PUBLIC PERCEPTIONS OF ADOLESCENCE ON SOCIAL MEDIA: A BIG DATA ANALYSIS OF TWITTER DATA

By

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ABSTRACT

Despite the crucial role of adolescence in human development, little research has explored how the general public perceives this stage of life. Existing research has primarily examined individual perceptions of adolescence and focused on the negative and stereotyped perceptions based on the storm-and-stress view of adolescence. The current study employed both theory-driven and data-driven approaches enabled by machine learning and big data analytics to understand public perceptions of adolescence on Twitter. I extracted millions of publicly available tweets that discussed adolescence in 2019 on Twitter, and employed word embeddings, a neural network algorithm, to analyze the latent meanings of different words in the data as reflecting public perceptions. I then analyzed the outputs of word embeddings to identify public perceptions of adolescence for different terms of adolescence as well as different subgroups of adolescents based on race/ethnicity, gender, and sexual orientation. A unique mixed-methods analytic approach was developed, in which I first leveraged the quantitative analysis of word embeddings to generate descriptors that were closely associated with adolescence, and then conducted qualitative content analysis of the descriptors while referencing the original tweets. Results suggested that adolescence is a complex and comprehensive construct that cannot be captured by a single item. While certain terms of adolescence such as teen was perceived as negative and stereotypical, the overall construct of adolescence was perceived as neutral or positive. Both similarities and differences existed in the perceptions of different subgroups of adolescents, with certain issues being identified such as the lack of voices in anti-racism movements for Asian adolescents. My dissertation can also inform future practices to promote positive framing of adolescence and create a better digital environment for adolescent development.

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PREFACE

Acknowledgement of Bias and Harmful Content

This dissertation incorporates content from public posts on Twitter collected through the Twitter API during the study period. It is important to note that some of the content may contains bias, offensive language, or harmful depictions, such as stereotyped, racist, sexist language related to adolescents. I have included these materials with the sole purpose of illustrating the perceptions and depictions of adolescence on Twitter in 2019. It is crucial to clarify that these contents do not align with, represent, or reflect my personal perceptions or opinions regarding adolescence. My intent is to analyze and discuss the external perspectives found on Twitter during the specified time frame.

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CHAPTER 1: INTRODUCTION

Contemporary research generally acknowledges adolescence as a distinct developmental period that occurs between childhood and adulthood. In the field of developmental science, adolescence has become a crucial area of study, prompting extensive investigations into its defining characteristics (see review by Crosnoe & Johnson, 2011). However, the way in which research views adolescence is not constant but rather evolving (National Academies of Sciences, Engineering, and Medicine, 2019). The pioneering psychologist credited with initiating the scientific study of adolescence, Stanley Hall (1904) described adolescence as a period of storm and stress, seeing conflicts and abnormality as universal and immutable during adolescence. In contrast, later generations of researchers have revisited this view and proposed more positive perspectives to understand adolescence (e.g., revisited storm-and stress view that negative characteristics such as risky behavior is more prevalent but not universal during adolescence, Arnett, 1999; positive youth development that highlights positive characteristics such as responsibility and creativity, Damon, 2004). Alongside this revolution in academia, multiple discernible youth cultures began to emerge in the public fields since the 1950s (e.g., the Mods; Austin & Willard, 1998), leading to diversified portraits of adolescence capturing the lives of young people from various sociodemographic backgrounds (e.g., region, race/ethnicity, religion, etc.; Jeffrey & Dyson, 2008).

Despite the crucial role of adolescence in human development, little research has explored how the general public perceives this stage of life. Specifically, there is a dearth of studies that examine the collective attitudes and beliefs about adolescence held by a group of people, also known as public perceptions of adolescence (Dowler et al., 2006). Informed by theories highlighting the importance of sociocultural influences on development (e.g.,

Bronfenbrenner, 1979), values and beliefs that are pervasive in the larger social contexts (e.g., social norm) have a strong impact on adolescent development (Benner et al., 2022; Wang et al., 2019). Similarly, public perceptions of adolescence could be another meaningful factor in the sociocultural context that influences adolescent development. Negative and stereotyped perceptions of adolescence may pose stereotype threat (Steele & Aronson, 1995) to adolescents and hinder their development, whereas positive perceptions may empower adolescents to promote their positive development (Benson, 1997).

Although research has not directly examined *public* perceptions of adolescence, a handful of studies has investigated *individual* perceptions of adolescence held by parents and adolescents themselves as well as their influences on development (e.g., Buchanan & Holmbeck, 1998; Qu et al., 2016). This research shows that youth whose parents or who themselves hold negative and stereotyped perceptions of adolescence (e.g., expecting rebelliousness and alienation during adolescence) tend to have poor developmental outcomes such as increased externalizing behaviors and parent-child conflicts (Buchanan, 2003; Buchanan & Hughes, 2009). Although these studies provide initial evidence for the value of investigating perceptions of adolescence, they have used small community samples to examine *individual* perceptions that cannot be immediately generalized to public perceptions. Investigating public perceptions of adolescence will deepen the scholarly understanding of the broader sociocultural context within which young people develop. Moreover, by gaining a better understanding of how the public perceives adolescence, we can take the first step towards shaping public discourse and promoting positive youth development through effective framing of adolescence in public spaces (Kendall-Taylor, 2020).

Social media, an important context for contemporary adolescent development (Uhls et al., 2017), can serve as a valuable source of information to understand public perceptions of adolescence. Social media provides the general public with a platform to share information, experiences, and perspectives around various issues (Weinberg, 2009). The content and discourse on social media, as well as the values and beliefs associated with such information, have been found to influence adolescent beliefs and behaviors around sexual development (e.g., Bleakley et al, 2009) and emotion regulation (e.g., Marino et al., 2020). Among various social media platforms, Twitter is a popular site where millions of active users post millions of small bursts of information per day (Twitter, 2022a). National data show that U.S. adolescents between 13 to 17 years old have a high level of exposure to social media platforms, with 23% of them indicating having used Twitter ever (Vogels et al., 2022). An emerging body of literature has examined public perceptions and opinions around a variety of topics such as presidential election (Karami et al., 2018) and mental health (e.g., Pavlova & Berkers, 2022) on Twitter. Similarly, studying perceptions of adolescence on Twitter can provide valuable insights into the social media context, laying the groundwork for understanding the developmental implications of these perceptions in future research.

Beyond the lack of attention to public perceptions, previous research is also limited by the focus on negative perceptions of the adolescence (e.g., risk-taking and rebelliousness) that are heavily informed by earlier developmental theories, such as the storm and stress view (Buchanan & Holmbeck,1998). This narrow focus on negative perceptions ignores the positive and neutral perceptions of adolescence that have been emphasized by more recent adolescent theories (e.g., adolescents have unique potentials and strengths; Damon, 2004), potentially precluding the understanding of a full range of views that may exist in the public. Furthermore,

existing research has exclusively investigated individual perceptions of the general adolescent population, without considering the diversity of adolescent subgroups (e.g., racial/ethnic and sexual minorities) who may have unique developmental contexts and characteristics (McLoyd & Steinberg, 1998). This omission may obscure potential differences in how adolescents from various sociodemographic backgrounds are viewed by the public. Understanding these differences is crucial to challenge the potential negative perceptions associated with adolescent subgroups and to promote positive development among diverse youth.

To address these limitations, the current study employed both theory-driven and data-driven approaches enabled by machine learning and big data analytics to understand public perceptions of adolescence on Twitter. I also conducted an initial exploration on how these public perceptions may differ for adolescents from various sociodemographic backgrounds (i.e., by gender, race/ethnicity, and sexual orientation). Specifically, I extracted information from big textual data (i.e., text entries obtained from Twitter) using unsupervised learning algorithms in word embedding models. This approach represented each word that appeared in the dataset as high-dimensional vectors, including terms of adolescence (e.g., "adolescent," "teen," "youth"), terms that indicated membership in adolescent subgroups based on race/ethnicity, gender, and sexual orientation (e.g., "boy," "girl," "lesbian"), and descriptors that may reflected Twitter users' perceptions of adolescence (e.g., "risk taking," "civic engagement," "creativity"). The associations between different terms (e.g., "adolescent" and "risk taking") can be quantitatively assessed, reflecting how people associate meanings of adolescence with different characteristics, which can be interpreted as public perceptions of adolescence on Twitter (e.g., Miklov et al., 2013). For the theory-driven approach, I tested how terms of adolescence were quantitative associated with pre-defined lists of descriptors (i.e., stereotypical vs. neutral descriptors, positive

vs. negative descriptors) compared to the terms of adult and people. For the data-driven approach, I developed an innovative method that leveraged both quantitative results and qualitative analysis. I first used the word embedding model to generate the top 60 descriptors (e.g., "creativity") that were found to be most closely associated with a certain term of adolescence (e.g., "adolescent"). I then recruit coders to conduct qualitative content analysis of the descriptors while referencing example tweets that contained the descriptors to identify themes regarding public perceptions of adolescence. My dissertation revealed a full range of characteristics and themes that people associate with adolescence, including both positive, neutral, and negative perceptions, for diverse populations. The results provided insights into how the public perceives adolescence and can inform future efforts to promote positive framing of adolescence in public discourse.

CHAPTER 2: THEORETICAL FRAMEWORKS

Understanding how researchers define and characterize the term of adolescence can be the first step of unpacking public perceptions of adolescence, specifically about who is in the stage of adolescence and what are the characteristics of the stage. Although few theoretical works have directly discussed the importance of public perceptions of adolescence, developmental theories such as the ecological systems theory (Bronfenbrenner, 1979, 1995) and positive youth development (Damon, 2004) can inform the current study by highlighting how social values and beliefs can impact adolescent development. In this section, I first reviewed the trends of definition of adolescence as a developmental stage. I then summarized theoretical views of adolescence since Hall's (1904) initial conception. I also discussed theoretical frameworks that may inform the importance of studying public perceptions of adolescence.

Adolescence as A Developmental Stage

From a historical perspective, the understanding and definition of adolescence continued to evolve over time. The word "adolescence" was first used in English in the 15th century, which meant "to grow up or to grow into maturity (Lerner & Steinberg, 2009, p. 3)," yet it did not refer to a specific developmental period at that time. Thirteen-year-olds are considered adolescents and immature in the current society, but they would be considered adults in western countries in the 16th century (Staff, 1995). Scholars generally acknowledge Stanley Hall as discovering and defining adolescence in its modern sense (Henig, 2010) and initiating the scientific study of adolescence (Arnett, 1999). Hall (1904) defined adolescence as a new developmental period between 12 and 25 years of age, characterized by storm and stress, seeing adolescence as the recapitulation of a turbulent transitional time in the evolutionary history of human race.

The modern concept of adolescence continues to evolve after Stanley Hall (1904). As of now, adolescence is widely accepted by both scholars and lay people as a developmental stage between childhood and adulthood. Current researchers generally acknowledge adolescence as a distinct phase with both biological maturation and major social role transitions (Sawyer et al., 2018). The World Health Organization has formally defined adolescence as the period between 10 and 19 years of age (Kuruvilla et al., 2016).

Several other terms are often used to refer to a roughly similar developmental stage. The term "teenage" has been used interchangeably with "adolescence" in academia (e.g., Altikulac et al., 2019). The term "puberty/pubescence" refers to the process of sexual maturation accompanied by significant changes in body, brain, and behavior (Mendle et al., 2019), which has been acknowledged as a key element in the physical and cognitive development during adolescence (Sawyer et al., 2018). The term "youth" became popular after the United Nations' first International Youth Year in 1985 (Sawyer et al., 2018). Youth was formally defined as a social category without age boundaries (United Nations Educational, Scientific and Cultural Organization; UNESCO, 1985), yet the United Nations usually include people between 15 and 24 years of age when reporting statistics, which overlaps with the age definition of adolescence but also includes young adulthood or emerging adulthood. Indeed, researchers now consider the period between 18 and 24 years of age as emerging adulthood, of which the characteristics such as identity exploration and instability resemble adolescence more compared to adulthood (Arnett, 2000).

Theoretical Views of Adolescence

While adolescence as a developmental period can be neutral, the valence of its characteristics – whether positive or negative – can differ across theoretical frameworks. Stanley

Hall's (1904) initial definition of adolescence was closely associated with his storm-and-stress view of adolescence. Specifically, Hall (1916) extended Darwin's concept of biological evolution into a psychological theory of recapitulation, suggesting that different developmental periods can be seen as recapitulations corresponding to different stages in the evolutionary history of human race. The period of adolescence in Hall's (1916) framework corresponds to the turbulent transitional stage in human history, therefore characterized with high levels of emotional disturbance and stress. The so-called storm-and-stress view of adolescence was also adopted by psychoanalysts such as Anna Freud (1946, 1958), who argued that conflicts and abnormality is universal and immutable during adolescence. Hall's storm-and-stress view of adolescence corresponds to a major trend of contemporary research that focuses on internalizing and externalizing problems in adolescents (e.g., Memmott-Elison et al., 2020). While such research does not necessarily reflect any negative perceptions of adolescence within each study itself, the large proportion of adolescent studies with a deficit perspective may indicate an overall negative characterization of adolescence in academics (Arnett, 1999; Rich, 2003).

Nevertheless, later generations of researchers have shifted their perspectives of adolescence from Hall's (1904) storm-and-stress view. On the one side, researchers have revisited the storm-and-stress view, reaching to the conclusion that although the levels of storm and stress such as risky behavior and emotional conflicts are more likely to increase during adolescence, the overall degree is moderate, and there are individual differences as well as cultural variations (Arnett, 1999). On the other side, more positive theoretical frameworks have been proposed to capture the whole picture of adolescence. For instance, the positive youth development (PYD) framework suggested that previous research on adolescence focused more on the negative aspects, such as the deficits of adolescents, and underestimated the true

capacities of them, therefore proposing to focus more on the positive aspects (e.g., positive attitudes such as self-efficacy, positive competence such as empathy, positive behaviors such as social engagement) and capture the full potential of adolescents (e.g., Damon, 2004; Larson, 2000). The PYD framework has widely been adopted to guide the directions of research on adolescence as well as to facilitate practices to promote adolescent development, such as to understand and promote youth civic engagement (Youniss et al., 2002), suggesting an increasingly positive characterization of adolescence in the research field.

Another central theme in adolescent research, identity development, also reflects the complexity of crisis and opportunities during this developmental period. Erikson's (1968) theory posits that the primary psychosocial task of adolescence is identity formation with both opportunities and crisis for adolescent development. On the one side, increased cognitive and physical abilities as well as independence and autonomy enable adolescents to explore topics such as vocations, ideologies, and relationships through the interactions with schools, communities, and neighborhoods, which may help adolescents form their identity. On the other side, changing physical, cognitive, and environmental factors lead adolescents to experience some form of role confusion, in which adolescents doubt the meaning and purpose of their existence. Therefore, Erikson (1968) suggested that adolescents must form their identity to solve the crisis of role confusion. While Erikson (1968) mainly discussed the theme of identity development from the perspective of solving developmental crisis and conflict, later research has emphasized more on the opportunities of identity development during adolescence, such as adolescence as a period when individuals actively explore the characteristics of the self (Meeus, 2011) and develop self-concepts such as self-esteem (Harter, 1998). Researchers have also explored adolescents' identity development in specific social categories such as ethnic and racial

identity development, in which ethnic/racial minority adolescents may face challenges such as stereotypes (Way et al., 2013) but also benefit from it by navigating through racism and oppression (Phinney & Kohatsu, 1997).

Moreover, later generations of researchers have increasingly realized the importance of sociocultural backgrounds for understanding adolescent development. For example, when examining adolescence in non-western cultures, Margaret Mead (1928) found that Samoa people did not have a clear conception of adolescence and most children there had a smooth transition between childhood and adulthood with a minimum level of storm and stress. This line of research has led contemporary researchers to emphasize cultural and individual differences in the understanding of adolescent development (e.g., Arnett, 1999) and to investigate diverse populations (McLoyd & Steinberg, 1998), leading to diversified characterizations of adolescence rather than assuming adolescent characteristics as universal. For instance, while identity development has been found to be a key feature of adolescence across cultures, the patterns of identity development and its key factors (e.g., cultural values) may vary across different adolescent subgroups (e.g., ethnic/racial groups, Smith, 1991; sexual-minority youth, Savin-Williams, 2011).

In line with this trend, contemporary research on adolescence has emphasized contextual factors in adolescent development. By reviewing literature, Dornbusch (1989) concluded that research on adolescence has shifted from studying individual adolescents carrying out their developmental tasks (e.g., cognitive development, identity development) to understanding the intersections between adolescents and their environments. Such a trend has been strengthened in later works, with more and more research adopting theories such as the ecological systems theory (Bronfenbrenner & Morris, 1998) and the life course paradigm (Elder, 1998) to

investigate contextual factors in adolescence (Crosnoe & Johnson, 2011). Adolescence is now seen as embedded in multiple layers of social systems (Crosnoe & Johnson, 2011).

Contextual factors such as peer relationships have been seen as one of the most important characteristics (e.g., adolescents are oriented to and impacted by their peers for both positive outcomes such as prosocial behavior and negative outcomes such as substance use) of adolescence (Brown & Larson, 2009). In addition to peer relationships, other contexts such as family, school, and neighborhood have also been highlighted in contemporary research. Specifically, adolescents' relationship with their parents remains to be impacting their development, including positive relationship such as closeness and warmth, positive relationship such as conflicts and disagreements, and other themes such as autonomy seeking/support, communication, conflict resolution (Smetana & Rote, 2019). Adolescents spend more time in school than other settings and engage in important activities such as learning and extracurricular activities (Waters et al., 2009). Researchers have also highlighted adolescent-teacher relationship, peer interaction, school culture, school safety in the school context for adolescence (Eccles & Roeser, 2011). Meanwhile, neighborhood has been considered as an important context for adolescent development in terms of externalizing and internalizing problems, academic achievement, health, and cultural development, especially for adolescents from underrepresented or minoritized backgrounds (White et al., 2021).

Theoretical Views on Public Perceptions of Adolescence

Although there is no widely accepted definition of public perceptions of adolescence in the literature, I proposed the following definition based on previous discussions of public perceptions of other topics, such as food, risk, and health (Dowler et al., 2006). Public perceptions of adolescence can be defined as the collective beliefs, attitudes, understanding,

impression, or opinions of the general public towards adolescence as a developmental period and towards adolescents as a group. This definition is also informed by Buchanan and Holmbeck's (1998) work on individual perceptions of adolescents, which refers to the beliefs and attitudes that individuals (e.g., parents, young people themselves) hold towards adolescents as a social category. By contrast, public perceptions of adolescence capture the broader views of society as a whole, reflecting the collective attitudes and opinions of the general public towards this critical period of development. To date, there are few theoretical works that specifically discuss public perceptions of adolescence. However, the importance of this topic can be inferred from several classical theories related to adolescent development.

Bronfenbrenner's (1979, 1995) ecological systems theory suggested that adolescent development is embedded in multiple ecological systems. In this theory, public perceptions of adolescence are perhaps most relevant in the macrosystem. Macrosystem refers to the culture or society including its values and ideologies that shapes the fundamental background of development and impacts the structures and relationships among the other systems (e.g., the exosystem consisting of multiple social structures that indirectly influence the developing individual such as neighborhood and parents' workplaces). Public perceptions of adolescence can be an important factor in this system because it can be seen as an element of sociocultural values, therefore fundamentally impacting other systems such as the perceptions of adolescents held by neighbors, parents, and teachers as well as their attitudes towards and interactions with the adolescents based on their perceptions. While Bronfenbrenner (1979) discussed more on social categories such as socioeconomic status and ethnicity in the macrosystem, adolescence can also be seen as an important social category that has profound developmental implications.

Specifically, public perceptions of adolescence can also be incorporated as an important contextual factor into Bronfenbrenner's (1995, 2005) process-person-context-time (PPCT) model, in which he emphasized the interrelatedness between the developing *person* and the developmental *contexts* (i.e., the ecological systems such as the macrosystem of the culture or society) via reciprocal interactional *processes* over *time*. Public perceptions of adolescence in the macrosystem can impact other developmental *contexts* that are more proximal to the developing individual. For instance, public perceptions of adolescence can be adopted by parents and teachers in the microsystem (i.e., the immediate settings in which the developing individual can interact with such as family and school) as individual perceptions of adolescence or as social norms about adolescent development if certain perceptions become pervasive in the settings. Public perceptions of adolescence can also impact the developing *person* by shifting how one perceive and expect one's self-development in the current developmental stage. Then, individual perceptions of adolescence as held by individuals (e.g., parents, teachers, and the developing person) and social norms about adolescent development can impact the developing *person* through reciprocal *processes* such as parent-child and teacher-student interactions. For instance, parental beliefs on development may impact their parenting attitudes and behavior (Sigel, 1985). Adolescents' own perceptions about their social categories (e.g., gender) can also impact their own developmental outcomes (e.g., gender stereotypes, Starr & Simpkins, 2021).

The positive youth development (PYD) framework (e.g., Benson, 1997; Lerner et al., 2005) also speaks to the importance of understanding public perceptions of adolescence. In Benson's (1997) framework of developmental assets, he highlighted the importance of multiple internal and external assets to facilitate adolescent development, many of which are related to perceptions of adolescence. For instance, Benson (1997) advocated positive values (e.g., caring,

honesty) and identity (e.g., personal power, positive view of personal future) as internal assets, which can only be achieved when the adolescents have a positive perception of their own age group. Benson (1997) also advocated empowerment from multiple contexts (e.g., community, school, and family) such as acknowledging the value of youth in the community, which requires positive perceptions of adolescence to be prevalent in these contexts. Furthermore, Lerner and colleagues' (2005) 6Cs models of PYD proposed competence, confidence, connection, character, caring/compassion, and contribution as six important indicators of PYD. The second indicator of confidence suggested that the individual should establish a global positive view of the self, which requires the developing adolescents to possess a positive perception of their own age group. From this perspective, positive perceptions of adolescence should be established in multiple contexts (e.g., community, school, and family) as well as the developing adolescents themselves, all of which are impacted by public perceptions of adolescence as illustrated in the prior discussion on the PPCT model. Although contemporary researchers have revisited Hall's storm-and-stress view of adolescence, adolescent research and practices are still influenced by Hall's perspective, focusing more on themes related to the storm-and-stress view, such as risky or problem behaviors and mood disruptions (Arnett, 1999; Rich, 2003), which may strengthen the negative perceptions of adolescence held by the public and further hinder the positive development of adolescents. The PYD framework has the potential to break such a chain of negative influences by advocating a positive framework of understanding adolescence.

In addition to developmental theories, several basic psychological and communication theories also help explain the importance of how we understand or perceive adolescence. For instance, the theory of self-fulfilling prophecies suggests that public perceptions or beliefs have a strong impact on individual beliefs, which will in turn impact individual behavior based on the

prophecies of self-fulfilling (i.e., the phenomenon whereby the expectations about an individual or entity result in the individual or entity acting in the ways that confirm the expectations; Jussim, 1986, 1991). The theory of self-fulfilling prophecies is also relevant to the theory of stereotype threat, which suggests that stereotyped perceptions of social groups may cause the group members to confirm such perceptions by engaging in particular activities (Spencer et al., 2016). From this perspective, public perceptions of adolescence may impact adolescent development through self-fulling, in which adolescents may tend to behave in ways that confirm public perceptions of adolescence. In addition, communication research on framing effects suggests that perceptions or beliefs can influence how we frame or present certain issues in communication messages, which will in turn influence how the audience perceive the issues from the messages and their later behaviors (e.g., Entman, 1993; Vliegenthart & van Zoonen, 2011).

CHAPTER 3: LITERATURE REVIEW

While extensive research has investigated the characteristics of adolescence, less attention has been paid to people's perceptions of adolescence. A handful of studies have examined and measured individual perceptions of adolescence (e.g., Buchanan & Holmbeck, 1998; Gross & Hardin, 2007; Hines & Paulson, 2006) as well as the impact of such perceptions on adolescent development (e.g., Buchanan, 2003; Qu et al., 2016; Qu et al., 2018). However, these study all surveyed small samples of participants and focused on the school and family contexts. They also employed a theory-driven approach that tended to focus on negative perceptions of adolescence. In this section, I presented a literature review of existing research that measured individual perceptions of adolescence or examined the impact of individual perceptions of adolescence on adolescent development. I then discussed the limitations of existing research.

