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Behavioral and Neural Correlates of Implicit Social Influence in Adolescence and Young Adulthood: Considering the Role of Peers and Mothers

By

JOSEPH S. VENTICINQUE

DISSERTATION

Submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Human Development

in the

OFFICE OF GRADUATE STUDIES

of the

UNIVERSITY OF CALIFORNIA

DAVIS

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2024

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ABSTRACT

Social influence is a normative phenomenon whereby individuals adjust their behaviors, thoughts, and/or feelings to meet the demands of their social context. Prior work has demonstrated that adolescents are particularly sensitive to explicit forms of social influence from their peers and parents, resulting in numerous effects on their neurobiology and behavior. Furthermore, work has found that implicit forms of social influence differentially modulate young adults' neural response patterns. Relatively little is known, however, about whether characteristics of adolescents, as well as aspects of their relationships with socially influential agents, relate to individual differences in behavioral and neural sensitivity to implicit social influence. This dissertation reports on two studies in adolescents and young adults that collectively examined the behavioral outputs and neural underpinnings of implicit forms of social influence from peers and mothers, and considered qualities of their relationships with these social partners, as well as age and gender effects. Study 1 investigated whether conflict and perceived relationship quality with one's mother across early to late adolescence was associated with neural responses to experimentally-manipulated, implicit peer influence later in young adulthood. Study 2 used a novel behavioral task paradigm to test whether implicit social influence of a mother's and a friend's preferences impacted adolescents' own preferences, and assessed if shifts in their preferences varied based on adolescents' sex and age, as well as quality of relationship with each social agent. Results from Study 1 indicated that higher levels of adolescent-maternal conflict experienced across multiple years of adolescence was associated with young adults' elevated neural response to implicit peer influence cues in brain regions involved in salience detection and reward processing. Conversely, having a higher quality adolescent-maternal relationship was associated with reduced neural responses to implicit peer

influence cues in the same brain regions. Results from Study 2 demonstrated that adolescent girls, compared to boys, were more likely to align their preferences with those of their friend than their mother. An age-related effect further demonstrated that older adolescents were more likely to show this pattern than were younger adolescents, however there was no significant interaction of age and gender. Quality of relationship with mother or friend did not have a significant effect on adolescents' preference shift. Taken together, these studies revealed that adolescents and young adults differentially process and respond to implicit social influence cues from close others, as manifest in their behavioral and brain responses. A comprehensive understanding of the types of social cues adolescents and young adults attend to, from whom, and when in development has the potential to inform intervention work designed to offset potentially negative social influences and promote youths' adaptive responses to the information conveyed from influential others in their social contexts.

CHAPTER ONE

GENERAL INTRODUCTION

Social influence is a phenomenon whereby others exert significant sway over an individual's thoughts, feelings, and behaviors (Cialdini & Goldstein, 2004; Turner, 1991). This phenomenon is particularly important to understand because of the well-documented heightened sensitivity to social influence from peers during adolescence relative to childhood and adulthood (Chein et al., 2011; Nelson et al., 2016; Steinberg & Monahan, 2007). Traditionally thought to peak in mid-adolescence, susceptibility to peer influence increases linearly across adolescence, and even extends into the second decade of life (Somerville, 2013; Steinberg & Monahan, 2007). Furthermore, a growing body of literature has examined individual differences in adolescents' and young adults' susceptibility to peer influence at multiple levels of analysis. Such variability in sensitivity to peers has been linked to both negative behaviors, such as risky driving (Mirman & Curry, 2016; Smorti et al, 2014), engaging in delinquency (Monahan et al., 2009), or substance use (Allen et al., 2012; Trucco et al., 2011), and positive behaviors, such as academic achievement (Wentzel & Muenks, 2016) and engaging in prosocial acts (Choukas-Bradley et al., 2015; van Hoorn et al., 2016). More work is needed, however, examining the range of factors that contribute to individual differences in sensitivity to social influence during adolescence and young adulthood in order to inform ways to promote a host of health-related outcomes.

Neural Responses to Social Influence

Research advancements involving neuroimaging techniques have helped to establish the role of the brain in indexing variability to peer influence with particular focus on aspects of the social context modulating individual susceptibility (Schriber & Guyer, 2016). For example, variability in the response of brain regions involved in salience detection and reward-processing

has been reported with some adolescents being particularly attuned to peers' opinions, for better or worse, with links to decision-making and resistance to peer influence (Jarcho et al. 2012; Pei et al., 2020; Venticinque et al., 2021). One explanation for heightened susceptibility to peer influence during adolescence is related to maturational changes in how the brain processes and integrates peer-related social information. In adolescence, the brain is thought to undergo a social reorientation toward being particularly sensitive to peer input (Nelson et al., 2016). Thus, the confluence of increased neural "tuning" toward peers and dynamic shifts in social environments may render adolescents particularly sensitive to the influence of others, which in turn directs their thoughts, feelings, and behaviors. Understanding how the adolescent brain and associated behaviors may be more or less susceptible to peer influence has the potential to identify youth who may be at risk for the deleterious effects of heightened peer sensitivity (e.g., increased risk-taking behaviors) or who may benefit from leveraging the influence of peers to promote positive behaviors (e.g., engaging in volunteerism).

The Role of Mothers in Adolescent Sensitivity to Social Influence

Although individuals tend to become increasingly peer oriented during adolescence, evidenced at both behavioral (Allen et al., 2012; Fuligini et al., 2001) and neural (Crone & Dahl, 2012; Nelson et al., 2016) levels of analysis, parents remain salient agents of socialization, providing feedback and support during adolescence. Evidence suggests that the subjective value adolescents ascribe to parental versus peer influence differs by context, such that parents tend to have more sway with their children on topics regarding major life decisions, such as academic or career planning, but that peers hold more weight in areas regarding identity and social status (Biddle, Bank, & Marlin, 1980; Sebald & White, 1980). A growing line of research has begun to examine whether specific aspects of the mother-adolescent relationship (e.g., reported conflict,

relationship quality) are associated with behavioral and health outcomes for adolescents (Hair et al., 2009; Moed et al., 2015; Weymouth et al., 2016); however, this remains untested as it applies to neural sensitivity to social influence. Prior work has reported individual differences in various aspects of the adolescent-maternal relationship, such as the ways in which mothers and children communicate (e.g., seeking advice, verbal disagreements; Laursen & Collins, 2003) and fluctuations in their ability to get along across the adolescent years (e.g., overall relationship quality; Gao & Cummings, 2019; Smetana & Rote, 2019). To date, however, it remains largely unknown whether individual differences in the degree to which adolescents and their mothers have conflicts and the overall quality of their relationship shape behavioral or neural sensitivity to social influence cues. Additionally, a gap in the field remains with regard to how adolescents are influenced by mothers and peers both simultaneously and relative to each other, and how this impacts their own thoughts and opinions. In real-world contexts, individuals often make decisions considering and weighing the opinions of multiple, sometimes competing, sources of influence. Better understanding how adolescents behaviorally and neurophysiologically respond to social information delivered from multiple salient sources, and in different modes (e.g., explicit vs. implicit deliveries), would advance the field by providing insight into the mechanisms underlying how adolescents process complex forms of social influence.

Developing More Ecologically Valid Task Paradigms

A growing body of research has demonstrated that the adolescent brain is particularly sensitive to peer-evaluated cues in their environments. Much of the current neuroimaging work examining peer influence has focused on explicit influences, such as the delivery of overt displays of valenced evaluations from peers. For example, one line of studies has used functional magnetic resonance imaging (fMRI) paradigms to simulate social media platforms in order to

deliver explicit displays of peer ratings of photographs (e.g., “50 likes”; Sherman et al., 2016). Similarly, other research teams have designed tasks that show the popularity of a set of stimuli (e.g., works of art) by providing informants’ ratings overtly on the screen (Welborn et al., 2016). However, research has shown that neural susceptibility to peer influence in young adults appears to extend to even subtle, incidental exposures to peer-evaluated information (Venticinque et al., 2021). Subtle exposures to social influence more closely reflect real-world contexts in which social information is embedded in everyday life ubiquitously. For example, logos of popular brands can be salient social status symbols that hold indirect value deemed by peers’ opinions. Indeed, neuroimaging research has begun to examine how the adolescent brain processes implicitly instantiated social cues provided by peers. Results from this work indicate that differences in the valence of implicit peer-evaluated cues (i.e., stimuli that were manipulated to be popular or unpopular among similarly-aged peers) can be detected at the level of the brain even when participants are not able to consciously recall the valenced differences in popularity ascribed to the stimuli (Venticinque et al., 2021). In line with these previous findings, a recent call has proposed expanding our understanding of peer influence cues to include more implicit forms of exposures (Do et al., 2020).

In addition to existing behavioral and neuroimaging research being limited by only focusing on explicit forms of social influence, many of the existing social influence task paradigms also include social influence that is provided only by hypothetical social partners (Irani et al., 2023; Venticinque et al., 2021; Welborn et al., 2016). In other words, participants may see ratings of stimuli that supposedly were rated by similarly-aged peers who had previously participated in the same study or ratings from another source such as from social media profiles (Irani et al., 2023; Venticinque et al., 2021; Welborn et al., 2016). Experimental

designs often include hypothetical peers due to the difficulty of recruiting participants' own real-life peers or the limited feasibility of obtaining ratings of stimuli from adolescents' close social partners. This leaves open questions about whether youth respond similarly to implicit forms of social influence that are delivered by familiar close others, such as friends, classmates, or parents. Additionally, little is known about how adolescents reconcile social influence from multiple sources of familiar others simultaneously, as is often how youth experience social influence in everyday social scenarios. To my knowledge, no study to date has examined how implicit social influence cues delivered by multiple familiar close others (e.g., different agents of social influence) affect adolescents' own behavior, such as shifting their preferences.

The Current Studies

Expanding upon the growing body of literature aimed at understanding social influence processes among youth, this dissertation broadly investigates how adolescents and young adults process and respond at behavioral and neural levels of analysis to social influence cues delivered implicitly. In both studies, consideration of adolescents' relationship factors with proximal agents of socialization (i.e., mothers and peers) are included to the extent that they relate to how adolescents respond to implicit social influence cues. Due to limited work assessing the role of fathers in social influence processes during adolescence, this dissertation focuses primarily on the adolescent-maternal relationship. Study 1 investigated how adolescent-maternal relationship factors (i.e., conflict and perceived relationship quality) measured across adolescence related to neural responses in brain regions in the salience detection (e.g., insula and anterior cingulate cortex) and reward processing (e.g., caudate nucleus) networks during young adulthood. Study 2 used a novel social influence task designed to deliver implicitly instantiated social influence cues from two real-life social agents (i.e., a friend and mother) to test shifts in adolescents'

preferences. In Study 2, the validity of the newly developed behavioral task (i.e., assessing the extent to which delivery of social influence was associated with changes in adolescents' preferences) was first assessed, including summarizing characteristics of adolescents' task performance. Study 2 then examined participant age-, participant gender-, and relationship-related effects (e.g., perceived relationship quality with each social partner) on adolescents' propensity to shift their own preferences toward the preferences of their real-life friend or their mother.

The two studies herein involved analyzing longitudinal (Study 1) and cross-sectional (Study 1 and Study 2) data, drawing upon existing data from a sample of Mexican-American youth and their families (Study 1) and a community sample of adolescents (aged 10-17 years) and their mothers collected for this dissertation (Study 2). The studies included in this dissertation address gaps in the existing behavioral and neuroimaging social influence literatures in several ways. By utilizing tasks that deliver social influence in a more subtle, implicit fashion, the current studies extend existing social influence studies that largely relied tasks that used explicit, overtly communicated stimuli, typically from only one social source. Additionally, Study 2 recruited a real-life friend and mother of each adolescent participant to address gaps in the literature pertaining to whether social influence processes extend beyond hypothetical peers (e.g., ratings from supposed similarly-aged peers either online or who have previously participated in the study). Furthermore, including multiple sources of influence within the same study, Study 2 enhanced the ecological generalizability of the existing literature by more fully capturing the types of social influence that adolescents encounter, and particularly by mimicking the fact that they often consider input from multiple, sometimes simultaneous sources of influence. Each study was developed based upon theoretical frameworks and previous research

findings to provide novel insights into how adolescents process and respond to social influence cues implicitly delivered from multiple familiar close others (i.e., their mother and real-life friend). Thus, this dissertation establishes a foundation for deepening our understanding of how family and peer relationships contribute to the behavioral and neurobiological correlates associated with implicit forms of social influence among adolescents and young adults.

CHAPTER TWO

STUDY 1: ASSOCIATIONS AMONG ADOLESCENT-MATERNAL RELATIONSHIP FACTORS AND SUBSEQUENT NEURAL RESPONSES TO PEER INFLUENCE IN YOUNG ADULTHOOD

Adolescence has been characterized as a period of social reorientation in which the brain becomes increasingly sensitive to peers (Blakemore, 2008; Nelson, Jarcho, & Guyer, 2016). A cascade of neurobiological, hormonal, and physiological changes renders adolescents uniquely sensitive to social information from their environment, particularly as they spend increased time with peers (Lam et al., 2014). Parents still remain a primary agent of socialization during adolescence however, which has been supported by evidence showing salient effects of the parent-child relationship on children's behavior and neurobiological development throughout the second decade of life (Smetana et al., 2019). In contrast to commonly held conceptions of adolescence, limited evidence suggests that parents also continue to have more sway during young adulthood than has been previously suggested (Butterfield et al., 2021; Brauer & De Coster, 2015). Thus, relationships with parents remain salient and influential agents of socialization during adolescence, potentially exerting lasting effects into young adulthood on how youth respond to peer influence.

Behavioral research has demonstrated that aspects of the adolescent-mother relationship (e.g., relationship quality, psychological control, conflict) are associated with adolescents' susceptibility to peer influence. In one study, maternal warmth was negatively associated with adolescent susceptibility to peer pressure and greater frequency of maternal-adolescent conflict was associated with higher rates of adolescent delinquent behaviors with friends (Chan & Chan, 2013). In another study, higher levels of emotional autonomy from parents was related to greater

resistance to peer influence on adolescents' engagement in negative behaviors (B'amaca & Umana-Taylor, 2006), suggesting that parents who meet adolescents' developmental need for independence buffers them from negative outcomes. Understanding the mechanisms by which family relationships can sensitize adolescents to positive and negative aspects of their peer relationships is important as it may inform intervention efforts aimed at mitigating negative aspects of peer susceptibility, such as delinquent behaviors which adolescents often engage in with friends high in similarity to themselves (Richmond et al., 2019). Bornstein and Putnick (2021) have argued that assessing family-level constructs longitudinally across adolescence has the potential to reveal more accurate "relative standings" of families than at a single time-point. For example, one study found that adolescent-perceived relationship quality with a mother predicted depressive symptoms only when averaging scores across four waves of analysis, but not at any single time point (Branje et al., 2010).

To begin to delineate sensitization mechanisms, a growing line of research has examined whether reported differences in peer susceptibility based on parental factors can be detected at the level of the brain (Do et al., 2020; van Hoorn, et al., 2018; Welborn et al., 2016). Using fMRI methods, researchers have been able to identify specific neural circuitry that is engaged in response to situations involving influence from parents or peers. Studies have shown that differences in family relationship quality during adolescence confer neurodevelopmental risk for maladaptive outcomes. For example, one longitudinal study found that higher levels of adolescent-mother conflict across adolescence undermined effective coupling of the neural signals within the anterior insula (a region involved in salience detection) and ventral striatum (a region involved in reward processing) when adolescents made decisions involving risk (Guassi Moreira & Telzer, 2018). Additionally, overall higher levels of conflict in the home have been

associated with higher reactivity of the ventral striatum and amygdala (regions involved in reward and fear processing, respectively) when adolescents anticipated social rewards (Turpyn et al., 2021). These patterns of family relationships have implications for peer relationships as adolescents who experience higher levels of home conflict might be particularly motivated to turn to peers. Thus, family conflict may be a factor that increases the salience of peers and their opinions, thereby heightening the degree to which peer relationships are rewarding. Furthermore, higher levels of adolescent-parent conflict early in adolescence are associated with longitudinal decreases in activation of the ventrolateral prefrontal cortex (vlPFC), indicative of less engagement in cognitive control when completing a task requiring the inhibition of a behavior (McCormick, Qu, & Telzer, 2016). Taken together, these findings suggest that negative family contexts, primarily studied with mothers, contribute to neural differences among adolescents, particularly in brain regions involved in social cognition and reward processing. It is also important to note that some degree of family dysfunction is normative (Barcai, 1981) and none of the reviewed studies reflect more extreme difficult parent-child relationships such as those involving child maltreatment.

Evidence from neuroimaging work has also suggested that maternal presence may buffer altered neural response in brain regions involved in social cognition (e.g., temporoparietal junction) when adolescents process socially aversive stimuli, such as peer rejection. For example, patterns of neural response differed based on mother-adolescent attachment, whereby insecurely attached compared to securely attached adolescents showed more robust neural activation in regions implicated in social cognition in response to peer rejection (Rogers et al., 2021). This finding underscores the role that earlier experiences with a mother can have on shaping how adolescents process social information, particularly in stressful contexts. Another

study found that positive mother-adolescent relationships buffer neural sensitivity, primarily in the ventral striatum, when adolescents engage in risky decision-making with peers (Qu et al., 2015). Notably, in this study, concurrent relationship status with a mother at the time of scanning was not associated with ventral striatum reactivity during risky decision-making with peers, but rather increases in adolescent-maternal relationship quality across a two-year period (ages 15-17) was associated with declines in ventral striatum activation. Collectively, the findings from these two studies suggest that aspects of the mother-adolescent relationship (e.g., perceived relationship quality, conflict) across the formative years of brain development and identity formation in adolescence have robust effects on adolescent social information processing, specifically when characterizing the relationship across multiple time points.

Based on the existing literature, evidence has been accumulating that demonstrates ways in which parents and peers contribute to or modulate adolescent social information processing and its associated neural correlates. Despite this, little attention has been paid to identifying whether adolescents' conflict and overall quality of their relationship with their mother influence adolescents' neural sensitivity to cues that convey peer influence, especially more subtle forms of influence similar to those embedded in everyday social environments. Much of the extant neuroimaging literature has primarily focused on the role that mothers (with little work examining fathers) play in contributing to adolescents' neural sensitivity to peers (e.g., Guassi Moreira, et al., 2018; Telzer et al., 2015; Conner et al., 2012). Neuroimaging studies examining these topics have primarily used task designs that deliver mother vs. peer ratings of stimuli (e.g., explicit presentations of mother or peer ratings of a work of art; Welborn et al., 2016) to assess the impact of these sources of influence on brain and behavior. Little is known, however, about whether adolescents' experiences of their relationship with their mother over time contributes to

their processing of more subtle, everyday exposures of peer influence as young adults. Findings from an initial study demonstrated that young adults show heightened brain responsivity to implicit forms of peer influence (Venticinque et al., 2021). Specifically, young adults displayed greater activity in salience detection brain regions (e.g., anterior cingulate cortex, insula) to information imbued with social value (i.e., socially tagged) versus information that lacked any social attributions of value, and greater activity in reward processing brain regions (e.g., ventral striatum) to information deemed popular versus unpopular by putative peers (Venticinque et al., 2021). In other words, the brain was engaged by social information instantiated implicitly and these neural responses differed in reward-processing brain regions based on the ascribed value of the cues. To extend these previous findings, the current study was designed to test whether aspects of the adolescent-mother relationship (i.e., perceived conflict and relationship quality) measured across multiple years of adolescence (ages 10-16 years) predict neural susceptibility to implicitly delivered cues imbued with peer influence in young adulthood (approximately age 19).

The current study sought to address whether conflict and perceived relationship quality with one's mother across adolescence relates to neural responses in brain regions involved in salience-detection and reward processing using more subtle forms of peer influence. Furthermore, the present study was designed to examine aspects of the maternal-adolescent relationship assessed longitudinally across early- and mid-adolescence given that the cumulation of relationship experiences is important for understanding the "relative standing" of families (Bornstein & Putnick, 2021), thereby extending past research that has examined maternal-adolescent relationships measured at only one point in time. Additionally, the current study sought to address calls to move the field beyond reliance on findings from WEIRD populations (Henrich et al., 2010; Legare & Harris, 2016), by drawing on a sample of Mexican-origin young

adults, from families of low to moderate income. Furthermore, this sample was also selected because of its relevance to the study of family relationships, given Mexican cultural emphases on valuing one's family (e.g., familism; Taylor et al., 2012) while also potentially experiencing economic stressors that could heighten conflict in the parent-child relationship (Conger & Conger, 2002). As such, the current study tested the following hypotheses:

(H1) More frequent self-reported conflict with their mother measured across adolescence will be associated with (a) greater activity in brain regions involved in salience detection (e.g., anterior cingulate cortex, insula) for socially tagged vs. novel symbols (i.e., information that contained peer-rated information vs. not) and (b) greater activity in brain regions involved in reward-processing (e.g. caudate nucleus) for popular vs. unpopular symbols ostensibly rated by peers.

(H2) Greater self-reported relationship quality with their mother across adolescence will be associated with (a) less activation in regions of the salience detection network when young adults view socially tagged vs. novel symbols and (b) less activation in the caudate nucleus when young adults view popular vs. unpopular symbols ostensibly rated by peers.

