Example quotes (parent/ caregiver) |
|---------------|--|---|--|
| Game Content | HPV etiology | "What HPV is." "Learn about what HPV can cause" | "Just really get the basic thing, as far as the cancer for women, and for men the oral cancer stuff like that." |
| | HPV vaccine | "Why to get it." | "What are the side effects?" |
| | Prevention | "How do avoid getting it (HPV), besides getting a shot." | "I also think that if somehow that you could incorporate that HPV isn't the only STI. So, they need to be aware of protecting themselves in other ways as well." |
| Game Design | Communication (single vs. multiplayer) | "Yeah, we have mics and whatever, and if they also have mics, you can just talk to them online." | |
| | Music | "Calming music." "I think it's very distracting." | "Super Mario is a good one, I like to play that kind of games." |
| | Time/length | "A game for 15 minutes is perfect." | "I say 10-15 mins" |
| | Device | "Smartphone sometimes..., mainly computer & PS4." "Tablet." | "Tablet" |
| | Choice of gender | "You get to pick a girl or boy at the beginning." | |
| | Choice of receiving vaccine | "Encouragement like keep going, vaccines never give up and you could just press continue..hinting vaccines are effective no matter what, they will help you." | |
| | Choice of character | "Give them different things they can do... two characters have different abilities that can do different things for certain missions or whatever." | |
| | Reward (motivating factors) | "You collect the coins to upgrade like one game I play. You have to collect certain number of diamonds and (it will) change your background or something or like the design of the game." "I like the moving onto the next level thing. I could collect diamonds and points to buy stuff." | "Acknowledgment." "Say you get points by answering right based on what you've learned." |
| Storyline | Action/fighting/defense | "Like weapons to fight off different types of HPVs." "It could be like you have to be simulating the life of a vaccine in trying to defend off all the viruses." | "HPV is like a zombie. They combat you. And then you get it for shot as a weapon." |

| Themes | Sub-themes | Example quotes (adolescent) | Example quotes (parent/ caregiver) |
|---------------|-------------------|---|--|
| | | "Viruses like spreading around the entire world, so the vaccine would have to go stage to defend off all the viruses until the whole globe is cleared" | |
| | Sport | "Soccer probably, basketball" | "If you choose wrong answer, the goalie stops the ball. If it is the right answer, you score the goal and get the rewards for it." |
| | Role-playing | "Like RPG games." "Like with the healer." | "I can see something like a scenario, like a group of kids talking about the hesitation about getting shots. They have a conversation like what shot are you getting? what is this? What is the vaccine for? What do I expect from it? I know somebody who did not have that, and this happened. You could throw in some situations like what people look like when they get older and didn't have the vaccine." |
| | Art/fashion | "The dress is a vaccine and protects those people who wear it from getting HPV." | |
| | Puzzle | "Puzzle-based strategy games, where you can team up with few people and have them fight off a horde of enemies. I like it because you can just use your brain." | |

The qualitative data collected from our FAB provided valuable insights for the content and format of the game development. Interventions incorporating theoretical constructs of HBM have shown promising results to promote vaccination and sexual and reproductive health among adolescents [24, 25]. Since our findings addressed the main constructs of HBM and TPB, a game-based intervention developed based on the findings will provide a strong theoretical foundation to support its effect in vaccination intention and more importantly, vaccine uptake behavior.

The game serves as an engaging platform for conveying credible HPV Information to facilitate effective learning among adolescents and their caregivers. Entertaining games designed with HPV education purposes could further empower adolescents and their caregivers to make conscious health decisions. Concerning characteristics of the target group, the educational game embedded with motivating elements, such as tailored information based on child's sex, choice of avatar and characters, rewards, length of the game, and preferred gaming devices could possibly outperform the conventional educational game. Consistent with prior research [26,27], our findings supported the benefits of incorporating these design features into the game to help adolescents and caregivers maintain engagement in the intervention.

This research is unique as we engaged the target population to co-design this theory-based intervention. We listened and engaged FAB, the end users, in the intervention design process as equal partners to make it more credible and applicable, and more readily to be translated into the real world. Providing an informative yet engaging form of game-based intervention could foster communication between the adolescent, caregiver, and healthcare provider, and consequently achieve earlier, non-gender biased protection and better health outcomes.

Two study limitations are noted. First, only English-speaking participants were included in this study. Future research should include more diverse population including non-English speaking participants to address their unique needs. This would assist in the generalizability of game-based intervention to families speaking different languages and sharing different cultures. Second, our sample size was relatively small. However, our data reached the saturation

point [28,29] as there was no additional new information could be attained from our participants.

4. CONCLUSION

Healthcare providers, including nurses, play a vital role to educate and advocate for patients. As healthcare providers often find promotion of HPV vaccination challenging in clinical settings due to competing demands on their time, game-based education offers a feasible and scalable approach that requires minimal staff time/effort in clinical settings to address the gap. Game-based education that engage both adolescents and caregivers also offers opportunity for conversation between them to become educated on preventative measures [17].

The findings of this study will assist healthcare providers and researchers in the development of a tailored, theory-based game intervention that incorporated key theoretical constructs proven to promote vaccination behavior, as well as the desired design features to motivate and engage adolescents and their caregivers in learning. Understanding key factors, such as knowledge and awareness, the preferred source of gathering health information, perceived barriers, benefits, facilitators, severity and susceptibility of contracting the virus, self-efficacy communicating with a healthcare provider, cues to action, and subjective norms provides a critical basis to develop an engaging and effective educational game. The findings will help us develop a game-based intervention using a fun and popular medium at different settings (e.g., clinics, home, school). Increased efforts to educate, advocate, and implement HPV prevention must continue, as one caregiver emphasized, "Get HPV vaccine and you're protecting for a lifetime!"

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT

All authors declare that written informed consent was obtained from participants for presenting

aggregated results to scientific journals and conferences. A copy of the written consent is available for review by the Editorial office/ Chief Editor/Editorial Board members of this journal."

ETHICAL APPROVAL

We received IRB approval from Arizona State University (IRB ID: STUDY00008341). All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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