Running head: GENE-ENVIRONMENT INTERPLAY BETWEEN PEERS' BEHAVIORS AND SOCIAL RETICENCE

Gene–Environment Interplay in the Link of Friends' and Non-Friends' Behaviors with Children's Social Reticence in a Competitive Situation

Fanny-Alexandra Guimond [1]

Mara Brendgen [1, 2]

Frank Vitaro [2,3]

Nadine Forget-Dubois [4]

Ginette Dionne [4]

Richard E. Tremblay [2,5,6,7]

Michel Boivin [4]

[1] Department of Psychology, University of Quebec at Montreal, Canada, [2] Ste. Justine Hospital Research Centre, Montreal, Canada, [3] School of Psycho-education, University of Montreal, Canada, [4] Department of Psychology, Laval University, Quebec City, Canada, [5] Departments of Psychology, Psychiatry, and Pediatrics, University of Montreal, Canada, [6] International Network for Early Childhood Health Development: University College Dublin, Ireland, [7] INSERM (669), France. Corresponding Author: Mara Brendgen, Ph.D., Department of Psychology, University of Quebec at Montreal, C.P. 8888 succursale Centre-ville, Montreal, Quebec, Canada, H3C 3P8, email: Brendgen.Mara@uqam.ca

Funding was provided by the Social Sciences and Humanities Research Council of Canada, the Fonds Québécois de la Recherche sur la Société et la Culture, the Canadian Institutes of Health Research, and the Fonds de Recherche en Santé du Québec. We thank Jocelyn Malo for coordinating the data collection and Jacqueline Langlois and Hélène Paradis for data management and preparation.

Abstract

This study used a genetically informed design to assess the effects of friends' and non-friends' reticent and dominant behaviors on children's observed social reticence in a competitive situation. Potential gene-environment correlations (rGE) and gene-environment interactions (GxE) in the link between friends' and non-friends' behaviors and children's social reticence were examined. The sample comprised 466 twin children (i.e. the target children), each of whom was assessed in kindergarten together with a same-sex friend and two non-friend classmates of either sex. Multilevel regression analyses revealed that children with a genetic disposition for social reticence showed more reticent behavior in the competitive situation and were more likely to affiliate with reticent friends (i.e. rGE). Moreover, a higher level of children's reticent behavior was predicted by their friends' higher social reticence (i.e. particularly for girls) and their friends' higher social dominance, independently of children's genetic disposition. Children's social reticence was also predicted by their non-friends' behaviors. Specifically, children were less reticent when male non-friends showed high levels of social reticence in the competitive situation, and this was particularly true for children with a genetic disposition for social reticence (i.e. GxE). Moreover, children genetically vulnerable for social reticence seemed to foster dominant behavior in their female non-friend peers (i.e. rGE). In turn, male non-friends seemed to be more dominant as soon as the target children were reticent, even if the target children did not have a stable genetic disposition for this behavior.

Keywords: Social Reticence, social dominance, gene-environment interaction, gene-environment correlation, friends

Gene-Environment Interplay in the Link of Friends' and Non-Friends' Behaviors with Children's Social Reticence in a Competitive Situation

Although most young children enjoy playing with their peers, some deliberately withdraw themselves from the peer group for different reasons. Depending on the child's motivation to withdraw, the general concept of social withdrawal can be subdivided into different subtypes. For instance, *social disinterest* represents children who simply prefer to play alone (Coplan, Prakash, O'Neil, & Armer, 2004), whereas *social reticence* or *anxious-solitude* describe children who would like to play with their peers but are too anxious to do so (Coplan, Rubin, Fox, Calkins, & Stewart, 1994). For these latter children, interacting with new (or even with familiar) peers results in a conflict between their motivation to engage in social interactions and their high level of social fear and anxiety (i.e. approach-avoidance conflict). As a consequence, they often observe their peers from a distance and remain unoccupied (Coplan et al., 1994). Due to their relational difficulties, reticent children often have problems adapting to challenging social situations (Gazelle & Druhen, 2009). In demanding peer situations, withdrawn children tend to generate fewer solutions for social problems, display less prosocial behavior and be less assertive and competitive than other children (Gazelle et al., 2005; Schneider, 1999, 2009). However, self-confidence, social assertiveness and initiative are required for successful adaptation in individualistic and competitive societies (Chen, Cen, Li, & He, 2005) and reticent children have difficulties developing these valued characteristics. Not surprisingly, reticent behavior predicts later psychosocial difficulties such as peer exclusion and internalized disorders such as anxiety and depression (Boivin, Hymel, & Bukowski, 1995; Goodwin, Fergusson, & Horwood, 2004; Ladd, 2006). Because of its multiple negative repercussions, the present study focuses

specifically on social reticence but also draws upon findings regarding other social withdrawal subtypes, since many studies examined social withdrawal as a broader construct.