Additional analyses were conducted for each hypothesis to assess potential differences in results as a function of adolescent-maternal conflict and relationship quality at the age closest to the measurement of neural response, which was age 16. The focus on age 16 was driven by age 16 being the closest timepoint at which the adolescent-maternal relationship variables were collected in relation to the fMRI scan. Furthermore, age 16 may mark an age at which adolescent-parent relationship dynamics are particularly salient. For example, Mastrotheodoros and colleagues (2020) found that the highest frequency and intensity of adolescent-parent conflict was reported at age 16 in a sample of 13–18-year-old adolescents. Prior work has also

suggested that the desire for identity development and individuation away from parents is greater in middle adolescence (ages 14-17) relative to early adolescence (10-13) (McLean et al., 2010), possibly driving increased levels of adolescent-maternal conflict.

Method

Participants

Participants were 46 young adults from Mexican-origin families (24 males, M_{Age} = 19.2 years, *SD* = .54, range = 18.3–20.1 years) who participated in a neuroimaging sub-study of a multi-year, prospective, longitudinal study on risk and protective factors of substance use in Mexican-origin youth called the California Families Project (CFP). Participants in the parent CFP study included 674 Mexican-origin families who had a fifth-grade child (51.2% male, M_{Age} = 10.4 years, *SD* = .61) that was drawn randomly from school rosters in Sacramento and Woodland, California, during the 2006–2007 and 2007–2008 school years. For the neuroimaging sub-study, 90 participants from the parent study were recruited based on data from measures (Elliott et al., 1985; Gibbons et al., 2004; Shaffer et al., 2000) indicating either they had abstained from substance use and would continue to do so (N = 47), or had engaged in (N = 43) substance use as of the 9th grade (age 14–15). Three years later, a follow-up of the neuroimaging sub-study was conducted to recruit up to 50 (determined by follow-up study budget) of the original 90 participants equally across original recruitment status. Participants were contacted again and invited to participate, leading to 46 who enrolled (25 of whom had engaged in substance use as of the 9th grade) and completed a set of neuroimaging tasks and questionnaires at the average age of 19. Three participants were excluded from analyses due to excessive motion in the scanner, yielding a sample of 43 young adults for all analyses. Findings using these participants have been published in Venticinque et al., (2021), which established neural response

patterns to the neuroimaging task used in the present study and in relation to self-reported susceptibility to peer influence.

Procedures and Materials

Study procedures were approved by the university's institutional review board. At waves 1, 3, 5, and 7 (ages, 10, 12, 14, and 16; respectively), participants completed a battery of measures assessing a wide range of child, parent, and family characteristics. Procedures during these visits included completion of questionnaires used in the analyses of the current study. Between the ages of 18 and 20, the same participants visited a medical research facility to participate in the neuroimaging component of the study. Procedures during the neuroimaging scan visit included: obtaining participants' written informed consent, training on fMRI tasks using a mock scanner, completing questionnaires, and undergoing a structural MRI and three-task based fMRI scans (totaling about 1.5 hours), one of which was the social influence task used for the present analyses. All participants elected to complete all measures in English. Participants were monetarily compensated for study participation.

Measures

Maternal-Adolescent Conflict

The Parent-Adolescent Conflict Scale (PACS; Jensen-Campbell & Graziano, 1996) was obtained at waves 1, 3, 5, and 7 (corresponding to ages 10, 12, 14, and 16 years; respectively) of the CFP parent study. The PACS assesses the frequency of conflicts between adolescents and parents through two separate surveys on which adolescents report the conflict they experience with their mother and with their father separately. The current study only drew upon adolescents' perceived conflicts with their mother to aid in interpretation of findings within the existing literature for which studies involving father-adolescent conflict and adolescent neural sensitivity

to social influence is lacking. Across 10-items, the PACS includes general disagreements (minor and serious) and is intended to measure conflicts as a dyadic unit, rather than separate the behavior of either actor. Sample items for the scale include questions such as: "How often have you and your mother had a serious disagreement or argument?" and "Over the past 3 months, how often have you and your mom given each other the silent treatment?" Responses on this scale were on a 4-point Likert scale ranging from 1 (Almost never or never) to 4 (Almost always or always) and were averaged across the 10 items to create a total score of adolescent-reported frequency of conflict with their mother. Cronbach's alpha at each time point within the original, parent CFP sample were .81 (averaged across waves), suggesting good reliability. The PACS has demonstrated adequate construct validity in its association with other measures of conflict (Jensen-Campbell & Graziano, 1996).

Maternal-Adolescent Relationship Quality

Maternal-adolescent relationship quality was measured using the adolescent-reported Relationship Quality with Mother scale (RQM; Melby & Conger, 2001) at each of waves 1-7 (7 timepoints total) as part of the original CFP parent study (ages 10-16). Adolescents completed separate evaluations of their mothers and fathers individually, however only the perceived relationship quality with mothers was used for the present study to aid interpretation of the findings with the existing literature. The RQM is a 4-item questionnaire adapted from the Iowa Youth and Families Project (Conger & Elder, 1995) to serve as an overall evaluative judgment of the parent-adolescent relationship. Scores were obtained from adolescent-reported perceptions of their relationship with their mother. A sample item on this scale includes, "How satisfied with your relationship with your mother would you say you are?" Responses on this scale were on a 4-point Likert scale ranging from 1 (very dissatisfied) to 4 (very satisfied) and were averaged to

create a total score of adolescent-perceived relationship quality with their mother. In the CFP parent study sample, Cronbach's alpha at each time point were .78 (averaged across waves), suggesting good reliability. In a study from the Iowa Youth and Families project, this measure has shown adequate construct validity relative to other measures of relationship quality (Flynn et al., 2018).

Social Influence Task

The Social Influence Task (SIT) is an adaptation of a task used by Mason et al., (2009) as reported in Venticinque et al., (2021) (see Figure 1.1). The task included 30 abstract symbols unfamiliar to participants, thus lacking social meaning associated with the stimuli prior to participation in the study. Twenty of the 30 symbols were selected randomly to be used in the pre-scanning portion of the task: 10 to be implicitly tagged as "popular" and 10 implicitly tagged as "unpopular." The remaining 10 symbols were used as novel symbols shown only during the fMRI scan. Two hundred same-aged peer faces were included in the pre-scan "social instantiation" part of the SIT.

In the pre-scan portion of the task ("social instantiation"), participants were told hundreds of same-aged individuals were shown pairs of abstract symbols and that these ostensible peers indicated which symbols they preferred. Participants were also told they would see pictures of these peers, followed by a display of the two symbols the peer saw and which symbol the peer selected. Participants then had to press one of two designated buttons in accordance with the symbol the peer preferred. Participants were told to pay close attention to which symbols were selected but that they would not be tested on this information. Participants completed 200 trials (each 2500 ms in duration) in which a randomly selected picture of a new same-aged actor appeared in the center of the screen (lasting 750 ms). Next, two symbols appeared below the

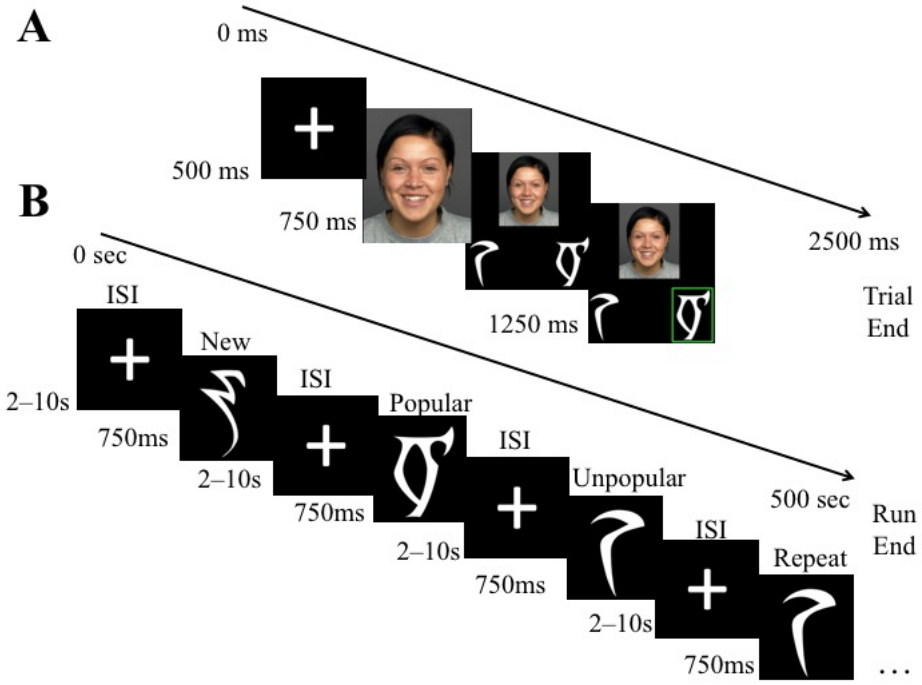


Figure 1.1 ***Design of Social Influence Task*****. (A)** Timeline depicting one trial during the pre-scanning social "instantiation" phase. In each of the 200 trials, participants were presented with the face of a same-aged actor in the center of the screen for 750 ms. Next, two symbols appeared below the face and a green box appeared around the target actor's preferred symbol, lasting 1250 ms. Each trial was separated by a 500 ms fixation cross. Participants were instructed to make a left or right button press to indicate on which side of the screen the preferred symbol appeared. **(B)** Timeline depicting a sample run of the fMRI phase of the task. Symbols (popular, unpopular, and novel) were randomly presented one by one in the center of the screen, separated by 0–12s jittered inter-stimuli intervals (ISI) depicting fixation crosses to tease apart the signal associated with each symbol type. Participants were asked to press a button every time a symbol was presented twice in a row (representing a "repeat" trial).

picture and a green box appeared around the symbol that was supposedly preferred by the peer (lasting 1250 ms). Trials were separated by a 500 ms fixation cross. Participants were instructed to make a left or right key press using arrow keys on the keyboard to indicate the side of the screen on which the chosen symbol was presented. For half of the trials, the chosen symbol was displayed on the left and for the other half, on the right, to promote participant engagement. Symbols were implicitly socially tagged as popular vs. unpopular through the proportion at which they were shown to be the preferred symbol; popular symbols were shown to be preferred in 90% of the trials in which they appeared as part of a symbol pairing, whereas unpopular symbols were preferred in only 10% of relevant trials. All symbols were shown the same number of times. The purpose of this pre-scan task was to incidentally expose participants to peers' preferences.

In the scanner, participants were instructed that they would view symbols again, some of which they saw before and some of which were new. Participants completed a 1-back memory task in which they were told to press a button each time they saw the same symbol presented twice in a row. The purpose was to ensure that participants paid attention to all symbols during the task. The task was presented in two runs of approximately 8 minutes each. Each run contained 90 trials of fixed duration (750 ms): 27 popular, 27 unpopular, and 36 novel symbols, with 6 trials from each category being a repeated-symbol trial. In the interval between stimuli, a fixation cross was shown for a variable duration of 2–10s (jittered period) to maximize general linear model contrast efficiency and reduce expectancy effects. Trial types were pseudo-randomized within each run and run order was counterbalanced across participants. Stimuli were presented using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) and back

projected onto a screen at the end of the bore of the magnet that participants viewed using a mirror mounted to the head coil.

SIT fMRI acquisition parameters

Scanning was conducted using a Siemens 3-Tesla TIM Trio MRI scanner with a 32-channel head coil (Siemens Medical Solutions, Erlangen, Germany). Scanning parameters for the T2-weighted echoplanar functional image acquisition were: voxel size = 3.5 × 3.5 × 3.5 mm, number of slices = 35, slice thickness = 3.5 mm, repetition time (TR) = 2000 ms, echo time (TE) = 27 ms, flip angle = 80º, interleaved slice geometry, and field of view (FOV) = 224 mm. The first four volumes were discarded to ensure magnet stabilization. A high-resolution structural scan was acquired per subject using a T1-weighted standardized magnetization-prepared, spoiled gradient recalled echo sequence (208 slices, 95 mm thick; TR = 2500 ms; TE = 4.33 ms; flip angle = 7º; FOV = 243 mm; inversion time: 800 ms; 256 × 256 matrix).

FMRI Data Processing and Statistical Analyses

Preprocessing and analysis of fMRI data were conducted using Analysis of Functional NeuroImages (AFNI: www.afni.nimh.nih.gov/afni, version AFNI_18.2.14; Cox, 1996). Preprocessing of functional neuroimaging data included slice timing correction, rigid body motion correction with 6 degrees of freedom, co-registration of functional data with brain-extracted structural images normalized to the Montreal Neurological Institute (MNI) stereotaxic atlas, and nuisance regression of the 6 rigid body motion parameters. Proper alignment was confirmed visually for each participant. Spatial smoothing with 4-mm Gaussian kernel, full-width at half maximum was conducted. Volumes with head motion > 1 mm from the previous volumes were censored during further processing. Three participants missing > 20% of total

volumes following motion censoring were excluded resulting in a total sample of 43 participants using in analyses.

For first level (at the individual level) processing, the SIT was modeled as an event related design with 6 trial types (popular, unpopular, novel, and repeat symbols, button presses, and fixation cross). Using AFNI's *3dDeconvolve* function, each trial type was modeled as a gamma variant function and blood-oxygen level dependent (BOLD) responses were obtained for each participant. Following the model used in Venticinque et al., (2021), the contrasts of interest were "socially tagged" (popular + unpopular) symbols > novel symbols and popular > unpopular symbols. The 6 motion parameters (x, y, z, roll, pitch, and yaw) were included in the model to account for individual variation due to head motion.

For group-level analyses, a region of interest (ROI) approach was used, guided by clusters of significant activation identified in our previous study using this task (Venticinque et al., 2021). Accordingly, analyses for this study were constrained to voxels within the (1) left insula, (2) right anterior cingulate cortex (ACC; areas involved in salience detection) and (3) bilateral caudate nucleus (left and right averaged together) involved in reward processing. Using AFNI's anatomical atlases, masks were created to define the voxels that fall within the three specified ROIs. Next, beta coefficients were extracted for both contrasts of interest (i.e., socially tagged > novel and popular > unpopular symbols) for each ROI across all participants. An ROI approach was preferable to a whole-brain analysis for the present study because limiting the number of statistical comparisons to within a few functionally-defined regions reduces the risk of Type I error and maximizes the signal-to-noise ratio (Poldrack, 2007).

Data Analyses

A series of linear regressions were conducted using IBM SPSS Statistics (Version 29) to test associations between scores on the PACS and the RQM (each averaged across the ages of 10-16) and neural responses (i.e., extracted beta coefficients of each contrast for each specified ROI) to the SIT at roughly age 19. Thus, three separate regression analyses were conducted to test: (1) adolescent-maternal conflict predicting salience-detection based neural activation to socially tagged vs. novel symbols, (2) adolescent-maternal conflict predicting reward-processing based neural activation to popular vs. unpopular symbols, (3) adolescent-maternal relationship quality predicting salience-detection based neural activation to socially tagged vs. novel symbols, and (4) adolescent-maternal relationship quality predicting reward-processing based neural activation to popular vs. unpopular symbols. For these analyses, scores on the PACS and the RQM were separately averaged across waves 1-7 of the CFP parent study. Due to the modest sample size, no other covariates of interest (e.g., gender) were included in the regression models. Post-hoc linear regression analyses were also conducted using mean scores of the PACS and RQM at wave 7 (age 16) as predictor variables and extracted beta coefficients from relevant ROIs for each contrast of interest as outcome variables.

Results

Descriptive statistics of maternal-adolescent relationship variables are presented in Table 1.2. Correlations among main study variables are shown in Table 1.2. Regression results of neural activity within the ROIs for each adolescent-maternal relationship variable are presented in Table 1.3 and Table 1.4.

Table 1.1 *Means and standard deviations (SDs) of maternal-adolescent conflict and the relationship quality scores at each wave (ages 10-16).*

Wave	PACS Mean	PACS *SD*	RQM Mean	RQM *SD*
1 (age 10)	1.61	.31	3.39	.51
3 (age 12)	1.58	.42	3.33	.53
5 (age 14)	1.61	.45	3.11	.58
7 (age 16)	3.27	.68	2.93	.90

Note: $N = 43$. PACS = Parent-Adolescent Conflict Scale, RQM = Relationship Quality with Mother Scale. Means and standard deviations of scores on the PACS and RQM are reported for each wave that they were collected in the parent CFP study (i.e., waves 1, 3, 5, 7). Scores on the PACS were on a 4-point Likert scale ranging from 1 (Almost never or never) to 4 (Almost always or always). Scores on the RQM were on a 4-point Likert scale ranging from 1 (Very dissatisfied) to 4 (Very satisfied).

Table 1.2 *Bivariate correlations among study variables.*

	1	2	3	4	5	6	7
1. Mean (10-16) PACS Scores	-	-	-	-	-	-	-
2. Mean Age 16 PACS Scores	.86**	-	-	-	-	-	-
3. Mean (10-16) RQM Scores	-.61**	-.66**	-	-	-	-	-
4. Mean Age 16 RQM Scores	-.43**	-.57**	.75**	-	-	-	-
5. Left Insula Activity	.26	.30*	-.18	-.32*	-	-	-
6. Right ACC Activity	.20	.30*	-.19	-.30*	.85**	-	-
7. Bilateral Caudate Activity	.07	-.03	.16	.18	.41**	.43**	-

Note: $N = 43$, PACS = Parent-Adolescent Conflict Scale; RQM = Relationship Quality with Mother Scale, *$p < .05$. **$p < .01$.

To test my *a priori* hypotheses, I conducted regression analyses using mean scores of the PACS and RQM averaged across waves 1-7 as predictor variables and beta coefficients for each ROI and its corresponding contrast as outcome variables. Results from these analyses showed no significant associations between adolescent-maternal conflict averaged across adolescence and neural activity when young adults viewed socially tagged versus novel symbols in salience-detecting brain regions: left insula (β = .26, p = .09) and right ACC (β = .20, p = .20), or viewed popular versus unpopular symbols in reward-processing brain regions: bilateral caudate nucleus (β = .002, p = .96). Similarly, there were no significant associations between adolescent-maternal relationship quality averaged across adolescence and neural activity when young adults viewed socially tagged versus novel symbols in salience-detecting brain regions: left insula (β = -.19, p = .21) and right ACC (β = -.19, p = .21), or viewed popular versus unpopular symbols in reward-processing brain regions: bilateral caudate nucleus (β = .16, p = .29). Thus, considering previous research findings (e.g., Mastrotheodoros et al., 2020) and relatively low and stable variance in adolescent-reported scores of conflict and relationship quality with mothers at waves 1, 3, and 5 as compared to wave 7 (see Table 1.2), results presented in the remainder of this study include post-hoc analyses of adolescent-maternal conflict and relationship quality only at wave 7 (age 16) as predictor variables. Results from the regression analyses are reported in Table 1.3.

Table 1.3 *Regression results with adolescent-maternal conflict and relationship quality averaged across waves (ages 10-16) as predictor variables and neural activity in three ROIs at age 19 as outcome variables.*

Outcome	Predictor	*b*	*beta*	sr^2	*p-value*	Fit
Activity in Left Insula	(Intercept)	-.13				
	PACS (all waves)	.96	.26	.06	.09	
	RQM (all waves)	-.06	-.19	.03	.23	
						R^2 = .066
Activity in Right ACC	(Intercept)	-.08				
	PACS (all waves)	.07	.20	.04	.20	
	RQM (all waves)	-.06	-.19	.04	.21	
						R^2 = .040
Activity in Bilateral Caudate	(Intercept)	-.03				
	PACS (all waves)	.00	.00	.00	.96	
	RQM (all waves)	.03	.16	.03	.29	
						R^2 = .000

Note: $N = 43$, ROI = regions of interest, ACC = anterior cingulate cortex, PACS = Parent-Adolescent Conflict Scale, RQM = Relationship Quality with Mother Scale, *b* = unstandardized regression weights, *beta* = standardized regression weights, sr^2 = semi-partial correlation squared, *p*-value = statistical significance at $p < .05$. Neural activity in the left insula and right ACC were from the contrast of socially tagged vs. novel symbols. Neural activity in the bilateral caudate (averaged across left and right) were from the contrast of popular vs. unpopular symbols.

Associations between Adolescent-Maternal Conflict and Neural Response to Peer Influence

Post-hoc analyses involving the latest occurring adolescent-maternal conflict measure available and brain assessments were used to address hypothesis 1. In line with my expectation for H1a, there was a significant association between adolescent-maternal conflict at age 16 and neural responses to implicit peer influence in brain regions in the salience-detection network at age 19. Greater frequency of adolescent-maternal conflict was associated with greater neural activation in both the left insula (β = .31, p = .040) and right ACC (β = .30, p = .031) when young adults viewed socially tagged versus novel symbols (see Figure 1.2, panel A and B, respectively). Contrary to my expectation for H1b, the association between adolescent-maternal conflict and neural activity in the bilateral caudate nucleus when young adults viewed popular versus unpopular symbols was not significant (β = .204, p = .194).