Individual Perceptions of Adolescence

A growing body of literature suggests that people with different identities (e.g., parents, teachers, college students, and adolescents) and country of origin (e.g., the U.S., Netherlands, and China) have had stereotyped perceptions of adolescents since the 1960s (e.g., Friedman, 1975; Gross & Hardin, 2007; Qu et al., 2016). For instance, in a survey conducted in 1965, American teachers agreed that adolescence is a period with great emotional disturbance and complete personality change (Friedman, 1975). In the 1980s, 192 American college students (approximately 75% female, 73% White) generally agreed with the storm-and-stress view of adolescence (Holmbeck & Hill, 1988), and 90 elementary school teachers and 636 parent pairs of early adolescents (97% identified their children as White) in the U.S. endorsed stereotyped beliefs that adolescence is a difficult period (Buchanan et al., 1990). In the 1990s, 361 college

students (53% female, 89% White) and 112 parents of adolescents (69% mothers) in the U.S. indicated more negative perceptions of adolescence such as risk-taking and rebellious compared to neutral or positive perceptions such as friendly and conforming (Buchanan & Holmbeck, 1998). In the 2000s, 106 American college students in the (79% female, 44% White) exhibited both explicit and implicit stereotyping of adolescents compared to older adults (Gross & Hardin, 2007), while 1112 teachers and social workers attending training programs in Hong Kong had much more negative comments of adolescence (e.g., "problematic self-conceptions," "irresponsible," "materialistic") compared to positive comments (e.g., "creative," "energetic"; Shek & Chan, 2011). In the 2010s, 203 American adolescents (46% female, 73% White) were more likely to perceive adolescence as a time of decreased family responsibility and increased school disengagement compared to 194 Chinese adolescents (54% female, 99% Han decent; Qu et al., 2016).

Among these studies, two of them specifically explored the contents and structures of individual perceptions of adolescence in a systematic manner. Buchanan and Holmbeck (1998) first asked 62 college students and 61 parents (demographic information was not reported) to answer open-ended questions about adolescent personality characteristics, they selected 48 descriptors from participants' answers and also added 17 descriptors based on their understanding of academic and popular literature. Then, they developed the descriptors into scales and administered the questionnaires to 361 college students (53% female, 89% White) and 112 parents (69% mothers, the majority had a college degree or beyond). Principle components analysis resulted in 9 factors with positive, negative, and neutral perceptions, including risk-taking/rebellious, friendly, problem behaviors, conforming, etc. They also did a series of measurement analysis to establish reliability and validity. This scale ("Stereotypes of

Adolescents") is often used by studies to examine perceptions of adolescence their influence on adolescent development. However, these studies mainly focused on the subscales with negative perceptions (e.g., risk-taking/rebelliousness, problem behaviors, and internalizing problems; Buchanan & Hughes, 2009; Hines & Paulson, 2006).

Using a similar approach, Qu et al. (2016) asked 203 U.S. adolescents (46% female, 73% White) and 194 Chinese adolescents (54% female, 99% Han decent) to write descriptions or characteristics of youth their age using an open-ended measure. The responses were coded into one of the four categories, including individuation, responsibility, social relationships, and emotionality. The categories were developed based on Buchanan and Holmbeck's work (1998) while also ensuring interrater reliability. Qu et al. (2016) also developed a closed-ended measure that was administered to the same participants after the open-ended measure. This measure also included four categories based on developmental literature (i.e., individuation, family responsibility, school engagement, and peer orientation), and items were developed by the research team or modified from other relevant scales (e.g., the family responsibility scale, Fuligni et al., 1999). They used reliability and confirmative factor analysis to evaluate the measure. Both results from the open-ended measure and closed-ended measure were compared between U.S. adolescents and Chinese adolescents. For the open-ended measure, American adolescents perceived adolescence as more associated with identity exploration, bullying, being disrespectful, and being oriented towards peers as well as less associated with being responsible, experiencing positive emotions. For the closed-ended measure, American adolescents were more likely to characterize adolescence as a time of individuation from parents, heightened disengagement from school, and not being responsible to the family.

In addition to academic research, several public reports have also investigated public perceptions of adolescence using survey data or media materials (e.g., Aubrun & Grady, 2000; Gilliam & Bales, 2001; Bostrom, 2004). For instance, Bostrom (2001) reviewed a series of public polls that surveyed peoples' perceptions of adolescence nationally in the U.S. (e.g., the CBS News Poll, the ABC News Poll, and polls conducted by the Gallup Organization, each surveyed between 800 and 3,000 adults that were randomly selected using certain sampling strategies) and found that American adults tend to have a negative perception of adolescence and such perception is becoming more and more negative. Several reports from the Frameworks Institute analyzed the media contents about adolescents (e.g., prime-time entertainment programming, Aubrun & Grady, 2000) and found that the media tends to show a negative and stereotyped image of the general adolescent population, which may in turn strengthen the negative perceptions of adolescents held by the public.

The Impact of Individual Perceptions of Adolescence

There is an emerging line of research examining the impact of individual perceptions of adolescence on adolescent development (e.g., Buchanan, 2003; Qu et al., 2016; Qu et al., 2018). Focusing on parents' perceptions of adolescence, several studies show that negative perceptions of adolescence are associated with negative parental attitudes and behaviors, leading to less desirable developmental outcomes of their children. For example, one study found that among 75 mothers (89% White), those holding more positive beliefs about adolescents as a group tended to have more positive expectations for their own children in adolescence; they also expected a closer relationship with their children (Buchanan, 2003). Another study found that parents holding a storm-and-stress view of adolescence exhibited more authoritarian parenting, less supportive of their adolescents' autonomy (Holmbeck, 1996). Moreover, among 1193 parents

(62% mothers), those with stereotyped perceptions of adolescence tended to have children with lower self-rated of social ability and having more deviant friends (Jacobs et al., 2005).

A newer body of literature has investigated youth's own understanding of adolescence and shown that stereotyped perceptions of adolescence held by youth themselves may hinder their positive development, yet interventions may be implemented to shift their perceptions and promote positive development (e.g., Qu et al., 2016; Qu et al., 2018; Qu et al., 2020). For example, among 270 adolescents (52% female, 64% White), those holding a storm-and-stress view of adolescence also showed parallel behavior and attributes one year later (e.g., externalizing behavior and internalizing symptoms, Buchanan & Hughes, 2009). Among 203 U.S. adolescents (46% female, 73% White) and 194 Chinese adolescents (54% female, 99% Han decent), American youth's understanding of adolescence as associated with less family responsibility and more school disengagement explained the observed differences that American youth were less engaged in school compared to Chinese youth (Qu et al., 2016). Among 23 adolescents (43% female, 64% White), those holding stereotyped perceptions of adolescence in middle school showed altered prefrontal cortex activation during cognitive control during the transition to high school, which was in turn associated with more risk taking (Qu et al., 2018). An intervention countering youth's stereotypes of adolescence promoted youth's academic engagement and performance as well as decreased their risk taking among middle school students in China (Study 1: 125 youths, 48% female, 99% Han decent; Study 2: 319 youths, 50% female; Qu et al., 2020).

Limitations of Existing Research

Although previous research has examined individual perceptions of adolescence and tested their impact on adolescent development, there are several limitations associated with this

body of work. First, existing research mainly examined perceptions of adolescence from the perspectives of parents, teachers, and youth, focusing on the school and family contexts. Few studies have investigated this topic from the perspective of the general public (Heintz-Knowles, 2000; Nichols & Good, 2004). The ecological systems theory suggests that youth development is embedded in multiple systems and the transactions among systems (Bronfenbrenner, 1979). Public perceptions of adolescence reflect the societal value on the social category of adolescence and therefore serve as an important contextual factor in the macrosystem. They can impact individual perceptions of adolescence in other systems (e.g., teachers in school, parents in family), which will in turn influence the developing adolescents through reciprocal processes such as teacher-student and parent-child interactions. In fact, both Buchanan and Holmbeck (1998) and Qu et al. (2016) suggested that perceptions of adolescence held by parents and youth are influenced by societal stereotypes or the society's mainstream ideas. Therefore, it is essential to examine public perceptions of adolescence from a broader perspective as the underlying context for individual perceptions.

Furthermore, existing research has primarily employed a theory-driven approach and focused more on the negative perceptions of adolescence as informed by Hall's (1904) storm-and-stress view. For instance, both Buchanan & Holmbeck (1998) and Qu et al. (2016) coded participants open-ended responses about their perceptions of adolescence into a limited number of categories based on developmental theories. Their follow-up studies focused more on the negative perceptions of adolescence that reflect the storm-and-stress view rather than other neutral or positive themes that were identified in their initial work (e.g., Buchanan & Hughes, 2009; Qu et al., 2018; Qu et al., 2020). The focus on negative perceptions also overlooks positive or neutral views of adolescence that are emphasized to a greater degree by later theoretical work

(e.g., the PYD framework). A data-driven approach that examines a full range of public perceptions may better address this limitation and facilitate future theoretical development.

Moreover, existing research focuses on perceptions of the general adolescent population without paying attention to various subgroups by race/ethnicity, gender, and sexual orientation. Research has identified various stereotypes being held towards adolescents based on their social categories (e.g., gender stereotypes; Ellemers, 2018). It remains unknown how public perceptions of adolescence may differ by social categories (e.g., gender, race, ethnicity, sexual orientation). For instance, adolescent boys may be perceived as more associated with rebellion and risk taking compared to adolescent girls (Abbott-Chapman et al., 2008). Racial/ethnic minority adolescents may be perceived as more engaged with risky health behaviors compared to the general adolescent population (Wallace et al., 2011). On the other hand, social media posts about adolescent subgroups may not reflect stereotypes but convey messages about the actual developmental disparities such as gender disparities in STEM (Beede et al., 2011). Such messages may also be captured as reflecting public perceptions that we need to address these disparities. Either for the stereotypes or the disparities associated with different subgroups of adolescence, little is known about how they unfold in public perceptions of adolescence. Investigating the differential perceptions associated with adolescent subgroups may be the first step towards addressing inequality among adolescent subgroups in broader contexts via potential prevention and intervention programs that seeks to promote the positive framing of adolescent subgroups in public perceptions.

Finally, the definition and characteristics of adolescence have kept evolving in accordance with sociocultural changes, and public perceptions of adolescence may also be constantly shifting. For instance, as the society has increasingly advocated for the importance of

youth engagement in facilitating positive social change (e.g., MacKay et al., 2020), public perceptions of adolescence may become more associated with positive themes such as contributing to the society. Furthermore, Bronfenbrenner's (1995, 2005) suggested in his PPCT model that the macrotime (i.e., the macro-level time factor that impacts development) involves the changing expectations in the larger society, which requires capturing potential changes in public perceptions of adolescence. Therefore, an update of knowledge on the perceptions of adolescence is needed.

My dissertation sought to address the aforementioned limitations with two major aims: 1) to provide an updated, comprehensive, and data-driven description of current public perceptions of adolescence, with a focus on the social media platform of Twitter, which can expand the previous work from the individual level to a broader context; 2) to conduct initial exploration of how public perceptions of adolescence differ by various adolescent subgroups (e.g., racial/ethnic, gender, and sexual minorities).

Twitter as a Unique Window

The society has entered into the era of Web 2.0, with Internet users actively creating contents and interacting with each other in online communities (Cormode & Krishnamurthy, 2008). As of 2018, 45% of American adolescents reported that they were online almost constantly, and 44% reported being online several times a day (Anderson & Jiang, 2018). Social media platforms, such as Twitter, is becoming the major and most important online communities and attracting more and more Internet users. Twitter is a free microblogging social network platform that allows users to post small bursts of information called tweets within 140 characters of length. As of 2018, Twitter has more than 330 million active users monthly, and these users produced more than 500 million tweets per day; around 32% of American adolescents were using

Twitter (Anderson & Jiang, 2018), a much higher rate than that of adults (24%; Perrin & Anderson, 2019).

Twitter has become one of the most important platforms for users to express their opinions across various issues on the Internet (Java et al., 2007). An extensive body of research has examined political expression on Twitter (e.g., Vaccari et al., 2015), and to a lesser extent sexual assault (PettyJohn et al., 2018) and public health (Hays & Daker-White, 2015). A recent study examined perceptions of older adults and COVID-19 on twitter (Jimenez-Sotomayor et al., 2020). Similarly, Twitter can be a unique window to explore people's perceptions of adolescence. The information sharing and opinion expression nature of the platform, as well as the large number of users and posts, may enable generalization of users' perceptions of adolescence. Moreover, tweets reflect a more spontaneous form of opinion expression (Christensen, 2011), rather than responses given during intentional inquires such as surveys or interviews. This approach enables us to explore public perceptions of adolescence in a more naturalistic and realistic way, avoiding potential biases that may arise from asking participants to report their views in a more controlled setting and, thus, enhancing the study's ecological validity.

Using a Big Data and Machine Learning Approach

I employed a big data and machine learning approach to examine public perceptions of adolescence on Twitter. Big data and machine learning have recently been introduced into social sciences (e.g., Jacobucci & Grimm, 2020; McFarland et al., 2016), yet the paradigms and standards of their applications have yet to be established. Grimmer et al. (2021) suggested that machine learning is better to be applied to discover new concepts, measure the prevalence of the concepts, assess causal effects, and make predictions. These applications may facilitate social

sciences to move from a deductive approach, where we make predictions based on theories and test them, to an inductive approach, where we learn from observations.

The focus of my dissertation can be seen as discovering and measuring the public perceptions of adolescence in big data, which is suitable for using machine learning with an agnostic and inductive approach. Although the concept of adolescence is not new and has already been formally defined, there is no clear definition or theoretical account on public perceptions of adolescence. Public perceptions of adolescence can be best captured by describing how the public perceive adolescence, rather than identify them by judging if the data meet a certain theoretical account of adolescence. Therefore, it is appropriate to use the big data/machine learning approach for my dissertation, and my research questions also align more with the agnostic approach because of my research focus and methodology.

Unpacking the Meanings of Adolescence Using Word Embeddings

Word embedding models are a powerful machine learning tool that has widely been employed in the field of artificial intelligence and natural language processing. By feeding textual data from large corpora to a word embedding model, the model will extract information from the data based on the cooccurrence of words and then represent the meanings of words as high-dimensional vectors (i.e., word embeddings). The resulting word embeddings can be thought of as a way of measuring a construct with multiple items or variables. While conventional social science research typically measures a construct using a small set of items (e.g., 2-10 items), word embeddings represent the meanings of each word using hundreds of dimensions (e.g., 300 dimensions; Grag et al., 2018; Kozlowski, 2019). This allows for a much more nuanced characterization of word meanings. Indeed, word embeddings have been found to show compositionality, an interesting attribute suggesting that word embeddings can capture the

latent meanings of words (Mikolov et al., 2013). For instance, the word embeddings of "Vietnam" plus the word embeddings of "capital" was found to be close to the word embeddings of "Hanoi", which is indeed the capital of Vietnam.

If word embeddings can capture the latent meanings of words in large corpora, they can be interpreted as reflecting perceptions of the words held by the people writing the texts, as the use of words are subjective and reflect individual's understanding about the words. Indeed, an emerging body of literature has shown that word embeddings may be used in this way. Inspired by the Implicit Association Test (IAT) in psychology, Caliskan et al. (2017) developed the Word-Embedding Association Test (WEAT) based on word embeddings trained with big textual data collected from the Internet. Whereas IAT assessed human participants' biases with experiments, WEAT assessed how different words was associated with each other in the space of word embeddings as reflecting biases (e.g., if the word embeddings of the word of "flower" is closer to positive terms compared to the word embeddings of "insect"). The two tests are comparable as they can assess the same set of biases. Their results showed that many findings from IAT can be replicated in WEAT, suggesting that human biases in big data can be identified with word embeddings as indicating potential bias in people's language.

Grag et al. (2018) trained a word embedding model with 100 years of English literature data and focused specifically on gender and ethnic stereotypes. Specifically, they measured gender and ethnic stereotypes as the relative distance between a term for gender/ethnicity (e.g. "woman") and a neutral term (e.g., "researcher") compared to the opposite term for gender/ethnicity (e.g. "man"). In this example, the measure corresponds to gender stereotype towards the occupation of researcher. Moreover, Grag et al. (2018) took a historical perspective and analyzed 100 years of textual data to identify the patterns of change. The identified

trajectories of gender and ethnical stereotypes were found to be meaningful, such that historical trends (e.g., how "woman" is close to "researcher" compared to "man") were also closely associated with demographic and occupation shifts (e.g., the actual prevalence of females in academia). This study provides another example of how word embeddings can capture the latent meanings of terms in big data and reflect stereotypes associated with gender and ethnicity.

Kozlowski et al. (2019) presented another example of constructing the meanings of terms using word embeddings trained with English literature data. They identified six dimensions of class based on literature (i.e., affluence, cultivation, employment, education, status, morality) and explored the meanings of these dimensions by examining how the word embeddings of these dimensions (e.g., "rich" and "poor" as capturing the dimension of affluence) in relation to the word embeddings of other sociological constructs of interests (e.g., gender, race/ethnicity, occupation, etc.). Kozlowski et al. (2019) specifically made the claim that word embeddings can be used to analyze the cultural meanings of important constructs in theory.

The aforementioned three studies have validated the basic analytic framework of training word embeddings and analyzing the associations between word embeddings of different terms to interpret the meanings of terms. The meanings of terms as interpreted based on word embeddings are not objective but rather subjective to the data, capturing latent nuances underlying the data. The current study will train word embeddings using Twitter data about adolescence. Because Twitter data are user-generated contents that are related to users' opinion expression, interpreting the latent meanings of terms related to adolescence may reflect public perceptions of adolescence on Twitter.

I think this analytic approach has several advantages. First, the word embeddings are high-dimensional, usually with 300 dimensions. Although it is difficult to interpret the meanings

of each dimension, the 300 dimensions as a whole may better capture the complexity and nuances compared to other conventional quantitative approaches such as factor analysis. Second, this analytic approach is data-driven and unsupervised. No prior knowledge or assumptions need to be fed into the algorithm, it is thus more likely to capture more meanings and perceptions of adolescence, whereas previous studies have mostly relied on theory-driven approaches and focused on the storm-and-stress view.

The Current Study

The current study sought to move from previous work that measured individual perceptions of adolescence to assessing public perceptions of adolescence in a broader context. To achieve this, I leveraged a large dataset consisting of millions of tweets about adolescence from Twitter that is extracted throughout 2019 before the COVID-19 pandemic. The use of big data may enhance the generalizability of the current study to capture public perceptions on social media. The dataset is relatively new and can provide an updated description of perceptions of adolescence, which may be reflective of the change in sociocultural backgrounds in recent years. Empowered by word embedding models, an innovative and powerful machine learning tool that can extract information from textual data and construct the meanings of concepts with hundreds of dimensions, the current study also has the potential to transcend previous work by not only focusing on negative perceptions but also explore and evaluate other forms of perceptions. Furthermore, the current study also explored public perceptions of adolescence for different adolescent subgroups (e.g., racial/ethnic and sexual minorities), which may fill in the scarce in literature as there are few studies investigating this issue.

My dissertation has two aims that are descriptive and exploratory in nature. As such, I presented some general hypotheses informed by prior work and theories of adolescence.

Aim 1. To describe public perceptions of adolescence on Twitter. I hypothesize that, overall, there is a negative perception (e.g., the storm-and-stress view) of adolescence on Twitter, which may be indicated by the observation that terms of adolescence (e.g., "teenage") are more closely associated with negative or stereotypical descriptors (e.g., "rebellious") compared to positive or neutral descriptors (e.g., "patience") based on prior research on individual perceptions (Buchanan & Holmbeck, 1998). However, I also expect to identify positive and neutral perceptions (e.g., youth civic engagement) of adolescence on Twitter, as indicated by the observation that terms of adolescence are also closely associated with neutral and positive descriptors.

Furthermore, themes of public perceptions of adolescence can be identified from Twitter data, as achieved by conducting qualitative thematic analysis to assign descriptors that are closely associated with adolescence into different themes. Specifically, analyzing word embeddings can generate a list of relevant terms (e.g., "friend") associated with the terms of adolescence, which resemble existing approaches in which participants were asked to assign descriptors to adolescence (Buchanan & Holmbeck, 1998; Qu et al., 2016). I can then code the list of relevant terms into different themes to facilitate the understanding of perceptions of adolescence.

Aim 2. To explore potential variations in public perceptions of adolescents from various subgroups (based on race/ethnicity, gender, and sexual orientation). This will be done by using quantitative comparisons of how different terms of adolescent subgroups (e.g., "female adolescent") differ in their associations with descriptors and qualitative comparisons of how different themes can be identified with different adolescence subgroups (based on the aforementioned steps of qualitative thematic analysis). For instance, I hypothesize that

racial/ethnic minority adolescents will be more closely associated with descriptors and themes related to risky behavior and less associated with competence compared to the general adolescent population. Male adolescents will be more closely associated with descriptors and themes related to risky behavior, autonomy, competence compared to female adolescents. Adolescents belonging to the LGBTQ+ groups may be uniquely associated with descriptors and themes related to their sexual orientation.

CHAPTER 4: METHODOLOGY

Data

The Twitter data were extracted using the Historical PowerTrack API (application programming interface; Twitter, 2022b) provided and authorized by the Developer Platform of Twitter, Inc, which is a common data extraction approach in research using Twitter data (e.g., Jimenez-Sotomayor et al., 2020). The API is a commercial enterprise API that provides access to the entire historical archive of public Twitter data with certain rules of search since the initiation of the Twitter platform. The data extracted from the API were all publicly available (i.e., they were searchable and could be seen by Twitter users on Twitter) at the time of extraction.

To identify tweets that are relevant for adolescence, I searched a set of keywords related with adolescence (i.e., adolescent, adolescents, adolescence, adolescency, teen, teens, teenage, teenagers, youth, youths, juvenile, juveniles, juvenility, juvenescence, puberty, pubertal, pubescent, pubescents, pubescence, youngster, youngsters, tween, tweens). The keywords were selected based on English dictionaries, literature on adolescence, and consultation with researchers studying adolescent development. Based on the keywords, I extracted a 10% random sample (the highest ratio of sampling that Twitter can offer) of all tweets that were written in English, posted in 2019 (between December 31, 2018 and January 1, 2020), and contained any of the aforementioned keywords (n = 8,094,988) by accessing the Historical PowerTrack API via python. The data were extracted in 2020 with the support of funding from the Research Scholars Award issued by the College of Social Sciences at Michigan State University. The time period of 2019 was chosen due to the consideration of avoiding potential influences of the COVID-19 pandemic on Twitter environment.

The extracted data were recorded in the format of JavaScript Object Notation (JSON), containing both the text part of the tweets and the metadata (e.g., user profiles). For the purpose of the current study, I focused on the text part of the tweets, whereas the metadata may be analyzed for future research to contextualize the tweets.

The extracted data can be categorized into original tweets (n = 2,455,227; 30.3%) and retweets (n = 5,639,761; 69.7%). Whereas original tweets were solely written and posted by the users, retweets were based on original tweets but were reposted by users. Some retweets also contained comments of the users who retweeted the original tweets. Because both original tweets and retweets can reflect users' perceptions of adolescence, I kept both types for data analysis. For retweets, I merged the text of the original tweets that the users reposted with the comments, as both parts may reflect the users' perceptions of adolescence.

There were 4,367,889 tweets (54.0% of all tweets) that were duplicates in terms of the text part, consisting of 1.9% of the original tweets and 76.6% of the retweets, suggesting that duplicate tweets were prevalent in retweets but not original tweets. Because duplicate tweets may result in potential biases in the word embedding model by overweighing these samples compared to other tweets, I excluded the duplicate tweets. As sensitivity analysis, I also trained another word embedding model that included the duplicate tweets. The results were less meaningful compared to the model without duplicate tweets. For instance, the word embedding of "teenager" was found to be most closely associated with "think" in sensitivity analysis, because a tweet containing text of "my teenager thinks so" had many duplicates in the dataset. After removing duplicates, the results were more meaningful as the associations among different terms were more reflective of their meanings rather than simply co-occurrence.

The final analytic sample included 3,727,099 tweets, consisting of 2,407,476 original tweets (64.6%) and 1,319,623 retweets (35.4%).