Peer-Group Dynamics and Children's Social Reticence

Although social reticence is relatively stable across different contexts, recent studies suggest that the expression of children's reticent behavior may be significantly influenced by specific environmental factors such as peers' behavior (Gazelle & Druhen, 2009; Gazelle & Rudolph, 2004). Withdrawn children are less likely to be accepted by their playmates and more likely to experience negative interactions (Gazelle & Rudolph, 2004) and reticent behavior could therefore, at least in part, be a reaction to other peers' behavior. Indeed, research shows that socially reticent children are less assertive and use withdrawn strategies more frequently than other children when confronted with rejecting and excluding peers (Wichmann, Coplan, & Daniels, 2004). This submissive interactional style when dealing with challenging peer situations may cause a vicious cycle whereby withdrawn children's avoidance of social activities with classmates may further enhance their negative peer relations. As a consequence, withdrawn children may become even more anxious and reticent, especially when confronted with assertive or rejecting peers. By the same token, a non-menacing environment with less excluding peers may help reduce the expression of children's social reticence (Gazelle & Ladd, 2003).

Past research has mainly focused on the effect of rejecting and excluding peers on children's reticent behavior. However, challenging peer situations do not only encompass those that are clearly negative (e.g., peer rejection) but also those that involve competition with others for a limited resource. Because they avoid their peers, reticent children miss important social learning experiences that help them deal with social situations that require negotiation and competition (Green & Cillessen, 2008). As a consequence, it may be difficult to compete later on

for valued limited resources such as attractive partners, interesting jobs or limited admittances to higher education programs. It is therefore crucial to better understand how reticent children's behavior in a competitive situation may vary as a function of other peers' behavior. Socially dominant children who efficaciously gain access to a limited resource often use a variety of strategies that may range from aggression to more prosocial behaviors (Green & Cillessen, 2008; Hawley, 2002). Reticent children are not only less likely to utilize these behaviors but the presence of dominant peers in a competitive situation, who are highly successful in gaining access to resources, may prompt reticent children to withdraw even more. It is possible, however, that the effect of peers' dominant behavior on children's social reticence may also depend on the relation that children have with these peers. Indeed, unlike dominant strangers or 'non-friends', the presence of dominant friends may provide social support in stressful situations.

Friendships and Children's Social Reticence

Most socially withdrawn children have at least one mutual and stable friend despite their relational difficulties (Rubin, Wojslawowicz, Rose-Krasnor, Booth-LaForce, & Burgess, 2006; Schneider, 1999). The presence of a friend in a challenging social situation such as a competition may help children achieve their social goals. For instance, LaFreniere and Charlesworth (1987) showed that friend dyads had more access to a limited resource than non-friend dyads in a competitive situation. However, the extent of the advantages gained from having friends in a competitive situation may not be uniform but also depend on the friends' characteristics. For example, Rubin and colleagues (2006) found that withdrawn children and their best friends often seem to share the same psychosocial difficulties and to suffer from similar negative peer treatment. Hence, friendship may not play a protective role when friends are socially reticent, withdrawn or anxious. In line with this notion, the previously cited study of LaFreniere and

Charlesworth (1987) also showed that groups composed of highly dominant friends, who used prosocial, quasi-agonistic (e.g., command, push/pull) and opportunistic behaviors, were more effective in the control of the limited resource than groups mainly composed of low dominant friends, who spent more time on the periphery of the social scene. In a competitive situation, children affiliating with socially reticent friends may therefore behave similarly to how their friends behave. On the other hand, dominant friends may foster the use of effective problem-solving strategies instead of avoiding social difficulties (Burgess, Wojslawowicz, Rubin, Rose-Krasnor, & Booth-LaForce, 2006).