Associations between Adolescent-Maternal Relationship Quality and Neural Response to Peer Influence

Post-hoc analyses involving the latest occurring adolescent-maternal relationship quality measure available and brain assessments were used to address hypothesis 2. In line with my expectation for H2a, there were significant associations between adolescent-maternal relationship quality at age 16 and neural responses to peer influence at age 19 in brain regions within the salience-detection network. Greater satisfaction in adolescents' relationship with their mothers was negatively associated with neural activation both the left insula (β = -.33, p = .034) and right ACC (β = -.307, p = .045) when young adults viewed socially tagged versus novel symbols (see Figure 1.3, panel A and B, respectively). Contrary to my expectation for H2b, the association between adolescent-maternal relationship quality and neural activity in the bilateral

caudate nucleus, involved in reward-processing, when young adults viewed popular versus unpopular symbols was not significant (β = .182, p = .243).

Table 1.4 *Regression results with adolescent-maternal conflict and relationship quality at age 16 as predictor variables and neural activity in three ROIs at age 19 as outcome variables.*

Outcome	Predictor	*b*	*beta*	sr^2	*p-value*	Fit
Activity in Left Insula	(Intercept)	.11				
	PACS (at age 16)	.08	.31	.09	.04*	
	RQM (at age 16)	-.06	-.33	.10	.03*	
						R^2 = .100
Activity in Right ACC	(Intercept)	-.10				
	PACS (at age 16)	.08	.30	.09	.03*	
	RQM (at age 16)	-.05	-.30	-.08	.04*	
						R^2 = .091
Activity in Bilateral Caudate	(Intercept)	-.01				
	PACS (at age 16)	-.00	.20	.00	.19	
	RQM (at age 16)	.02	.18	.03	.24	
						R^2 = .001

Note: N = 43, ROI = regions of interst, ACC = anterior cingulate cortex, PACS = Parent-Adolescent Conflict Scale, RQM = Relationship Quality with Mother Scale, * = $p < .05$, b = unstandardized regression weights, *beta* = standardized regression weights, sr^2 = semi-partial correlation squared, p-value = statistical significance at $p < .05$. Neural activity in the left insula and right ACC were from the contrast of socially tagged vs. novel symbols. Neural activity in the bilateral caudate (averaged across left and right) were from the contrast of popular vs. unpopular symbols.

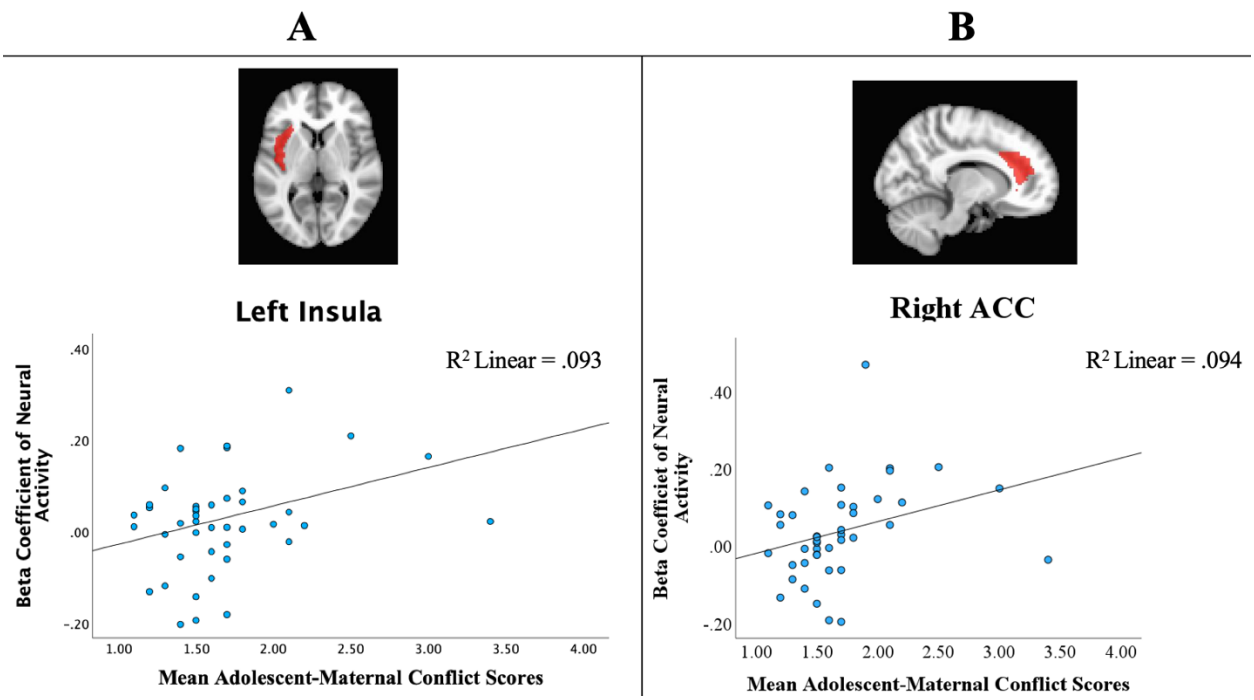


Figure 1.2.

Associations between Adolescent-Maternal Conflict and Neural Activity to Socially Tagged vs. Novel Symbols. Scatter plots depicting the association between mean adolescent-maternal conflict scores at wave 7 (age 16) and the beta coefficients extracted from both the: left insula (A) and right ACC (B) (masks of voxels within those regions presented above the graphs) when participants viewed socially tagged versus novel symbols (age 19). Regression lines and equations are fit over the data in the scatter plots. N = 43.

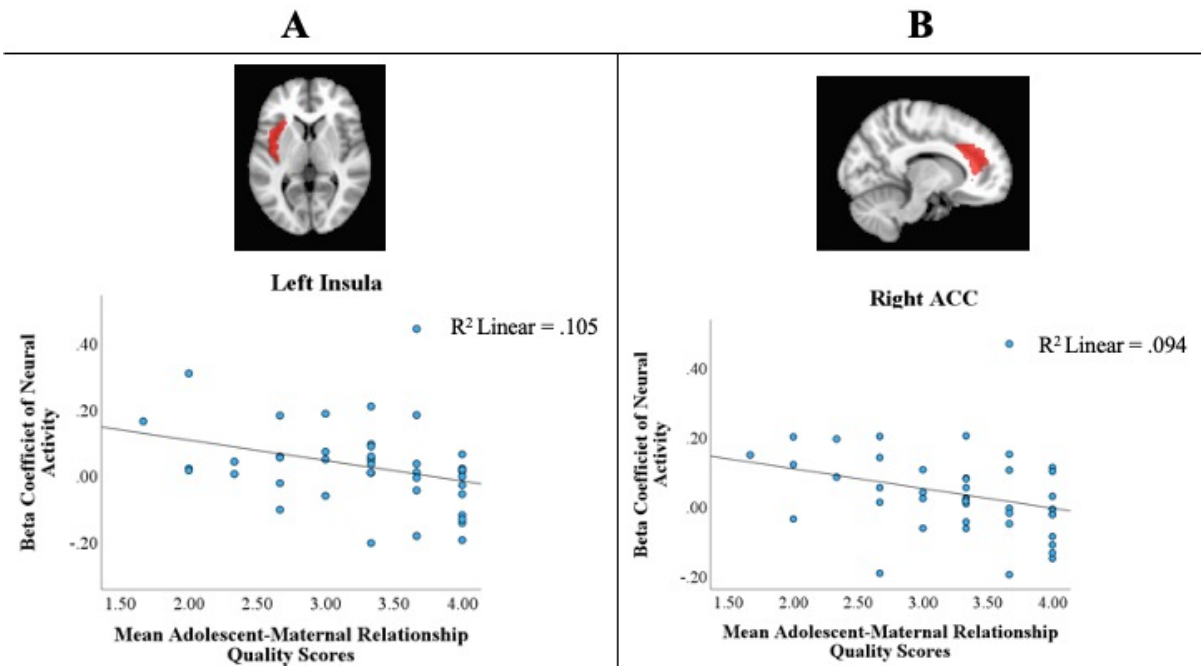


Figure 1.3

Associations between Adolescent-Maternal Relationship Quality and Neural Activity to Socially Tagged vs. Novel Symbols. Scatter plots depicting the association between mean adolescent-maternal relationship quality scores at wave 7 (age 16) and the beta coefficients extracted from both the left insula (A) and right ACC (B) (masks of voxels within those regions presented above the graphs) when participants viewed socially tagged versus novel symbols (age 19). Regression lines and equations are fit over the data in the scatter plots. N = 43.

Discussion

The aim of the present study was to examine associations between adolescent-maternal relationship factors (i.e., reported conflict and relationship quality) measured in adolescence and neural responses to peer influence in a sample of Mexican-origin young adults. First, I found that a higher reported frequency of adolescent-maternal conflict at age 16 was positively associated with neural activity in the right ACC and left insula (brain regions involved in salience detection) when viewing socially-instantiated peer cues versus novel non-tagged cues. This finding is consistent with previous work that has shown the ACC is preferentially engaged following the experience of negative aversive events, such as social conflict (Braem et al., 2017). Thus, one explanation for this finding may be that conflict with mothers during adolescence (a proxy for negative relationship dynamics; Hofer et al., 2013) may result in the hyperactivation of the ACC. In turn, ACC activity has been shown to be elevated when viewing emotionally salient (e.g., a face depicting an emotional expression) relative to neutral (e.g., a table) stimuli, regardless of the valence of the emotional cues (i.e., positive or negative emotions) (Duggirala et al., 2022). The ACC has also been demonstrated to be engaged when adolescents view socially-relevant stimuli such as receiving acceptance or rejection feedback from fictitious peers (Gunther Moor et al., 2010; Guyer et al., 2012). Another node of the salience detection network, the insular cortex, has been shown to be involved in switching between and maintaining attention to emotionally salient stimuli (Menon & Uddin, 2010). In addition to responding to emotional stimuli, the left insula has been demonstrated to be engaged when participants viewed social stimuli (e.g., viewing a social interaction of similarly-aged actors; Cacioppo et al. 2009). Taken together, increased conflict with mothers during adolescence may sensitize brain regions (e.g., the insula and ACC) involved in processing emotional and socially salient input from the

environment. Subsequently, this neural sensitivity may be reflected in young adults displaying a heightened awareness to peer influence, which has been shown to be highly salient and valued during adolescence and young adulthood (Giletta et al., 2021) via neural activity to socially-tagged cues. The current study is among the first to show that this phenomenon extends to subtle, implicitly-delivered forms of peer influence in young adulthood.

Conversely, I found that adolescents who reported greater satisfaction with the relationship they had with their mother at age 16 had reduced neural activity in the left insula and right ACC (brain regions involved in salience detection) when viewing socially-instantiated peer cues versus novel cues. The current study is the first to suggest that a more satisfying relationship with mothers during adolescence may buffer young adults from processing implicit instantiations of peer influence as highly salient cues via diminished activation in the ACC and insula. Indeed, the present finding is consistent with behavioral work showing that a more positive adolescent-parent relationship quality is associated with diminished depressive symptoms in response to peer-related stressors (Hazel et al., 2014). This association has also been shown to extend into young adulthood, such that positive parental relationship quality is associated with diminished rumination and depressive symptoms among first-year college students (Guassi Moreira et al., 2016). Thus, counter to our interpretation with respect to adolescent-maternal conflict, the present findings suggest that a more satisfying relationship quality with mothers at age 16 may buffer adolescents from being drawn to peer influence cues via attenuated neural responses in the ACC and insula. This implies that adolescents who have a stronger relationship with mothers, at an age when conflict has been reported to be the most intense (Mastrotheodoros et al., 2020), may attend less to peer opinions relative to adolescents who have a less satisfying relationship with their mother.

Unexpectedly, there was no association between either adolescent-maternal conflict or relationship quality in adolescence and reward-based neural activity in the caudate nucleus when viewing peer-endorsed cues that differed in valence (i.e., popular or unpopular symbols). These findings are in contrast to previous findings showing, using a whole-brain approach, that viewing popular versus unpopular stimuli elicited activity in the caudate (Venticinque et al., 2021). Although I take caution in interpreting null results, one potential reason the current study may not have detected significant differences in caudate activation is that by using a more stringent ROI approach, our analyses were constrained to voxels anatomically defined to be within the caudate (contrary to our previous whole-brain approach; Venticinque et al., 2021). The caudate nucleus is a substantially smaller brain region, by volume, than the insula or ACC (Cirak et al., 2020), possibly limiting our ability to detect an effect within this region.

Cultural values that are strongly emphasized among Hispanic-American or Latinx families may also have contributed to the reported findings. For example, research has shown that familism (i.e., having an increased familial orientation) was a protective factor for Mexican-origin adolescents exposed to deviant peers (Germán et al., 2009) as well as for Mexican-origin adolescents with larger left hippocampal volumes in reducing depressive symptoms over time (Schriber et al., 2016). Furthermore, researchers have argued that Mexican-origin adolescents may be more resistant to peer influence due to an increased emphasis on respect for parental input, known as “respeto” (Bamáca & Umana- Taylor, 2006). Although not specifically tested in this study, it is possible that Mexican-origin adolescents may be less susceptible to peer influence cues (relative to their White counterparts) as a function of an increased familial orientation.

Limitations

The findings reported for this study must be considered in the context of some limitations. First, the sample of the current study is relatively modest in size, potentially limiting its power to detect expected effects and constraining the types of models that could be tested. Although the current sample exceeds guidelines for the minimum recommended size for group-level task-based fMRI (Pajula & Tohka, 2016), it is possible that hypotheses related to reward-processing in the caudate nucleus would be supported if tested with a larger sample size. A second limitation is the gap in time between the collection of the adolescent-maternal relationship factors (i.e., conflict and relationship quality) at age 16 and the fMRI scan at roughly age 19. It is possible that the dynamics of the family may have altered during that period of time, positively or negatively, especially as participants may have transitioned into college or the workforce. Third, conflict and relationship quality variables relied solely on adolescent self-reports. Additional objective measures (e.g., behavioral observations) or reports from multiple sources may be necessary to fully characterize the adolescent-maternal relationship. Fourth, there was relatively low endorsement of adolescent-maternal conflict or dissatisfaction in the adolescent-maternal relationship quality at ages 10, 12, and 14. Limited variability in adolescent reports of adolescent-maternal relationship variables may have hindered the ability to detect effects in subsequent brain activity.

Future Directions

The findings from the present study raise new questions that should be addressed in future work. First, in order to understand how the family environment and adolescent brain track together, taking a concurrent longitudinal approach would facilitate the ability to test how the family environment and brain dynamically interact to influence each other over time. Future studies should collect measures of family-dynamics contemporaneously with measures of neural

activity elicited by peer influence tasks. A concurrent measurement approach would provide insight into how the current family environment relates to neural sensitivity to peer influence, rather than relying on self-reported developmental history. Furthermore, measuring neural responses to peer influence in tandem with relationship factors at multiple time-points across adolescence would allow for a more fine-grained cross-lagged analysis to examine the bidirectional associations of brain-based and self-reported measures over time. Gender differences in understanding how the adolescent-maternal relationship contributes to neural sensitivity to peer influence should be examined as there is evidence to suggest that adolescent girls relative to boys report higher relationship closeness with mothers (Ruhl et al., 2015). Additionally, future work is needed to test the extent to which conflict and relationship quality with fathers may be similar or unique from maternal influence in shaping adolescent sensitivity to peer influence. Finally, future studies should test how cultural values commonly held among Hispanic-American or Latinx families (e.g., familism, respeto) may contribute to behavioral and neural sensitivity to peer influence cues.

Conclusion

Taken together, positive and negative aspects of the family environment experienced during adolescence contribute to sensitization of the brain to, or buffering from, peer influence in young adulthood, a hallmark of social development even during the transition into adulthood. The study herein provides novel insight that suggests increased conflict with mothers during adolescence may cue individuals to attending to even subtle forms of peer-endorsed cues, as indexed by brain activity in relevant salience-detecting nodes. Conversely, having a more satisfying relationship quality with mothers during adolescence may diminish the salience of peer-endorsed cues by attenuating brain activity, and thus attention to such cues, in the same set

of regions. These findings have implications for designing and implementing interventions delivered to adolescents. Specifically, the present study identified specific factors in the home environment that enhanced or diminished the salience of peer-related cues. Thus, future interventions could be designed to target the types of information adolescents are paying attention to as well as the experiences adolescents have within the family environment. The present study contributes to a growing field aimed at understanding socio-contextual factors that impact how adolescents perceive, process, and respond to peer influence cues in their everyday social environments.

CHAPTER THREE

STUDY 2: IMPLICIT MATERNAL VERSUS PEER INFLUENCE ON ADOLESCENTS' PREFERENCES: A NEW TASK PARADIGM

In real-world contexts, adolescents often must consider multiple, sometimes simultaneous sources of influence coming from those around them. According to Erikson's theory of psychosocial development, one of the key developmental tasks of adolescence is to continue to establish autonomy from parents and explore identity formation (Erikson, 1980), which both feed into the decisions that one makes. During adolescence, parental monitoring tends to decrease and adolescents' unsupervised time with peers tends to increase, affording them new opportunities to explore aspects of their identity (Choudhury, Blakemore, & Charman, 2006; Simons Morton et al., 2014), especially within the peer context. One salient aspect of identity formation during this period is preference formation, whereby adolescents explore and form their own opinions in a variety of domains (Schacter & Ventura, 2008). This ranges from developing preferences regarding seemingly minor topics such as music (Bonneville-Rousey et al., 2013) to potentially more consequential preferences about political affiliations (Rekker et al., 2019). In pursuit of forming their preferences, adolescents often weigh input from multiple close others (e.g., parents and peers) and reconcile to what extent, and in what contexts, the opinions of others are most salient and potentially alter their preferences (Steinberg & Silverberg, 1986).

Relatively little research has directly tested how adolescent preference formation is influenced by both parents and peers. A line of research, however, has emerged examining how adolescents and young adults make decisions that force them to consider providing benefits to parents or to peers, sometimes at the cost of the other relationship and typically in the context of gaining financial rewards (Braams & Crone, 2017; Guassi Moreira et al., 2018). For example, in

a neuroimaging gambling task in which adolescents (aged 9-18) could win money for a peer or a mother, adolescents displayed both age-related increases in self-reported pleasure winning money for a friend relative to a mother and increases in ventral striatum reactivity (a brain region involved in reward processing; Braams & Crone, 2017). This finding aligns with assertions that adolescents become increasingly oriented toward their peers during adolescence due to changes in the brain, physical development, and age-specific social context demands (Nelson et al., 2016). Relatedly, a study examining the role of mothers and peers on regulating children's and adolescents' stress response demonstrated that maternal presence during a social stress test reduced cortisol stress reactivity among children, but not adolescents, further highlighting the diminished influence of parents on physiology between childhood and adolescence (Hostinar et al., 2015). Characterizing when, and to what extent, individuals' preferences shift from being more influenced by peers than parents during adolescence is important to investigate as it might reveal clues about sensitive periods in which one social agent may have more sway over another on adolescents' behavior. Extending later into development, Guassi Moreira and colleagues (2018) created a modified version of the Columbia Card Task (Figner et al., 2019) to test how young adults (aged 18-30) make gambling decisions that benefitted a peer or parent, at the direct detriment of the relationship that they did not choose. Results from this study showed that young adults were more likely to make decisions that benefitted their parent, at the expense of a friend, than vice versa. Furthermore, this effect was moderated by the reported relationship quality with parents and friends, whereby better adolescent-reported relationship quality was related to increased likelihood of that close other being selected for a gambling win (Guassi Moreira et al., 2018). These findings highlight age-related differences in decision-making that benefit parents or

friends. Whether or not a similar pattern involving weight given to parents versus peers extends to adolescent preference formation remains unknown.

Many of the commonly used task paradigms designed to assess the effects of social influence on behavior and brain indices rely on direct, explicit deliveries of social information. For example, several studies have used simulated feedback designs to deliver positive and negative evaluations to participants from peers (e.g., "This person liked you."; Guyer et al., 2012; Jarcho et al., 2016; Somerville et al., 2006), simulated social media platforms to display pictures with an explicitly manipulated number of "likes" (Sherman et al., 2016), or other scenarios in which participants are told how popular or unpopular a series of stimuli are (e.g., "Your peer's rating was 75"; Welborn et al., 2016). However, in everyday social environments, information regarding the opinions of others is often subtly embedded. For example, logos from popular brands are indirect measures of the opinions of others and can be salient social status symbols seen, for example, on peers' clothing at school. In line with that formulation, findings from one study show that young adults had a stronger neural response to popular food brands than less popular generic brands (Fehse, et al., 2017). Other work has shown that implicit instantiations of social influence also have robust effects on brain activity (Venticinque et al 2021). Specifically, young adults displayed increased activity in brain regions involved in salience detection (e.g., insula and anterior cingulate cortex) in response to implicitly instantiated social symbols relative to novel symbols and increased activity in reward-processing brain regions (e.g., caudate nucleus) in response to popular versus unpopular symbols (Venticinque et al., 2021). Given these patterns in young adults, the current study was designed to develop and assess a method to characterize implicit influence on behavioral indices of shifts in preferences

among adolescents, with the potential for later adaptation in order to examine underlying neural mechanisms of social influence among adolescents.