Data Analysis

Data Cleaning

Following previous research analyzing Twitter data (e.g., Eichstaedt et al., 2015), I applied a series of steps to clean the textual data, with the goals of removing meaningless texts, standardizing words in different forms, and facilitating the training of the word embedding model, including: 1) lowercasing all the letters; 2) removing textual patterns that were meaningless, including the initial parts of retweets (e.g., "rt @author:"), the parts when users were mentioning other uses (e.g., "@author"), the hashtag symbol ("#"; a hashtag is a word or phrase that classifies or categorizes the accompanying text, usually used to facilitate the discussion of the same topic; I only removed the "#" symbol but kept the word or phrase), website links (e.g., "www.google.com"); 3) removing punctuations that were not in the middle of a word (e.g., "whether you're a new parent, grand parent, first-grader" was cleaned as "whether you're a new parent grand parent first-grader"); 4) removing numbers that were not tied to letters (e.g., "4themany" was kept but "19 01 11" was removed); 5) tokenizing the tweets (i.e., separating a tweet into a list of tokens; tokens are individual linguistic units; e.g., "you make me a teenager" was tokenized as "you," "make," "me," "a," "teenager"); 6) lemmatizing the tokens (i.e., shifting the inflected or variant forms of the same word into the original form; e.g., "a teenager goes to school" was cleaned as "a teenager go to school").

To facilitate the training and interpretation of the word embedding model, I manually shifted different keywords of adolescence to more consistent forms. Specifically, keywords of "adolescents," "adolescence," and "adolescency" were shifted to "adolescent". Keywords of

"teens," "teenager," "teenagers," and "teenage" were shifted to "teen". Keywords of "juveniles," "juvenility," and "juvenescence" were shifted to "juvenile". Keywords of "pubertal," "pubescent," "pubescents," and "pubescence" were shifted to "puberty". Keywords of "youngsters" were shifted to "youngster". Keywords of "tweens" were shifted to "tween". Therefore, there were seven terms of adolescence left, including "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween".

Sentiment Analysis

To better understand the descriptives of the data, I conducted sentiment analysis of the data using the VADER (Valence Aware Dictionary and sEntiment Reasoner; Hutto & Gilbert, 2014) algorithm. VADER is an algorithm that was specifically designed to distinguish sentiments expressed in social media. VADER evaluates the sentiments of tweets by identifying sentiment intensity lexicons (i.e., words that indicate sentiment intensity based on existing research) as well as integrating rules (e.g., the exclamation point "!" increases the sentiment intensity without modifying the semantic orientation; for this part of the analysis I did not remove punctuations from the data). Previous research suggested that this algorithm outperformed other lexicon-based models, machine learning models, and even human raters in analyzing the sentiment of tweets (Hutto & Gilbert, 2014). VADER can automatically analyze the tweets and provide scores for positive sentiment, negative sentiment, neutral sentiment, and the overall sentiment. For positive, negative, and neutral sentiment, the scores range from 0 to 1, with higher scores indicating higher levels of sentiment. For overall sentiment, the scores range from -1 to 1, with scores higher than .05 indicating positive sentiment, scores lower than -.05 indicating negative sentiment, and scores between -.05 and .05 indicating neutral sentiment. I fed all the tweets into the VADER algorithm and generated sentiment scores for each tweet. I then compared the

average sentiment scores among tweets containing different terms of adolescence (i.e., "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween") using ANOVA.

Word Embedding Model

I used the word2vec algorithm (Miklov et al., 2013), an unsupervised neural network model that only require the input of large corpora data and then generate word embeddings (i.e., representations of words) for all the different words in the data as vectors with multiple dimensions (i.e., word embeddings). This approach has been employed by recent studies to analyze the meanings and perceptions of sociological concepts such as gender, ethnicity, and social class (Grag et al., 2018; Kozlowski et al., 2019). While the algorithm is complex and its internal possessing mechanisms remain to be a black box, its output of word embeddings as high-dimensional vectors can be simply interpreted as constructing the latent meanings of words using multiple dimensions, which are learned from the data. Each word in the data will be assessed using the same set of dimensions. Therefore, their associations can be quantitatively assessed using cosine similarity (a mathematical formula to calculate the distance of two vectors). Such associations may be used for theoretical interpretation, such as why a word of interest (e.g., "adolescent") is more closely associated with another word (e.g., "risk-taking") compared to other words (e.g., "driving"). In the context of the current study, since the data were user-generated contents around adolescence on Twitter, the meanings of various words of adolescence (e.g., "teen") can be interpreted as reflecting public perceptions of adolescence on Twitter.

After data cleaning, the tweets were fed into the word2vec model. For each tweet, the model identified all the words in the tweet and analyzed words with their surrounding words, representing each word as vectors with multiple dimensions. Following previous research using the word2vec algorithm to analyze the meanings of words (e.g., Kozlowski et al., 2019), I set the

size of the context window (i.e., the number of words that are identified as surroundings) as 10, the number of vector dimensions as 300, and the minimum requirement for word occurrence as 20 (i.e., words that appeared less than 20 times in the dataset would not be represented as vectors).

Word2vec is an unsupervised machine learning model and there is no golden standard in evaluating model performance. While some of previous studies validated model outputs by testing if the word embeddings can be applied to pass syntactic and semantic analogy tasks (e.g., if the word embedding of "worse" minus the word embedding of "bad" resembles the word embedding of "higher" minus the word embedding of "high"; e.g., Grag et al., 2018), they used larger datasets with billions of words and the datasets were domain-general, whereas the dataset used in the current study was smaller (i.e., hundreds of tweets) and domain-specific (all related to adolescence on Twitter). Nevertheless, even with a smaller dataset, word2vec can still be applied to synthesis information from the data and represent words into meaningful word embeddings, given that its mechanism is to factorize a word-context matrix and embed words into the contexts of data (Levy & Goldberg, 2013). Because the focus of the current study is on adolescence, I validated the model outputs by examining the word embeddings of terms of adolescence (i.e., "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween"). I tested if the word embeddings of these terms were close to each other (i.e., the cosine similarity scores among them) compared to other words (i.e., the cosine similarity scores between any of the word embedding of terms of adolescence and any of 1,000 random word embeddings in the model). I noted that no prior information or knowledge (e.g., "adolescent" is similar to "teenager") was fed into the model. Therefore, if the model can automatically build closer associations among terms

of adolescents compared to other words, it may suggest that the concept of adolescence has been formed in the model and can be used for further analysis.

A conceptual illustration of representing words as word embeddings is shown in Figure 1.

[Figure 1]

Public Perceptions of Adolescence

Word embedding models can capture the latent meanings of words in contexts, therefore the model used in the current study captured the latent meanings of words in tweets, which reflected public perceptions on Twitter. To analyze the public perceptions of adolescence on Twitter, I focused on the word embeddings of the aforementioned seven terms (i.e., "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween"). In addition, I also created a new word embedding as the centroid of the seven word embeddings (i.e., the center point of the seven terms in the word embedding model, which should capture their shared meanings) as a composite measure of the construct of adolescence. Therefore, there were altogether eight word embeddings of adolescence as the focus of analysis, including "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," "tween," and the composite measure.

For each word embedding of adolescence, I computed the cosine similarity scores (range: 0 and 1; Miklov et al., 2013) between it and the word embedding of any other word (i.e., the descriptor, as it is not a term of adolescence but can be used to describe perceptions of adolescence) that was ever used in the Twitter data (e.g., "rebellious," "responsibility"). These similarity scores capture the closeness of association between a pair of words (e.g., "teen" and "rebellious") in terms of their latent meanings in the data.

I employed two approaches to analyze public perceptions associated with these word embeddings of adolescence. The first one is a theory-driven approach testing the associations

between terms of adolescence and other pre-defined descriptors. The second approach is data-driven without prior assumptions. Both approaches are described in the following sections.

Quantitative Analysis of Valence of Public Perceptions. Informed by previous work that examined the stereotypes of adolescence (Gross & Hardin, 2007), which tested how human participants linked the construct of adolescence (i.e., "teenager") with a set of stereotypical descriptors(e.g., "stubborn") and another set of neutral descriptors (e.g., "chair") compared to the construct of adulthood (i.e., "adult"), I compared how each word embedding of adolescence (i.e., "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," "tween," and the composite measure) as well as the word embedding of "adult" and "people" ("adult" was selected based on Gross & Hardin's (2007) work; "people" was selected as a more neutral term; I did not select "child" or "children" as the comparison terms, as they sometimes refer to adolescents) was linked with a set of stereotypical descriptors used in previous work (i.e., "rebellious," "reckless," "risk-taking," "stubborn," "rude," "impulsive," "selfish," "crazy"; adapted from Buchanan & Holmbeck, 1998; Gross & Hardin, 2007) and another set of neutral descriptors (i.e., "get," "say," "still," "also," "thing," "would," "as," "go"; identified from the data). For each word embedding of adolescence (e.g., "adolescent") and the word embedding of adulthood (i.e., "adult"), I computed the cosine similarity scores between it and any of the aforementioned stereotypical descriptors (e.g., "rebellious") and neutral descriptors (e.g., "get"). I then compared the average cosine similarity scores for stereotypical descriptors and neutral descriptors using paired sample *t*-tests. I further compared different terms using two-way ANOVA examining the main effects of term and descriptor type (stereotypical vs. neutral) as well as their interaction effect on the cosine similarity scores.

Informed by previous work that examined the biases of gender and ethnicity terms in word embedding models (Caliskan, 2017; Grag et al., 2018), which tested how the word embeddings of gender and ethnicity terms were linked with positive descriptors (e.g., "honest") and negative descriptors (e.g., "evil"), I compared how each word embedding of adolescence (i.e., "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," "tween," and the composite measure) as well as the word embedding of adult and people was linked with a set of positive descriptors (i.e., "agreeable," "bright," "diligent," "gentle," "helpful," "honest," "kind," "nice"; identified from the data) and a set of negative descriptors (i.e., "aggressive," "careless," "dishonest," "foolish," "rude," "lazy," "selfish," "silly"; identified from the data). For each term of adolescence (e.g., "adolescent") and the term of adulthood (i.e., "adult"), I computed the cosine similarity scores between it and any of the aforementioned positive descriptors (e.g., "agreeable") and negative descriptors (e.g., "aggressive"). I then compared the average cosine similarity scores for positive descriptors and negative descriptors using paired sample *t*-tests. I further compared different terms using two-way ANOVA examining the main effects of term and descriptor type (positive vs. negative) as well as their interaction effect on the cosine similarity scores.

A Mixed Methods Analysis of Themes of Public Perceptions. The second approach is data-driven without prior assumptions. I extracted a list of 60 descriptors (similar to prior work that analyzed around 60 descriptors to identity individual perceptions of adolescence, Buchanan & Holmbeck, 1998) that are most closely associated with each word embedding of adolescence, excluding other terms of adolescence (since these terms will be closely related to each other) and meaningless words (e.g., "people," "say," "think," etc.). I first presented the lists of descriptors in word cloud figures, in which descriptors that were closer to the word embeddings of adolescence

were of larger sizes. I then conducted qualitative content analyses (Vaismoradi et al., 2016) of these descriptors to describe public perceptions of adolescence associated with these word embeddings of adolescence. I recruited three coders who were graduate students studying human development. They read the descriptors and example tweets (i.e., tweets that contained a certain term of adolescence and a descriptor), coded the descriptors into different themes, and interpreted the themes in a qualitative manner. The themes were interpreted in terms of how they reflect Twitter users' perceptions of adolescence.

Since there were eight word embeddings of adolescence (i.e., "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," "tween," and the composite measure), I built eight lists with 480 descriptors (some of the descriptors may be the same across different terms of adolescence) and 1,440 example tweets (three randomly selected tweets for each descriptors; all coders agreed that three tweets were enough to help them identify how the descriptors can reflect certain perceptions of adolescence, but I acknowledged that other perceptions of adolescence may be reflected in tweets that we did not select as examples; I did not select more than three example tweets because extracting and coding more tweets were time-consuming). I first randomly selected 50% of the 480 descriptors as the pilot data, had the three coders code the pilot data independently (i.e., identifying themes and assigning the descriptors into the themes), compared and discussed their coding results to establish consensus, and then developed a coding scheme of different themes and their coding criteria. I then had the three coders code the rest of the descriptors based on the coding scheme. I checked interrater reliability based on Cohen's (1960) kappa and the interrater reliability was satisfactory (Cohen's kappa = .86). The few inconsistent coding results were further resolved by the team during coding meetings. This coding approach and procedures are consistent with Qu et al. (2016).

A conceptual illustration of data analysis in this part is shown in Figure 2.

[Figure 2]

During the coding process, the coders and I found that the word embedding model identified descriptors and example tweets that reflected online sexual abuse of adolescents that are outside of the scope of the current study. I believed this was a critical issue to be addressed to create a safe social media space for youth. However, these contents do not necessarily reflect public perceptions of the nature of adolescence or adolescent development. As such, I removed these descriptors in the word cloud figures and did not code descriptors or tweets related to online sexual abuse as themes for the perceptions of adolescence. The removed descriptors and example tweets are available upon request from me. I discussed the potential implications of these contents in the discussion section.

Public Perceptions of Subgroups of Adolescents

The outputs of word embedding models have been found to have additive compositionality, such that the word embeddings of different words can be combined to create a meaningful new word embedding (Miklov et al., 2013). For instance, Miklov et al. (2013) demonstrated that, in their word embedding model, combining the word embeddings of "Vietnam" and "capital" generated a new word embedding that was close to the word embedding of "Hanoi", which was indeed the capital of Vietnam. This property of word embeddings can be utilized to analyze public perceptions of subgroups of adolescents. Specifically, I combined the word embedding of the composite measure of adolescence (i.e., the centroid of the word embeddings of "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween") with other terms indicating subgroups of adolescents (i.e., race/ethnicity: "Black," "Latinx," "Asian," "White"; gender: "boy," "girl"; sexual orientation: "gay," "lesbian," "LGBT"; I

identified these terms from the data as they were frequently used to indicate group identity; I did not include other subgroups because they were less frequently mentioned in the dataset) to created new word embeddings. For each word embedding of adolescent subgroups, I applied the same set of analyses as described in the last section, including testing stereotypes in subgroups of adolescents and qualitative content analysis based on the results from the word embedding model. During qualitative content analysis, the coders first coded the descriptors and identified the themes for each subgroup separately. The coders then divided the word embeddings of subgroups of adolescents into the categories of race/ethnicity (Black adolescents, Latinx adolescents, Asian adolescents, White adolescents), gender (male adolescents and female adolescents), and sexual orientation (gay adolescents, lesbian adolescents, LGBT adolescents; the three groups are not mutually exclusive; I selected these three groups because they were frequently mentioned in the data compared to other groups) and further refined, compared, and interpreted the themes within each category separately to facilitate the identification of themes and comparison.

Similar to the above investigation, during the coding process, the coders and I identified descriptors and tweets that captured online sexual abuse of adolescents. I removed these descriptors in the word cloud figures and did not code them as themes for the perceptions of adolescence. The removed descriptors and example tweets are available upon request from me. I discussed the potential implications of these contents in the discussion section.

Positionality Statement

As the author of the dissertation, I acknowledge my standpoint as a researcher studying adolescent development, an educated Chinese man growing up in China, and a young adult who has not entered the job market. As a researcher studying adolescent development, I may tend to interpret the word embeddings in association with existing research on adolescence, which may

limit my ability to identify public perceptions of adolesence that have not been addressed by literature. As an educated Chinese man growing up in China, my interpretation of the word embeddings may be biased due to my group identity and culture. As a young adult who has not entered the job market, my perspectives on adolescence may be constrained by my own age group and work condition. Meanwhile, the data I analyzed were tweets on Twitter. I have a Twitter account but I am not an active Twitter user, therefore I may be unfamiliar with certain idioms of the tweets and may not understand the tweets well. I acknowledge my positionality influenced the current study to some extent. I tried to avoid potential bias of data interpretation by consulting people from diverse standpoints (e.g., active Twitter users growing up in the U.S.) about the meanings of tweets.

The coders I recruited for qualitative analysis generally acknowledge their standpoints as researchers or students studying human development. They may also tend to associate the word embeddings with existing research rather than identify public perceptions of adolescence that have not been addressed by literature.

CHAPTER 5: RESULTS

Descriptives

Table 1 presents the number of tweets containing the terms of adolescence (i.e., "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween") with an example tweet for each term. Table 2 presents the mean and standard deviation (SD) for four types of sentiment scores (i.e., positive, negative, neutral, and overall) for tweets containing different terms of adolescence. Except the term of "juvenile," tweets containing other terms of adolescence were overall slightly or moderately positive, whereas tweets containing the term of "juvenile" tended to be neutral.

[Table 1]

[Table 2]

MANOVA suggested that tweets containing different terms of adolescence differed significantly in the four types of sentiment scores, $F(4, 3639482) = 8672.70$, $p < .001$, partical $\eta^2 = .01$. Post-hoc analyses using Tukey tests suggested that all pair-wise comparisons were significant due to large sample size. From the descriptives as presented in Table 2, tweets containing terms of youth and youngster tended to be more positive compared to other tweets, indicating more positive public perceptions on Twitter. Tweets containing terms of juvenile and teen tended to be more negative compared to other tweets, indicating more negative public perceptions on Twitter.

Word Embeddings

The average cosine similarity score for all the pairs among the word embeddings of adolescence (i.e., "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween") was .29 ($SD = .09$), whereas the average cosine similarity score for any of the word embedding

of adolescence with any of 1,000 random word embeddings was .12 (*SD* = .07), suggesting that the model successfully distinguish the concept of adolescence by associating different terms of adolescence closer compared to other random words. Figure 3 presents a plot describing the relative location of different terms of adolescence as well as some other words that were close to them in the word embedding model in a two-dimensional space (i.e., the word embeddings had 300 dimensions and I used t-distributed Stochastic Neighbor Embedding to reduce the dimensions to 2 for visualization).

[Figure 3]

Public Perceptions of Adolescence

Quantitative Analysis of Valence of Public Perceptions

Table 3 presents the average cosine similarity scores for different word embeddings of adolescence, "adult," and "people" in their associations with stereotypical descriptors (i.e., "rebellious," "reckless," "risk-taking," "stubborn," "rude," "impulsive," "selfish," "crazy") and neutral descriptors (i.e., "get," "say," "still," "also," "thing," "would," "as," "go") as well as results of the paired sample *t*-tests.

[Table 3]

All the word embeddings of adolescence and adulthood were significantly less associated with stereotypical descriptors compared to neutral descriptors (because the neutral terms I selected were common words that frequently occurred with other words in the data), yet such degree differed to some degree. The word embedding of "people" tended to be more closely associated neutral descriptors compared to stereotypical descriptors, followed by "teen," the composite measure of adolescence, "youth," "adult," and "youngster," whereas the word embedding of "juvenile" tended to be more closely associated with stereotypical descriptors vs.

neutral descriptors compared to other word embeddings, followed by “adolescent,” “puberty,” and “tween”.

Two-way ANOVA test suggested that the main effect of word embedding was significant, $F(9,140) = 14.71$, $p < .001$, partical $\eta^2 = .49$. The main effect of descriptor type (stereotypical vs. neutral) was significant, $F(1,140) = 321.45$, $p < .001$, partical $\eta^2 = .70$. The interaction effect between word embedding and descriptor type was also significant, $F(9,140) = 5.94$, $p < .001$, partical $\eta^2 = .28$, suggesting that different word embeddings did differ in their relative association with stereotypical vs. neutral descriptors.

Table 4 presents the average cosine similarity scores for different embeddings of adolescence, adult, and people in their associations with positive descriptors (i.e., “agreeable,” “bright,” “diligent,” “gentle,” “helpful,” “honest,” “kind,” “nice”) and negative descriptors (i.e., “aggressive,” “careless,” “dishonest,” “foolish,” “rude,” “lazy,” “selfish,” “silly”) as well as results of the paired sample *t*-tests.

[Table 4]

The word embeddings of “youth” and “youngster” were significantly more closely associated with positive descriptors compared to negative descriptors, whereas the word embedding of “juvenile” was significantly more closely associated with negative descriptors compared to positive descriptors. Other terms did not differ in their associations with positive vs. negative descriptors, yet their associations with positive descriptors tended to be slightly stronger (except people).

Two-way ANOVA test suggested that the main effect of word embedding was significant, $F(9,140) = 3.79$, $p < .001$, partical $\eta^2 = .20$. The main effect of descriptor type (positive vs. negative) was not significant, $F(1,140) = 2.37$, $p = .126$, partical $\eta^2 = .02$. The interaction effect

between word embedding and descriptor type was marginally significant, $F(9,140) = 1.79$, $p = .075$, partical $\eta^2 = .10$, suggesting that different word embeddings did differ in their relative association with positive vs. negative descriptors.

A Mixed Methods Analysis of Themes of Public Perceptions

I identified distinct patterns of themes for different word embeddings of adolescence. Table 5 presents the summary of themes associated with different word embeddings (the composite measure of adolescence was not included as it was comprised of themes associated with the other terms).

[Table 5]

"Adolescent". Figure 4 presents the descriptors associated with the word embedding of "adolescent," with larger font sizes indicating higher levels of closeness.

[Figure 4]

Two themes emerged for the term of "adolescent," including:

1) Research on adolescence to be advocated: identified from descriptors that were about research or frequently used in academic language.

"*Important paper that robustly challenges claims for high incidence of bipolar disorder in children & adolescents made by some US studies. In fact suggests much research shows prevalence rate of 0% below 18 years of age.*"

Most of the descriptors that were found to be closely associated with the term of "adolescence" were the ones that are frequently used in academic research, with many of the example tweets introducing research on adolescence or discussing relevant issues. The top five descriptors that were identified into this theme were "meta-analysis," "systematic review," "springerlink," "comorbidity," "psychosocial".

2) Concern for adolescent health: identified descriptors that were related to physical or mental health issues of adolescents.

"*Sometimes children and adolescents suffer from depressive symptoms or are even have a #depression.*"

Many descriptors were related to physical and mental health issues, with some of them also identified in the previous theme of advocating research on adolescence. The top five descriptors that were identified into this theme were "mum-to-be," "nutrition," "comorbidity," "health," "over-nutrition".

"Teen". Figure 5 presents the descriptors associated with the word embedding of "teen". I identified descriptors that indicated online sexual abuse of adolescents. These descriptors were removed in the figure and not coded for public perceptions of adolescence. The removed descriptors are available upon request from the author.

[Figure 5]

One theme emerged for the term of "teen," including:

1) Hate and bias for teenagers. Identified from descriptors that expressed or indicated negative attitudes towards teenagers.

"*Fuck teens in your area.*"

"A *fucking loser that takes to social media more than a teenage girl trying to one up another.*"

The descriptors of "fuck" and "fucking" were found to be most closely associated with the term of "teen," with the example tweets reflecting users' hate and bias for adolescence. Such bias can be implicit, with several example tweets implicitly but not explicitly linked the term of

“teen” with undesirable characteristics. The top five descriptors that were identified into this theme were “fuck,” “fucking,” “horny,” “dirty,” “worthless”.

“Youth”. Figure 6 presents the descriptors associated with the word embedding of “youth”.

[Figure 6]

Three themes emerged for the term of “youth,” including:

1) Youth as an important element of society. Identified from descriptors related to social units (e.g., “country,” “community”) and descriptors that indicated the importance of youth.

“*Leaders like Hong Hoang, who mobilized a youth-led movement to create a greener world after becoming the first Vietnamese person to visit Antarctica*.”

Descriptors and example tweets in this theme highlighted the importance of youth in society, such as leading social movements and being regarded as the future of society. The top five descriptors that were identified into this theme were “support,” “country,” “nation,” “future,” “community”.

2) Youth with positive characteristics. Identified from descriptors related to positive characteristics of youth.

“*Youths contribute to economy and the growth of Nigeria.*”

Many descriptors and example tweets indicated the positive characteristics, such as leadership, kindness, and prosocial attitudes. The top five descriptors that were identified into this theme were “leader,” “great,” “young,” “good,” “well”.

3) Youth to be empowered and supported. Identified from descriptors related to help and support.

"*End 2018 being the change you wish to see. help us spread kindness & empower youth. together, we can prevent #bullying*."

Some descriptors and example tweets called for empowering or supporting youth. Some also expressed concern for youth status and the solutions to improve their status, such as youth status in the job market. The top five descriptors that were identified into this theme were "support," "hope," "help," "opportunity," "work".

"Juvenile". Figure 7 presents the descriptors associated with the word embedding of "juvenile".