As argued above, peers that are present in a specific situation may have a direct effect on the expression of a child's reticent behavior, depending on their affiliative closeness to the child. To our knowledge, no study has simultaneously examined both the effect of friends' and non-friends' behaviors on preschool children's social reticence in a challenging social situation. The first objective of the present study was therefore to examine the unique effects of friends' and non-friends' reticent behavior on children's observed social reticence in a competitive situation for a limited resource. However, the effects of peers' behavior on children's social reticence may themselves depend on the child's personal characteristics. Indeed, several authors have proposed that children's anxious-withdrawn behavior may be the result of an interaction between the child's predisposition for this behavior and the characteristics of a specific social situation (Fox et al., 2005; Gazelle & Ladd, 2003; Gazelle et al., 2005). The second objective was therefore to examine the role of children's genetic vulnerability for social reticence in the link between their peers' behavior and children's observed social reticence.

The Role of Genetic Risk in the Link between Peers' Behavior and Children's Social Reticence

Findings from genetically informed research such as twin studies suggest that social withdrawal in children is partly explained by genetic factors, with estimates of genetic effects varying between 40% and 75% (Hocksta, Bartels, Hudziak, Van Beijsterveldt, & Boomsma, 2008; Polderman, Posthuma, De Sonneville, Verhulst, & Boomsma, 2005). Genetic influences do not operate independently of environmental influences, however, but may work through different mechanisms of gene-environment interplay, notably via gene-environment correlations (rGE) or gene-environment interactions (GxE). Three types of rGE may play a role in the link between peers' behavior and children's social reticence: *passive*, *active* and *evocative* (Rutter, Moffitt, & Caspi, 2006). A *passive* rGE arises when individuals receive both genetic and environmental risk factors from their parents. For instance, reticent parents, who have passed along their genetic make-up to their child, may act as "architects" of their child's friendship relations (Parke & Buriel, 2007). These parents may befriend other socially reticent parents and their children may be more likely to affiliate with the reticent family friends' children. An *active* rGE occurs when individuals seek out environments consistent with their genetic disposition. For example, children with a genetic disposition for social reticence may be more likely to affiliate with friends with similar behavioral characteristics. Reticent children's friendship affiliations may also result from an *evocative* rGE, which arises when individuals' genetically influenced behavior elicits specific reactions from their environment. Specifically, because of their withdrawn behaviors, reticent children may be ignored as potential friends by dominant children, and may therefore end up forming social bonds with each other by default, rather than by active choice. An *evocative* rGE may also cause children, who are at genetic risk for social reticence, to be more likely than others to evoke dominance and assertiveness in their peers.

GxE refers to a process whereby the degree of exposure to a certain environment moderates the influence of genetic factors on behavior or vice versa (Brendgen, 2012). GxE may correspond to an environmental trigger process, which occurs when environmental conditions exacerbate an individual's genetic predisposition for a specific developmental outcome. For instance, Fox and colleagues (2005) found that children from a family with low social support were more likely to develop behavioral inhibition in middle childhood if they had a specific genetic predisposition (i.e. if they were carriers of the short 5-HTT allele). In line with such an environmental trigger process of GxE, it is possible that non-friends' dominant and possibly intimidating behavior may foster the expression of children's social reticence only (or mostly) for children who are genetically at risk for this behavior. A different GxE may be found in regard to friends' behavior, however. Indeed, friends' social reticence may elicit withdrawn behavior in genetically vulnerable children, as these children may be especially prone to imitating their friends' withdrawn behavior. Hence, exposure to aggressive friends has been linked to increased aggression especially in children who are genetically at risk for aggression (Van Lier et al., 2007) and a similar GxE process may be observed in regard to social reticence. Although rGE and GxE have often been investigated separately, the two processes can co-occur, and the same environmental risk factors may be involved.

The Present Study

The present study used a competitive task for a limited resource in order to examine how reticent preschool children's behavior in a competitive situation may vary as a function of other peers' behavior. The preschool (i.e. kindergarten) period was chosen because early peer relations represent an important source of influence on children's social development (Gazelle & Ladd, 2003) and because kindergarten classes constitute the first structured peer environment that

virtually all children are exposed to. So far, however, little is known about early withdrawn children's friendships and their potential influence on children's own reticent behavior.