Many of the existing social influence task paradigms include social influence delivered by hypothetical peers (Irani et al., 2023; Venticinque et al., 2021; Welborn et al., 2016). In other words, participants may be told that ratings of stimuli presented to them were provided by other similarly-aged participants who have previously completed the study they are currently enrolled in (Welborn et al., 2016) or were from a previous study of other adolescents (Irani et al., 2023; Venticinque et al., 2021). Questions remain, however, about how adolescents respond to opinions provided by (or believed to be provided by) familiar agents of socialization (i.e., friends, parents). To our knowledge, no study to date has examined delivery of implicit social influence cues (e.g., preference ratings) associated with multiple close others and how they relate to shifts in adolescents' own preferences. Thus, the current study aimed to address this gap by designing a novel task, in which adolescents were presented with supposed ratings of stimuli, delivered implicitly, by both a real-life friend and by their mother. Following subtle exposures to the opinions of two different types of close others (i.e., a friend and mother), we tested whether adolescents' own preferences for the stimuli, as a form of social conformity, would more closely align with one source of influence or the other.

In sum, additional research is needed to address limitations of the task paradigms used in the extant literature in order to more accurately capture subtle, incidental exposures to peer influence (Mason et al., 2009; Venticinque et al., 2021) from multiple real-life close others. In doing so, new tasks can more accurately simulate how adolescents experience and reconcile social influences on their preferences in their everyday lives. Thus, the current study sought to expand on existing work in several ways. First, although a limited set of studies has used a task

design that included both a mother and a peer condition, they were largely focused on decision-making, leaving it unknown how these two conditions might both influence adolescents' own preferences. Second, since most of the literature has used explicit cues of influence and demonstrated significant effects on decision-making, a task that delivers influential information implicitly is needed to determine whether this form of delivery influences adolescents' own preferences. Third, there is a gap in the existing literature whereby current social influence tasks have mainly included social influence cues only provided by hypothetical sources of influence rather than a familiar one (e.g., a real-life friend). Fourth, examining age-related and gender differences in shifts in preference, as influenced by the preferences of their mother and a peer, is needed to begin to understand developmental changes in how adolescents' preferences might change in the face of influence coming from multiple sources. Finally, examining how aspects of adolescents' relationships with real-life sources of influence (e.g., perceived relationship quality) is needed to better understand whether differences in relationship dynamics might contribute to how adolescents respond to the influence of close others.

The Current Study

The aim of the present study was three-fold. The first goal was to develop and assess the validity of a novel method to measure the implicit influence of close others on a shift in adolescents' preferences. This was done by adapting work reported in Venticinque et al., (2021), which included young adults and only a fictitious peer, to include real-life close others, add a mother condition, and test the paradigm in a sample of adolescents. The second goal was to examine the effect of individual differences, specifically participant age and gender, on the degree to which the implicitly delivered social information changed adolescents' preferences. Finally, the third goal was to test the effect of adolescents' quality of relationship with each

source of influence on shifts in their preference of information endorsed by their mother or a peer. The hypotheses for the current study were as follows:

(H1): Adolescents' preference ratings of symbols following the delivery of implicitly imbued social value (endorsed or not endorsed by mother or peer) will increase relative to their baseline ratings, indicating that the task was effective at shifting adolescents' preferences to be more positive overall.

(H2): Adolescents' preference ratings of symbols following the delivery of implicitly imbued social information will vary by the source of influence (i.e., from a friend or mother), the endorsement status (i.e., endorsed or not endorsed), and the interaction of source of influence and endorsement status. Specifically, in their ratings made after the social influence task, adolescents will show a stronger preference for symbols: (a) rated by their friend compared to their mother; (b) that were endorsed relative to not endorsed; (c) among those rated by their friend, as endorsed relative to not endorsed; (d) among those rated by their mother, as endorsed relative to not endorsed; and (e) among those endorsed, by their friend relative to their mother. Furthermore, (f) no difference in preference ratings was expected among symbols that were not endorsed by the friend or the mother. Due to baseline ratings being made prior to endorsement status or source of influence (e.g., symbols endorsed by mother did not yet exist before the task began), interactions of these factors with time were not examined.

(H3): Adolescents' preference ratings of symbols following the delivery of implicitly imbued social information will vary based on individual differences. Specifically, (a) there will be an age-related effect such that older compared to younger adolescents will align more closely, as evidenced by a greater difference score in preference rating, with the endorsed preferences of a friend; (b) there will be a gender effect such that girls relative to boys will align their

preferences more closely (i.e., greater difference score) with the endorsed preferences of their friend; (c) when considering the interaction of age and gender, older adolescent girls versus older adolescent boys will align more closely with a friend's endorsed preferences, and younger adolescents will not differ by gender.

(H4): Adolescents who report having a more satisfying relationship with their friend will align more closely with their friend's endorsed preferences; relative to their mother's endorsements.

(H5): Adolescents who report having a more satisfying relationship with their mother will align more closely with their mother's endorsed preferences; relative to their mother's endorsements.

Method

Participants

Participants were 100 adolescents (60 females, M_{Age} = 13.3 years, *SD* = 2.2 years, range = 10-17 years) recruited from Northern California. Of the total sample, 55 were younger adolescents (33 females, M_{Age} = 11.6 years, *SD* = 1.2 years, range = 10-13 years) and 45 were older adolescents (27 females, M_{Age} = 15.3 years, *SD* = 1.2 years, range = 14-17 years). Self-reported race of adolescents included: 63% White/Caucasian, 22% Mixed race, 6% Asian, 5% Hispanic/Latino, 1% Black/African-American, 1% Native American, and 1% Pacific Islander. The median household income for participants was $120,000 and above (see Appendix B for complete participant demographics).

Eligibility criteria for study participation included: (1) appropriate age to participate in the study; (2) having normal or corrected-to-normal vision to complete the computer-administered task; (3) both the youth and one female parent or legal guardian were willing to participate; (4) having a friend aged 10-17 who was also willing to participate in the study with

their mother; and (5) absence of developmental disorders or delays that impede social relationships, such as severe Autism Spectrum Disorder or Down's Syndrome. Participants were recruited through various methods including: online parent/family groups (e.g., Facebook), community events (e.g., farmers' market), advertising at local middle and high schools, contacting potential participants who met eligibility criteria based on medical records provided by the UC Davis Clinical and Translational and Science Center. Only one child per family was allowed to participate in the current study. All families who identified another family (i.e., a friend and their mother) willing to participate were successfully enrolled and completed the study.

Procedures

All study procedures were approved by the university's institutional review board. First, after establishing contact with a mother of a 10–17-year-old child through the aforementioned recruitment channels and determining interest and eligibility, the family was asked to identify one of the adolescent's similarly-aged male or female friends and their mother who may be interested in participating with the study with them. Then, the second family was contacted, all study procedures were explained, and their eligibility was determined, if interested. Once a pair of adolescent friends and their mothers were deemed eligible for the study, both adolescent-mother dyads were invited to attend, at the same time, a one-hour, in-person study at a research facility in Northern California. When both families arrived for the study visit, written consent was obtained from both mothers and adolescent participants. Next, a digital camera was used to take a photograph of each of the four participants to be used in the social influence computer task; participants were told their photograph would be deleted at the end of the study. For the photograph, participants were instructed to stand against a neutral-colored wall, look straight

ahead, and smile. Mothers were then taken to another room and completed a 10-minute questionnaire, reporting on the demographics of their family and aspects of their relationship with their child (e.g., conflict and relationship quality). Once mothers completed the questionnaire, they were escorted to a waiting room for the remainder of the study visit, in an effort to not impact the adolescents' participation in the social influence task.

Adolescent participants were separated into two adjoining rooms. One participant was randomly selected to be the first to complete questionnaires on a laptop computer. This participant was instructed to complete a series of surveys and, once finished, to wait for further instruction. These surveys included measures of various aspects of their relationship with their mother and with the friend who accompanied them to the study visit, as well as their own perceptions of their susceptibility to social influence. Meanwhile, the second participant was instructed that they would be completing the computer-based task first. First, this participant completed a paper-and-pencil measure to indicate how much they liked 50 symbols they had never seen before. As participants completed this initial survey, study personnel uploaded photographs of all four participants from the digital camera to a desktop computer to be used in the social influence computer task. Next, adolescents were told that before the study visit, their mother and friend previously had provided ratings of how much they each liked the same set of symbols (this statement was untrue, unbeknownst to the participant) and they would be seeing the results of those ratings. The participant then completed the 8-minute Mother and Peer Influence Task (MPIT) on a desktop computer in which they viewed the supposed ratings from their friend and mother (see Figure 2.1 for details). The task was counterbalanced such that half of the participants saw the supposed ratings from their mother first and their friend second, and vice versa. After completing the MPIT, participants filled out a post-task pencil-and paper

questionnaire to provide a second set of ratings of how much they liked the same set of 50 symbols (in reversed order). Finally, they completed a memory task asking them to recall the ratings they viewed during the MPIT. Once both participants finished completing their respective tasks (i.e., completing the online surveys or the measures related to the MPIT), they switched rooms and completed the other half of the study measures, following the same set of instructions.

Upon completing both portions of the study protocol (i.e., questionnaires and the computer-based task), adolescent participants were reunited with their mothers. Next, study personnel debriefed all four participants on the purpose of the study and explained the need to use mild deception as part of the social influence task (i.e., no ratings were provided by the friend or mother before the visit). All participants completed all measures in English. Adolescent participants were monetarily compensated for their study participation.

Measures and Materials

Stimulus Selection

Selection of stimuli for the present study was largely guided by the images included in tasks used in past work (Mason et al., 2009; Venticinque et al., 2021). In those studies, 30 abstract symbols, never seen before by participants, were used (20 symbols used in the social instantiation task and 10 novel symbols not used in the task). Abstract symbols were chosen to minimize any prior bias to stimuli before participating in the social instantiation task. In the adapted version used in the current study, additional stimuli were necessary to account for the addition of another task condition (i.e., influence from mother). Thus, 20 additional abstract symbols were selected for use in this version of the task. This resulted in a total of 50 stimuli: 20 symbols for the friend condition, 20 symbols for the mother condition, and 10 novel unused in either condition.

Symbol Preference Rating Questionnaire

Preferences for symbols was measured using a paper-and-pencil measure. Images of all 50 symbols across stimulus types (i.e., friend endorsed, friend not endorsed, mother endorsed, mother not endorsed, and novel; described in detail in the next section) were presented in a pseudo-randomized order. For each symbol, participants responded to how much they liked or disliked the picture on a 7-point Likert scale (1 = "dislike a lot"; 2 = "dislike moderately"; 3 = "dislike slightly"; 4 = "neither like nor dislike"; 5 = "like slightly"; 6 = "like moderately"; 7 = "like a lot) as an index of their preference for each symbol. All participants were presented symbols in the same order. Two versions of the rating questionnaire were created (i.e., a pre-task and post-task survey). The post-task survey asked participants to complete the same task, however the symbols were presented in the reverse order to address order effects.

Mother and Peer Influence Task

Following completion of the pre-task survey, participants were asked to complete a task at a desktop computer in the laboratory. Participants were told that, prior to the study visit, the friend who was accompanying them on the visit and their mother previously completed their own ratings of the symbols they just saw and we instructed them not to inform the participant about this aspect of the study. Additionally, we told participants that their friend was completing a separate computer task from the one they were given. Researchers instructed participants that, throughout their completing a computer task, they would be seeing the results of what their friend and mother thought about the symbols. Participants were told they would see a photo of either their mother or the friend who accompanied them on the visit, then a display of two of the symbols that the mother or friend had supposedly previously rated, and finally told a green box would appear around the symbol given a higher rating by the friend or mother (lasting 1250 ms).

Trials were separated by a 500 ms fixation cross. Participants were instructed to make a left or right key press using arrow keys on the keyboard to indicate the side of the screen on which the chosen symbol was presented. Regardless of when the participant made a selection, the trial was set to end at 2500ms. For half of the trials, the chosen symbol was displayed on the left and for the other half, on the right, to promote participant engagement. Depending on the version of the task (i.e., Version A or B), participants were told that they would either be seeing all of the selections made by their mother first and then their friend or vice versa.

The task was created and implemented using E-Prime 3.0 software (Psychology Software Tools, Pittsburgh, PA). The task consisted of 200 trials (100 selections from the friend and 100 selections from the mother) and lasted approximately 8-minutes (see Figure 1). Symbols were implicitly socially tagged as endorsed or not endorsed by the friend or mother through manipulating the proportion with which they were shown to be the preferred symbol; endorsed symbols were shown to be preferred in 90% of the trials in which they appeared as part of a symbol pairing, whereas not endorsed symbols were preferred in only 10% of relevant trials. Of the 50 symbols previously rated by participants, 40 were included in the task (10 symbols that were manipulated to be endorsed by the friend, 10 symbols that were not endorsed by friend, 10 symbols that were endorsed by the mother, 10 symbols that were not endorsed by the mother). The remaining 10 symbols were novel symbols that were not implicitly instantiated to have any social value and were not included in the task (but were still rated by participants in the pre- and post-task ratings). There was no overlap between symbols supposedly rated by mothers or friends. In other words, each symbol only belonged to one of the five categories and was not supposedly rated by both the friend and mother. The presentation order of symbol pairings was pseudo-randomized within the block of mother or friend ratings. To reduce cognitive load

associated with switching between sources of influence between each trial, either all 100 of the friend ratings were presented first (Version A) or all 100 of the mother ratings were presented first (Version B), followed by the other source of influence. Participants were randomly selected to complete either Version A or Version B.

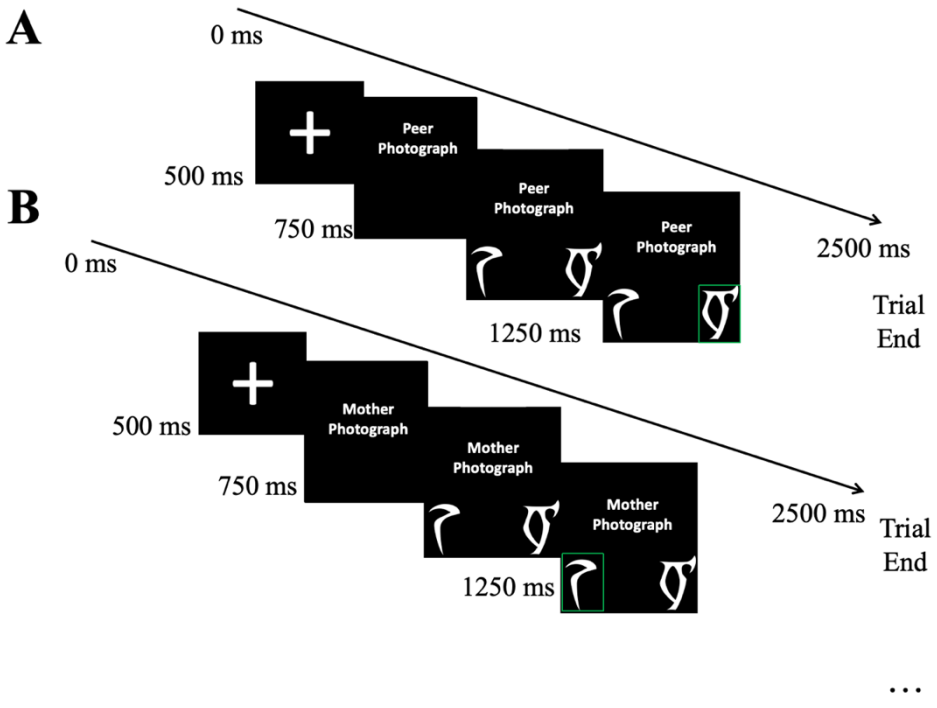


Figure 2.1

Design of the Mother and Peer Influence Task

(A) Timeline depicting one trial in which the selection of symbol preference is being presented from a friend. In each trial, participants were presented with the photograph of the friend attending the study visit in the center of the screen for 750 ms. Next, two symbols appeared below the photograph and a green box appeared around the friend's preferred symbol, lasting 1250 ms. Each trial was separated by a 500 ms fixation cross, and participants were instructed to make a left or right button press to indicate on which side of the screen the preferred symbol appeared. **(B)** Timeline depicting one trial in which the selection of symbol preference is being presented from a mother. The duration and instructions for this trial type were the same as the description in the peer trials. These trial types were presented to participants with 100 trials of each type. Half of the participants were presented the 100 friend trials first and the 100 mother trials second and vice versa.

Memory Questionnaire

The extent to which participants were able to consciously recall which symbols were selected during the social instantiation task was assessed using a memory recall questionnaire. This was delivered as a pencil-and-paper measure in which participants were asked to indicate which symbol of each pair they had seen was previously selected (as indicated by the green box). Participants responded by writing either "L" to indicate the symbol on the left or "R" to indicate the symbol on the right. The measure consisted of 50 pairs, representing 25% of the total trials (to reduce subject fatigue) for both supposed selections by the friend and the mother (i.e., 25 pairs of friend-rated symbols and 25 pairs of mother-rated symbols). These pairings were randomly selected from the total trial list and participants were all given the same set of 50 pairs to report on. Pairs of friend selections were presented first and then the selections from the mother. Novel stimuli were not included in this questionnaire.

Relationship Quality with Mother and Friend

Perceived relationship quality with the mother was measured using the adolescent-reported Relationship Quality with Mother scale (RQM; Melby & Conger, 2001). The RQM is a 4-item scale adapted from the Iowa Youth and Families Project (Conger & Elder, 1995) designed to serve as an overall evaluative judgment of the parent-adolescent relationship. Scores were obtained from adolescent-reported perceptions of their relationships with their mother. A sample item on this scale includes, "How satisfied with your relationship with your mother would you say you are?" Responses on this scale were on a 4-point Likert scale ranging from 1 (very dissatisfied) to 4 (very satisfied) and were averaged to create a total score of adolescent-perceived relationship quality with their mother. In a study from the Iowa Youth and Families Project, this measure has shown adequate construct validity relative to other measures of

relationship quality (Flynn et al., 2018). Relationship quality with a friend was assessed using an adapted version of the RQM. For consistency in comparing between participant ratings of their relationship quality with both close others, the same items were used to assess perceived relationship quality with the friend. Participants completed the same 4-items, instead responding about the friend who accompanied them on the study visit (see Appendix B). Mother reported relationship quality with their child was not used in this study as it was outside of the scope of this initial characterization of how individual differences (e.g., age and gender) of adolescents' and their own perceived relationship with their friend and mother impact their preference ratings.

Data Analytic Strategy

Statistical analyses for this study were conducted using IBM SPSS Statistics (Version 29). Initial analyses included bivariate correlations among study variables. Next, I summarized characteristics of task performance including: 1) pre-task and post-task ratings of symbols, averaged across those endorsed and not endorsed by both adolescents' friend and mother, 2) adolescents' attention while completing the social instantiation task, and 3) adolescents' memory accuracy in regard to which symbols were endorsed and not endorsed, following the social instantiation task. With regard to attention, I calculated overall accuracy of making a correct left or right button press across the 200 task trials. In order to assess incorrect responses due to indiscriminate button pushes, I computed a discrimination index (Pr; i.e., hit rate – false alarm rate). With regard to memory, participants' memory of which symbol was selected (i.e., the left or the right) from 25% of the total 200 pairs (25 ratings from friend and 25 ratings from mother) was calculated to reflect the average percentage correct of identifying whether the left or right symbol was selected among the 50 ratings (25 from their friend and 25 from their mother).

To address the first goal of the study, I tested the overall validity of the task paradigm (i.e., whether preferences of symbols changed following the social instantiation task) using a 2 x 2 x 2 within-subjects repeated-measures ANOVA. This analysis examined adolescents' preferences for symbols as a function of: 1) time (pre-task or post-task), 2) source of influence (friend or mother), and 3) endorsement status (endorsed or not endorsed). However, in line with the goal and design of the study, in the event of a significant three-way interaction, planned post hoc comparisons were only conducted for ratings made post-task (i.e., following the social instantiation task) as pre-task ratings were of symbols that had not yet been ascribed social meaning.

To test the second goal of the study of examining the effect of individual differences, specifically participant age and gender, on the degree to which the implicitly delivered social information changed adolescents' preferences (represented as difference scores), two between-subjects multivariate analysis of variance (MANOVA) tests were conducted. Difference scores were created as a measure of adolescents' shift in preferences made after completing the social instantiation task accounting for their pre-task ratings by subtracting their pre-task ratings from their post-task ratings. This was completed for each condition (e.g., pre-task ratings of symbols later endorsed by friend subtracted from post-task ratings of friend endorsed symbols). Positive scores reflected an increase in preference for a symbol and negative scores reflected a decrease in preference following the task. Differences scores for each category (i.e., friend endorsed, friend not endorsed, mother endorsed, and mother not endorsed) were averaged for each participant and used as the dependent variables in further analyses. Participants' stage of development (operationalized as ages 10-13 for younger adolescents and ages 14-17 for older adolescents) and participant gender were used as between-subjects factors to test hypotheses.

The first MANOVA included participant age and participant gender as between-subjects factors, and difference scores for peer endorsed and mother endorsed symbols as outcome variables. The second MANOVA included participant age and participant gender as between-subjects factors and difference scores for peer not endorsed and mother not endorsed symbols as outcome variables. The endorsed and not endorsed outcomes were examined separately in two models (i.e., (a) endorsed by friend and mother, and (b) not endorsed by peer and mother) as the variables in these pairings were more conceptually interrelated, in line with recommendations from Cole and colleagues (1993), rather than including all four variables in one model. Bivariate correlations between memory scores and difference scores of the four symbol types (i.e, friend endorsed, mother endorsed, friend not endorsed, mother not endorsed), as well as two independent samples t-tests assessing memory differences between: 1) younger and older adolescents, and 2) boys and girls were conducted.