[Figure 7]

One theme emerged for the term of "juvenile," including:

1) Juvenile justice and delinquency. Identified from descriptors related to justice and delinquency.

"*Earlier this month, congress passed the juvenile justice and delinquency prevention act that now awaits presidential signature*."

Most of the descriptors and example tweets were related to juvenile justice and delinquency affairs. The top five descriptors that were identified into this theme were "delinquent," "delinquency," "justice reform," "justice," "peer justice".

"Puberty". Figure 8 presents the descriptors associated with the word embedding of "puberty".

[Figure 8]

One theme emerged for the term of "puberty," including:

1) Puberty as a period of physical development and sexual maturation. Identified from descriptors related to physical development and sexual maturation, many of which were physiological terms.

"*Sophia began identifying as a boy at 11 years old...to halt the effects of female puberty*."

Most descriptors were physiological terms with the example tweets introducing pubertal phenomenon or discussing relevant issues. Some also expressed concern for health issues in puberty. The top five descriptors that were identified into this theme were "blocker," "hormone," "hrt," "estrogen," "testosterone".

"Youngster". Figure 9 presents the descriptors associated with the word embedding of "youngster".

[Figure 9]

One theme emerged for the term of "youngster," including:

1) Youngster sports players getting attention. Identified from descriptors related to sports.

"*A mixture of first team players and youngsters will all get their chance to impress ahead of 2019!*"

Most of the descriptors were the names of young sports players or related to sports. The example tweets expressed interests and support for youngster sports players. The top five descriptors that were identified into this theme were "Arsche," "player," "Sanju Samson," "Minamino," "best".

"Tween". Figure 10 presents the descriptors associated with the word embedding of "tween".

[Figure 10]

One theme emerged for the term of "tween," including:

1) Tweens' everyday life. Identified from descriptors related to tweens' life and activities. "*What do you buy? gift ideas for teens who love dogs #giftfinder #teensandtweens*"

Descriptors and example tweets were about tweens' life in many aspects, such as reading, friendship, birthday, etc. Many of the tweets seemed to be posted by parents of tweens, such as finding the books or gifts for their children. The top five descriptors that were identified into this theme were "kids book," "childrens book," "gift finder," "birthday gifts," "school library".

Composite measure. Figure 11 presents the descriptors associated with the word embedding of the composite measure of adolescence (i.e., the centroid of the word embeddings of "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween"). I identified descriptors that indicated online sexual abuse of adolescents. These descriptors were removed from the figure and not coded for public perceptions of adolescence. The removed descriptors are available upon request from the author.

[Figure 11]

Descriptors did not indicate any new themes but recalled many the themes identified above, including youth with positive characteristics (e.g., "good," "better"), youth to be empowered and supported (e.g., "help," "support"), tweens' activities and life (e.g., "life," "family"), concern for adolescent health (e.g., "mum-to-be," "dosing"), youth as an important element of society (e.g., "today," "change"), puberty as a period of physical development and sexual maturation (e.g., "biological"). The coders agreed that themes associated with the composite measure of adolescence were overall positive whereas few negative or stereotypical descriptors were found to be associated with the composite measure.

Public Perceptions of Subgroups of Adolescents

Leveraging the property of addictive compositionality of word embeddings, I generated new word embeddings that can represent subgroups of adolescents by combining certain indicators of group identity (e.g., "boy") and the composite measure of adolescence (i.e., the centroid of the word embeddings of "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween"), including male adolescents ("boy"), female adolescents ("girl"), Black adolescents ("Black"), Latinx adolescents ("Latinx"), Asian adolescents ("Asian"), White adolescents ("White"), LGBTQ+ adolescents ("gay," "lesbian," "LGBT").

Quantitative Analysis of Valence of Public Perceptions

Table 6 presents the average cosine similarity scores for different word embeddings of subgroups of adolescents in their associations with stereotypical descriptors (i.e., "rebellious," "reckless," "risk-taking," "stubborn," "rude," "impulsive," "selfish," "crazy") and neutral descriptors (i.e., "get," "say," "still," "also," "thing," "would," "as," "go") as well as results of the paired sample *t*-tests. As comparisons, I also added the word embeddings of the composite measure (i.e., the centroid of the word embeddings of "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween"), adulthood ("adult"), and a neutral term ("people").

[Table 6]

All the word embeddings were significantly less associated with stereotypical descriptors compared to neutral descriptors (because the neutral terms I selected were common words that frequently occurred with other words in the data), yet such degree differed by word embeddings. The word embeddings of both male and female adolescents showed tendency towards neutral descriptors rather than stereotypical descriptors, compared with other word embeddings. The

word embedding of Latinx adolescents were more closely associated with stereotypical descriptors rather than neutral descriptors, compared with other word embeddings.

Two-way ANOVA test suggested that the main effect of word embedding was significant, $F(11,168) = 12.05$, $p < .001$, partical $\eta^2 = .44$. The main effect of descriptor type (stereotypical vs. neutral) was significant, $F(1,168) = 645.08$, $p < .001$, partical $\eta^2 = .79$. The interaction effect between word embedding and descriptor type was also significant, $F(11,168) = 5.29$, $p < .001$, partical $\eta^2 = .26$, suggesting that different word embeddings did differ in their relative association with stereotypical vs. neutral descriptors.

Table 7 presents the average cosine similarity scores for word embeddings of subgroups of adolescents in their associations with positive descriptors (i.e., "agreeable," "bright," "diligent," "gentle," "helpful," "honest," "kind," "nice") and negative descriptors (i.e., "aggressive," "careless," "dishonest," "foolish," "rude," "lazy," "selfish," "silly") as well as results of the paired sample *t*-tests. As comparisons, I also added the word embeddings of the composite measure (i.e., the centroid of the word embeddings of "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween"), adulthood ("adult"), and a neutral term ("people").

[Table 7]

All the word embeddings did not differ significantly in their associations with positive vs. Neutral descriptors, yet most of them had slightly stronger association with positive descriptors compared to negative descriptors, except gay adolescents and people.

Two-way ANOVA test suggested that the main effect of word embedding was significant, $F(11,168) = 2.52$, $p < .01$, partical $\eta^2 = .14$. The main effect of descriptor type (positive vs. negative) was significant, $F(1,168) = 2.02$, $p = .157$, partical $\eta^2 = .01$. The interaction effect

between word embedding and descriptor type was not significant, $F(11,168) = 0.45$, $p = .931$, partical $\eta^2 = .03$, suggesting that different word embeddings did not differ in their relative association with positive vs. negative descriptors.

A Mixed Methods Analysis of Themes of Public Perceptions

I identified distinct patterns of themes for different word embeddings of subgroups of adolescence. Table 8 presents the summary of themes associated with different word embeddings.

[Table 8]

Black adolescents. Figure 12 the descriptors associated with the word embedding of Black adolescents, with larger font sizes indicating higher levels of closeness. I identified descriptors that indicated online sexual abuse of adolescents. These descriptors were removed from the figure and not coded for public perceptions of adolescence. The removed descriptors are available upon request from the author.

[Figure 12]

Two themes emerged for Black adolescents, including:

1) Black adolescents engaging in social justice movements. Identified from descriptors related to social movements.

"*Stop telling the Black youth half a bread is better than nothing, we want the whole bakery*."

Many descriptors and example tweets were related to Black movements, showing support and proud of the Black identity, while some also expressed hate for White people. The top five descriptors that were identified into this theme were "bbconly," "say no to white boys," "history," "black twitter movement," "black lives matter, black is better".

2) Concern for Black adolescents' life. Identified from descriptors related to adolescents' life and activities.

"*Almost half of Black youth in the US grow up in the bottom 20% of the income distribution*."

Similar to what I identified for the word embedding of "tween", some descriptors were about Black adolescents' life in many aspects, such as fashion, school, and family. However, the example tweets were not just about Black adolescents' life. Many example tweets discussed problems in or concern for Black adolescents' life. The top five descriptors that were identified into this theme were "poncho_free," "melaninpoppin," "school," "family," "group".

Latinx adolescents. Figure 13 the descriptors associated with the word embedding of Latinx adolescents, with larger font sizes indicating higher levels of closeness.

[Figure 13]

One theme emerged for Latinx adolescents, including:

1) Increasing racial equity for Latinx adolescents. Identified from descriptors related to racial equity.

"*New reports confirm #soda companies disproportionately target #latino & #black youth with their #caffeine laced.*"

Descriptors and example tweets associated with Latinx adolescents were primarily related to racial equity, with example tweets highlighting unequal conditions of Latinx adolescents or advocating racial equity for them. The top five descriptors that were identified into this theme were "representationmatters," "racialjustice," "hispanicheritagemonth," "educolor," "minoritymentalhealthmonth".

Asian adolescents. Most of the descriptors were identified as related to online sexual abuse of adolescents. Therefore, I did not present the descriptor or code them as perceptions of adolescence. The descriptors are available upon request from the author.

White adolescents. Figure 14 the descriptors associated with the word embedding of White adolescents, with larger font sizes indicating higher levels of closeness. I identified descriptors that indicated online sexual abuse of adolescents. These descriptors were removed from the figure and not coded for public perceptions of adolescence. The removed descriptors are available upon request from the author.

[Figure 14]

Two themes emerged for White adolescents, including:

1) Hate and Bias for White adolescents. Identified from descriptors that expressed or indicated negative attitudes towards White adolescents.

"*Stupid white girls*."

"*What's happening in the home that's making these White teenage boys shoot up schools*?"

Similar to what I identified with the word embedding of "teen," many descriptors and example tweets associated with White adolescents expressed hate and bias for White adolescents. Such attitudes can be held implicitly but not explicitly expressed, such as the aforementioned example in which the users associated White teenage boys with school shooters. The top five descriptors that were identified into this theme were "fuck," "fucking," "wrong," "bad," "weird".

2) White adolescents involved in discussion about race and racism. Identified from descriptors related to race and racism.

"*If you are a white female teen and have a black boyfriend, don't have fear, at least one of your friends will follow your example soon! #irmovement #womengoingblack #interraciallife #junglefever #blackisbetter #blackguysonly #saynotowhiteboys2019*"

Some descriptors and example tweets criticized White adolescents for being a racist or supremacist, yet some advised them not to do so. The top five descriptors that were identified into this theme were "racist," "supremacist," "supremacy," "white nationalism," "white supremacist terrorism".

Comparison between subgroups by race. I identified a theme related to racism and racial movements for both Black, Latinx, and White adolescents, yet such theme was missing for Asian adolescents. White adolescents had a theme of hate and bias for White adolescents, yet this theme was not identified for other subgroups, suggesting that the negative and stereotypical perception of adolescence may be mainly associated with White adolescents.

Male adolescents. Figure 15 presents the descriptors associated with the word embedding of male adolescents, with larger font sizes indicating higher levels of closeness. I identified descriptors that indicated online sexual abuse of adolescents. These descriptors were removed from the figure and not coded for public perceptions of adolescence. The removed descriptors are available upon request from the author.

[Figure 15]

One themes emerged for male adolescents, including:

1) Male adolescents' everyday life. Identified from descriptors related to male adolescents' life and activities.

"*A teenage boy on holiday*"

Many descriptors and example tweets were about male adolescents' life in many aspects, such as school, family, and friendship. The top five descriptors that were identified into this theme were "school," "family," "son," "group," "home".

Female adolescents. Figure 16 presents the descriptors associated with the word embedding of female adolescents, with larger font sizes indicating higher levels of closeness. I identified descriptors that indicated online sexual abuse of adolescents. These descriptors were removed from the figure and not coded for public perceptions of adolescence. The removed descriptors are available upon request from the author.

[Figure 16]

One themes emerged for female adolescents, including:

1) Female adolescents' everyday life. Identified from descriptors related to female adolescents' life and activities.

"*The retention rate for girls playing youth sports can be so much better.*"

Some descriptors and example tweets were about female adolescents' life in many aspacts, such as school, family, friendship, sports, and entertainment. The top five descriptors that were identified into this theme were "family," "daughter," "school," "friend," "life".

Comparison between subgroups by gender. All the coders agreed that although both male and female adolescents were identified with the theme about their everyday life. Such theme was more evident for male adolescents compared to female adolescents (i.e., more descriptors were identified into the theme for male adolescents compared to female adolescents).

Gay adolescents. Most of the descriptors were identified as related to online sexual abuse of adolescents. Therefore, I did not present the descriptor or code them as perceptions of adolescence. The descriptors are available upon request from the author.

Lesbian adolescents. Most of the descriptors were identified as related to online sexual abuse of adolescents. Therefore, I did not present the descriptor or code them as perceptions of adolescence. The descriptors are available upon request from the author.

LGBT adolescents. Figure 17 presents the descriptors associated with the word embedding of LGBT adolescents, with larger font sizes indicating higher levels of closeness.

[Figure 17]

One theme emerged for gay adolescents, including:

1) Increasing awareness and supporting LGBT adolescents. Identified from descriptors related to LGBTQ+ movements.

"*#hope #loveislove one man's advice for friends and relatives of lgbtq youth.*"

Most of the descriptors associated with LGBT adolescents were about LGBTQ+ movements, with example tweets expressing support of these movements or concern for the unfair condition of LGBTQ+ adolescents. The top five descriptors that were identified into this theme were "pridemonth," "homophobia," "loveislove," "lgbtqoftwitter," "nooutsiders".

Comparison between LGBTQ+ subgroups. All the coders agreed that the descriptors associated with LGBT adolescents were different from the other two subgroups (i.e., gay adolescents and lesbian adolescents) as the theme was mainly about supporting LGBTQ+ adolescents.

CHAPTER 6: DISCUSSION

Social media is an influential developmental context that young people have contact with on a daily basis. However, we currently know little about how social media portraits adolescents, which may have important implications for young people's everyday well-being and how young people think about themselves. My dissertation addressed this critical gap in the literature by exploring public perceptions of adolescence on Twitter using a big data, machine learning approach. I first employed a theory-driven and quantitative approach to test how various terms of adolescence (i.e., "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween") was associated with stereotypical (vs. neutral) or positive (vs. negative) descriptors compared to the terms of adult and people. Results showed that the overall construct of adolescence was not perceived as negative or stereotypical but relatively neutral and unstereotypical. Moreover, perceptions varied by different terms of adolescence (e.g., "youth" vs. "juvenile"), suggesting that adolescence is a comprehensive construct that may not be captured by a single term. I then developed a data-driven and mixed-methods approach in which I generated lists of 60 descriptors that were most closely associated with terms of adolescence and then conducted qualitative content analysis on the descriptors while reference example tweets containing the descriptors. For each term of adolescence, a variety of themes were identified including not only negative themes but also neutral and positive themes. These themes highlighted public perceptions of adolescence in various aspects and many of them were meaningful in terms of promoting adolescent development. I also explored variations in perceptions of adolescents by race/ethnicity, gender, and sexual orientation, highlighting both risk and resilience processes within each adolescent subgroup. In this section, I discussed the details of my findings as well as their interpretation and implications for future research and practices. I also discussed the

methodology of my dissertation in terms of its strengths, implications for future research, and limitations.

Understanding Adolescence Using the Word Embedding Model

The word embedding model was built by feeding cleaned tweets into the algorithm. The model then automatically learned the associations of different words in the data and represented each word in the dataset as a word embedding with 300 dimensions. Although there has been no absolute measure to evaluate model performance, I found evidence suggesting that the word embedding model I built successfully distinguished the concept of adolescence. Without any prior information or knowledge, the model associated terms of adolescence (i.e., "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween") closer to each other compared to other random words, indicating that the model captured the concept of adolescence based on these terms. Furthermore, other words that were found to be closely associated with the terms of adolescence appeared to be meaningful and capture public perceptions of adolescence, such as words related to teenagers' life and environment (e.g., "parent," "friend," "school"), youth's role in society (e.g., "country," "world," "change").

While existing literature has employed word embedding models to extract and analyze implicit meanings of constructs such as social class (Kozlowski et al., 2019) and race/ethnicity (Grag, 2018) in large corpora, the data they used were relatively large (i.e., billions of words were fed into the model), domain-general (i.e., the content of the data were not limited to a specific topic), and formal (i.e., the data were from published news or books). My dissertation further validated the use of word embedding models to explore the implicit meanings of adolescence in a dataset that was relatively small (i.e., millions of tweets, with total word count less than one billion), domain-specific (i.e., the data were tweets related to the discussion of

adolescence), and informal (i.e., the language used in tweets was somewhat informal). Therefore, my dissertation may inform future work to apply word embedding models to smaller datasets to analyze the meanings of words in specific contexts.

This approach may contribute to existing literature in two ways. First, existing studies analyzing people's perceptions or opinions of certain constructs usually recruited a small sample of participants and intentionally collected their responses using structured questions (e.g., parental opinion of school sexuality education; Heller & Johnson, 2012). It is possible to collect a textual dataset consisting of people's expression of opinions around certain topic and then use word embeddings to identify people's opinions associated with relevant terms. This approach may complement existing studies by leveraging bigger data (because it may be easier to access larger textual datasets compared to recruiting participants) and identifying opinions in a data-driven manner (rather than theory-driven).

Second, existing studies analyzing big textual data usually employed a series of traditional linguistic modeling to analyze the data, such as latent Dirichlet allocation (LDA, Blei et al., 2003) and Linguistic Inquiry and Word Count (LIWC, Pennebaker et al., 2001), these modeling techniques have been shown to be less accurate compared to word embeddings (e.g., Rudkowsky et al., 2018). It is possible to update such analyses using word embeddings to better extract information from the data. For instance, Kern et al. (2013) analyzed over 70,000 Facebook users' posts to examine the aging positivity effect (i.e., older people are happier than young people) with traditional modeling techniques, whereas it is now possible to update their analysis by feeding data into a word embedding model and test how the term of "old" is associated with terms indicating positive emotions compared to the term of "young".

Public Perceptions of Adolescence on Twitter

Quantitative Analysis of Valence of Public Perceptions

I used two different approaches using word embeddings to analyze public perceptions of adolescence on Twitter. The first one was a theory-driven approach in which I tested how the word embeddings of adolescence were associated with two sets of pre-defined descriptors (i.e., stereotypical vs., neutral descriptors, positive vs. negative descriptors) in comparison with other terms (i.e., "adult" and "people"). Results suggested that although the overall construct of adolescence as reflected by the composite measure (i.e., the centroid of the word embeddings of "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween") did not show higher tendency towards stereotypical/negative descriptors vs. neutral/positive descriptors, compared with the word embeddings of "adult" and "people", different terms varied in their associations with stereotypical/negative descriptors vs. neutral/positive descriptors. Specifically, the word embeddings of "juvenile," "adolescent," and "puberty" showed higher levels of tendency towards stereotypical descriptors (vs. neutral descriptors) compared with "teen," "youth," and "youngster", indicating relatively stereotypical perceptions associated with these terms. The word embedding of "juvenile" showed higher levels of tendency towards negative descriptors (vs. positive descriptors) compared with other terms, indicating negative perceptions associated with the term of "juvenile". The word embedding of "youth" and "youngster" showed higher levels of tendency towards positive descriptors (vs. negative descriptors) compared with other terms, indicating positive perceptions.

Based on my exploration of the data and the qualitative content analysis in the next section, the finding that the term of "juvenile" was associated with more stereotypical and negative descriptors may not indicate Twitter users' perceptions, but rather reflect the language

habit that “juvenile” is usually used in delinquency or criminal events, which are also associated with some stereotypical descriptors (e.g., “rebellious,” “risk-taking”) and negative descriptors (e.g., “aggressive,” “foolish”).The findings that the terms of adolescent and puberty also showed more stereotypical perceptions may also be impacted by language habit as the two terms were usually used in academic language and the tweets were mostly about research and popular science. In this sense, stereotypical descriptors that were associated with the terms of adolescent and puberty may not reflect Twitter users’ stereotypical perceptions, but rather indicate that tweets talking about research and knowledge on adolescence are more focused on negative aspects, such as rebellion and risky behavior. Indeed, Rich (2003) suggested that contemporary research on adolescence still focuses more on negative aspects. Except for juvenile, all the other terms of adolescence did not show significant tendency towards negative (vs. positive) descriptors, suggesting that the overall public perceptions of adolescence is not negative but neutral on Twitter. Although I identified several negative themes in the qualitative analysis, such negative themes and tweets were found to be not prevalent in the dataset, and there were other positive and neutral themes. Furthermore, the terms of youth and youngster showed positive perceptions, with the qualitative analysis identified primarily positive themes associated with the two terms, such as youth with positive characteristics and youngster sports players getting attention.

These findings suggested that adolescence is a comprehensive construct and may not be fully captured by a single term. Gross and Hardin (2007) used the term “teenager” in comparison with “adult” and conducted an IAT experiment, and results suggested that participants held an implicit stereotype that they tended to associate “teenager” with stereotypical descriptors (vs. neutral descriptors; the stereotypical descriptors they used were the same as I used in the current

study) compared to "adult". The results of my dissertation also suggested that the word embedding of "teen" showed higher levels of tendency towards stereotypical descriptors (vs. neutral descriptors; mean difference = -.09) compared to the word embedding of "adult" (mean difference = -.19). However, Gross and Hardin's (2007) finding may be limited as they only tested the term of "teenager". Switching to other terms such as "youth" may result in less stereotypical results, as indicated by my dissertation. Therefore, future work analyzing perceptions of adolescence may consider the use of different terms rather than using a single term to indicate adolescence.

Furthermore, existing research analyzing individual perceptions of adolescence generally indicated that people hold overall negative and stereotypical perceptions of adolescence (e.g., Buchanan & Holmbeck, 1998) or focused on the negative and stereotypical aspects (e.g., Buchanan & Hughes, 2009; Qu et al., 2016). However, my dissertation suggested that the overall construct of adolescence (i.e., the centroid of the word embeddings of "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween") was not perceived as negative or stereotypical. This finding may inform future research to focus more on positive or neutral perceptions of adolescence.

Besides, although theoretical frameworks such as positive youth development have advocated positive perceptions of adolescence (e.g., Lerner et al., 2015) and non-profit organizations such as the FrameWorks Institute has been calling for shifting the frame of how the public perceive adolescence (Kendall-Taylor, 2020), existing research has rarely suggested ways to shift public perceptions of adolescence into more positive forms. My finding that the terms of "youth" and "youngster" tended to be more positive and unstereotypical may inform education and communication practices to shift the framing of adolescence by using these terms more when

referencing adolescence. Since the terms of "youth" and "youngster" are already perceived as positive and unstereotypical by the public, using these terms to reference adolescence may influence the readers to associate positive perceptions with adolescence, therefore re-framing public perceptions of adolescence. Communication research has already demonstrated that shifting the terms can help re-frame public perceptions of social events such as climate change movements (e.g., Newell et al., 2015).

A Mixed Methods Analysis of Themes of Public Perceptions

Before discussing the results, I note that the descriptors and themes associated with terms of adolescence should be understood as reflecting unique associations rather than common associations. For instance, it is possible that positive descriptors and themes also exist in tweets containing the term of "teen," but if they are more prevalent in tweets containing the term of "youth," they will be more likely to be identified with the term of "youth" rather than the term of "teen". Therefore, although I discussed each term of adolescence and its unique association with certain descriptors and themes, the results should be understood conjointly across different terms of adolescence, which were captured by the composite measure of adolescence. I also note that the quantitative analysis of valence of public perceptions may not be consistent with the mixed methods analysis of themes of public perceptions, as the prior analysis was theory-driven based on pre-defined descriptors from existing literature but the latter analysis was data-driven based on the outputs of word embeddings. Most of the pre-defined descriptors in the quantitative analysis did not appear to be closely associated with terms of adolescence in the mixed methods analysis.

Quantitative analysis of textual data may be restricted in its ability to extract nuances from the texts and therefore ignores the meaningful contexts of texts. To better dig information

from the data, I developed a mixed-methods approach in which I first extracted descriptors that were closely associated with the word embeddings of adolescence using the word embedding model, and then conducted qualitative content analysis by coding the descriptors and referencing example tweets containing the descriptors. The qualitative content analysis identified distinct patterns of themes for different word embeddings of adolescence, echoing the findings that different word embeddings of adolescence showed different levels of stereotypes in quantitative analysis.