The first objective of the present study was to examine the additive and unique effects of friends' and non-friends' reticent and dominant behavior on children's observed social reticence, while controlling for children's genetic disposition for social reticence. The second objective was to examine potential rGE and GxE in the link of friends' versus non-friends' dominant and reticent behavior with children's social reticence. Due to the scarcity of studies on young reticent children's friendships, our hypotheses were based on the previously mentioned studies with older children and young adolescents. Specifically, we expected that children genetically at risk for social reticence may affiliate with friends who have similar psychosocial difficulties, indicating rGE. Friends' reticence may, in turn, further augment children's reticent behavior, and this may be especially true for children with a genetic risk for such behavior (GxE). Moreover, as mentioned previously, children's reticent behavior is likely not only influenced by friends' behavior, but also by the behavior of other peers that are present in a competitive social situation. In that regard, we expected that children genetically at risk for social reticence may foster dominant behavior in other children they interact with, again indicating rGE. In turn, non-friends' dominant behavior may further augment children's social reticence, and this pattern was again expected to be particularly strong for genetically vulnerable children (GxE).

Finally, the third objective was to investigate whether the additive and interactive effects of genetic risk and friends' and non-friends' behavior on children's reticent behavior differ for boys and girls. Several studies have shown that socially withdrawn boys suffer more negative peer-related consequences than withdrawn girls (Coplan et al., 2004; Gazelle & Ladd, 2003). Hence, children may imitate to a lesser extent a male than a female friend's reticent behavior

because social reticence seems to be less normative and accepted for boys. For the same reason, it is also possible that children and their friends take more advantage of reticent behavior shown by male non-friends to increase their chances of gaining access to a limited resource. To test our hypotheses we used a behavioral genetic design based on monozygotic (MZ) and dizygotic (DZ) twins reared together, whose reticent behavior was observed in kindergarten in a competitive situation involving a same-sex friend as well as two non-friend peers of either sex.

Method

Participants

The 233 twin pairs (138 MZ pairs, 95 same-sex DZ pairs) participating in this study were part of a population-based sample of 448 MZ and same-sex DZ twin pairs from the greater Montreal area who were recruited at birth between November 1995 and July 1998. Zygosity was assessed at 18 months based on physical resemblance via the Zygosity Questionnaire for Young Twins (Goldsmith, 1991). For a subsample of these same-sex twin pairs (n = 123), DNA was collected to test for 10 highly polymorphous genetic markers. The comparison of zygosity based on the similarity of these genetic markers with zygosity based on physical resemblance revealed a 94% correspondence rate, which is similar to rates obtained in older twin samples (Forget-Dubois et al., 2003). Eighty-four percent of the families were of European descent, 3% were of African descent, 2% were of Asian descent, and 2% were Native North Americans. The remaining families (9%) did not provide ethnicity information.

The demographic characteristics of the twin families were compared to those of a sample of single births that is representative of the large urban centers in the province of Quebec (SantéQuébec, Jetté, Desrosiers, & Tremblay, 1998) when the children were 5 months of age. The results showed that the same percentage (95%) of parents in both samples lived together at

the time of birth of their child(ren); 44% of the twins compared to 45% of the singletons were the first born children in the family; 66% of the mothers and 60% of the twins' fathers were between 25 and 34 years old compared to 66% of mothers and 63% of fathers for the singletons; 17% of the mothers and 14% of the twins' fathers had not finished high school compared to 12% and 14% of mothers and fathers respectively for the singletons; the same proportion of mothers (28%) and fathers (27%) in both samples held a university degree; 83% of the twin parents and 79% of singleton parents were employed; 10% of the twin families and 9% of the singleton families received social welfare or unemployment insurance; finally 30% of the twin families and 29% of the singleton families had an annual total income of less than CAN$30,000, 44% (42%) had an annual total income between CAN$30,000 and CAN$59,999; and 27% (29%) had an annual total income of more than CAN$60,000. These results indicate extremely similar socio-demographic profiles in the twin sample and the representative sample of single births.

The sample was followed longitudinally at 5, 18, 30, 48, and 60 months focusing on a variety of child-related and family-related characteristics. A sixth wave of data collection was completed at six years of age to assess children's social adaptation in kindergarten. The present paper describes findings from the data collection in the spring of the kindergarten year and the average age at assessment was 72.7 months (3.6 *SD*). To be included in the present study, twins needed to have participated in the observational task in kindergarten (n = 233 twin pairs) and there was therefore no missing data. Twins participating in the observational task did not differ from those who did not participate in regard to child temperament or any of the socio-demographic measures mentioned previously at 5 months.

Procedure

Active written consent from the parents of all children in the classroom as well as verbal assent from all children was obtained. Data collection took place in the spring to ensure that the children knew each other. The sociometric procedure took 45 minutes. The observational task took place in a separate room in school approximately one to two weeks after the first classroom visit. All measures and instruments were approved by the Institutional Review Board and the school board administrators.