To test the third goal of the study of examining the extent to which the relationship quality with both the friend and mother (assessed separately) was related to changes in adolescent preferences socially instantiated symbols by their friend and mother, two multivariate analyses of covariance (MANCOVAs) were conducted. The first MANCOVA included relationship quality with friend as a covariate, and difference scores for peer endorsed and mother endorsed symbols as outcome variables. The second MANCOVA included relationship quality with mother as a covariate, and difference scores for peer endorsed and mother endorsed symbols as outcome variables.

Results

Descriptive Information

Bivariate correlations between overall pre-task preference ratings of symbols and each of the mean post-task preference ratings for symbols both endorsed and not endorsed by both participants' friend and mother are presented in Table 2.1. Correlations among difference scores (representing adolescents' change in preference from pre-task to post-task) of symbols endorsed and not endorsed by both friend and mother, with participant age, participant gender, relationship quality with friend and mother, memory accuracy, and attention accuracy are presented in Table 2.2.

Table 2.1 *Bivariate correlations of overall mean pre-task preference ratings and mean post-task preference scores from symbols endorsed and not endorsed by friend and mother.*

	1	2	3	4
1. Overall pre-task preference ratings	-	-	-	-
2. Post-task friend endorsed	.17	.	-	-
3. Post-task mom endorsed	.21*	.45*	.	-
4. Post-task friend not endorsed	.08	.34*	-.10	.
5. Post-task mom not endorsed	.10	-.17	.12	.08

Note: $N = 100$. * = significance at $p < .05$. Overall pre-task ratings = the mean of participants' four pre-task preferences for symbols that later were instantiated as endorsed or not endorsed by their friend and mother.

Table 2.2 *Bivariate correlations among difference scores between pre-task and post-task preference ratings of symbols endorsed and not endorsed by friend and mother with relevant study variables.*

	1	2	3	4	5	6	7	8	9
1. Diff. friend endorsed	-	-	-	-	-	-	-	-	-

2. Diff. friend not endorsed	.17	-	-	-	-	-	-	-	-
3. Diff. mom endorsed	.35**	.07	-	-	-	-	-	-	-
4. Diff. mom not endorsed	.11	.13	.40*	-	-	-	-	-	-
5. Participant age	.38**	.10	.02	.11	-	-	-	-	-
6. Participant gender	.23*	.11	.21*	-.07	.13	-	-	-	-
7. RQ with friend	-.12	-.09	-.04	-.07	-.02	.07	-	-	-
8. RQ with mom	.08	.08	.12	-.04	-.17	-.09	.04	-	-
9. Memory accuracy	.05	.10	.06	.09	.04	.12	.03	.06	-
10. Attention accuracy	.23*	.11	.24*	.18	.07	.09	.04	.05	.21*

Note: $N = 100$, Diff. = subtraction of pre-task preferences from post-task preferences, RQ = relationship quality scores, *$p < .05$. **$p < .01$.

Characteristics of Task Performance

Preferences of Symbols. Participants' pre- and post-task mean preference ratings by task conditions (i.e., friend endorsed, friend not endorsed, mother endorsed, mother not endorsed) are presented in Table 2.3.

Table 2.3 *Mean reported preferences of all symbols before and after social instantiation task.*

Symbol Preference	Pre-Task Mean (*SD*)	Post-Task Mean (*SD*)
Friend Endorsed	3.9 (.08)	4.4 (.09)
Friend Not Endorsed	3.8 (.08)	3.8 (.09)
Mother Endorsed	3.9 (.09)	4.2 (.08)
Mother Not Endorsed	3.7 (.09)	3.8 (.09)

Note: $N = 100$. Pre-task preference scores were obtained before the social instantiation task. Post-task scores were obtained after the social instantiation task. Ratings ranged from (1 = "dislike a lot" to 7 = "like a lot"), *SD* = standard deviation.

Attention and Memory. When assessing participants' overall accuracy on left or right button pushes during the task (as a measure of attention), on average, participants identified 91.1% of trials correctly ($SD = 2.2$, range = 75%- 98%). Furthermore, results of calculating a discrimination index (hit rate- false alarm rate) revealed an average discrimination of 172 out of 200 trials ($M = 86\%$, $SD = 3.1$), suggesting that participants were engaged throughout the task with mean accuracy levels above chance. With regard to memory of which symbol was selected (i.e., the left or the right) from 25% of the total 200 pairs (25 ratings from friend and 25 ratings from mother), on average, participants identified 59% of trials correctly ($SD = .081$, range = 38% - 78%).

Manipulation Check

The first goal of the present study was to establish the validity of the novel social instantiation task design. I conducted analyses to test differences between participants' preferences before and after the social instantiation task for friend- and mother-rated symbols that varied in endorsement status. A 2 x 2 x 2 within-subjects, repeated-measures ANOVA was conducted to examine the effect of time (pre-task, post-task), source of influence (friend, mother), and endorsement status (endorsed, not-endorsed) on adolescents' preferences of symbols. In support of hypothesis 1, there was a main effect of time on adolescent' preferences, $F(1, 99) = 4.77$, $p = .03$, such that adolescents' preference ratings were significantly higher post-task ($M = 4.0$, $SD = .07$) compared to pre-task ($M = 3.8$, $SD = .08$), as per the task design. In support of hypothesis 2, there was (H2a) a main effect of source of influence on adolescent

preferences, $F(1, 99) = 9.15$, $p = .003$, whereby symbols rated by the friend ($M = 4.3$, $SD = .07$) were more preferred than those rated by the mother ($M = 4.1$, $SD = .06$), and (H2b) a main effect of endorsement status on adolescent preferences, $F(1, 99) = 6.3$, $p = .014$, whereby endorsed symbols ($M = 4.1$, $SD = .06$) were more preferred than not-endorsed symbols ($M = 3.7$, $SD = .05$).

Finally, there was a significant interaction effect between source, time, and endorsement status on adolescent preferences ($F(1, 99) = 5.82$, $p = .018$). To interpret the interaction effect, in line with the goal of the study to demonstrate the effectiveness of the novel task in changing preferences, I only present findings related to the interaction of source and endorsement in the post-task condition (i.e., following the social instantiation task). Post-hoc tests partially supported hypothesis 2 such that: (H2c) adolescents' post-task preferences for symbols were significantly higher when endorsed by their friend ($M = 4.4$, $SD = .09$) than when not endorsed by their friend ($M = 3.8$, $SD = .09$), ($p < .01$); (H2d) there was no significant difference in post-task ratings of symbols endorsed by their mother relative to not endorsed by their mother ($p = .08$; contrary to expectation); (H2e) adolescents' post-task preferences for symbols were significantly higher when endorsed by their friend ($M = 4.4$, $SD = .09$) than when endorsed by their mother ($M = 4.2$, $SD = .09$) symbols, ($p = .02$), and (H2f) there was no significant difference in post-task ratings of symbols not endorsed by their friend relative to not endorsed by their mother ($p = .36$). The complete within-person repeated-measures ANOVA results are presented in Table B1 in Appendix B.

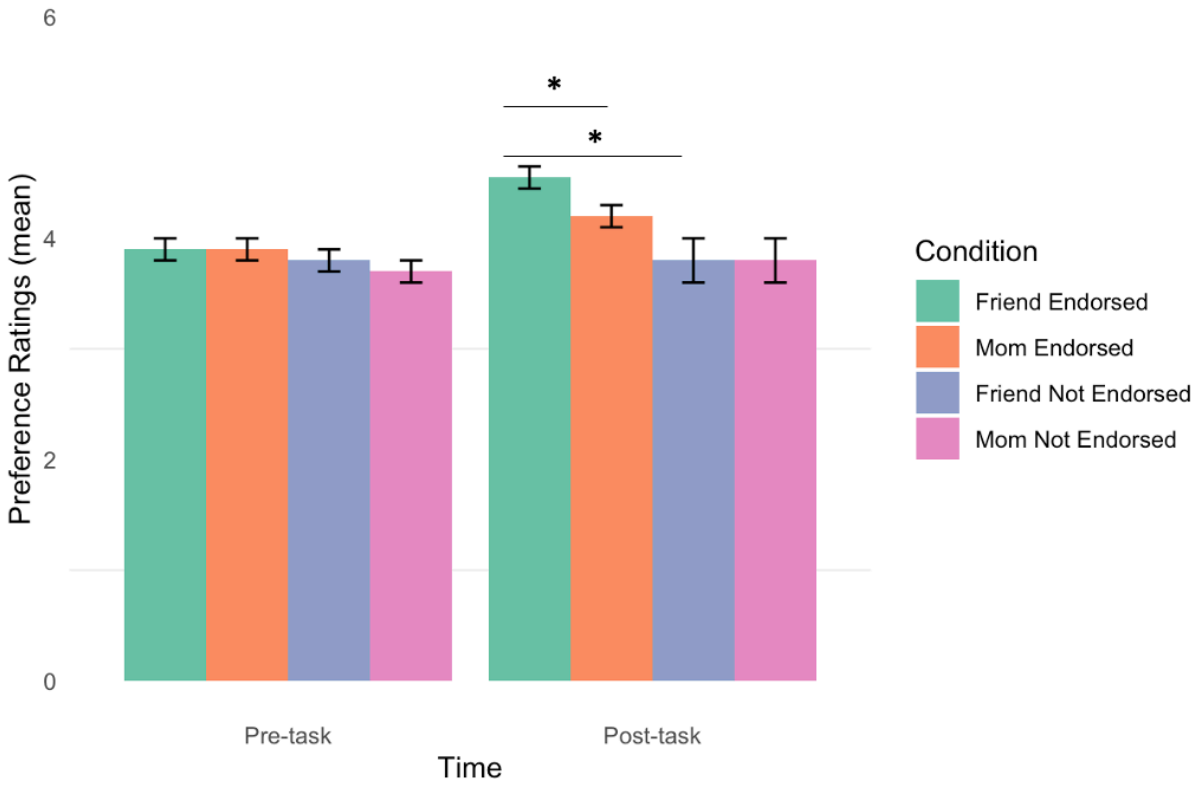


Figure 2.2

Task Effects. Bars represent adolescents' average pre-task and post-task preferences of symbols endorsed and not endorsed by their friend and mother. Error bars represent standard error of the mean. * $p < .05$.

Effects of Participant Age and Gender

Two between-subjects MANOVAs, with stage of development (i.e., early- or mid-adolescence), participant gender, and the interaction of age and gender as between-subjects factors were conducted to examine their effects on (a) difference scores in adolescents' preferences of friend endorsed and mother endorsed symbols and (b) difference scores in adolescents' preferences of friend not endorsed and mother not endorsed symbols. Difference scores, represented as the subtraction of the pre-task ratings from the post-task ratings, were created to represent participants' change in preferences of symbols resulting from viewing implicit influence from the friend and mother.

For the MANOVA on endorsed symbols, two significant effects were revealed in the omnibus multivariate tests: participant age (Wilk's Λ = .94, F (2, 95) = 2.83, p =.03) and participant gender (Wilk's Λ = .82, F (2, 95) = .41, p = .01). There was no effect of the interaction of age and gender on difference scores in adolescents' preferences to friend endorsed and mother endorsed symbols, Wilk's Λ = .99, F (2, 95) = 10., p = .60. For significant multivariate effects, follow-up tests of between-subjects effects were interpreted below. Results of MANOVA tests are summarized in Table 2.4.

In support of hypothesis 3, (H3a) there was a significant effect of participant age (i.e., younger or older adolescents) on propensity to change their preferences after exposure to friend endorsed symbols, F (1, 95) = 4.39, p =.03. Specifically, older adolescents (M = .68, SD = .94) versus younger adolescents (M =.26, SD = .94) had a greater increase in their preference ratings to friend endorsed symbols. However, there was no significant effect of participant age on propensity to change their preferences after exposure to mother endorsed symbols (F(1,95) = .45, p = .54 (see Figure 2.3). Furthermore, (H3b) there was a significant effect of participant gender on adolescents' propensity to change their preferences of both friend endorsed (F(1,95) = 4.74, p =. 02) and mother endorsed (F(1,95) = 1.73, p =. 03) symbols. Specifically, girls reported greater increases in their preferences to friend endorsed (M = .65, SD = .94) and mother endorsed (M = .40, SD = .91) symbols than boys (M = .20, SD = .81 and M = .12, SD = .82; respectively) (see Figure 2.4). However, (H3c) there was no significant interaction of age and gender as shown in the multivariate tests above, contrary to expectation.

A second between-subjects MANOVA, with participant age (i.e., younger or older adolescents), participant gender, and the interaction of age and gender as between-subjects factors, was conducted to examine difference scores in adolescents' preferences of friend not

endorsed and mother not endorsed symbols. Results from the omnibus multivariate tests yielded no significant results for participant age, participant gender, or age x gender. Thus, the follow-up tests of between-subjects effects were not interpreted (results are presented in Table B2 in Appendix B). Due to no significant effects on adolescent preference changes to symbols *not* endorsed by their friend or mother being present, the results pertaining to relationship quality presented in the sections below only include difference scores for preferences of endorsed symbols.

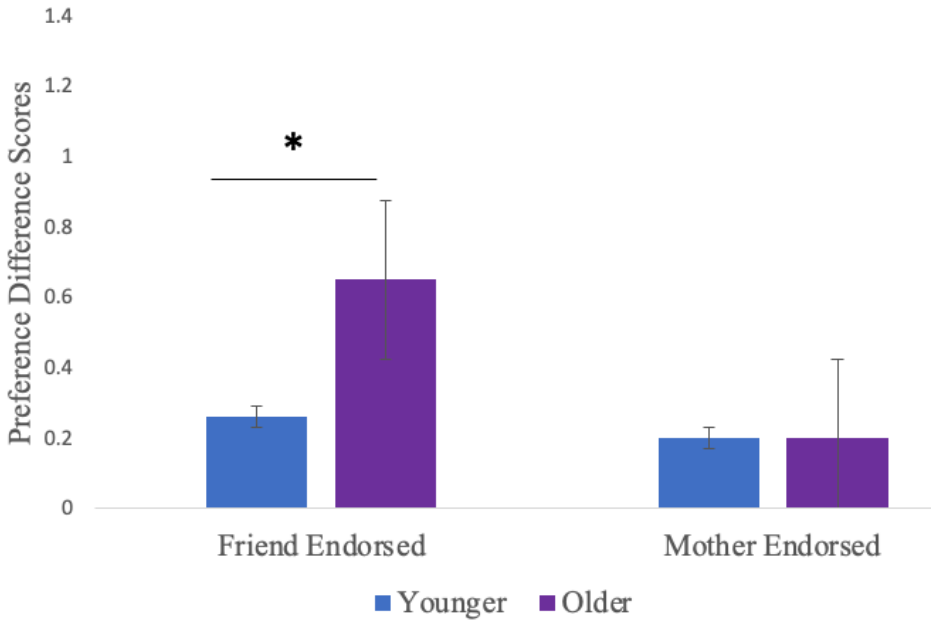
Memory accuracy scores were not correlated with changes in adolescent preferences to friend endorsed (r = .05, p = .71), friend not-endorsed (r = .10, p = .80), mother endorsed (r = .06, p = .94), and mother not-endorsed (r = .09, p = .70) symbols. Two independent-samples t-tests revealed that memory accuracy did not differ between boys and girls ($t(98)$ = -1.2 , p = .08) or between younger and older adolescents ($t(98)$ = -.42 , p = .67). These findings suggest that the results found in change in preference were not driven by participants' ability to recall ratings from the social instantiation task and thus, it was not necessary to control for memory accuracy in the presented models.

Table 2.4 *Results of MANOVA test of participant age, gender, and age x gender effects on shift in preference ratings after implicit endorsement of symbols by friend and mother*

Tests	Λ	F^o	p^o	$F^{b\text{-}s}$	$p^{b\text{-}s}$	η_p^2
Pref. for friend and mother endorsed						
Participant age	.94	2.83	.03*	-	-	-
Friend endorsed	-	-	-	4.39	.03*	.04
Mother endorsed	-	-	-	.45	.54	.04
Participant gender	.82	10.0	.01*	-	-	-
Friend endorsed	-	-	-	4.74	.02*	.05
Mother endorsed	-	-	-	1.73	.03*	.04
Participant age x gender	.99	.41	.60	-	-	-

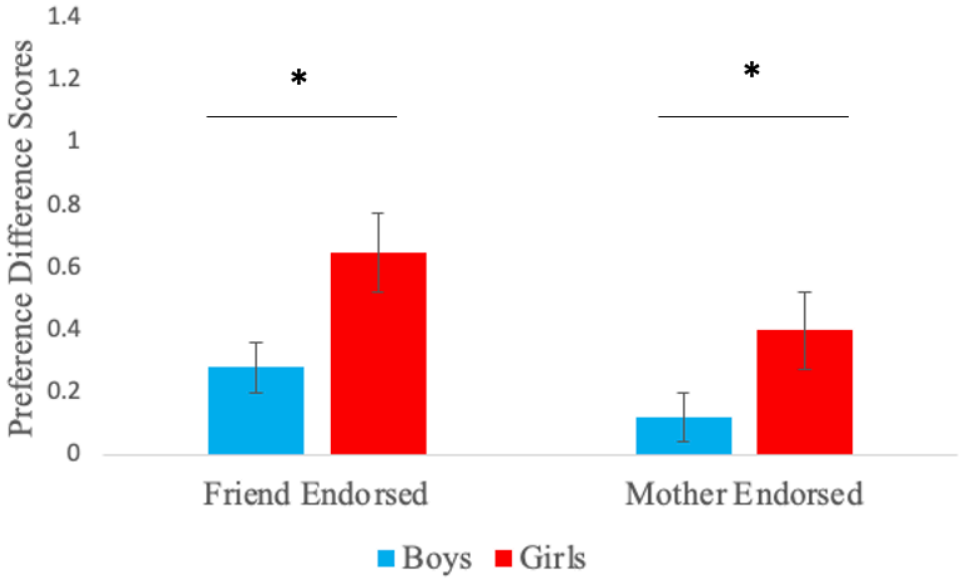
Note: $N = 100$. Λ = Wilk's Lambda, F^o = *f*-statistic of omnibus multivariate tests, p^o = significance of omnibus multivariate tests, $F^{b\text{-}s}$ = *f*-statistic of between-subjects tests, $p^{b\text{-}s}$ = significance of between-subjects tests, η_p^2 = partial eta-square, * = significance at $p < .05$.

Figure 2.3



Age-related Differences in Adolescent Preference Ratings after Implicit Endorsement of Symbols by Friend and Mother. Bars represent average difference scores (between pre- and post-task questionnaires) of adolescent preferences of friend endorsed and mother endorsed symbols. Results are separated by age (i.e., younger adolescents (ages 10-13) and older adolescents (ages 14-17). Error bars represent standard error of the mean. * $p < .05$. N = 100.

Figure 2.4



Gender Differences in Adolescent Preference Ratings after Implicit Endorsement of Symbols by Friend and Mother. Bars represent average difference scores (between pre- and post-task questionnaires) of adolescent preferences of friend endorsed and mother endorsed symbols. Results are separated by gender. Error bars represent standard error of the mean. * $p <$ .05. N = 100.

Effects of Relationship Quality with Friend and Mother

To test the effects of relationship quality with friend and mother on adolescents' preference changes to symbols endorsed by friend and mother, two between-subjects MANCOVAs were conducted. First, omnibus multivariate tests of the MANCOVA (Table 2.5) revealed that there was not a significant effect of relationship quality with friend on preference for friend endorsed and mother endorsed symbols, Wilk's $\Lambda = .98$, $F\ (1, 97) = .73$, $p = .40$. Similarly, omnibus multivariate tests of a second MANCOVA (Table 2.6) revealed that there was not a significant effect of relationship quality with mother on preference for friend endorsed and mother endorsed symbols, Wilk's $\Lambda = .95$, $F\ (1, 97) = .76$, $p = .46$. Results from these analyses did not support hypotheses 4 and 5.

Table 2.5 *Results of MANCOVA tests with participant relationship quality with friend as a covariate on shift in preference for friend endorsed and mother endorsed symbols.*

Tests	Λ	F^o	p^o
Preference for friend and mother endorsed			
Relationship quality with friend	.98	.73	.40

Note: Λ = Wilk's Lambda, F^o = *f*-statistic of omnibus multivariate tests, p^o = significance of omnibus multivariate tests.

Table 2.6 *Results of MANCOVA tests with participant relationship quality with mother as a covariate on shift in preference for friend endorsed and mother endorsed symbols.*

Tests	Λ	F^o	p^o
Preference for friend and mother endorsed			
Relationship quality with mother	.95	.76	.46

Note: $N = 100$. Λ = Wilk's Lambda, F^o = *f*-statistic of omnibus multivariate tests, p^o = significance of omnibus multivariate tests.