Specifically, the word embedding of "adolescent" was found to be associated with themes of research on adolescence to be advocated and concern for adolescent health, reflecting the academia's interests in adolescence. Indeed, adolescent health has been acknowledged as a central issue in contemporary study of adolescence (e.g., Patton et al., 2016) and an emerging line of work has begun to investigate the role of social media on adolescent health (e.g., Shaw et al., 2015). My dissertation suggested that discussion of the word "adolescent" on Twitter was centered around the themes of adolescent research and health, which may add to this line of work and inform future study to analyze specific contents of discussion about adolescent health on Twitter. While researchers studying health communication have investigated general health communication on Twitter, such as the topics of health communication and the role of health organizations (e.g., Park et al., 2016), such investigation is rare on adolescent health communication (e.g., Barry et al., 2016). My dissertation provides initial clue that there was discussion about adolescent health that served as an eminent theme in Twitter users' discussion of adolescence, and future work may analyze such discussion to promote the understanding of adolescent health communication on Twitter as well as to facilitate positive health communication.

The word embedding of "teen" was found to be associated with the theme of hate and bias for teenagers, suggesting that although contemporary research on adolescence has advocated a positive view of adolescence (e.g., positive youth development; Benson, 1997; Lerner et al., 2005) and emphasized multiple themes of adolescent development such as ecological systems (Bronfenbrenner, 1979, 1995) and identity development (Erikson, 1968), the storm-and-stress view of adolescence (Hall, 1904) may still be influential and the negative/stereotypical perceptions of adolescence as identified in previous research (e.g., Buchanan & Holmbeck, 1998; Qu et al., 2016) may still be prevalent in contemporary social media, with social media users explicitly expressing hate and bias towards adolescence or implicitly associating adolescence with undesirable characteristics. This type of posts may further strengthen the storm-and-stress view of adolescence by influencing other social media users who join the discussion or read the messages. This type of posts may also impact adolescent well-being by hurting adolescent social media users who encounter these messages. Indeed, adolescents' use of social media has been found impact their well-being and one of the underlying mechanisms is through their browsing behavior, in which negative information may increase negative emotions such as depressive mood (Weinstein, 2018). Education and communication practitioners may take steps to reduce or counter such posts in order to shift the negative framing of adolescence and protect adolescents from reading negative information.

Themes associated with "youth" were found to be quite positive, including youth as an important element of society, youth with positive characteristics, and youth to be empowered and supported. These themes are in line with the framework of positive youth development (PYD). Specifically, the themes I identified met Benson's (1997) advocate of empowering youth from multiple social contexts (e.g., community, school, and family). The descriptors and example

tweets I coded acknowledged the value of youth in society and proposed empowerment of youth. The relatively positive themes of youth on Twitter may partly reflect PYD's efforts of proposing positive framing of youth. They can also be used by education and communication practitioners to strengthen positive perceptions of adolescence and counter negative perceptions in the future.

Themes associated with "juvenile," "puberty," and "youngster" were found to be closely associated with specific fields (i.e., justice, physiology, and sports), including juvenile justice and delinquency, puberty as a period of physical development and sexual maturation, and youngster sports players getting attention, due to the relatively narrower usage in the English language. The term of "tween" was found to be associated with the theme of tweens' everyday life, suggesting that "tween" may be a neutral term that is broadly linked with various aspects of adolescence. These themes highlighted a diverse range of themes that Twitter users associated with adolescence, rather than just the negative or stereotypical perceptions that were focused on in previous studies (e.g., Buchanan & Holmbeck, 1998; Qu et al., 2016)

The composite measure of adolescents was found to capture multiple themes associated with different terms of adolescence, with positive and neutral themes being more evident compared to negative themes. This finding suggested that the overall public perceptions of adolescence may be positive on Twitter, echoing my quantitative analysis in the prior section. While existing research investigating perceptions of adolescence mainly focused on the negative aspects (e.g., Buchanan, 2003; Qu et al., 2016), my analysis suggested that positive and neutral perceptions may be more evident on social media. Although negative perceptions of adolescence may impact adolescent development such that parents who held negative perceptions of adolescents tended to have their own children showing parallel behavior (e.g., Jacobs et al., 2005) and adolescents who held negative perceptions of their age group tended to have less family

responsibility and school engagement (Qu et al., 2016), positive and neutral perceptions of adolescence may also influence adolescent development, such as the PYD advocates positive perceptions of adolescence to facilitate positive youth development (e.g., Benson, 1997). Therefore, future work may focus more on the positive and neutral aspects of public perceptions of adolescence to fill in the gap of literature and better promote positive youth development.

Overall, combining word embeddings with qualitative content analysis, I was able to generate multiple meaningful themes associated with different terms of adolescence. While some of the themes can be indicated from existing literature, such as hate and bias for teenagers as indicated by the storm-and-stress view of adolescence (Hall, 1904), I also identified other themes that has rarely been discussed in previous research, such as youth as an important element of society, and youth to be empowered and supported. These themes suggested that more aspects of public perceptions of adolescence are present in social media, rather than just the storm-and-stress view. Some of the themes are worth attention from future researchers and practitioners to create a more positive and healthy environment for positive youth development. For instance, the positive themes associated with "youth" (i.e., youth as an important element of society, youth with positive characteristics, and youth to be empowered and supported) may be utilized by education and communication practitioners to re-frame public perceptions of adolescence into more positive forms by referencing adolescence as youth. While existing researchers have emphasized the negative impact of negative perceptions of adolescence (e.g., Buchanan, 2003), my dissertation also contributes to this line of work by identifying the theme of hate and bias for teenagers, suggesting that such negative and stereotypical perception still exist on social media and practitioners may take actions to reduce such perception to facilitate positive youth development.

Methodologically, while there is an emerging line of work that advocates the use of computational methods to combine computational methods with qualitative analysis (e.g., Nelson, 2020), to my knowledge, my dissertation is among the first set of studies that integrated machine learning with qualitative content analysis. I leveraged the word embedding model's ability to synthesize information from big data and capture latent meanings of terms. To embed abstract results generated by the word embedding model into more detailed contexts, I developed a coding approach through which coders read the descriptors and example tweets to identify qualitative themes from the results. This approach was able to identify meaningful themes that captured public perceptions of adolescence on Twitter and demonstrated advantages over pure quantitative or qualitative analysis. Compared to pure quantitative analysis, my approach combined quantitative results (i.e., the top 60 descriptors that were most closely associated with the term of adolescence) with qualitative analysis of the descriptors and example tweets, which helped me to put the descriptors into specific contexts of tweets and better understand *how* and *why* the descriptors were associated with adolescence. Without the qualitative analysis, quantitative results of how a certain term of adolescence was associated with a certain descriptor would be difficult to interpret. Compared to pure qualitative analysis, my approach was able to synthesis information from millions of tweets and generate the most relevant descriptors associated with adolescence. Without the quantitative word embedding model, it would be impossible to process millions of tweets and identify the most relevant themes associated with adolescence. Future work can leverage or further develop this analytic approach to better analyze big textual data and promote the understanding of social/psychological constructs in big data.

Public Perceptions of Subgroups of Adolescents

Quantitative Analysis of Valence of Public Perceptions

Applying the same analytic approach to test the quantitative association between different word embedings of subgroups of adolescence and pre-defined sets of descriptors, I also found that different word embedings of subgroups of adolescence varied in their associations with stereotypical/negative descriptors vs. neutral/positive descriptors. Specifically, focusing on race/ethnicity (i.e., Black, Latinx, Asian, and White), Latinx adolescents showed higher levels of tendency towards stereotypical descriptors (vs. neutral descriptors), yet they also showed slightly higher levels of tendency towards positive descriptors (vs. negative descriptors). The other race/ethnic groups (i.e., Black, Asian, and White) did not show significant tendency towards stereotypical descriptors (vs. neutral descriptors) or positive descriptors (vs. negative descriptors). I discussed potential explanation in the next section of themes of public perceptions. Male adolescents and female adolescents did not show much difference in their associations with stereotypical/negative descriptors vs. neutral/positive descriptors. The two subgroups both appeared to be relatively neutral compared with other subgroups of adolescence. The results suggested that gender-related bias and stereotypes may not be evident in tweets related to adolescence on Twitter. Focusing on sexual orientation (i.e., gay, lesbian, and LGBT), LGBT adolescents were found to show higher levels of tendency towards positive descriptors (vs. negative descriptors). I also discussed potential explanation in the next section of themes of public perceptions.

Although there is a handful research analyzing public perceptions of adolescence for the general adolescent population (e.g., Buchanan, 2003), few existing studies have explicitly investigated public perceptions of subgroups of adolescence, probably due to the complexity that

such investigation requires examining both group identity and the developmental period of adolescence. Therefore, my analytic approach may inform future work to analyze complex constructs by combining different word embeddings to generate new constructs that captured the latent meanings from different concepts. For instance, my dissertation combined the composite measure of adolescence with the word embeddings of group membership indicator (i.e., "boy" and "girl"). Future work may explore other combination of word embeddings (e.g., combining the word embedding of "adolescence," "boy," and "Black") to analyze public perceptions of more specific subgroups of adolescents.

A Mixed Methods Analysis of Themes of Public Perceptions

Subgroups by race/ethnicity. I observed both similarities and notable differences in the themes associated with adolescents of different racial/ethnic subgroups. For Black, Latinx, and White adolescents, I observed themes about social justice movements, race/ethnicity and racism, with Black and Latinx adolescents' participation in anti-racism movements been discussed or promoted, and White adolescents' passively involved into such discussion. Racism is an important context for adolescent development in the United States, with White individuals being prioritized over racial/ethnic minorities in the society (García Coll et al., 1996; Roberts, 2012), which can operate through media (Jones, 1997). Racial/ethnic minority adolescents who are more stressful experiences of racism tend to have more engagement in anti-racism actions (e.g., Hope et al., 2022). Racial/ethnic minority adolescents' participation in discussions related to social movements may also serve as a socialization process, especially for the development of their racial/ethnic identity when engaging in anti-racism movements (Umaña-Taylor et al., 2014). Therefore, experiences of racism may engage Black and Latinx adolescents into social justice and anti-racism movements while also involving While adolescents into discussion, leading to

the themes I observed. These themes also reflected racial/ethnic adolescents' active civic engagement. Indeed, adolescent civic engagement has become an important theme in adolescent development (Chan et al., 2014), with adolescents highly engaged in social movements such as the Black Lives Matter movement (Baskin-Sommers et al., 2021). Future research on racial/ethnic minority adolescents' engagement in social justice movements may pay attention to the context of social media as currently there are few studies focusing this context.

Although experiences of racism and youth participation in anti-racism movements are also salient for Asian adolescents (e.g., Ballard, 2016), these themes were not identified in my analysis. This suggests that Asian adolescents' racial/ethnic experiences may be overlooked on Twitter. Indeed, recent research has already begun to discuss how racism against Asian youth may be overlooked compared to anti-Blackness (Lee et al., 2022). Future work may further explore the lack of representations and voices for Asian youth on social media and develop intervention programs to address this issue, such as identifying the reasons why voices for Asian youth are missing and developing programs to encourage Asian youth to express their voices. Education and communication practitioners may pay more attention to racial/ethnic minority groups other than the Black and Latinx to facilitate the discussion and movements of anti-racism for these groups.

For White adolescents, the theme of hate and bias for teenagers was specifically associated with this subgroup rather than others, suggesting that the storm-and-stress view of adolescence may be primarily associated with White adolescents. This finding resonates with a long-lasting discussion regarding the nature of storm and stress in adolescence. Whereas Stanley Hall (1904) suggested that storm and stress is universal yet acknowledging cultural variations, Margret Mead (1928) argued that storm and stress is not prevalent in non-western cultures. More

recent theoretical work generally acknowledged cultural variations and individual differences of adolescent development. For instance, Bronfenbrenner (1979, 1995) highlighted the impact of ecological systems such as culture and community on adolescent development. The positive youth development framework also emphasizes the role of culture on positive development, suggesting that the meanings of positive development may differ across cultural contexts (Shek et al., 2019). While most of existing research has not empirically compared the storm-and-stress view of adolescence for different subgroups of adolescence, Qu and colleagues (2016) found that U.S. youth (73% White) were more likely to see adolescence as a time of less family responsibility and school engagement compared to Chinese adolescents. My dissertation did not evaluate the actual levels of storm and stress in various subgroups, but suggested that the *perceptions* of adolescence as storm and stress may be primarily linked with White adolescents on Twitter, echoing Qu and colleagues' (2016) work.

Subgroups by gender. For both gender groups, I identified the theme of adolescents' everyday life, yet this theme was more evident for male adolescents compared to female adolescents, whereas descriptors that indicate online sexual abuse and sexual objectification were more prevalent for female adolescents compared to male adolescents, indicating potential gender inequity. I discussed potential issues in the section of Sexual Content and Potential Issues of Online Sexual Abuse and Sexual Objectification.

Subgroups of sexual minority adolescents. For LGBT adolescents, descriptors and example tweets expressed support for this subgroup, which may promote positive development for LGBT adolescents. Research has shown that LGBTQ+ adolescents use social media for self-expression and seeking social support (Selkie, et al., 2020) and social media use has been found to impact their sexual identity and well-being such as reducing their mental health concerns and

promoting positive emotions (e.g., Berger et al., 2022). Therefore, future work and practices may examine how discussion about LGBTQ+ adolescents may promote the well-being of them and facilitate positive discussion on Twitter.

Sexual Content and Potential Issues of Online Sexual Abuse and Sexual Objectification

Unexpectedly, this dissertation study identified descriptors and tweets that may indicate online sexual abuse and sexual objectification of adolescents in online spaces. Although I did not proceed into coding these descriptors as they are outside of the scope of the current study and do not necessarily reflect public perceptions of the nature of adolescence or adolescent development, I discussed potential implications of the findings here.

For the word embedding of "teen", I found that many descriptors were related to sexual contents, with the example tweets displaying teenagers as an attractive point to distribute sexual contents, even though the actual contents may be performed by adults. This may indicate sexual objectification (e.g., Fredrickson & Roberts, 1997) of teenagers. The original objectification theory suggested that women's body tends to be treated as an object for the pleasure and use of others in society, which can be reflected by the representation of women in the media (Fredrickson & Roberts, 1997). Recent work on sexual objectification has paid attention to the objectification of adolescents (e.g., Slater & Tiggemann, 2010). My finding may contribute to this line of work by showing that adolescents are objectified in sexual contents on the Internet. On the one hand, using teenagers as attractive points in sexual contents may indicate loopholes in the current law and justice system on child sexual abuse material. Whereas visual depiction of sexually explicit conduct involving someone under 18 years of age has been clearly identified as violating federal law on child sexual abuse material (Quayle & Taylor, 2004), textual depiction of sexual content involving someone under 18 years of age may receive less supervision. The

finding of my dissertation highlighted the need to supervise textual contents that may relate to child sexual abuse material on the Internet. On the other hand, the association between teen and sexual contents may also reflect sexual development and an emerging interest in sexuality among adolescent users themselves (Ponton & Judice, 2004). Sexual contents that used teenagers as attractive points may appeal to adolescent Twitter users and impact their well-being. Adolescents' use of sexual material and exposure to sexual contents on the Internet has also been found to impact adolescent development. For example, research shows that increasing use of Internet pornography is associated with decreased male adolescents' academic performance six months later (Beyens et al., 2014), and more frequent use of sexually explicit Internet material led to more permissive attitudes and more frequent experience with sexual behavior (Doornwarrd et al., 2015). Therefore, the spread of sexual messages about teenagers on Twitter may also impact adolescent well-being, and future work and practices may target this phenomenon to promote positive sexual development in adolescence.

For the word embedding of adolescent subgroups, I found that almost all the top 60 descriptors associated with Asian adolescents, gay adolescents, and lesbian adolescents were related to sexual contents, with the example tweets displaying these groups as an attractive point to distribute sexual contents. Although I also identified similar descriptors for other subgroups (e.g., Black and White adolescents), they were less prevalent. Similarly, I found that descriptors related to sexual contents were more prevalent for the word embedding of female adolescents compared to male adolescents. Moreover, when the descriptors and example tweets for male adolescents contained sexual contents, they were targeting more specifically for gay adolescents. These findings highlight certain adolescent subgroups (e.g., female, Asian, gay, and lesbian adolescents) as vulnerable groups that may be particularly targeted by sexual objectification and

child sexual abuse materials, who may need particular attention in research and practices that seek to address inequality in online spaces.

Overall, these findings suggest that potential issues of sexual objectification of adolescents and the spread of child sexual abuse materials may exist on Twitter. They may not necessarily reflect Twitter users' perceptions of adolescence, as many of the tweets may be posted by robot or commercial accounts that tried to propagandize sexual materials, yet they also reflected how adolescents are depicted in public spaces, as the tweets were all publicly available in 2019. For education and communication practitioners as well as law makers, my findings may inform practices to address the issues of sexual objectification of adolescents and the spread of sexual abuse materials on Twitter, with the goal of reducing relevant messages on social media. Moreover, Asian adolescents may require more attention as the issues were more evident among them compared to other racial/ethnic groups. Female adolescents may require more attention as they were more frequently targeted for sexual contents compared to male adolescents. Practitioners may also examine homosexual contents targeting male adolescents, gay and lesbian adolescents.

Implications and Limitations

Theoretical and Methodological Implications

While prior research on perceptions of adolescence mainly explored individuals' negative perceptions of adolescence in the family and school contexts, the current study shifted the literature to the broader context of social media and explored multiple themes of perceptions, which may contribute to a more comprehensive understanding of public perceptions of adolescence. Future work may build upon the current study to explore more themes and nuances in public perceptions of adolescence as well as to explore this issue in other contexts such as

TikTok, a more popular social media platform among adolescents. Whereas Twitter data are text-based and public perceptions of adolescence can be extracted using textual analysis, data from TikTok are video-based and may require a different methodology for data analysis.

Although developmental theories such as the ecological systems theory (Bronfenbrenner, 1979) have long emphasized the importance of macrosystem such as sociocultural values on adolescent development, existing research on adolescence has focused more on individuals and their proximal environments (e.g., family and school; Steinberg & Morris, 2001). While scholars have increasingly realized the importance of values and ideologies in the macrosystem and their impact on micro-level processes (e.g., structural racism; Rogers et al., 2021), few studies have directly examined factors in the macrosystem. Leveraging big data on social media and machine learning, the current study focused on the broader context of social media and explored how the developmental period of adolescence is perceived in this broader context. This approach may implicate future research to pay more attention to macro-level factors that impact development and directly examine such factors using big data and machine learning.

Conventional social science research tends to employ a deductive or theory-driven approach, in which researchers fit data to the theory (Grimmer et al., 2021). This approach has also been endorsed by existing research on perceptions of adolescence, with most studies adopted the storm-and-stress view of adolescence and focused more on the negative perceptions of adolescence. However, the current study employed an inductive or data-driven approach that first utilized an unsupervised, data-driven algorithm to extract information from the data, which may enable us to transcend the storm-and-stress view of adolescence and discover more themes around perceptions of adolescence from the data. The descriptors as identified in my dissertation were purely data-driven, and the selection process was not impacted by researchers' prior

knowledge or bias (e.g., researchers believing the storm-and-stress view may select negative descriptors over positive ones). This approach may inform future research to leverage data-driven approaches for research questions that have not been directly addressed by theories.

Practical Implications

While the PYD framework propose to focus on the positive aspects of adolescent development, which inherently advocates positive perceptions of adolescence, American adults and adolescents have still been found to endorse negative and stereotyped perceptions of adolescence (Buchanan & Holmbeck, 1998; Qu et al., 2016), which leads to undesirable developmental outcomes (Buchanan & Hughes, 2009; Qu et al., 2018). Furthermore, American media tends to present a negative image of adolescents, which may in turn strengthen the negative perceptions of adolescence (Nichols & Good, 2004). Kendall-Taylor (2020) has called for shifting the negative framing of adolescence to promote positive development, yet such efforts are still scarce. Qu and colleagues' (2020) intervention program shifted adolescents' stereotyped perceptions of their age group and promoted their positive development in the school context. Further work is needed to facilitate positive perceptions of adolescence in other contexts such as social media, which has had an increasing impact on adolescents (Best et al., 2014). The current study may lay the foundation for this line of work by facilitating the understanding of public perceptions of adolescence on social media, therefore informing media practitioners and providing insights on how to tackle the negative perceptions of adolescence in the future. For instance, the theme of hate and bias for teenagers that I identified suggests that the negative and stereotypical view of adolescence exists on social media and may impact adolescent social media users, especially for White adolescents. It is necessary to take actions to reduce such contents on social media, such as changing the recommendation algorithms of social media to make such

contents less viable to other users. While Twitter already has policy for hateful conduct that seeks to make hateful content less visible, hateful or biased content on adolescence existed in my dataset, suggesting that their algorithms can be improved to create a better environment for adolescents. The positive themes of youth (i.e., youth as an important element of society, youth with positive characteristics, and youth to be empowered and supported) suggested that Twitter users have an overall positive view of youth. Education and communication practitioners may use the term of "youth" more to reference adolescence to facilitate the positive framing of adolescence.

In addition, while existing research generally focuses on perceptions of the general adolescent population, the current study paid special attention to adolescent subgroups by gender, race/ethnicity, and sexual orientation, which may contribute to the understanding of the developmental contexts of these adolescent subgroups. By highlighting the unique perceptions associated with different adolescent subgroups, the current research may also inform intervention programs to facilitate a better environment for adolescent subgroups on social media. For instance, I identified themes related to anti-racism for Black and Latinx adolescents but not for Asian adolescents. Education and communication practitioners may continue to facilitate positive discussion around anti-racism for Black and Latinx adolescents while addressing the lack of voices of Asian adolescents and encourage them to speak on social media. For sexual minority adolescents, I found the theme of increasing awareness and supporting LGBT adolescents, such theme can be further promoted to improve the well-being of LGBTQ+ adolescents.

Limitations

The current study leveraged big data and machine learning to analyze public perceptions of adolescence on Twitter. Although the use of big data and unsupervised machine learning algorithms may allow the extraction of meaningful information from the data, such an analytic approach also has major methodological limitations.

First, unlike conventional research that directly surveys participants about their perceptions of adolescence, the current study used word embeddings to analyze the latent meanings of words in tweets and interpreted the results as reflecting Twitter users' perceptions of adolescence, which is an indirect way of investigating perceptions of adolescence. Therefore, the results may not always reflect public perceptions of adolescence. For instance, while I found that the term of "adolescent" was more closely associated with stereotypical descriptors (e.g., rebellious, risk-taking) compared to neutral descriptors, it is difficult to distinguish whether such association reflects stereotypical perceptions (e.g., Twitter users think that adolescents are rebellious) or actual disparities (e.g., Twitter users discuss the finding that adolescents tend to have higher levels of rebellious behavior). I tried to address this issue by referencing example tweets for the mixed-methods analysis to identify themes of public perceptions, during which the coders were instructed to read the example tweets and analyze if the descriptors in the tweets reflected certain perceptions of adolescence. However, this issue can be further complicated by the fact that there are many robotic users and commercial accounts on Twitter (Alothali et al., 2018). Tweets posted by these accounts may not reflect public perceptions of adolescence, as their depiction of adolescence may be of propaganda purposes. I did not address this issue in the current study but future work may remove posts from robotic or commercial accounts in data analysis.

Second, it is difficult to ensure the quality of Twitter data and exclude undesirable data (Salvatore et al., 2021), such as tweets irrelevant to adolescence, which may contribute meaningless information to the word embedding model. In my previous work analyzing public perceptions of adolescence using more than 20,000 tweets through qualitative content analysis, I found that almost 50% of the tweets were irrelevant to adolescence. The use of word embedding model may partly resolve this issue, as the model seeks to extract repeated information from the data as capturing the latent meanings of words, whereas irrelevant tweets tend to be random and may not contribute repeated information to the model.

Third, although the word embedding model is able to extract meaningful information from the data, compared to qualitative analysis, such extraction can be superficial and missing important, nuanced information by aggregating all the data to generate a universal representation of the words. The current study sought to address for this limitation by integrating word embeddings with qualitative content analysis. I also referenced example tweets when coding the descriptors, thus providing the contexts of the descriptors. However, the qualitative content analysis was mainly based on the output of the word embedding model (i.e., the descriptors were selected based on the model), therefore I may still fail to extract nuanced information or identify important themes if the word embedding model ignored such information during model training.

Fourth, although Twitter is a platform for opinion expression, it can only be used to understand clearly conveyed perceptions but not the aspects that users find difficult or not willing to express. Therefore, the perceptions of adolescence as identified in my dissertation mainly reflect Twitter users' perceptions that they expressed via tweets only.