Measures

Identification of friends and non-friends. As previously mentioned, the observational task (see also detailed description below) involved each twin child together with one close same-sex friend as well as two non-friend peers of either sex. To identify the friends and non-friends we used sociometric procedures in the twins' classrooms. Classmates' participation rate in the sociometric and friendship nomination task was 75% or higher. Booklets of photographs of all children in a class were handed out to each child in the class. Each child was asked to nominate up to three friends in their class. Because we were interested in friendship relations outside of sibling relationships, twins who were in the same classroom (25%) were not allowed to choose each other as friends. Friendships were considered reciprocal if both the twin and the friend nominated each other as friends. If the first friendship nomination was reciprocated, that friend was chosen for the social interaction task, otherwise the next nominated reciprocal friend was chosen. When a twin did not have a reciprocal friend or the reciprocal friend was not available, either because the friend was not at school on the day of the assessment or because both twins in the same classroom had selected the same best friend, his or her first nominated friend was chosen. In 88% of the cases, the target child (i.e. twin child) interacted with a reciprocal friend. Children observed without a reciprocal friend did not differ from those with a reciprocal

friendship with respect to the study variables. These children were therefore kept in the analyses in order to maximize statistical power to facilitate testing of interactions. Notably, in no case did the two twins of a pair interact with the same friend during the observational task.

In addition to the friendship nominations, all children in the class were asked to circle the photos of three classmates they most liked to play with (positive nominations) and of three children they least liked to play with (negative nominations). These nominations were used to select the two neutral non-friends of either sex present in the observational task. Specifically, in order to be selected, the two non-friends could not be nominated by the twin or his/her close friend as a most or least liked child (nor could the twin or his/her close friend be nominated by the two non-friends as a most or least liked child). The two neutral non-friends also were not friends with each other nor did they actively like or dislike each other. With this group composition (i.e. a twin, his/her close friend, a neutral boy and a neutral girl), we wanted the situation to reflect as much as possible the natural classroom context of the children, which typically comprises peers that a child is friends with and other classmates that a child is not friends with, as well as peers of the same and of the opposite sex. Although friendship nominations were not restricted to classmates of the same sex, close friends were always of the same sex, as is typical for this age period.

Observation of Social Reticence. The observational task was adapted from the Movie Viewer Situation (MV; Charlesworth & LaFreniere, 1983), a semi-structured play situation that elicits competition between children for a limited but attractive resource. The task took place in the spring of the kindergarten year and, as previously mentioned, involved one twin of each twin pair and three other children: the twin's close friend and two other peers from the twin's class (a boy and a girl not nominated as a friend or an enemy). In the task, three official positions were

available: one child could view 3D-images by looking into the MV glasses, a second child needed to press two buttons at the same time in order to turn the light on and a third child had to pull a rope in order to show new images. In summary, two children had to cooperate in order to allow another child to see the images, while the fourth child had no official position. It was through this last position (i.e. bystander position) that reticent behavior could be assessed. Indeed, although the MV task has been mainly used to assess social dominance in young children (see description below), it is also possible to observe children who, although they want to participate in the MV task, withdraw themselves into a bystander position (Guimond et al., 2012; LaFreniere & Charlesworth, 1987).

In previous studies, social reticence has been measured as solitary onlooking and/or solitary unoccupied behaviors in novel situations, notably with peers (Coplan et al., 1994; Rubin, Burgess, & Hastings, 2002). In the present study, solitary onlooking behavior was coded when the child was not involved in any official position and was not waiting for his or her turn but was still observing the other children from a distance. For example, the child was watching other children play but was not standing behind another child waiting for his or her turn nor helping another child. Solitary unoccupied behavior was coded when the child was standing out of reach of the MV box or was retreating from the peer group. For example, instead of participating in the activity or watching his or her peers, the child was wandering on the periphery of the activity. Hence, it was expected that reticent children, although they should be interested in playing with the attractive resource, would retreat from the action because they are anxious and wary in novel situations (i.e. approach-avoidance conflict) and because they may also lack the social competences and problem-solving strategies required in a challenging social situation.