Discussion

The current study aimed to test a novel social influence task designed to investigate changes in adolescents' preferences after viewing subtle input delivered from multiple close others (i.e., a mother and friend), similar to everyday instances of social influence. The first goal was to establish and assess the validity of the novel social instantiation task on adolescents' preferences to symbols endorsed or not endorsed by close others. The second goal was to examine the effect of individual differences, specifically participant age (categorized as younger adolescents (aged 10-13) and older adolescents (aged 14-17)) and gender, on the degree to which the implicitly delivered social information changed adolescents' preferences. Finally, the third goal was to test the effect of adolescents' quality of relationship with each source of influence on their changes in preferences to endorsed symbols.

Establishing and assessing the validity of the novel task created for the current study, adolescents reported changes in their preferences for symbols following viewing the supposed preferences of their friend and mother. Specifically, adolescents more strongly favored symbols after viewing them in the social instantiation task than they did in their initial ratings. This suggests that adolescents may be motivated to more favorably view social information (regardless of its value) when compared to information that has no social meaning. Additionally, adolescents rated symbols that were endorsed by their friend compared to their mother more favorably after the social instantiation task. This finding aligns with previous work that suggests adolescents may conform to the opinions or norms of their peer group as a means of fitting in (Field et al., 2023; Juvonen & Galvan, 2008; Laursen & Faur, 2022). Thus, being aware of what peers like and adjusting one's own opinions to be in accordance with peer preferences is a

normative and socially desirable experience among adolescents. Similarly, this finding is in line with limited prior evidence suggesting that when considering both friend and mothers, adolescents tend to make decisions that favor their friend over their mother (Guassi Moreira et al., 2020). The current study is the first to investigate whether the tendency to align with friends over mothers extends to considering implicitly delivered preferences. There were no reported differences in adolescent preference changes to symbols that were *not* endorsed by the friend or mother, suggesting that adolescents were potentially more motivated to change their opinions to what was endorsed by close others than what was not endorsed.

The expected age-related differences in differentially shifting preference based on social partner was supported. Older adolescents (ages 14-17) were more likely to increase their preferences after exposure to friend endorsed symbols rather than to mother endorsed symbols as compared to younger adolescents (10-13). This result aligns with findings from a body of research that suggests adolescents undergo a normative social reorientation in which throughout adolescence, individuation from the family unit increases and peers gain more sway and influence (Crone & Dahl, 2012; Nelson et al., 2016). As adolescents mature, parental monitoring tends to decrease (Simons-Morton et al., 2014) and adolescents begin to participate in more complex and diverse social settings as they continue to form their own identities, thereby affording more opportunity for exposure and forming responses to peer opinions (Finkenauer et al., 2019; Guyer et al., 2014; Mmari et al., 2021). Individuation from parents, in favor of establishing one's own identity is a key developmental task of adolescence, according to Erikson's theory of psychosocial development (Erikson, 1980). Findings from the current study suggest that high-school aged adolescents, relative to their younger counterparts, are particularly sensitive to the subtly embedded social value cues (e.g., logos of popular brands) in their

everyday environments. This increased sensitivity may render older adolescents uniquely vulnerable to the persuasive effects of targeted advertising campaigns (e.g., marketing of e-cigarettes), as well as school-based initiatives that harness the influence of peer norms (e.g., norms around substance-use). There was no such age-related difference for symbols not endorsed by their friend or mother, highlighting the increased relative value of what friends are endorsing during adolescence.

The current study also revealed gender differences related to adolescents' conformity to align with the opinions of a friend or peer. Specifically, adolescent girls relative to boys reported greater change in their opinions after viewing symbols endorsed by their friend. This finding is in line with prior behavioral (Guyer at al., 2014; Veldhuis et al., 2014) and neuroimaging work (Guyer et al., 2012; van der Meulen et al., 2017) that has shown that adolescent girls are more sensitive to peer evaluations and feedback than adolescent boys. During adolescence, girls are more acutely aware of aspects of their peer relationships, have higher concern for social evaluation, have a higher need for peer approval, and more preoccupied with thoughts of peers than are boys (French & Cheung, 2018; Rose & Rudolph, 2006; Rose & Smith, 2018). Interestingly, adolescent girls also displayed a greater shift in their opinions relative to boys when viewing symbols that were endorsed by their mother. This is in line with previous work that has found that adolescent girls tend to have higher reported closeness to mothers than do boys and feelings of closeness with mothers tends to decrease at a slower rate across adolescence for girls than for boys (Buist et al., 2002). Thus, adolescent girls may show a greater concern for considering their mother's thoughts when forming their own opinion and this effect may decrease more slowly across adolescence than for boys. There were no reported gender differences based on viewing symbols that were not endorsed by the friend or mother, further

suggesting that conforming to what others like rather than dislike may be more salient during adolescence.

Finally, there were no reported differences in changes in preferences based on the perceived relationship quality with the friend or mother. One explanation for this may be that participants in the current study showed little variability in their responses regarding relationship quality, often indicating high relationship satisfaction with both their friend and mother. Future studies will be needed of samples with greater variability in features of their relationships (e.g., conflict, closeness) to further investigate how aspects of the relationship with social partners impacts adolescents' propensity to conform to their opinions when forming their own preferences.

Limitations

Findings from this study must be considered in the context of some limitations. First, it is possible that participants did not find some aspects of the task to be believable. In other words, some adolescents might not have believed that we previously obtained ratings of the symbols from their friend and mother before participating in the study visit. We addressed this concern by providing participants with a free-response question at the end of the questionnaires in which they could optionally inform the research team of anything they would like us to know about their experience. No participant directly reported skepticism regarding the task on the free-response question. We decided to take this approach as previous work has suggested that explicitly asking participants about the believability of study deception can bias their reporting (Barrera & Simpson, 2012), and a funnel debriefing works to avoid biased responding. Additionally, a limitation of the current task design is that different symbols were used for the mother and friend conditions. Separate symbols were used for each of the mother and friend

conditions for several reasons. First, the current study sought to initially establish the validity of the novel task design in eliciting changes in adolescents' preferences for implicitly delivered social information before including more nuanced study conditions. Similarly, the inclusion of additional study conditions (e.g., symbols that are endorsed by friend but not by mother) would significantly increase the duration of the task, possibly resulting in participant fatigue. Given those considerations, the current task was unable to test adolescent responses to contradictory influence from a friend and mother.

Future Directions

Future studies and task paradigms are necessary to further probe how adolescents form their preferences in the context of social influence from close others. For example, future task designs are necessary to test how adolescents reconcile contradictory forms of social influence (e.g., social information that is endorsed by a friend, but not by a mother). Examining the effects of contradictory forms of social influence cues would expand our understanding of how adolescents form preferences considering multiple sources and more closely resemble how social influence cues are delivered in everyday scenarios. Future studies should incorporate eye-tracking methods with the current task design to provide a more comprehensive view into what symbols adolescents may have been attending to more than others. However, not all social influence processes have a clear behavioral corollary, evidenced by Venticinque and colleagues (2021). Gaining a better understanding of the underlying mechanisms (e.g., brain structure and function) that influence how adolescents form preferences while receiving subtle input from mothers and peers is necessary in future studies.

Conclusion

In sum, findings from the current study suggest that adolescents' preferences may be informed by subtle input from close others. Specifically, considering the opinions of friends and parents, particularly mothers, has the potential to influence how adolescents form their own preferences about socially relevant aspects of their everyday environments. By creating and testing a novel task paradigm that delivers subtle forms of social influence cues from multiple close others, the current study demonstrates that adolescents may change their opinions to more closely align with others in several relevant ways. For example, the current study suggests that after viewing social cues that were positively endorsed by both a friend and their mother, adolescents will tend to shift their opinions more favorably, thus conforming to the input from others. However, the influential power of peers and mothers may not be equal during adolescence. Findings from the current study suggest that during adolescence, the opinions of a friend may have considerably more sway than the opinions of a mother. This pattern was further demonstrated by uncovering an age-related effect, such that older adolescents (ages 14-17) displayed greater conformity to a friend's opinion relative to a mother's than younger adolescents (ages 10-13). Additionally, adolescent girls showed a stronger propensity to change their preferences after exposure to that of a friend or mother relative to their male counterparts. Contrary to expectation, there were no differences in preference changes based on the adolescent's perceived relationship quality with their friend or mother. The current study provides an initial understanding how adolescents' preferences may shift amidst social influence from multiple sources; still, more work is needed to understand underlying neurobiological mechanisms. By gaining a better understanding of how adolescents shape their opinions in the context of input from friends and parents can help inform intervention work geared toward

changing adolescents' attitudes about health-risk behaviors, such as substance use and risky decision-making.

CHAPTER FOUR

GENERAL CONCLUSION

Social influence is a common, normative experience in which others may impact how individuals think, feel, or behave (Turner, 1991). In adolescence specifically, a large body of research has shown that peers can have a significant impact in influencing how adolescents think, make decisions, form their own distinct identity, as well as their neurophysiology (Ashbourne & Daly, 2012; Guyer & Jarcho, 2018; Steinberg & Monahan, 2007). However, parents (specifically mothers) remain an important socializing agent during adolescence, albeit often to a lesser extent. Less is known about the role of adolescents' experiences with mothers (e.g., degree of conflict, perceived relationship quality or closeness) in shaping behavioral and neurobiological sensitivity to peer influence, as well as considering influence from peers and mothers simultaneously, as often exists in real-world scenarios during adolescence. Additionally, many of the existing task paradigms designed to deliver social influence cues to youth rely on explicit, overt forms of social influence (e.g., 50 "likes" on a social media photograph, Sherman et al., 2016), representing only a limited range of possible social influence experiences during adolescence. My dissertation addressed these gaps in the literature by being among the first to test how prior experiences with parents, specifically mothers, during adolescence impact later neural sensitivity to subtle forms of peer influence. Additionally, my dissertation presents and tests a novel social influence task paradigm that addresses limitations of existing tasks by delivering social influence in a more repeated, implicit fashion from multiple real-life close others, reflective of many everyday exposures to social influence during adolescence. Findings

from the studies in this dissertation provide a foundation for future behavioral and neuroimaging work on understanding how adolescents and young adults experience, process, and respond to subtle forms of social influence cues provided by multiple social agents.

Study 1 investigated the association between adolescent-maternal relationship factors (i.e., conflict and perceived relationship quality) measured across adolescence and subsequent neural responses to implicit forms of peer influence in young adulthood. Analyses used data from the longitudinal California Families Project, in which adolescents reported on conflict and perceived relationship quality with their mothers every two years from ages 10-16 and completed a social influence task while undergoing functional magnetic resonance imaging (fMRI) at age 19. Contrary to other commonly used social influence tasks that rely on explicit, overt influences from others (e.g., Welborn et al., 2016), the task used in Study 1 delivered social influence cues (i.e., supposed ratings from hypothetical similarly-aged peers) through repeated, subtle exposures. When averaging adolescent-reported conflict and relationship quality scores across all waves of collected data, to gain an overall picture of adolescent-maternal relationship dynamics across ages 10-16, there were no associations with neural responses in *a priori* brain regions of interest (guided by Venticinque et al., 2021) in the reward-processing and salience-detection brain networks. Post-hoc analyses were conducted only including adolescent-maternal conflict and relationship quality scores at age 16, given evidence that age 16 may be a time in which adolescent-maternal conflict is particularly salient (Mastrotheodoros et al., 2020), and it was the closest time-point of measured adolescent-maternal relationship variables in relation to the neuroimaging data collection.

Regression analyses revealed that adolescent-maternal conflict at age 16 was positively associated with neural activation both the left insula and right anterior cingulate cortex (ACC),

brain regions involved in salience-detection when young adults viewed socially tagged versus novel peer cues. Conversely, a better reported relationship quality with mothers at age 16 was negatively associated with neural activation in the left insula and right ACC when viewing socially tagged versus novel peer cues. Contrary to hypotheses, there were no reported associations between adolescent-maternal conflict or relationship quality at age 16 and brain activity in reward processing brain regions (e.g., caudate nucleus) when viewing cues instantiated to be popular or unpopular among similarly-aged peers. In sum, conflict with mothers during sensitive periods in adolescence may sensitize the brain to be more attentive to peer influence cues, whereas better reported relationship qualities with mothers may serve as a protective factor to peer influence cues.

Study 2 tested a novel behavioral social influence task that assessed adolescents' preference changes after viewing implicitly delivered social influence cues from multiple close others (i.e., a friend and mother). Expanding upon the task that was used in Venticinque et al. (2021) and in Study 1 of this dissertation, adolescents (aged 10-17) viewed repeated, subtle exposures to symbols that were either endorsed or not endorsed by both their real-life friend and their mother and reported how these social influence cues shifted their own preferences. Results from this study suggested that following a social instantiation task, adolescents shifted their preferences to more strongly prefer symbols that were imbued with social information (i.e., either endorsed or not endorsed by a friend or mother) compared to their initial ratings. Specifically, adolescents more strongly preferred symbols after they had been endorsed by a friend compared to symbols endorsed by their mother. Additionally, there was an age-related effect, such that older adolescents (aged 14-17) were more likely to prefer friend endorsed symbols after the task than younger adolescents (aged 10-13). Study 2 also found gender effects,

such that adolescent girls more strongly preferred symbols that were endorsed by both their friend and mother relative to adolescent boys. However, there was no significant interaction between age and gender. Additionally, there were no reported differences in these effects based on the reported relationship quality with either the adolescent's friend or mother. All reported differences were only related to symbols that were endorsed by friends or mothers and there were no differences based on symbols that were not endorsed, suggesting that shifting one's preferences after being exposed to what others like may be more salient and desirable than what others do not like. In sum, subtle exposures to the opinions of multiple close others have the potential to change the way adolescents think about social stimuli, dependent on their age, gender, the source of influence, and whether the influence is positive or negative. This improves upon existing task paradigms, by beginning to better simulate how social influence cues are often embedded in youths' everyday social environments (e.g., viewing logos of popular brands).

Taken together, these studies suggest that implicit forms of social influence and aspects of adolescents' relationship with the source of this influence (e.g., peers or mothers) can have robust and measurable effects on adolescents' neurobiology and behavior. Specifically, adolescents' social experiences with their mothers (e.g., conflict and perceived relationship quality) may sensitize or buffer areas of the brain involved in salience detection (e.g., insula and ACC) from responding to subtle peer influence cues in young adulthood. Additionally, adolescents displayed observable behavioral differences when considering subtle social influence cues from a peer and mother when reporting their own preferences, showing a bias for aligning with the opinions of a peer over a mother, particularly for adolescent girls and when participants were older. Overall, this dissertation highlights the need for further examination of behavioral and neurobiological mechanisms underlying how adolescents experience and respond to subtle

forms of social influence cues, in the context of input from multiple social agents. Uncovering the biopsychosocial factors related to how youth process the deluge of social cues embedded in their everyday environments has the potential to inform how future intervention work targeting youth can maximize the salience of the content and source of socially-relevant information.

REFERENCES

Allen, J. P., Chango, J., Szwedo, D., Schad, M., & Marston, E. (2012). Predictors of susceptibility to peer influence regarding substance use in adolescence. *Child development*, *83*(1), 337-350. https://doi.org/10.1111/j.1467-8624.2011.01682.x.

Ashbourne, L. M., & Daly, K. J. (2012). Changing patterns of family time in adolescence: Parents' and teens' reflections. *Time & Society*, *21*(3), 308-329. https://10.1177/0961463X10387689.

Barcai, A. (1981). Normative family development. *Journal of Marital and Family Therapy*, *7*(3), 353-359.

Barrera, D., & Simpson, B. (2012). Much ado about deception: Consequences of deceiving research participants in the social sciences. *Sociological Methods & Research*, *41*(3), 383-413. https://10.1177/0049124112452526.

Biddle, B. J., Bank, B. J., & Marlin, M. M. (1980). Parental and peer influence on adolescents. *Social Forces, 58*(4), 1057–1079.

B'amaca, M. Y., & Umana-Taylor, A. J. (2006). Testing a model of resistance to peer pressure among Mexican-origin adolescents. *Journal of Youth and Adolescence, 35*, 631-645. https://doi.org/10.1007/s10964-006-9055-4.

Blakemore, S. J. (2008). The social brain in adolescence. *Nature Reviews Neuroscience*, *9*(4), 267-277. https://doi.org/10.1038/nrn2353.

Bonneville-Roussy, A., Rentfrow, P. J., Xu, M. K., & Potter, J. (2013). Music through the ages: Trends in musical engagement and preferences from adolescence through middle

adulthood. *Journal of personality and social psychology*, *105*(4), 703. https://10.1037/a0033770.

Bornstein, M. H., & Putnick, D. L. (2021). Dyadic development in the family: Stability in mother–child relationship quality from infancy to adolescence. *Journal of Family Psychology*, *35*(4), 445. https://dx.doi.org/10.1037/fam0000794.

Braams, B. R., & Crone, E. A. (2017). Peers and parents: a comparison between neural activation when winning for friends and mothers in adolescence. *Social Cognitive and Affective Neuroscience*, *12*(3), 417-426. https://doi.org/10.1093/scan/nsw136.

Branje, S. J., Hale, W. W., Frijns, T., & Meeus, W. H. (2010). Longitudinal associations between perceived parent-child relationship quality and depressive symptoms in adolescence. *Journal of abnormal child psychology*, *38*(6), 751-763. https://doi.org/10.1007/s10802-010-9401-6.

Braem, S., King, J. A., Korb, F. M., Krebs, R. M., Notebaert, W., & Egner, T. (2017). The role of anterior cingulate cortex in the affective evaluation of conflict. *Journal of cognitive neuroscience*, *29*(1), 137-149. https://doi.org/10.1162/jocn_a_01023.

Brauer, J. R., & De Coster, S. (2015). Social relationships and delinquency: Revisiting parent and peer influence during adolescence. *Youth & Society*, *47*(3), 374-394. https://doi.org/10.1177/0044118X12467655.

Buist, K. L., Deković, M., Meeus, W., & Van Aken, M. A. (2002). Developmental patterns in adolescent attachment to mother, father and sibling. *Journal of youth and adolescence*, *31*, 167-176.

Butterfield, R. D., Silk, J. S., Lee, K. H., Siegle, G. S., Dahl, R. E., Forbes, E. E., ... & Ladouceur, C. D. (2021). Parents still matter! Parental warmth predicts adolescent brain function and anxiety and depressive symptoms 2 years later. *Development and psychopathology*, *33*(1), 226-239. https://10.1017/S0954579419001718

Cacioppo, J. T., Norris, C. J., Decety, J., Monteleone, G., & Nusbaum, H. (2009). In the eye of the beholder: individual differences in perceived social isolation predict regional brain activation to social stimuli. *Journal of cognitive neuroscience, 21*(1), 83-92. https://doi.org/10.1162/jocn.2009.21007

Chan, S. M., & Chan, K. W. (2013). Adolescents' susceptibility to peer pressure: Relations to parent–adolescent relationship and adolescents' emotional autonomy from parents. *Youth & Society*, *45*(2), 286-302. https://doi.org/10.1177/0044118X11417733

Choukas-Bradley, S., Giletta, M., Cohen, G. L., & Prinstein, M. J. (2015). Peer influence, peer status, and prosocial behavior: An experimental investigation of peer socialization of adolescents' intentions to volunteer. *Journal of youth and adolescence*, *44*, 2197-2210. https://doi.org/10.1007/s10964-015-0373-2

Choudhury, S., Blakemore, S.-J., & Charman, T. (2006). Social cognitive development during adolescence. *Social Cognitive and Affective Neuroscience, 1*(3), 165–174. https://doi.org/10.1093/scan/nsl024

Chein, J., Albert, D., O'Brien, L., Uckert, K., & Steinberg, L. (2011). Peers increase adolescent risk taking by enhancing activity in the brain's reward circuitry. *Developmental Science, 14*(2), 1-10. DOI: 10.1111/j.1467-7687.2010.01035.x.

Cialdini, R. B., & Goldstein, N. J. (2004). Social influence: Compliance and conformity. *Annu. Rev. Psychol.*, *55*, 591-621.

Çırak, M., Yağmurlu, K., Kearns, K. N., Ribas, E. C., Urgun, K., Shaffrey, M. E., & Kalani, M. Y. S. (2020). The caudate nucleus: its connections, surgical implications, and related complications. *World neurosurgery*, *139*, e428-e438. https://doi.org/10.1016/j.wneu.2020.04.027

Conger RD, & Conger KJ (2002). Resilience in Midwestern families: Selected findings from the first decade of a prospective, longitudinal study. *Journal of Marriage and Family, 64*(2), 361–373. 10.1111/j.1741-3737.2002.00361.x

Conger, R. D., & Elder, G. H. (1995). Families in troubled times: Adapting to change in rural America. Thousand Oaks, CA: SAGE Publications.

Conner, O. L., Siegle, G. J., McFarland, A. M., Silk, J. S., Ladouceur, C. D., Dahl, R. E., ... & Ryan, N. D. (2012). Mom—it helps when you're right here! Attenuation of neural stress markers in anxious youths whose caregivers are present during fMRI. *PloS one*, *7*(12), e50680. https://doi.org/10.1371/journal.pone.0050680

Cole, D. A., Maxwell, S. E., Arvey, R., & Salas, E. (1993). Multivariate group comparisons of variable systems: MANOVA and structural equation modeling. *Psychological Bulletin, 114*(1), 174–184. https://doi.org/10.1037/0033-2909.114.1.174

Cox, R. W. (1996). AFNI: software for analysis and visualization of functional magnetic resonance neuroimages. *Computers and Biomedical research*, *29*(3), 162-173. https://doi.org/10.1006/cbmr.1996.0014.