Fifth, although the current study explicitly focuses on the context of Twitter, the demographics of Twitter users are not representative of the U.S. population such as more male

users (Mislove et al., 2011). Future work may explore public perceptions of adolescence on other platforms, such as Facebook and Tik Tok, to facilitate the understanding of the topic in more contexts.

Sixth, my analysis only utilized the textual part of the data whereas the meta information such as user characteristics was left. Future work may incorporate meta information into analysis, such as comparing perceptions of adolescence between individual and organizational users.

Finally, the data I extracted are publicly available tweets posted in 2019. Public perceptions of adolescence and the digital environment of social media may be constantly shifting, therefore the results of the current study can only reflect public perceptions of adolescence on Twitter in 2019. What's more, the data were collected before the COVID-19 pandemic, public perceptions of adolescence may shift due to the pandemic and require future research to examine potential change.

Conclusion

The current study applied word embeddings, a machine learning model, to analyze millions of tweets about adolescence, in which different words were represented as high-dimensional vectors by the model as reflecting their latent meanings. The model was able to identify the latent construct of adolescence by associating different terms of adolescence close to each other. The association between a certain term of adolescence and another descriptor about adolescence (e.g., "rebellious") was interpreted as reflecting public perceptions of adolescence. I first employed a theory-driven and quantitative approach to examine if terms of adolescence were perceived as stereotypical (vs. neutral) or positive (vs. negative) compared to the term of "adult" and "people," finding that although the overall construct of adolescence was not perceived as stereotypical or negative, perceptions varied by different terms of adolescence,

suggesting that adolescence is a complex and comprehensive construct that cannot be captured by a single item. Existing research may be limited by their use of single term to reference adolescence. Certain terms of adolescence such as youth may be used more when referencing adolescence as it was perceived as less stereotypical and more positive, therefore promoting positive framing of adolescence.

I then developed an innovative method that employed a data-driven and mixed-methods approach to analyze word embeddings, in which I first generated lists of descriptors that were most closely associated with terms of adolescence and then conducted qualitative content analysis on the descriptors while referencing example tweets containing the descriptors to better understand how and why the descriptors were associated with adolescence. I was able to identify various meaningful themes from the descriptors, reflecting not only negative perceptions of adolescence, but also neutral and positive ones, with the themes suggesting an overall positive and neutral perception of adolescence on Twitter. The themes revealed several perceptions of adolescence that have rarely been addressed in literature, such as youth as an important element of society. Some themes can also inform future research and practices, such as addressing bias and offensive messages targeting adolescence on Twitter, leveraging the positive perceptions of youth to promote positive framing of adolescence.

I also generated word embeddings for subgroups of adolescents based on race/ethnicity, gender, and sexual orientation, and applied the same set of analysis on subgroups of adolescents. The results suggested both similarities and differences existed in the perceptions of different subgroups of adolescents. For instance, While Black, Latinx adolescents were involved in discussion about social justice and anti-racism movements, reflecting experiences of racism and participation in anti-racism movements among them, such discussion was missing for Asian

adolescents, suggesting lack of voices for them. White adolescents were found to be uniquely associated with the theme of hate and bias, suggesting that the storm-and-stress view of adolescence may mainly target White adolescents. Twitter users' discussed increasing awareness and supporting LBGT adolescents for LGBT adolescents, suggesting positive discussion for sexual minority adolescents. These results can also inform future research and practices, such as increasing the voices of Asian adolescents, promoting the well-being of racial/ethnic minority adolescents by engaging them in anti-racism movements, and promoting positive development for sexual minority adolescents.

Overall, my dissertation leveraged big data and machine learning to shift the literature from focusing on individual perceptions of adolescence in the family and school contexts to the broader context of social media. The analytic approach I used or developed was more inductive or data-driven, allowing me to capture several perceptions of adolescence that has rarely been addressed in literature, where as existing research mainly focused on the negative perceptions. My dissertation was also among the first set of studies that combined machine learning outputs with qualitative analysis, making the abstract and simple outputs more interpretable and putting them into specific contexts of the data. This approach may inform future studies to leverage big textual data to analyze public perceptions or meanings of other psychological/sociological constructs. My dissertation can also inform future practices to promote positive framing of adolescence and create a better digital environment for adolescent development, such as reducing harmful and bias messages about adolescence on Twitter and promoting positive framing of adolescence by using "youth" to reference adolescences. My dissertation also have several limitations regarding data interpretation, representativeness, and quality, the use of the word embedding model, and the timing of data collection.

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APPENDIX 1: TABLES

Table 1

Number of Tweets Containing Different Terms of Adolescence

Terms	Number of Tweets	Example Tweet
Adolescent	85,022	*teenage #pregnancy nutrition-nutritional needs for the adolescent mum-to-be*
Teen	1,694,602	*group conducts another search for missing teens*
Youth	1,500,895	*there is a thin line between enjoying your youth and destroying your future*
Juvenile	104,857	*earlier this month, congress passed the juvenile justice and delinquency prevention act that now awaits presidential signature*
Puberty	62,309	*hrt gives you the hormone levels of a typical male going through puberty*
Youngster	133,874	*he feels the youngster is in a 'very positive moment' mentally*
Tween	57,928	*where are the just-right books for tweens?*

Table 2

Sentiment Scores of Tweets Containing Different Terms of Adolescence

Terms	Positive Sentiment		Negative Sentiment		Neutral Sentiment		Overall Sentiment	
	Mean	(*SD*)	Mean	(*SD*)	Mean	(*SD*)	Mean	(*SD*)
Adolescent	.14	(.13)	.09	(.12)	.76	(.16)	.13	(.60)
Teen	.15	(.15)	.13	(.14)	.72	(.17)	.07	(.62)
Youth	.17	(.15)	.08	(.11)	.75	(.16)	.28	(.59)
Juvenile	.13	(.13)	.13	(.14)	.74	(.16)	-.02	(.63)
Puberty	.15	(.15)	.10	(.12)	.75	(.17)	.10	(.54)
Youngster	.20	(.16)	.08	(.11)	.72	(.16)	.33	(.57)
Tween	.15	(.13)	.08	(.11)	.77	(.15)	.19	(.60)

Note. For positive, negative, and neutral sentiment, the scores range from 0 to 1, with higher scores indicating higher levels of sentiment. For overall sentiment, the scores range from -1 to 1, with scores higher than .05 indicating positive sentiment, scores lower than -.05 indicating negative sentiment, and scores between -.05 and .05 indicating neutral sentiment.

Table 3

Average Cosine Similarity Scores for Different Word Embeddings of Adolescence in their Associations with Stereotypical Descriptors and Neutral Descriptors

Word Embedding	Stereotypical Descriptors		Neutral Descriptors		Mean Difference	Paired Sample *t*-tests		
	Mean	(*SD*)	Mean	(*SD*)		*t*	*p*	Cohen's *d*
Adolescent	.18	(.07)	.28	(.05)	-.09	-2.94	.012	-1.57
Teen	.19	(.09)	.46	(.04)	-.27	-7.27	.001	-3.89
Youth	.12	(.03)	.36	(.10)	-.25	-6.04	.001	-3.22
Juvenile	.17	(.07)	.25	(.03)	-.08	-3.01	.013	-1.61
Puberty	.17	(.04)	.27	(.04)	-.11	-4.58	.001	-2.45
Youngster	.15	(.09)	.33	(.06)	-.18	-4.35	.001	-2.33
Tween	.15	(.05)	.31	(.07)	-.16	-4.84	.001	-2.59
Composite	.26	(.06)	.51	(.06)	-.25	-7.67	.001	-4.10
Adult	.20	(.03)	.39	(.04)	-.19	-9.25	.001	-4.95
People	.20	(.07)	.53	(.08)	-.33	-7.98	.001	-4.26

Note. Stereotypical descriptors included "rebellious," "reckless," "risk-taking," "stubborn," "rude," "impulsive," "selfish," "crazy". Neutral descriptors included "get," "say," "still," "also," "thing," "would," "as," "go". Composite: composite measure of adolescence (i.e., the centroid of the word embeddings of "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween").

Table 4

Average Cosine Similarity Scores for Different Word Embeddings of Adolescence in their Associations with Positive Descriptors and Negative Descriptors

Word Embedding	Positive Descriptors		Negative Descriptors		Mean Difference	Paired Sample *t*-tests		
	Mean	(*SD*)	Mean	(*SD*)		*t*	*p*	Cohen's *d*
Adolescent	.15	(.05)	.13	(.05)	.02	0.77	.455	0.41
Teen	.17	(.07)	.14	(.05)	.03	0.90	.384	0.48
Youth	.18	(.07)	.10	(.04)	.08	2.58	.025	1.38
Juvenile	.12	(.07)	.20	(.07)	-.07	-2.13	.051	-1.14
Puberty	.13	(.07)	.13	(.03)	.00	0.11	.915	0.06
Youngster	.20	(.07)	.14	(.06)	.06	1.96	.071	1.05
Tween	.16	(.06)	.14	(.06)	.02	0.76	.459	0.41
Composite	.25	(.07)	.23	(.06)	.03	0.79	.445	0.42
Adult	.17	(.08)	.16	(.04)	.02	0.50	.626	0.27
People	.18	(.09)	.22	(.05)	-.03	-0.81	.434	-0.43

Note. Positive descriptors included "agreeable," "bright," "diligent," "gentle," "helpful," "honest," "kind," "nice". Negative descriptors included "aggressive," "careless," "dishonest," "foolish," "rude," "lazy," "selfish," "silly". Composite: composite measure of adolescence (i.e., the centroid of the word embeddings of "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween").

Table 5

Summary of Themes for Different Word Embeddings of Adolescence

Word Embedding	Theme	Top Five Descriptors	Example Tweets
Adolescent	Research on adolescence to be advocated	"meta-analysis," "systematic review," "springerlink," "comorbidity," "psychosocial"	*"Important paper that robustly challenges claims for high incidence of bipolar disorder in children & adolescents made by some US studies."*
	Concern for adolescent health	"mum-to-be," "nutrition," "comorbidity," "health," "over-nutrition"	*"Sometimes children and adolescents suffer from depressive symptoms or are even have a #depression."*
Teen	Hate and bias for teenagers	"fuck," "fucking," "horny," "dirty," "worthless"	*"Fuck teens in your area."*
Youth	Youth as an important element of society	"support," "country," "nation," "future," "community"	*"Leaders like Hong Hoang, who mobilized a youth-led movement to create a greener world after becoming the first Vietnamese person to visit Antarctica."*
	Youth with positive characteristics	"leader," "great," "young," "good," "well"	*"Youths contribute to economy and the growth of Nigeria."*
	Youth to be empowered and supported	"support," "hope," "help," "opportunity," "work"	*"End 2018 being the change you wish to see. help us spread kindness & empower youth. together, we can prevent #bullying."*
Juvenile	Juvenile justice and delinquency	"delinquent," "delinquency," "justice reform," "justice," "peer justice"	*"Earlier this month, congress passed the juvenile justice and delinquency prevention act that now awaits presidential signature."*
Puberty	Puberty as a period of physical development and sexual maturation	"blocker," "hormone," "hrt," "estrogen," "testosterone"	*"Sophia began identifying as a boy at 11 years old...to halt the effects of female puberty."*
Youngster	Youngster sports players getting attention	"Arsche," "player," "Sanju Samson," "Minamino," "best"	*"A mixture of first team players and youngsters will all get their chance to impress ahead of 2019!"*
Tween	Tweens' everyday life	"kids book," "childrens book," "gift finder," "birthday gifts," "school library"	*"What do you buy? gift ideas for teens who love dogs #giftfinder #teensandtweens"*

Table 6

Average Cosine Similarity Scores for Different Word Embeddings of Subgroups of Adolescence in their Associations with Stereotypical Descriptors and Neutral Descriptors

Word Embedding	Stereotypical Descriptors		Neutral Descriptors		Mean Difference	Paired Sample *t*-tests		
	Mean	(*SD*)	Mean	(*SD*)		*t*	*p*	Cohen's *d*
Boy	.21	(.07)	.52	(.05)	-.30	-9.04	.001	-4.83
Girl	.21	(.07)	.53	(.04)	-.32	-9.69	.001	-5.18
Black	.18	(.09)	.46	(.04)	-.28	-7.45	.001	-3.98
Latinx	.17	(.05)	.29	(.04)	-.13	-5.03	.001	-2.69
Asian	.17	(.07)	.37	(.03)	-.21	-7.16	.001	-3.83
White	.23	(.09)	.49	(.03)	-.26	-7.05	.001	-3.77
Gay	.21	(.06)	.39	(.04)	-.18	-7.14	.001	-3.82
Lesbian	.19	(.04)	.34	(.06)	-.14	-5.53	.001	-2.96
LGBT	.18	(.06)	.32	(.03)	-.14	-5.71	.001	-3.05
Composite	.26	(.06)	.51	(.06)	-.25	-7.67	.001	-4.10
Adult	.20	(.03)	.39	(.04)	-.19	-9.26	.001	-4.95
People	.21	(.07)	.53	(.08)	-.33	-7.98	.001	-4.26

Note. Stereotypical descriptors included "rebellious," "reckless," "risk-taking," "stubborn," "rude," "impulsive," "selfish," "crazy". Neutral descriptors included "get," "say," "still," "also," "thing," "would," "as," "go". Composite: composite measure of adolescence (i.e., the centroid of the word embeddings of "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween").

Table 7

Average Cosine Similarity Scores for Different Word Embeddings of Subgroups of Adolescents in their Associations with Positive Descriptors and Negative Descriptors

Word Embedding	Positive Descriptors		Negative Descriptors		Mean Difference	Paired Sample *t*-tests		
	Mean	(*SD*)	Mean	(*SD*)		*t*	*p*	Cohen's *d*
Boy	.21	(.09)	.20	(.05)	.01	0.15	.884	0.08
Girl	.21	(.09)	.19	(.05)	.02	0.57	.578	0.31
Black	.18	(.08)	.15	(.04)	.02	0.72	.486	0.39
Latinx	.16	(.04)	.13	(.05)	.04	1.46	.165	0.78
Asian	.16	(.07)	.13	(.05)	.01	0.46	.655	0.24
White	.23	(.10)	.23	(.05)	.00	0.02	.981	0.01
Gay	.18	(.08)	.20	(.05)	-.01	-0.37	.716	-0.20
Lesbian	.18	(.08)	.17	(.04)	.01	0.37	.718	0.20
LGBT	.21	(.08)	.15	(.05)	.06	1.75	.107	0.94
Composite	.25	(.07)	.23	(.06)	.03	0.79	.445	0.42
Adult	.17	(.08)	.16	(.04)	.02	0.50	.626	0.27
People	.18	(.09)	.22	(.05)	-.03	-0.81	.434	-0.43

Note. Positive descriptors included "agreeable," "bright," "diligent," "gentle," "helpful," "honest," "kind," "nice". Negative descriptors included "aggressive," "careless," "dishonest," "foolish," "rude," "lazy," "selfish," "silly". Composite: composite measure of adolescence (i.e., the centroid of the word embeddings of "adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween").

Table 8

Summary of Themes for Different Word Embeddings of Subgroups of Adolescence

Word Embedding	Theme	Top Five Descriptors	Example Tweets
Black adolescents	Black adolescents engaging in social justice movements	"bbconly," "say no to white boys," "history," "black twitter movement," "black lives matter," "black is better"	*"Stop telling the Black youth half a bread is better than nothing, we want the whole bakery."*
	Concern for Black adolescents' life	"poncho_free," "melaninpoppin," "school," "family," "group"	*"Almost half of Black youth in the US grow up in the bottom 20% of the income distribution."*
Latinx adolescents	Increasing racial equity for Latinx adolescents	"representationmatters," "racialjustice," "hispanicheritagemonth," "educolor," "minoritymentalhealthmonth"	"*New reports confirm #soda companies disproportionately target #latino & #black youth with their #caffeine laced."*
White adolescents	Hate and Bias for White adolescents	"fuck," "fucking," "wrong," "bad," "weird"	*"Stupid white girls."*
	White adolescents involved in discussion about race and racism	"racist," "supremacist," "supremacy," "white nationalism," "white supremacist terrorism"	*"If you are a white female teen and have a black boyfriend, don't have fear, at least one of your friends will follow your example soon!"*
Male adolescents	Male adolescents' everyday life	"school," "family," "son," "group," "home"	*"A teenage boy on holiday"*
Female adolescents	Female adolescents are attractive in sexual contents	"love," "nudeselfie," "nicetits," "nudegirls," "buyynudes"	*"Do you like adorable cute teengirls? of course you do! enjoy these leaked collection."*
LGBT adolescents	Increasing awareness and supporting LGBT adolescents	"pridemonth," "homophobia," "loveislove," "lgbtqoftwitter," "nooutsiders"	*"#hope #loveislove one man's advice for friends and relatives of lgbtq youth."*

APPENDIX 2: FIGURES

Figure 1

Conceptual Illustration of Representing Words as Word Embeddings

Data: tweets containing keywords related to adolescence (e.g., "adolescent," "teen")

"tRump has the mentality and maturity of a frig'n adolescent boy-child"

"Teens are intelligent and have leadership abilities."

Word embeddings: representing every word in the data with multiple (usually 300) dimensions, which is similar to conventional social science research that measures constructs through multiple items.

Word	Dimension 1 [b]	Dimension 2	…	Dimension 300
trump [a]	0.02	0.00	…	0.10
has	0.03	0.10	…	0.02
…	…	…	…	…
adolescent [c]	0.05	0.02	…	0.03
boy [c]	0.07	0.03	…	0.04
…	…	…	…	…
intelligent [c]	0.09	0.07	…	0.05
…	…	…	…	…

Note.

a. Every word in the data will be represented as word embeddings.
b. It is difficult to interpret the meanings of the specific dimensions, as the word embedding model is still a black box, but the 300 dimensions as a whole may capture the nuanced meanings of words. The focus of the current study is the associations between different word embeddings but not the dimensions.
c. The word "adolescent" is a term of adolescence, "boy" is an indicator of adolescent subgroups, "intelligent" is a descriptor.

Figure 2

Conceptual Illustration of Identifying Themes of Perceptions Using Word Embeddings

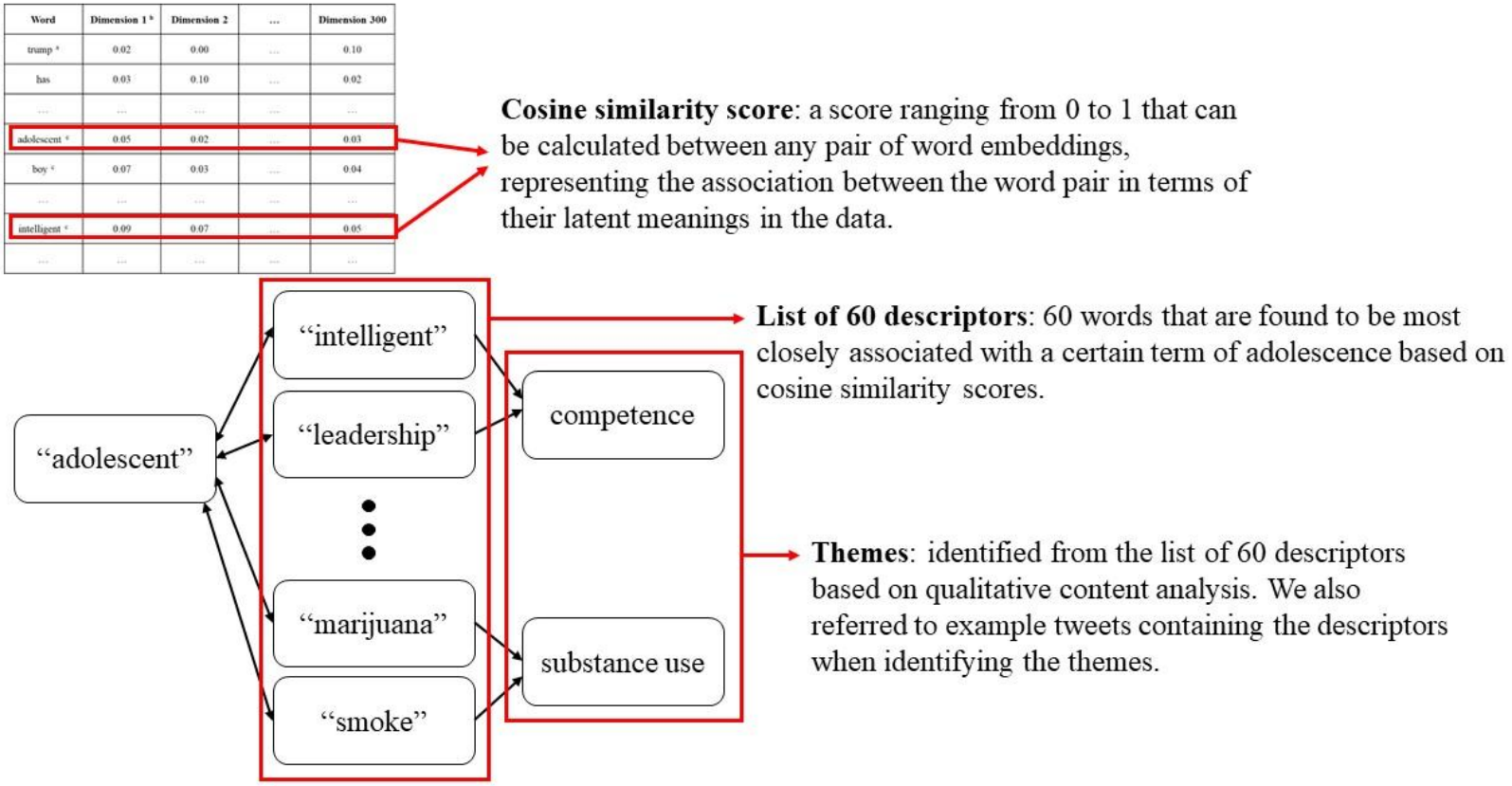
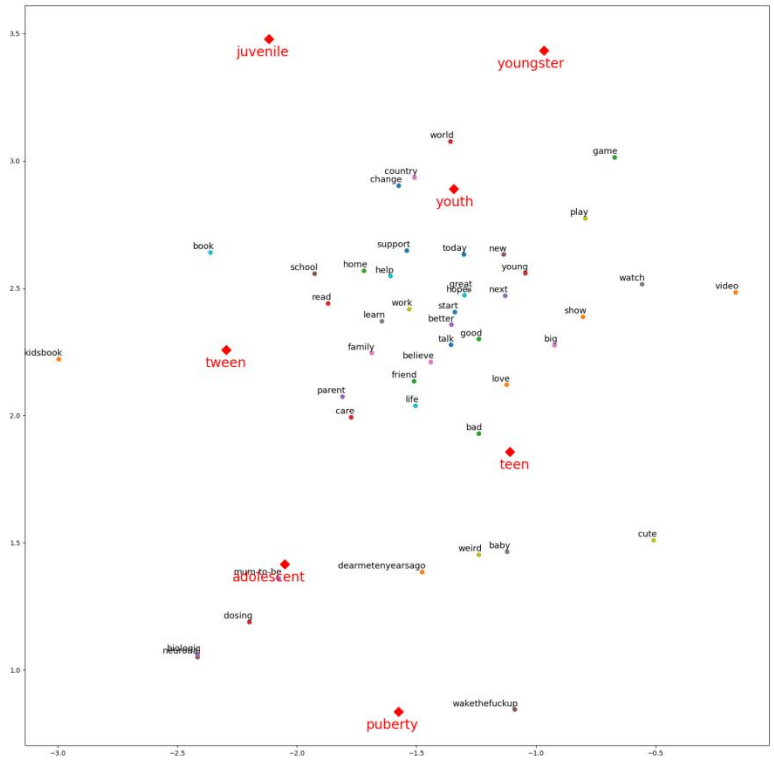


Figure 3

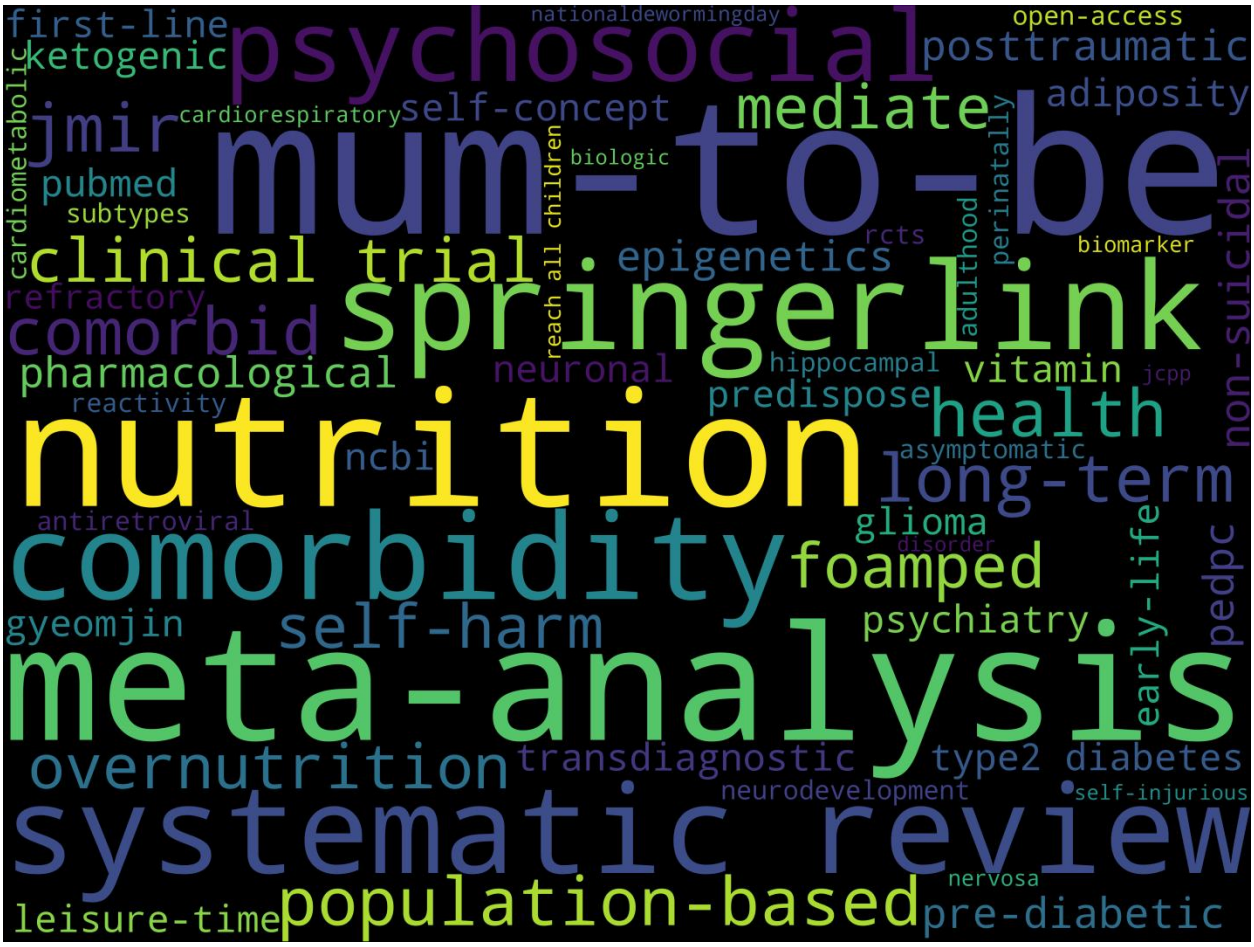
Relative Location of Different Terms of Adolescence in the Word Embedding Model



Note. The word embedding model represent different terms with 300 dimensions, which cannot be directly visualized. I used t-distributed Stochastic Neighbor Embedding to reduce the dimensions to two, therefore plotting the relative location of the terms of adolescence in a two-dimensional space with some other words that were closely associated with them.

Figure 4

Word Cloud Figure of the Top 60 Descriptors Associated with the Word Embedding of "Adolescent"



Note. Larger font sizes indicate higher levels of closeness between the descriptor and the word embedding of "adolescent".

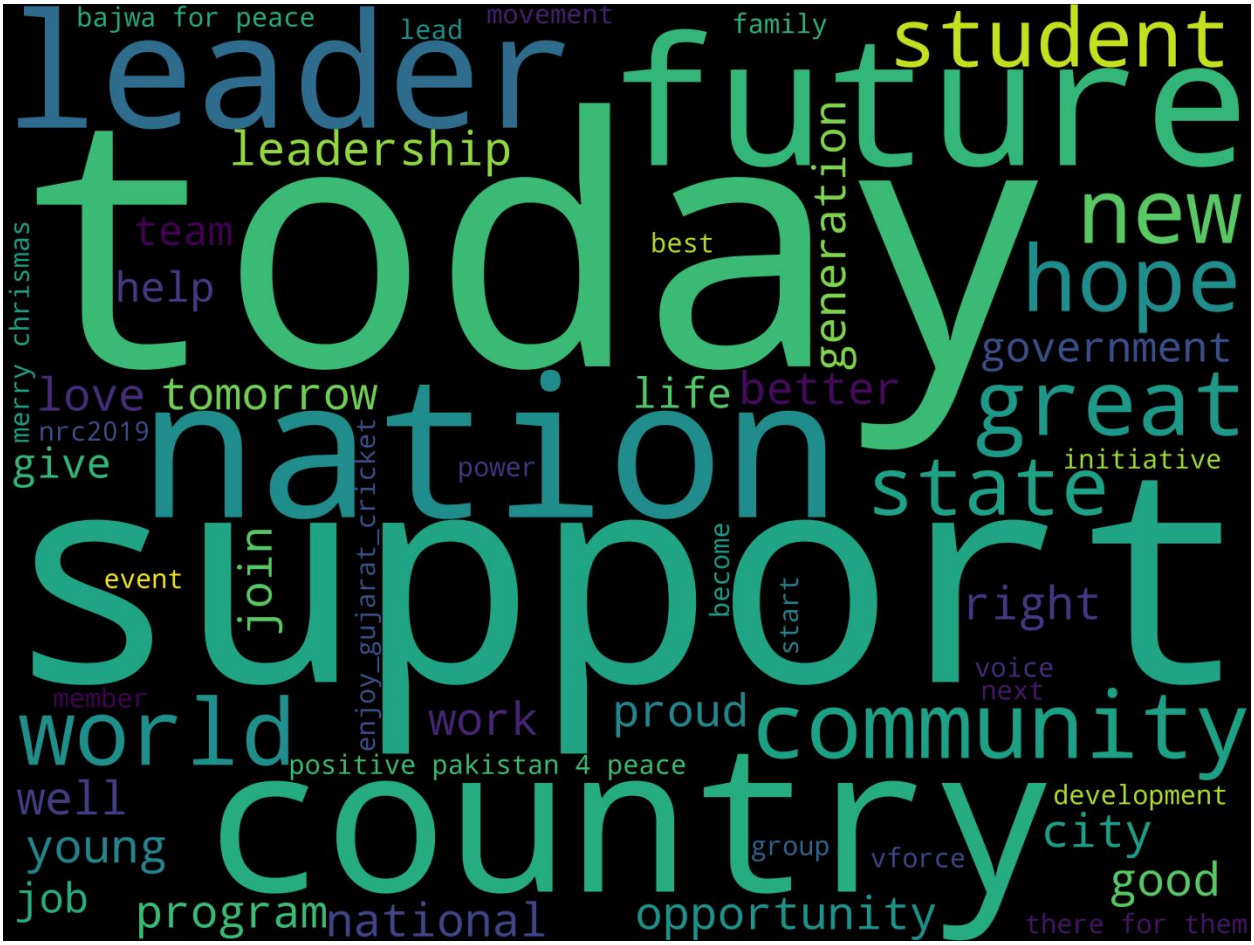
Figure 5

Word Cloud Figure of the Top 60 Descriptors Associated with the Word Embedding of "Teen"

Note. Larger font sizes indicate higher levels of closeness between the descriptor and the word embedding of "teen". I identified descriptors that indicated online sexual abuse of adolescents. These descriptors were removed and not coded for public perceptions of adolescence. The removed descriptors are available upon request from the author.

Figure 6

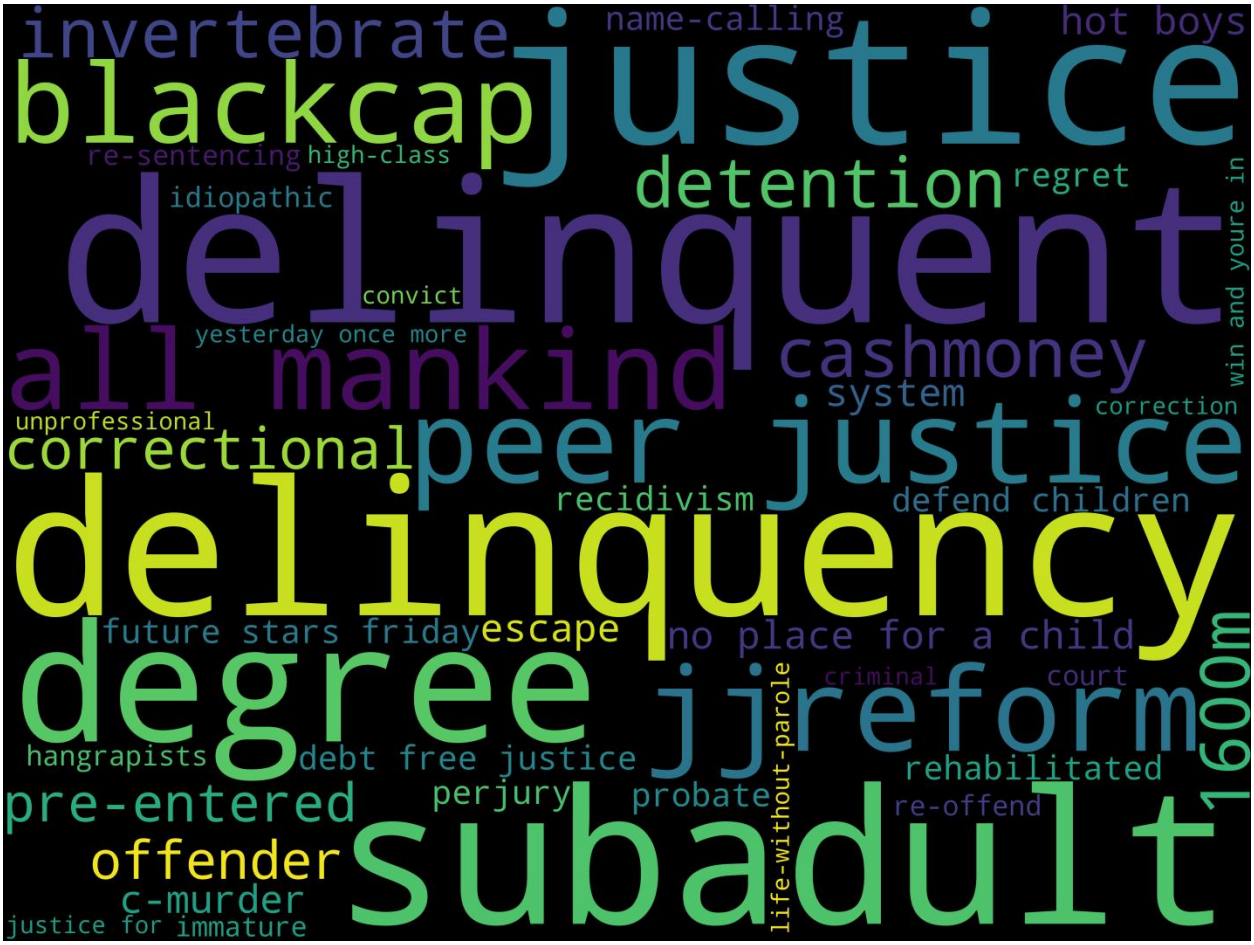
Word Cloud Figure of the Top 60 Descriptors Associated with the Word Embedding of "Youth"



Note. Larger font sizes indicate higher levels of closeness between the descriptor and the word embedding of "youth".

Figure 7

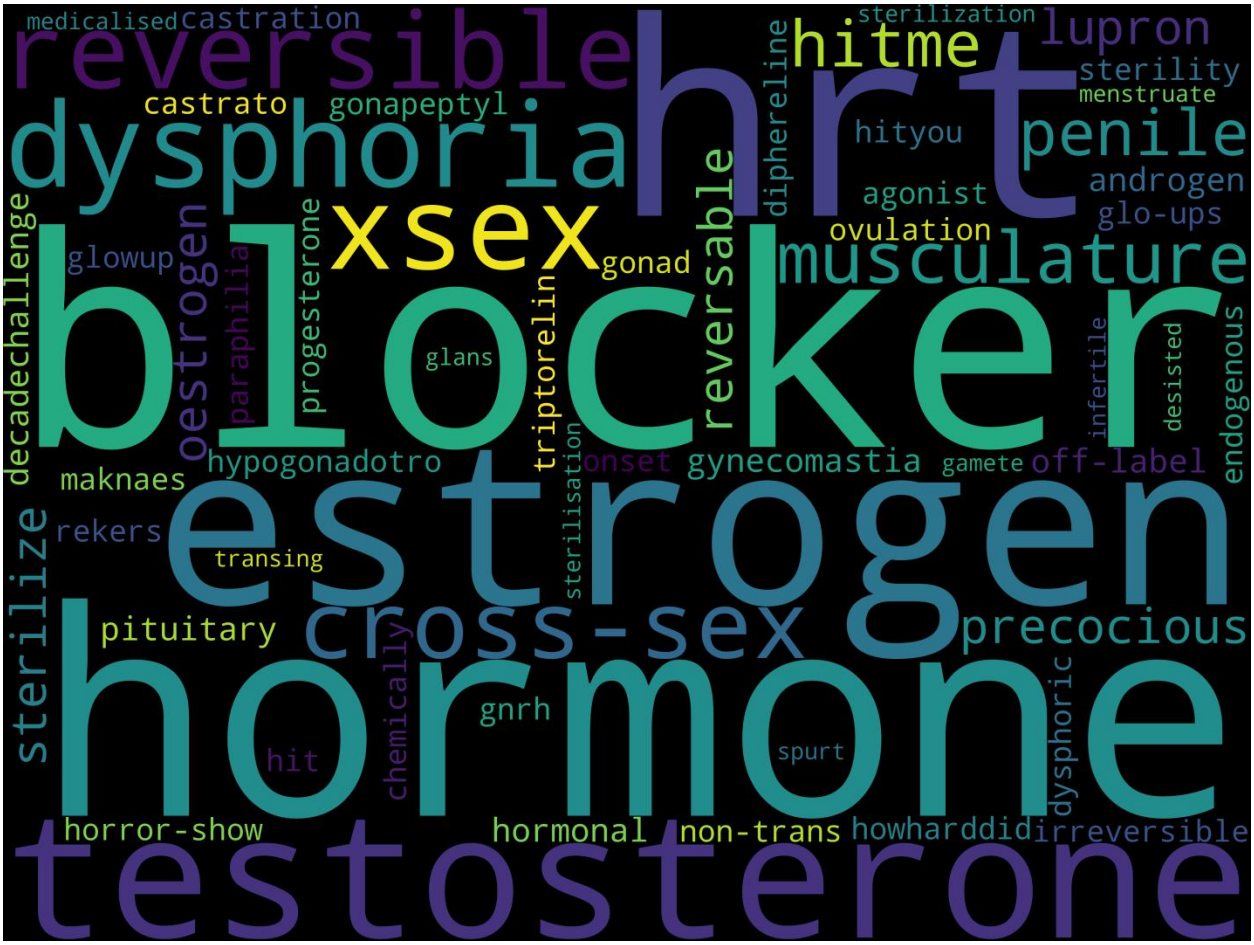
Word Cloud Figure of the Top 60 Descriptors Associated with the Word Embedding of "Juvenile"



Note. Larger font sizes indicate higher levels of closeness between the descriptor and the word embedding of "juvenile".

Figure 8

Word Cloud Figure of the Top 60 Descriptors Associated with the Word Embedding of "Puberty"



Note. Larger font sizes indicate higher levels of closeness between the descriptor and the word embedding of "puberty".

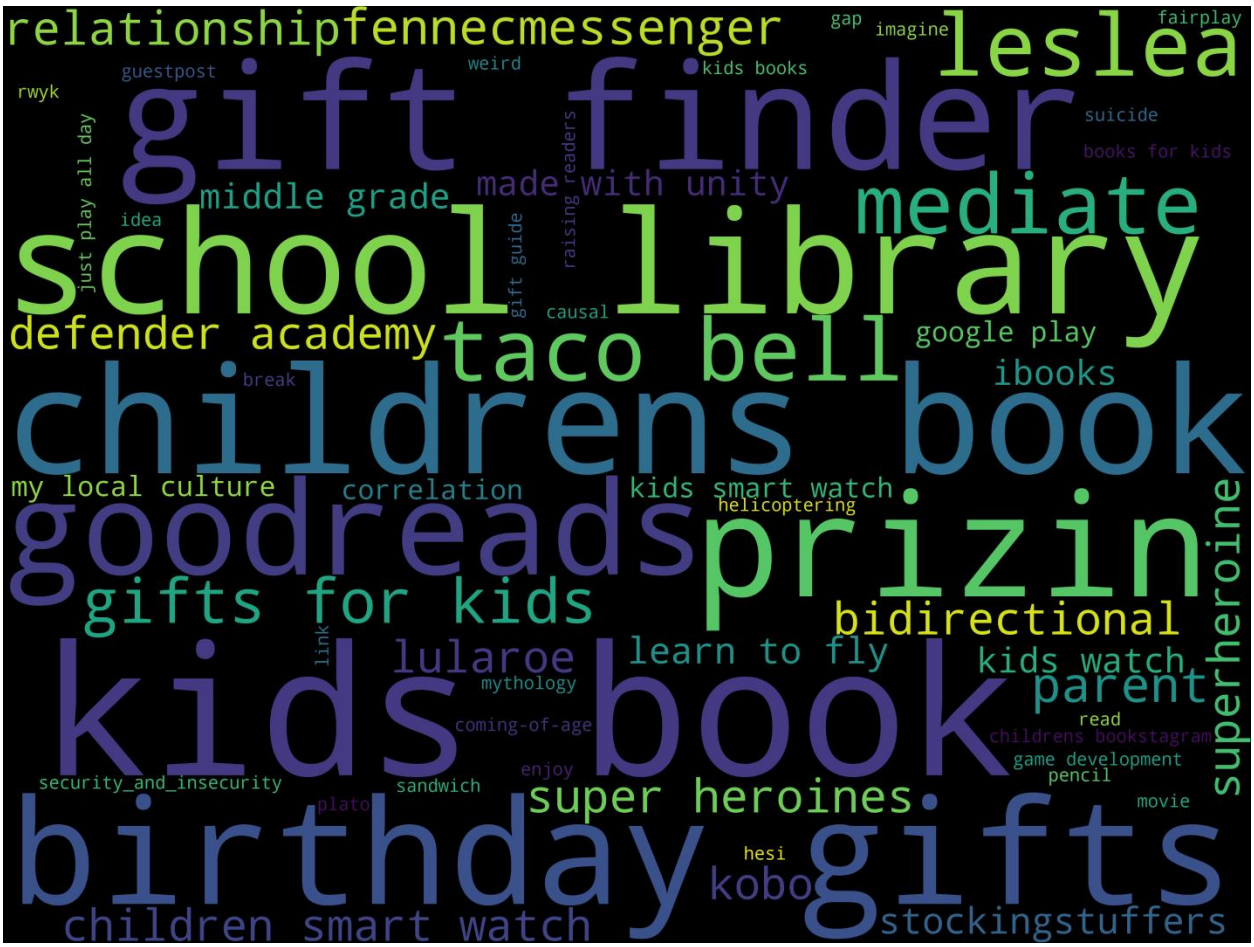
Figure 9

Word Cloud Figure of the Top 60 Descriptors Associated with the Word Embedding of "Youngster"

Note. Larger font sizes indicate higher levels of closeness between the descriptor and the word embedding of "youngster".

Figure 10

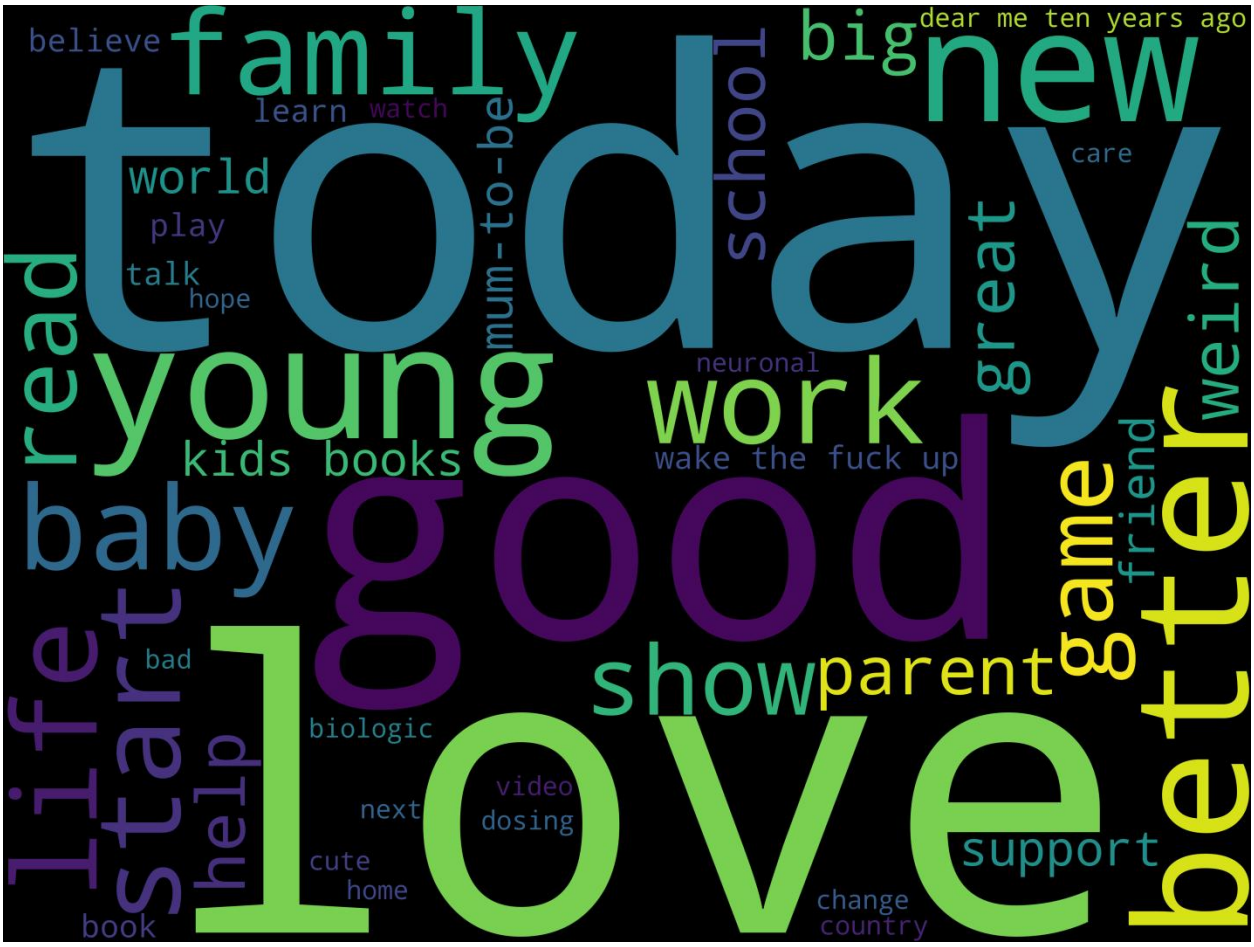
Word Cloud Figure of the Top 60 Descriptors Associated with the Word Embedding of "Tween"



Note. Larger font sizes indicate higher levels of closeness between the descriptor and the word embedding of "tween".