Crone, E. A., & Dahl, R. E. (2012). Understanding adolescence as a period of social–affective engagement and goal flexibility. *Nature reviews neuroscience*, *13*(9), 636-650. https://doi.org/10.1038/nrn3313

Do, K. T., McCormick, E. M., & Telzer, E. H. (2020). Neural sensitivity to conflicting attitudes supports greater conformity toward positive over negative influence in early adolescence. *Developmental cognitive neuroscience*, *45*, 100837. https://doi.org/10.1016/j.dcn.2020.100837

Duggirala, S. X., Belyk, M., Schwartze, M., Kanske, P., & Kotz, S. A. (2022). Emotional salience but not valence impacts anterior cingulate cortex conflict processing. *Cognitive, Affective, & Behavioral Neuroscience*, *22*(6), 1250-1263. https://doi.org/10.1016/j.neuropsychologia.2009.03.019

Elliott, D. S., Huizinga, D., & Ageton, S. S. (1985). *Explaining delinquency and drug use*. Sage.

Erikson, E. H. (1980). Identity and the Life Cycle. New York, NY: W. W. Norton & Company.

Fehse, K., Simmank, F., Gutyrchik, E., & Sztrókay-Gaul, A. (2017). Organic or popular brands--food perception engages distinct functional pathways. an fMRI study. *Cogent Psychology*, 4(1), 1284392. https://doi.org/10.1080/23311908.2017. 1284392.

Figner, B., Mackinlay, R. J., Wilkening, F., & Weber, E. U. (2009). Affective and deliberative processes in risky choice: age differences in risk taking in the Columbia Card Task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(3), 709. https:// 10.1037/a0014983

Field, N. H., Choukas-Bradley, S., Giletta, M., Telzer, E. H., Cohen, G. L., & Prinstein, M. J. (2023). Why adolescents conform to high-status peers: Associations among conformity, identity alignment, and self-esteem. *Child Development*. https://doi.org/10.1111/cdev.14038

Finkenauer, C., Willems, Y. E., Weise, M., & Bartels, M. (2019). The social context of adolescent relationships. In *Emotional well-being in the digital age.*

Flynn, H. K., Felmlee, D. H., Shu, X., & Conger, R. D. (2018). Mothers and fathers matter: The influence of parental support, hostility, and problem solving on adolescent friendships. *Journal of Family Issues*, *39*(8), 2389-2412. https://doi.org/10.1177/0192513X18755423

French, D. C., & Cheung, H. S. (2018). Peer relationships. *Handbook of adolescent development research and its impact on global policy*, *1*.

Fuligni, A. J., Eccles, J. S., Barber, B. L., & Clements, P. (2001). Early adolescent peer orientation and adjustment during high school. *Developmental psychology*, *37*(1), 28. https://doi.org/10.1037/0012-1649.37.1.28

Gao, M. M., & Cummings, E. M. (2019). Understanding parent–child relationship as a developmental process: Fluctuations across days and changes over years. *Developmental psychology*, *55*(5), 1046. https://dx.doi.org/10.1037/dev0000680

Germán, M., Gonzales, N. A., & Dumka, L. (2009). Familism values as a protective factor for Mexican-origin adolescents exposed to deviant peers. *The Journal of early adolescence, 29(1),* 16-42. https:// 10.1177/0272431608324475

Guassi Moreira, J. F., Miernicki, M. E., & Telzer, E. H. (2016). Relationship quality buffers association between co-rumination and depressive symptoms among first year college students. *Journal of youth and adolescence*, *45*, 484-493. https://doi.org/10.1007/s10964-015-0396-8

Guassi Moreira, J. F., Tashjian, S. M., Galván, A., & Silvers, J. A. (2021). Computational and motivational mechanisms of human social decision making involving close others. *Journal of Experimental Social Psychology*, *93*, 104086. https://doi.org/10.1016/j.jesp.2020.104086

Guassi Moreira, J. F., & Telzer, E. H. (2018). Family conflict is associated with longitudinal changes in insular-striatal functional connectivity during adolescent risk taking under maternal influence. *Developmental science*, *21*(5), e12632. https://doi.org/10.1111/desc.12632

Guassi Moreira, J. F., & Telzer, E. H. (2018). Mother still knows best: Maternal influence uniquely modulates adolescent reward sensitivity during risk taking. *Developmental science*, *21*(1), e12484. https://doi.org/10.1111/desc.12484

Guassi Moreira, J. F., Tashjian, S. M., Galván, A., & Silvers, J. A. (2020). Is social decision making for close others consistent across domains and within individuals? *Journal of Experimental Psychology: General*, *149*(8), 1509. https://dx.doi.org/10.1037/xge0000719

Gunther Moor, B., van Leijenhorst, L., Rombouts, S. A., Crone, E. A., & Van der Molen, M. W. (2010). Do you like me? Neural correlates of social evaluation and developmental trajectories. *Social neuroscience, 5*(5-6), 461-482. https://doi.org/10.1080/17470910903526155

Guyer, A. E., Caouette, J. D., Lee, C. C., & Ruiz, S. K. (2014). Will they like me? Adolescents' emotional responses to peer evaluation. *International journal of behavioral development*, *38*(2), 155-163. https://doi.org/10.1177/0165025413515627

Guyer, A. E., Choate, V. R., Pine, D. S., & Nelson, E. E. (2012). Neural circuitry underlying affective response to peer feed- 845 back in adolescence. *Social Cognitive and Affective Neuroscience, 7*(1), 81–92. https://doi.org/10.1093/scan/ nsr043

Guyer, A. E., Jarcho, J. M. (2018). Neuroscience and peer relations. In J. M., Bukowski, W. M., Laursen, B., & Rubin, K. H. *Handbook of peer interactions, relationships, and groups*, 177-199.

Guyer, A. E., McClure-Tone, E. B., Shiffrin, N. D., Pine, D. S., & Nelson, E. E. (2009). Probing the neural correlates of anticipated peer evaluation in adolescence. *Child development*, *80*(4), 1000-1015.

Gibbons, F. X., Gerrard, M., Lune, L. S. V., Wills, T. A., Brody, G., & Conger, R. D. (2004). Context and cognitions: Environmental risk, social influence, and adolescent substance use. *Personality & Social Psychology Bulletin, 30*(8), 1048–1061. https://doi.org/10.1177/0146167204264788.

Hair, E. C., Anderson Moore, K., Hadley, A. M., Kaye, K., Day, R. D., & Orthner, D. K. (2009). Parent marital quality and the parent–adolescent relationship: Effects on adolescent and young adult health outcomes. *Marriage & Family Review*, *45*(2-3), 218-248. https://doi.org/10.1080/01494920902733567

Hazel, N. A., Oppenheimer, C. W., Technow, J. R., Young, J. F., & Hankin, B. L. (2014). Parent relationship quality buffers against the effect of peer stressors on depressive symptoms from middle childhood to adolescence. *Developmental psychology*, *50*(8), 2115. https://10.1037/a0037192

Henrich, J., Heine, S. J., & Norenzayan, A. (2010). The weirdest people in the world? *Behavioral and Brain 855 Sciences, 33*(2–3), 61–83. https://doi.org/10.1017/S0140525X0999152X

Hofer, C., Eisenberg, N., Spinrad, T. L., Morris, A. S., Gershoff, E., Valiente, C., ... & Eggum, N. D. (2013). Mother–adolescent conflict: Stability, change, and relations with externalizing and internalizing behavior problems. *Social Development*, *22*(2), 259-279. https://doi.org/10.1111/sode.12012

Hostinar, C. E., Johnson, A. E., & Gunnar, M. R. (2015). Parent support is less effective in buffering cortisol stress reactivity for adolescents compared to children. *Developmental science*, *18*(2), 281-297. https://doi.org/10.1111/desc.12195

Irani, F., Muotka, J., Lyyra, P., Parviainen, T., & Monto, S. (2023). Social influence in adolescence: behavioral and neural responses to peer and expert opinion. *bioRxiv*, 2023-07. https://doi.org/10.1080/17470919.2024.2323745

Jarcho, J. M., Benson, B. E., Plate, R. C., Guyer, A. E., Detloff, A. M., Pine, D. S., ... & Ernst, M. (2012). Developmental effects of decision-making on sensitivity to reward: an fMRI study. *Developmental cognitive neuroscience*, *2*(4), 437-447. https://doi.org/10.1016/j.dcn.2012.04.002

Jarcho, J. M., Davis, M. M., Shechner, T., Degnan, K. A., Henderson, H. A., Stoddard, J., Fox, N. A., Leibenluft, E., Pine, D. S., & Nelson, E. E. (2016). Early-childhood social reticence predicts brain function in preadolescent youths during distinct forms of peer evaluation. Psychological Science, 27(6), 821–835. https://doi.org/10.1177/0956797616638319

Jensen-Campbell, L. A., Graziano, W. G., & Hair, E. C. (1996). Personality and relationships as moderators of interpersonal conflict in adolescence. *Merrill-Palmer Quarterly (1982-)*, 148-164.

Juvonen, J., & Galvan, A. (2008). Peer influence in involuntary social groups. *Understanding peer influence in children and adolescents*, 225-244.

Kretsch, N., & Harden, K. P. (2014). Pubertal development and peer influence on risky decision making. *The Journal of Early Adolescence*, *34*(3), 339-359. https://doi.org/10.1177/0272431613489373.

Lam, C. B., McHale, S. M., & Crouter, A. C. (2014). Time with peers from middle childhood to late adolescence: Developmental course and adjustment correlates. *Child development*, *85*(4), 1677-1693. https://doi.org/10.1111/cdev.12235

Laursen, B., & Collins, W. A. (2003). Parent---Child Communication During Adolescence. In *The Routledge handbook of family communication* (pp. 357-372). Routledge.

Laursen, B., & Faur, S. (2022). What does it mean to be susceptible to influence? A brief primer on peer conformity and developmental changes that affect it. *International journal of behavioral development*, *46*(3), 222-237. https:// 10.1177/01650254221084103

Legare, C. H., & Harris, P. L. (2016). The ontogeny of cultural learning. *Child Development, 87*(3), 633–642. http://doi.org/ 870 10.1111/cdev.12542

Mason, M. F., Dyer, R., & Norton, M. I. (2009). Neural mechanisms of social influence. Organizational Behavior and Human Decision Processes, 110(2), 152–159. https://doi.org/10.1016/ j.obhdp.2009.04.001.

Masten, C. L., Eisenberger, N. I., Pfeifer, J. H., Colich, N. L., & Dapretto, M. (2013). Associations among pubertal development, empathic ability, and neural responses while witnessing peer rejection in adolescence. *Child development*, *84*(4), 1338-1354. DOI: 10.1111/cdev.12056

Mastrotheodoros, S., Van der Graaff, J., Deković, M., Meeus, W. H., & Branje, S. (2020). Parent–adolescent conflict across adolescence: Trajectories of informant discrepancies and associations with personality types. *Journal of youth and Adolescence*, *49*, 119-135. https://doi.org/10.1007/s10964-019-01054-7

McCormick, E. M., Qu, Y., & Telzer, E. H. (2016). Adolescent neurodevelopment of cognitive control and risk-taking in negative family contexts. *NeuroImage*, *124*, 989-996. DOI: https://doi.org/10.1016/j.neuroimage.2015.09.063

McLean, K. C., Breen, A. V., & Fournier, M. A. (2010). Constructing the self in early, middle, and late adolescent boys: Narrative identity, individuation, and well-being. *Journal of research on adolescence*, *20*(1), 166-187.

Melby, J. N., & Conger, R. D. (2000). The Iowa family interaction rating scales: Instrument summary. In Family observational coding systems (pp. 49-74). Psychology Press.

Menon, V., & Uddin, L. Q. (2010). Saliency, switching, attention and control: a network model of insula function. *Brain structure and function*, *214*, 655-667. https://doi.org/10.1016/j.aap.2016.08.014

Mirman, J. H., & Curry, A. E. (2016). Racing with friends: Resistance to peer influence, gist and specific risk beliefs. *Accident Analysis & Prevention, 96*, 180–184. https://doi.org/10.1016/j.aap.2016.08.014

Mmari, K., Cooper, D., Moreau, C., Koenig, L., Martinez, M., Mafuta, E., ... & Blum, R. W. (2021). The social context of early adolescents in the Global Early Adolescent Study. *Journal of adolescent health*, *69*(1), S5-S15. https://doi.org/10.1016/j.jadohealth.2021.01.024.

Moed, A., Gershoff, E. T., Eisenberg, N., Hofer, C., Losoya, S., Spinrad, T. L., & Liew, J. (2015). Parent–adolescent conflict as sequences of reciprocal negative emotion: Links with conflict resolution and adolescents' behavior problems. *Journal of youth and adolescence*, *44*, 1607-1622. https://doi.org/10.1007/s10964-014-0209-5

Monahan, K. C., Steinberg, L., & Cauffman, E. (2009). Affiliation with antisocial peers, susceptibility to peer influence, and antisocial behavior during the transition to adulthood. *Developmental Psychology, 45*(6), 1520–1530. https://doi. org/10.1037/a0017417

Nelson, E. E., Jarcho, J. M., & Guyer, A. E. (2016). Social re-orientation and brain development: An expanded and updated view. *Developmental cognitive neuroscience*, *17*, 118-127. https://doi.org/10.1016/j.dcn.2015.12.008

Pajula, J., & Tohka, J. (2016). How many is enough? Effect of sample size in inter-subject correlation analysis of fMRI. *Computational intelligence and neuroscience*, *2016*, 2-2. https://doi.org/10.1155/2016/2094601

Pei, R., Lauharatanahirun, N., Cascio, C. N., O'Donnell, M. B., Shope, J. T., Simons-Morton, B. G., ... & Falk, E. B. (2020). Neural processes during adolescent risky decision making are associated with conformity to peer influence. *Developmental cognitive neuroscience*, *44*, 100794. https://doi.org/10.1016/j.dcn.2020.100794

Poldrack, R. A. (2007). Region of interest analysis for fMRI. *Social cognitive and affective neuroscience*, *2*(1), 67-70. https://doi.org/10.1093/scan/nsm006

Psychology Software Tools, Inc. [E-Prime 3.0]. (2016). Retrieved from https://support.pstnet.com/.

Qu, Y., Fuligni, A. J., Galvan, A., & Telzer, E. H. (2015). Buffering effect of positive parent–child relationships on adolescent risk taking: A longitudinal neuroimaging investigation. *Developmental cognitive neuroscience*, *15*, 26-34. https://doi.org/10.1016/j.dcn.2015.08.005

Rekker, R., Keijsers, L., Branje, S., & Meeus, W. (2019). The formation of party preference in adolescence and early adulthood: How and when does it occur in the multiparty context of the Netherlands? *Young*, *27*(1), 48-68. https:// 10.1177/1103308818757037

Richmond, A. D., Laursen, B., & Stattin, H. (2019). Homophily in delinquent behavior: The rise and fall of friend similarity across adolescence. *International Journal of Behavioral Development*, *43*(1), 67-73. https://doi.org/10.1177/0165025418767058

Rogers, C. R., Chen, X., Kwon, S. J., McElwain, N. L., & Telzer, E. H. (2021). The role of early attachment and parental presence in adolescent behavioral and neurobiological regulation. *Developmental Cognitive Neuroscience*, 101046. https://doi.org/10.1016/j.dcn.2021.101046

Rose A. J., Rudolph K. D. (2006). A review of sex differences in peer relationship processes: potential trade-offs for the emotional and behavioral development of girls and boys. *Psychological Bulletin*, *132*(1), 98–131. https://10.1037/0033-2909.132.1.98

Rose, A. J., & Smith, R. L. (2018). Gender and peer relationships. In Lerner, R. M., Petersen, A. C., & Silbereisen, R. K. (Eds.), *Handbook of adolescent development research and its impact on global policy.*

Ruhl, H., Dolan, E. A., & Buhrmester, D. (2015). Adolescent attachment trajectories with mothers and fathers: The importance of parent–child relationship experiences and gender. *Journal of Research on Adolescence, 25*(3), 427-442. https://doi.org/10.1111/jora.12144

Schachter, E. P., & Ventura, J. J. (2008). Identity agents: Parents as active and reflective participants in their children's identity formation. *Journal of research on Adolescence*, *18*(3), 449-476.

Schriber, R. A., Anbari, Z., Robins, R. W., Conger, R. D., Hastings, P. D., & Guyer, A. E. (2017). Hippocampal volume as an amplifier of the effect of social context on adolescent depression. Clinical psychological science : a journal of the Association for *Psychological Science, 5*(4), 632–649. https://doi.org/10.1177/2167702617699277.

Sebald, H., & White, B. (1980). Teenagers' divided reference groups: Uneven alignment with parents and peers. Adolescence (Vol. XV No, Vol. 15). Roslyn Hts., NY: Libra Publishers.

Shaffer, D., Fisher, P., Lucas, C. P., Dulcan, M. K., & SchwabStone, M. E. (2000). NIMH diagnostic interview schedule for children version IV (NIMH DISC-IV): Description, differences from previous versions, and reliability of some common diagnoses. *Journal of the American Academy of Child and Adolescent Psychiatry, 39*(1), 28–38. https://doi.org/10.1097/ 00004583-200001000-00014.

Sherman, L. E., Payton, A. A., Hernandez, L. M., Greenfield, P. M., & Dapretto, M. (2016). The power of the like in adolescence. *Psychological Science, 27*(7), 1027–1035. https://doi.org/10. 1177/0956797616645673

Simons-Morton, B. G., Pradhan, A. P., Bingham, C. R., Falk, E. B., Li, K., Ouimet, M. C., … Shope, J. T. (2014). Experimental effects of injunctive norms on simulated risky driving among teenage males. *Health Psychology, 33*(7), 616–627. https://doi.org/10.1037/a0034837.

Skoog, T., & Kapetanovic, S. (2022). The role of pubertal timing in the development of peer victimization and offending from early-to mid-adolescence. *The Journal of Early Adolescence, 42*(1), 5-32. https:// https://doi.org/10.1177/02724316211002265

Smetana, J. G., & Rote, W. M. (2019). Adolescent–parent relationships: Progress, processes, and prospects. *Annual Review of Developmental Psychology*, *1*, 41-68. https://doi.org/10.1146/annurev-devpsych-121318-084903

Smorti, M., Guarnieri, S., & Ingoglia, S. (2014). The parental bond, resistance to peer influence, and risky driving in adolescence. *Transportation research part F: traffic psychology and behaviour*, *22*, 184-195. https://doi.org/10.1016/j.trf.2013.12.001

Smetana, J. G., & Rote, W. M. (2019). Adolescent–parent relationships: Progress, processes, and prospects. *Annual Review of Developmental Psychology*, *1*, 41-68. https://doi.org/10.1146/annurev-devpsych-121318-084903

Somerville, L. H. (2013). The teenage brain: Sensitivity to social evaluation. *Current directions in psychological science*, *22*(2), 121-127. https://doi.org/10.1177/096372141347651.

Somerville, L. H., Heatherton, T. F., & Kelley, W. M. (2006). Anterior cingulate cortex responds differentially to expectancy violation and social rejection. *Nature Neuroscience, 9* (8), 1007–1008. https://doi.org/10.1038/nn1728

Steinberg, L., & Silverberg, S. B. (1986). The vicissitudes of autonomy in early adolescence. *Child Development,* 57(4), 841–851.

Taylor, Z. E., Larsen-Rife, D., Conger, R. D., & Widaman, K. F. (2012). Familism, interparental conflict, and parenting in Mexican-origin families: A cultural–contextual framework. *Journal of Marriage and Family, 74*(2), 312-327.

Telzer, E. H., Ichien, N. T., & Qu, Y. (2015). Mothers know best: redirecting adolescent reward sensitivity toward safe behavior during risk taking. *Social cognitive and affective neuroscience*, *10*(10), 1383-1391.

Trucco, E. M., Colder, C. R., Bowker, J. C., & Wieczorek, W. F. (2011). Interpersonal goals and susceptibility to peer influence: Risk factors for intentions to initiate substance use during early adolescence. *The Journal of early adolescence*, *31*(4), 526-547.

Turpyn, C. C., Jorgensen, N. A., Prinstein, M. J., Lindquist, K. A., & Telzer, E. H. (2021). Social neural sensitivity as a susceptibility marker to family context in predicting adolescent

externalizing behavior. *Developmental cognitive neuroscience*, *51*, 100993. https://doi.org/10.1016/j.dcn.2021.100993

van der Meulen, M., Veldhuis, J., Braams, B. R., Peters, S., Konijn, E. A., & Crone, E. A. (2017). Brain activation upon ideal-body media exposure and peer feedback in late adolescent girls. *Cognitive, Affective, & Behavioral Neuroscience*, *17*, 712-723. https://doi.org/10.3758/s13415-017-0507-y

van Hoorn, J., McCormick, E. M., Rogers, C. R., Ivory, S. L., & Telzer, E. H. (2018). Differential effects of parent and peer presence on neural correlates of risk taking in adolescence. *Social Cognitive and Affective Neuroscience*, *13*(9), 945-955. https://doi.org/10.1093/scan/nsy071

Venticinque, J. S., Chahal, R., Beard, S. J., Schriber, R. A., Hastings, P. D., & Guyer, A. E. (2021). Neural responses to implicit forms of peer influence in young adults. *Social Neuroscience*, 1-14. https://doi.org/10.1080/17470919.2021.1911843.