Figure 11

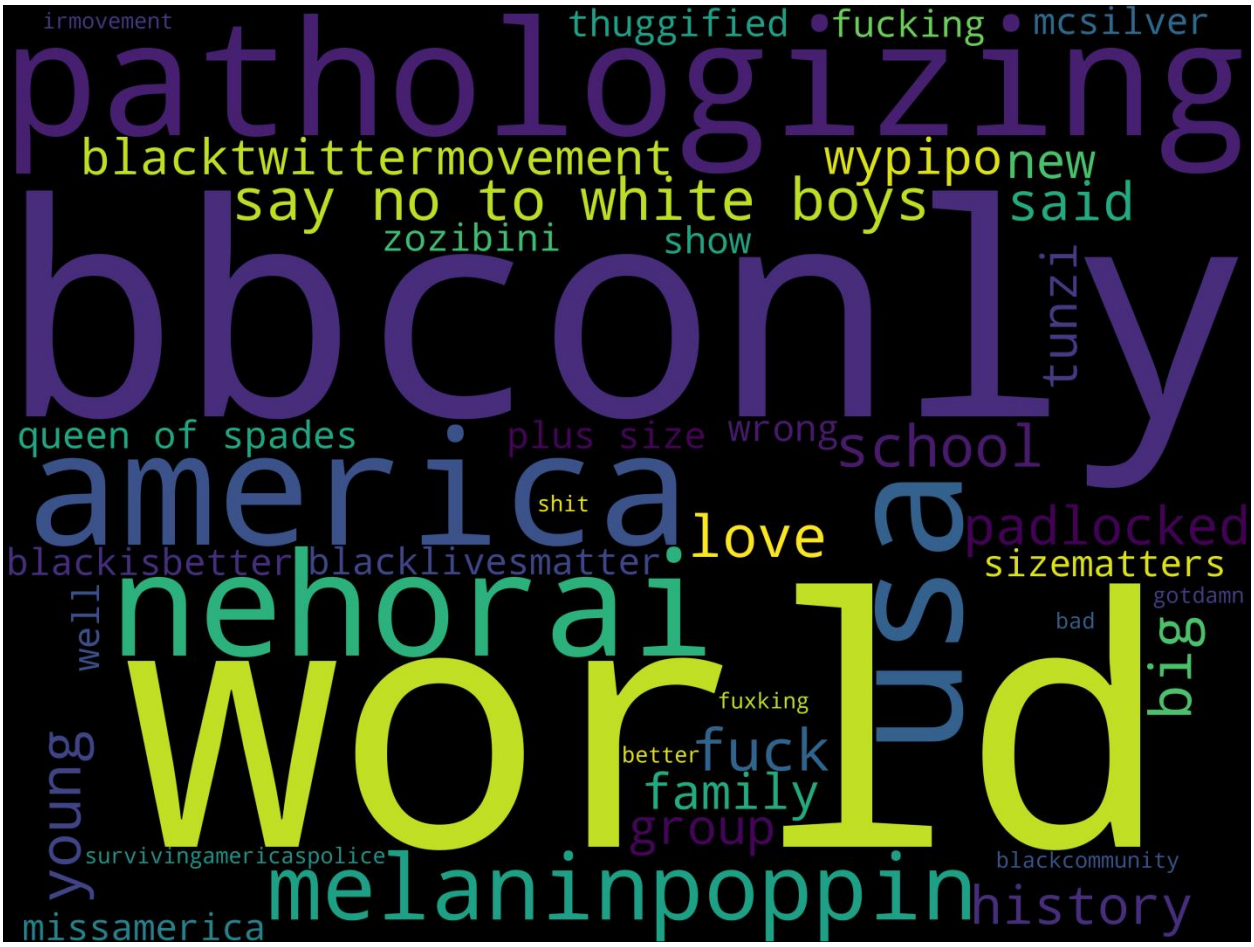
Word Cloud Figure of the Top 60 Descriptors Associated with the Composite Measure of Adolescent



Note. Larger font sizes indicate higher levels of closeness between the descriptor and the composite measure of adolescent. The composite measure of adolescence was constructed as the centroid of the word embeddings of adolescent," "teen," "youth," "juvenile," "puberty," "youngster," and "tween". I identified descriptors that indicated online sexual abuse of adolescents. These descriptors were removed from the figure and not coded for public perceptions of adolescence. The removed descriptors are available upon request from the author.

Figure 12

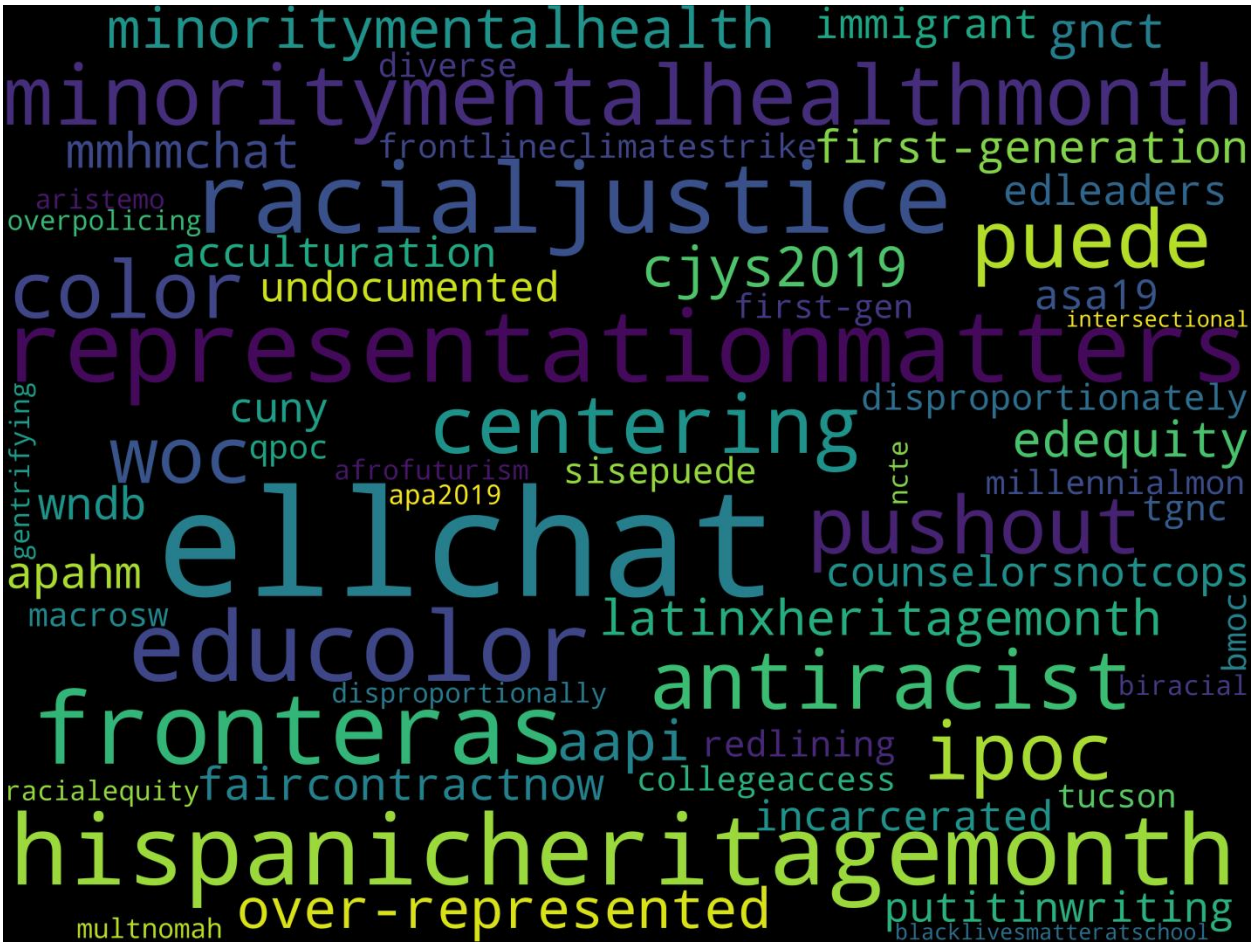
Word Cloud Figure of the Top 60 Descriptors Associated with the Word Embedding of Black Adolescents



Note. Larger font sizes indicate higher levels of closeness between the descriptor and the word embedding of Black adolescents. I identified descriptors that indicated online sexual abuse of adolescents. These descriptors were removed from the figure and not coded for public perceptions of adolescence. The removed descriptors are available upon request from the author.

Figure 13

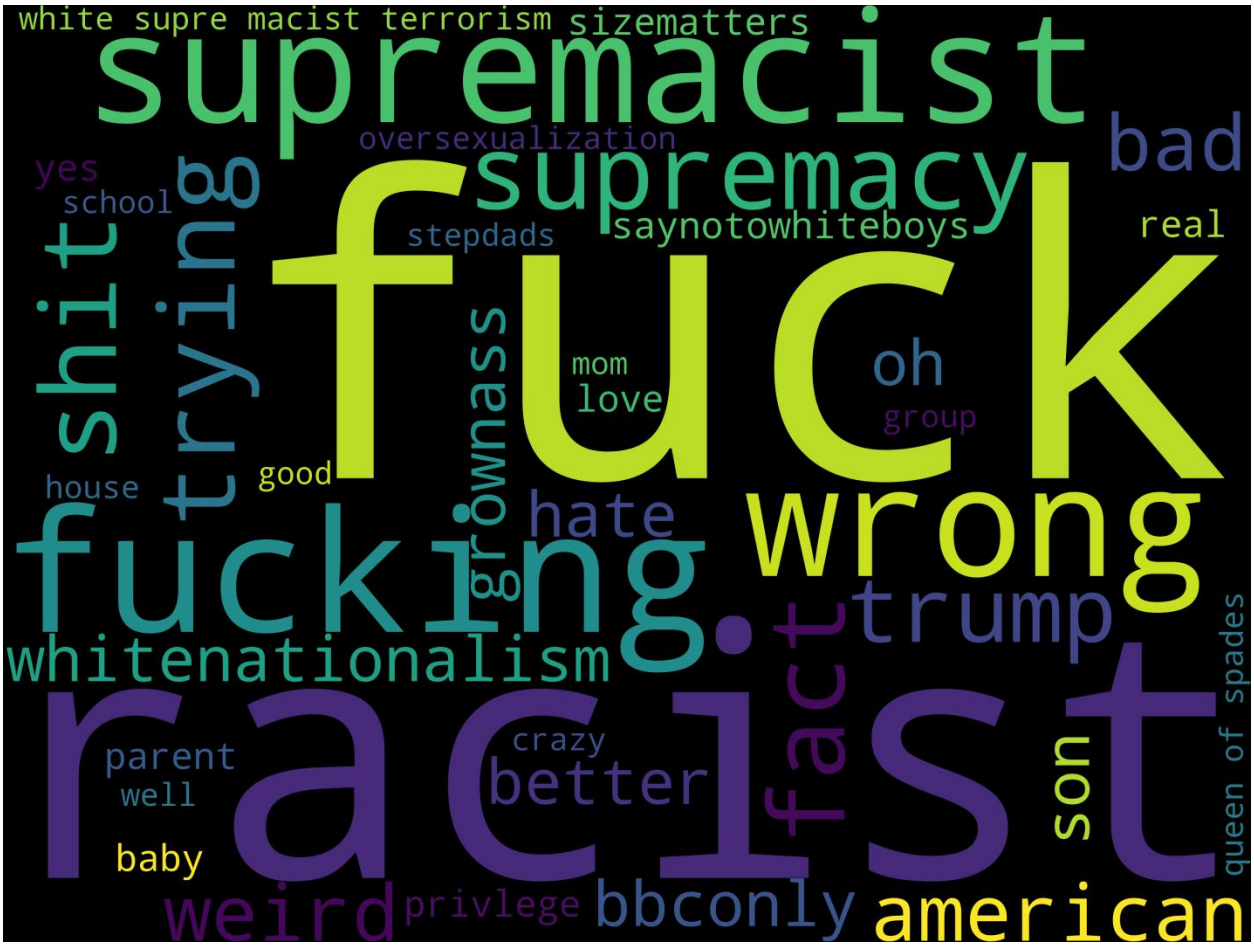
Word Cloud Figure of the Top 60 Descriptors Associated with the Word Embedding of Latinx Adolescents



Note. Larger font sizes indicate higher levels of closeness between the descriptor and the word embedding of Latinx adolescents.

Figure 14

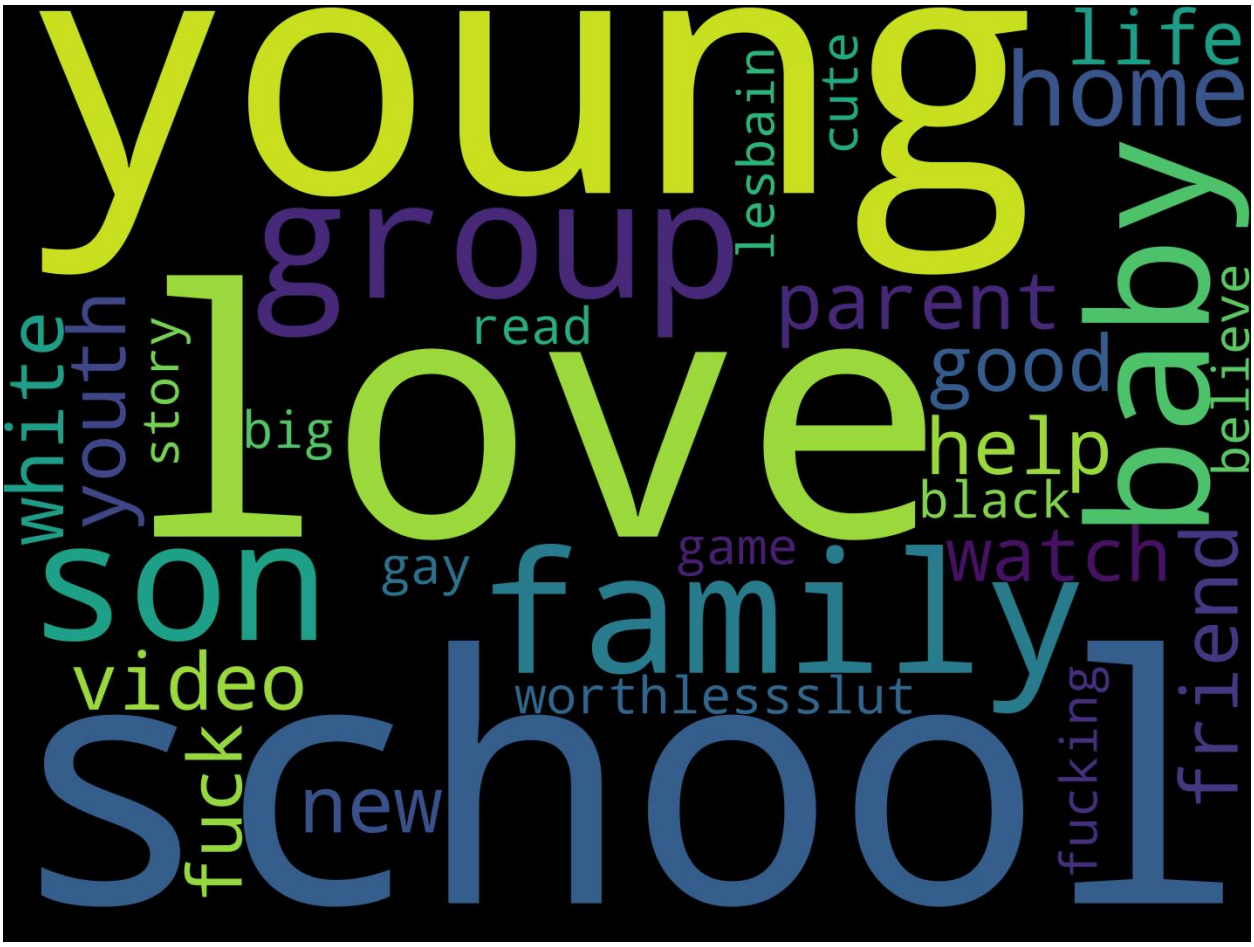
Word Cloud Figure of the Top 60 Descriptors Associated with the Word Embedding of White Adolescents



Note. Larger font sizes indicate higher levels of closeness between the descriptor and the word embedding of White adolescents. I identified descriptors that indicated online sexual abuse of adolescents. These descriptors were removed from the figure and not coded for public perceptions of adolescence. The removed descriptors are available upon request from the author.

Figure 15

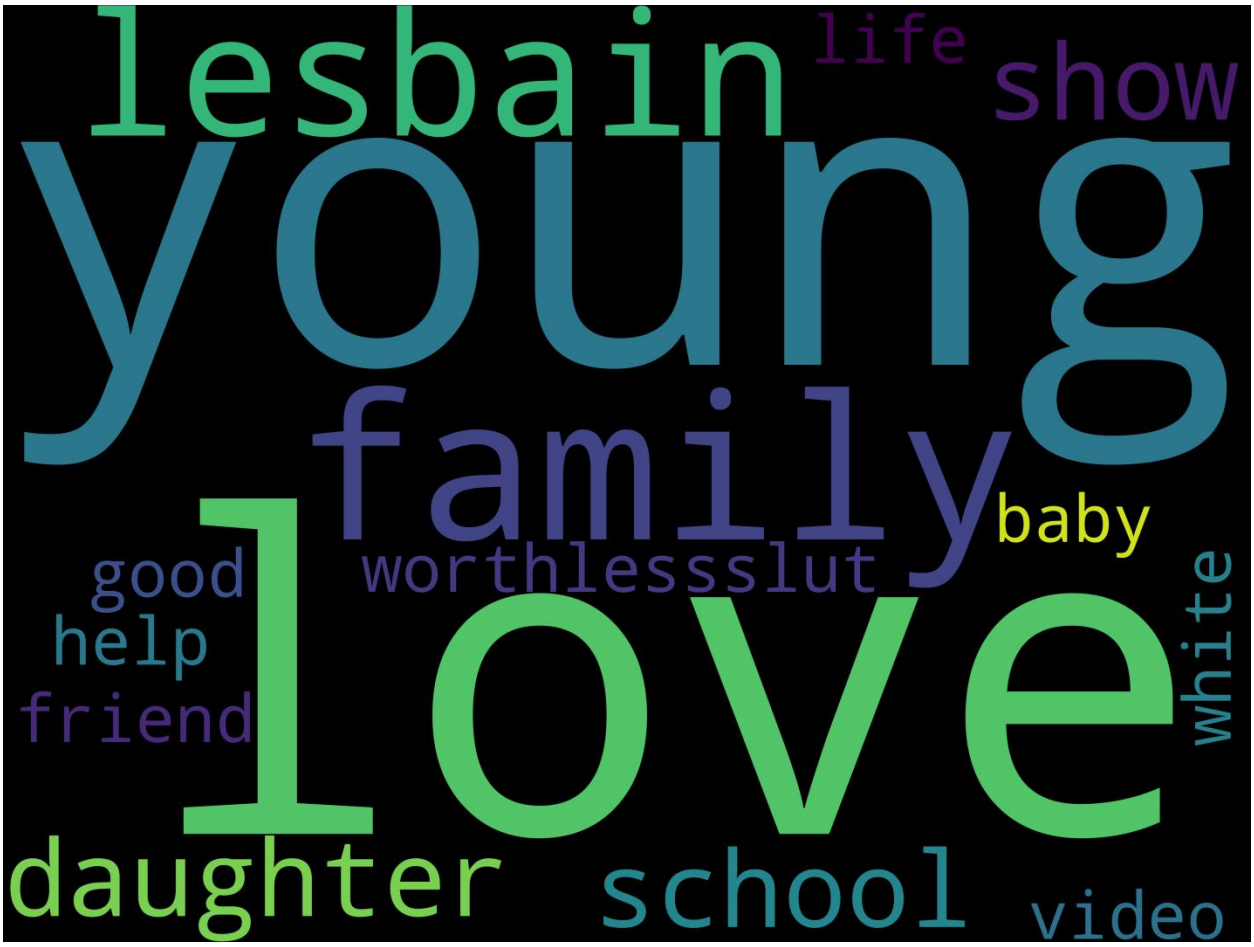
Word Cloud Figure of the Top 60 Descriptors Associated with the Word Embedding of Male Adolescents



Note. Larger font sizes indicate higher levels of closeness between the descriptor and the word embedding of male adolescents. I identified descriptors that indicated online sexual abuse of adolescents. These descriptors were removed from the figure and not coded for public perceptions of adolescence. The removed descriptors are available upon request from the author.

Figure 16

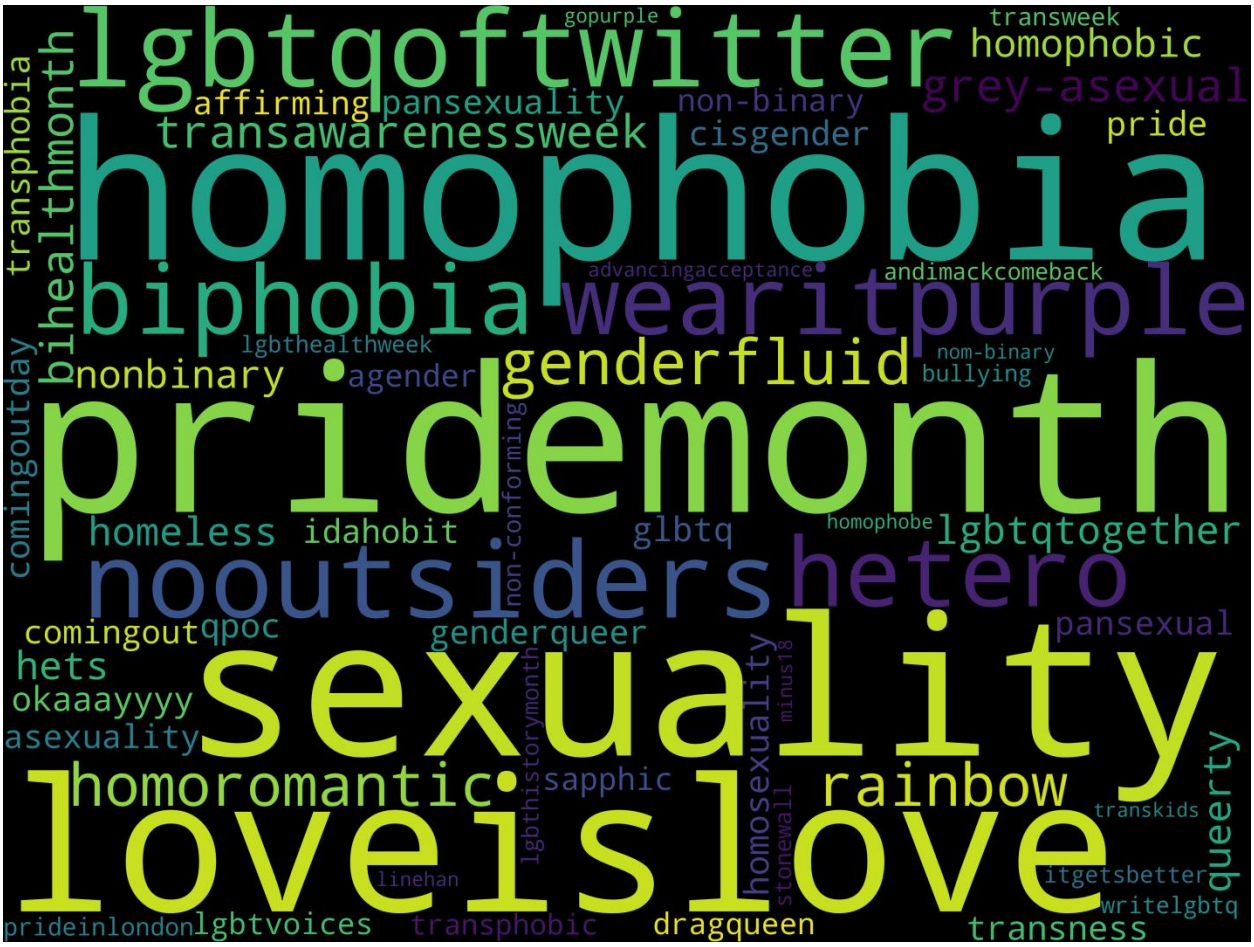
Word Cloud Figure of the Top 60 Descriptors Associated with the Word Embedding of Female Adolescents



Note. Larger font sizes indicate higher levels of closeness between the descriptor and the word embedding of female adolescents. I identified descriptors that indicated online sexual abuse of adolescents. These descriptors were removed from the figure and not coded for public perceptions of adolescence. The removed descriptors are available upon request from the author.

Figure 17

Word Cloud Figure of the Top 60 Descriptors Associated with the Word Embedding of LGBT Adolescents



Note. Larger font sizes indicate higher levels of closeness between the descriptor and the word embedding of LGBT adolescents