Welborn, B. L., Lieberman, M. D., Goldenberg, D., Fuligni, A. J., Galván, A., & Telzer, E. H. (2016). Neural mechanisms of social influence in adolescence. *Social cognitive and affective neuroscience*, *11*(1), 100-109. https://doi.org/10.1093/scan/ nsv095.

Wentzel, K. R., & Muenks, K. (2016). Peer influence on students' motivation, academic achievement, and social behavior. In Handbook of social influences in school con- texts: social-emotional, motivation, and cognitive outcomes (pp. 13–30).

Weymouth, B. B., Buehler, C., Zhou, N., & Henson, R. A. (2016). A meta-analysis of parent–adolescent conflict: Disagreement, hostility, and youth maladjustment. *Journal of Family Theory & Review*, *8*(1), 95-112.

APPENDIX A

Supplementary Materials for Study 1

Figure A1 Parent-Adolescent Conflict Scale

Child Report on Parents

Thinking about your mom, please tell me how often the following things happened in the past 3 months. **Pensando en tu mamá, por favor dime que tan seguido sucedieron las siguientes cosas en los últimos tres meses.**
Response Categories:
1 = Almost never or never/ Casi nunca o nunca
2= Sometimes/ A veces
3= A lot of the time/ Muchas veces
4= Almost always or always/ Casi siempre o siempre
8= Refusal
9= Don't know

pacm01	Over the past 3 months, how often have you and your mom disagreed with each other? En los últimos tres meses, ¿qué tan seguido estuvieron en desacuerdo tú y tu mamá?
pacm02	How often have you let your mom know that you were angry? ¿Qué tan seguido le dejaste saber a tu mamá que estabas enojado/a con ella?
pacm03	How often has your mom let you know that she was angry? ¿Qué tan seguido tu mamá te dejó saber que ella estaba enojada?
pacm04	You and your mom became very frustrated with each other. Tú y tu mamá se frustraron mucho el uno con el otro/la una con la otra.
pacm05	Over the past 3 months, how often have you and your mom given each other the silent treatment? En los últimos tres meses, ¿qué tan seguido tú y tu mamá se dejaron de hablar a propósito?
pacm06	You and your mom had a small argument or misunderstanding. Tú y tu mamá tuvieron una discusión pequeña o un desacuerdo.
pacm07	You and your mom gave each other dirty looks or rolled your eyes. Tú y tu mamá se dieron miradas feas o se hicieron gestos feos.
pacm08	You and your mom ignored each other. Tú y tu mamá se ignoraron uno al otro/una al otra.
pacm09	How often have you and your mom had a serious argument or fight? ¿Qué tan seguido tú y tu mamá tuvieron una seria discusión o pleito?
pacm10	You and your mom yelled or raised your voices at each other. Tú y tu mamá se gritaron o se levantaron la voz uno al otro/una al otra.

Figure A2 Relationship Quality with Mother Scale

The next set of questions will be about how things are between you and your [MOM/DAD]. Las siguientes preguntas serán sobre como te llevas con tu mama.	
rlqm01 rlqd01	How satisfied are you with your relationship with your [MOM/DAD]? Would you say…

	¿Qué tan satisfecha/o estás en cómo te llevas con tu mamá? Dirías tu...	
	1	Very dissatisfied/Muy insatisfecho/a
	2	Fairly dissatisfied/Más o menos insatisfecho/a
	3	Fairly satisfied/Más o menos satisfecho/a
	4	Very satisfied/Muy satisfecho/a
	8	Refusal
	9	Don't know
rlqm02 rlqd02	How happy are you with the way things are between you and your [MOM/DAD]? Would you say ... ¿Qué tan contento/a estás en como están las cosas entre tú y tu mamá? Dirías tu ...	
	1	Very unhappy/Muy triste
	2	Fairly unhappy/Más o memnos triste
	3	Fairly happy/Algo felíz
	4	Very happy/Muy felíz
	8	Refusal
	9	Don't know
rlqm03 rlqd03	How much do you talk to your [MOM/DAD] about things that you don't want others to know? Is it... ¿Qué tan seguido hablas con tu mamá de las cosas que no quieres que otros sepan?	
	1	Not at all/Nada
	2	A little/Un poco
	3	Somewhat/Algo
	4	Very much/Bastante
	8	Refusal
	9	Don't know

APPENDIX B

Supplementary Materials for Study 2

Table B1 *Descriptive statistics of sample demographics.*

Variable		Frequency	Percent
Age	*M* = 13.3 years	*SD* = 2.2 years, range = 10.0 - 17.9 years	
Gender			
Male		40	40
Female		60	60
Race			
White/Caucasian		63	63
Black/African-American		1	1
Hispanic/Latino		5	5
Asian		6	6
Mixed-Race		22	22
Native-American		1	1
Pacific Islander		1	1
Marital Status			
Married		85	85
Unmarried couple		3	3
Separated		2	2
Divorced		6	6
Never married		2	2
Widowed		2	2
Household Income			
$30,000-$90,000		16	16
$90,000-$120,000		14	14
Over $120,000		70	70

Note: $N = 100$. M = mean, SD = standard deviation.

Table B2 *Results of within-subjects repeated measures ANOVA with endorsement, time, and person as sources of variation and associated interactions.*

Source	SS	df	MS	*F*	*p*-value
Endorsement	2.14	1	2.14	6.22	.014*
Time	2.72	1	2.72	4.77	.031*
Person	4.22	1	4.22	9.15	.003**
Endorsement x Time	.50	1	.50	3.10	.081
Endorsement x Person	8.58	1	8.58	18.50	< .001***
Time x Person	1.26	1	1.26	8.53	.004**
Endorsement x Time x Person	.92	1	.92	5.83	.018*
Residuals	392.86	99	3.97	-	-

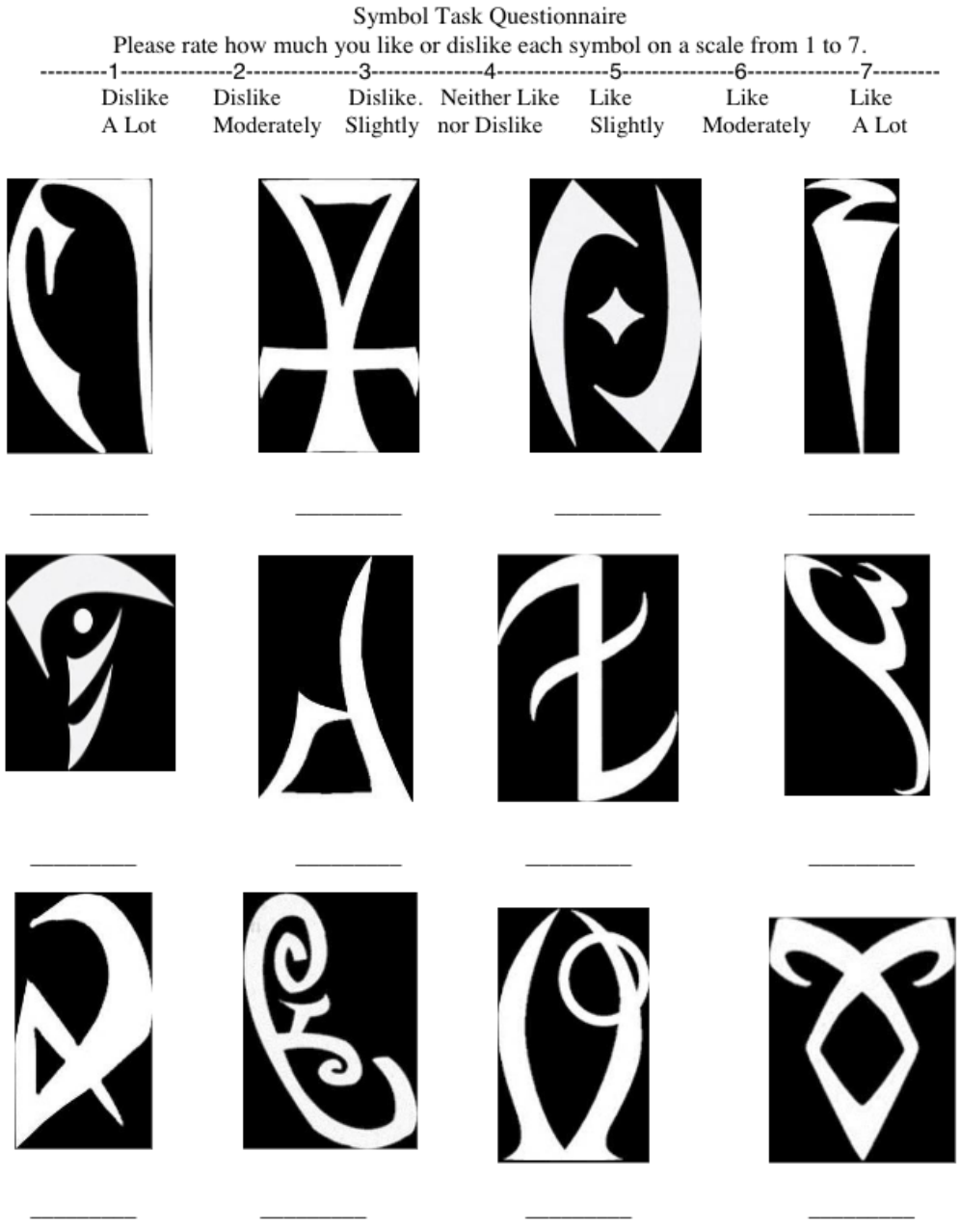
Note: $N = 100$. SS = sum of squares, df = degrees of freedom, MS = mean square, F = f-statistic, *p*-value = significance level, * = significance at $p < .05$, ** = significance at $p < .01$, *** = significance at $p < .001$.

Table B3 *Results of MANOVA test with participant age and participant gender as between-subjects factors on preference for friend not endorsed and mother not endorsed symbols.*

Tests	Λ	F^o	p^o
Pref. for friend and mother not endorsed			
Participant age	.92	2.23	.08
Participant gender	.91	2.61	.10
Participant age x gender	.84	1.20	.23

Note: $N = 100$. Λ = Wilk's Lambda, F^o = *f*-statistic of omnibus multivariate tests, p^o = significance of omnibus multivariate tests.

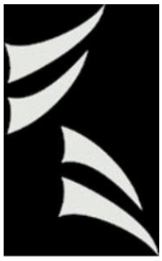
Figure B1 All Rated Symbols











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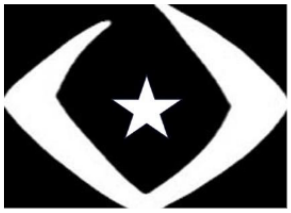
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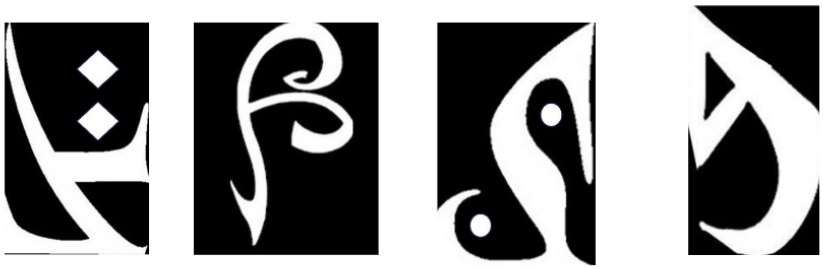
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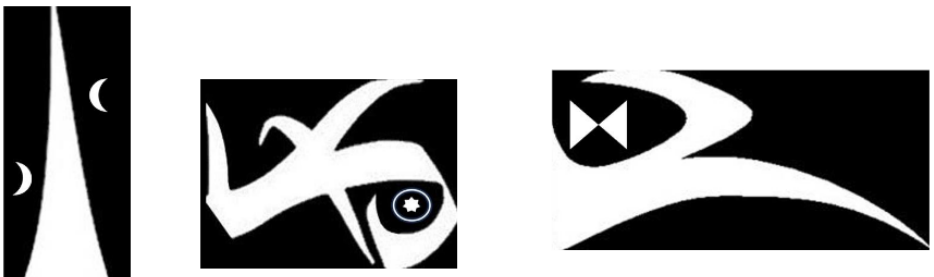


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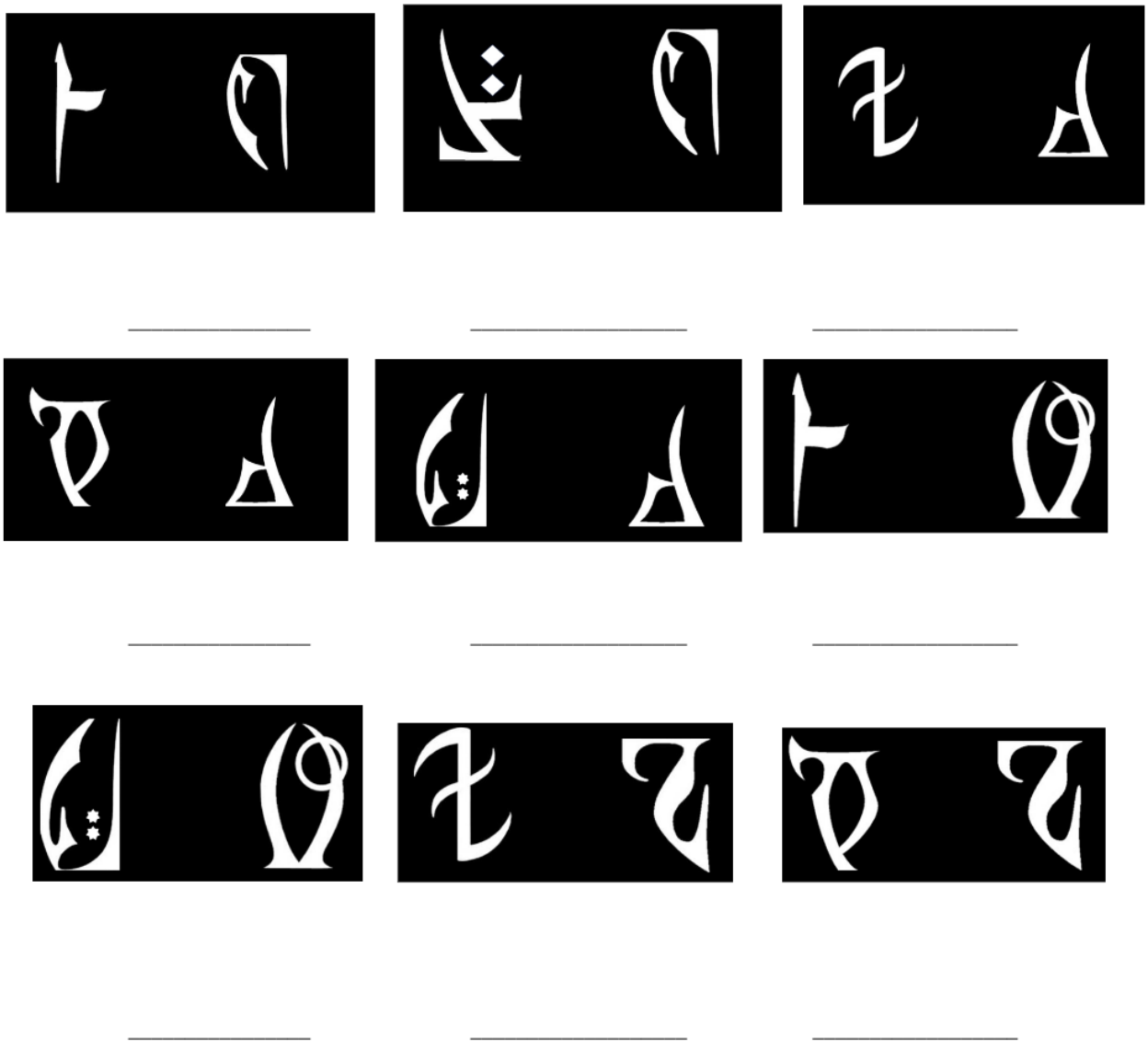




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Figure B2 Sample of Memory Questionnaire

Please indicate which of the symbols in the pair was selected by your **friend**, based on your memory of the computer task. **Write L for left or R for right**.

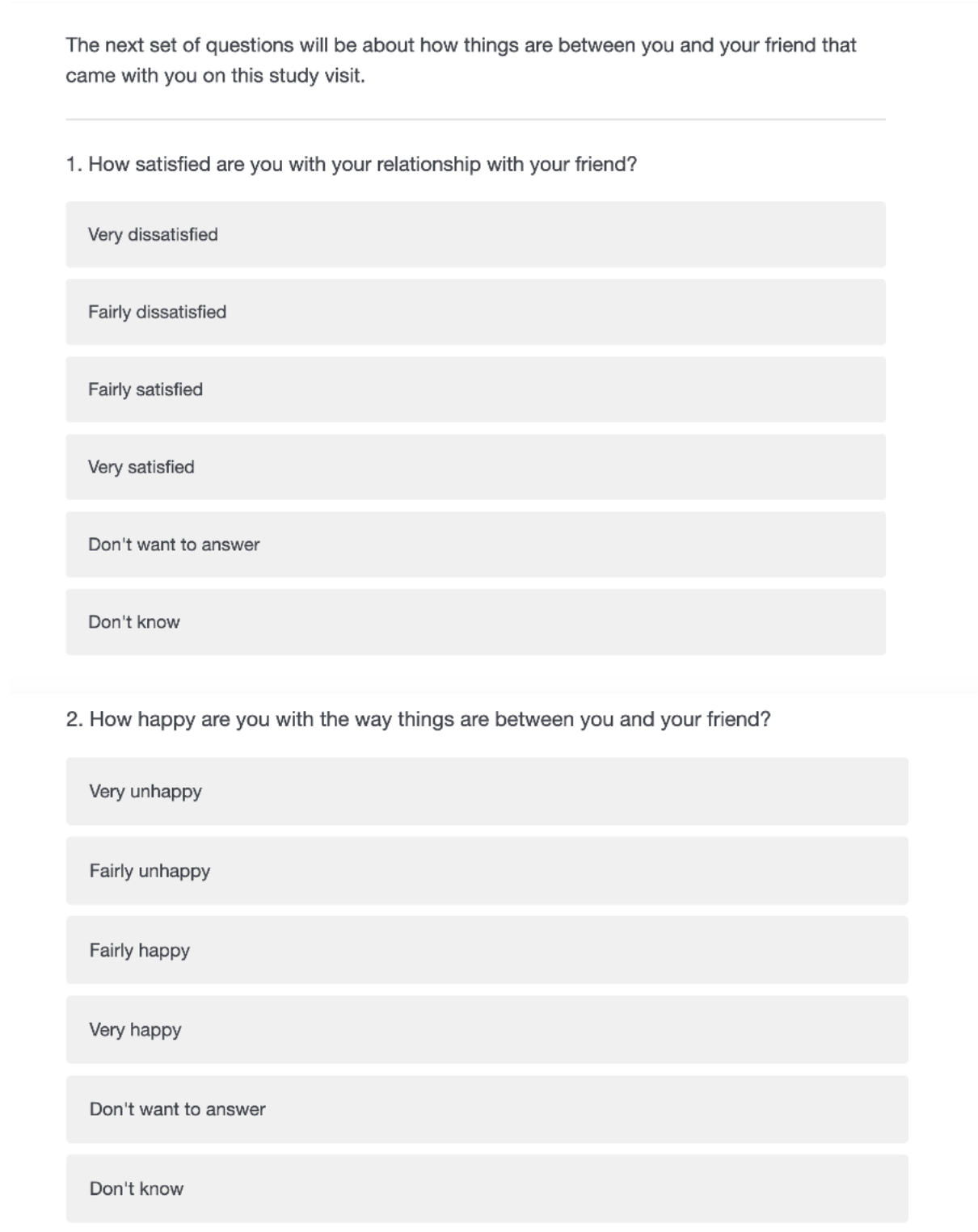


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Figure B3 Relationship Quality with Friend



3. Would you agree or disagree that being being friends has been an enjoyable experience?

- Strongly disagree
- Disagree
- Agree
- Strongly agree
- Don't want to answer
- Don't know

4. How much do you talk to your friend about things that you don’t want others to know?

- Not at all
- A little
- Somewhat
- Very much
- Don't want to answer
- Don't know

Figure B4 Relationship Quality with Mother

1. How satisfied are you with your relationship with your mother?

- Very dissatisfied
- Fairly dissatisfied
- Fairly satisfied
- Very satisfied
- Don't want to answer
- Don't know

2. How happy are you with the way things are between you and your mother?

- Very unhappy
- Fairly unhappy
- Fairly happy
- Very happy
- Don't want to answer
- Don't know

3. Would you agree or disagree that being raised by your mother has been an enjoyable experience?

- Strongly disagree
- Disagree
- Agree
- Strongly agree
- Don't want to answer
- Don't know

4. How much do you talk to your mother about things that you don’t want others to know?

- Not at all
- A little
- Somewhat
- Very much
- Don't want to answer
- Don't know

Figure B5 Free-Response Question Related to Study Manipulation