At the beginning of the task, an assistant explained the rules and the functioning of the MV to the children. Then, the assistant left the room and started a chronometer. Children had a maximum of seven minutes to play with the MV box and were video-taped. All children were observed continuously with the software *The Observer* with an event-sampling procedure. For each code, a percentage of time was calculated (i.e. the time during which the behavior occurred divided by the total time). Before the official coding began, the four coders were trained for reliability. They first had to code several "practice" cases in order to achieve preliminary inter-coder reliability (i.e. 70%) and then three specific cases were coded simultaneously for whom the coders had to achieve acceptable inter-coder reliability (i.e. 80%). Next, inter-coder reliability for solitary onlooking behavior and for solitary unoccupied behavior, respectively, was assessed on a randomly selected group of children representing seven percent of the total sample (i.e. 45 of 682 children). Both behaviors showed acceptable inter-coder reliability (*kappa* = .94 for solitary onlooking behavior and *kappa* = .72 for solitary unoccupied behavior). Solitary onlooking and solitary unoccupied are two distinct constructs of social reticence but were significantly correlated with each other in the twins ($r = .30$, $p < .001$), the friends ($r = .28$, $p < .001$), the male non-friends ($r = .33$, $p < .001$), and the female non-friends ($r = .27$, $p < .001$), and were therefore combined into a composite score of social reticence, separately for each twin ($M = 19.82$, $SD = 11.64$), his/her friend ($M = 18.36$, $SD = 11.01$), the male non-friend ($M = 22.06$, $SD = 12.19$) and the female non-friend ($M = 21.67$, $SD = 12.67$). Twin's observed social reticence was positively associated with peer nominations and teacher ratings of twins' social withdrawal in grade 1, respectively ($r = .17$, $p < .01$; $r = .18$, $p < .01$). These correlations were very similar to those found in other studies between different informants for inhibition, anxious-solitude and social reticence, ranging from $r = .19$ to $r = .24$ (Gazelle, 2006; Rubin et al., 2002).

Observation of Social Dominance. Social dominance of friends and non-friends was also measured in the MV task. Social dominance in the present study was conceptualized as an asymmetry in the resource control (Hawley, 2002; Plusquellec, François, Boivin, Pérusse, & Tremblay, 2007) without regard for the specific strategies children used to gain access to the resource. First, resource control was coded when a child was watching the interesting images through the MV glasses (i.e. the limited resource). For each child, a percentage of time was calculated for the resource control (i.e. the time during which the behavior occurred divided by the total time; *kappa* = 1). Social dominance as an asymmetry in the resource control was then calculated (i.e. the percentage of time the child controlled the resource divided by the total time the resource was controlled by any children), separately for each twin's same-sex friend (*M* = 28.62, *SD* = 16.59), male non-friend (*M* = 22.81, *SD* = 17.07) and female non-friend (*M* = 21.66, *SD* = 16.84). A Repeated Measures MANOVA, performed separately for each half of a twin pair to account for interdependence of the twin data, revealed no difference between the twin, the friend, and the non-friends in regard to the level of social reticence and social dominance in the MV situation (twin #1, *Wilks Lambda* = .99, *p* = .98, and twin #2, *Wilks Lambda* = .99, *p* = .98).

Results

Estimation of Genetic and Environmental Effects on Children's Social Reticence

The twin design makes it possible to assess the relative role of genetic factors and environmental factors associated with a given phenotype (Falconer, 1989). The examination of intra-pair correlations for MZ twins and same-sex DZ twins can be used to roughly estimate the sources of variability of social reticence in terms of genetic and environmental factors. The relative strength of additive genetic factors on individual differences (a^2) is approximately twice the MZ and same-sex DZ correlation difference, $a^2 = 2(r_{MZ} - r_{DZ})$. The relative strength of shared

environmental factors that affect twins within a pair in a similar way (c^2) can be estimated by subtracting the MZ correlation from twice the DZ correlation, $c^2 = 2r_{DZ} – r_{MZ}$. Non-shared environmental factors that uniquely affect each twin in a pair (e^2) are approximated by the extent to which the MZ correlation is less than 1, $e^2 = 1–r_{MZ}$. In the present study, the MZ correlation for reticent behavior (r = .35) appears to be almost twice as high as the same-sex DZ correlation (r = .19), suggesting a substantial contribution of genetic factors, whereas shared environmental influences may play only a small role. Still, the overall magnitude of the MZ correlation was well below 1.0, indicating a significant contribution of nonshared environmental factors.

Calculation of Genetic Risk for Reticent Behavior

An ordinal scale of genetic risk for socially reticent behavior was computed based on a formula developed by Ottman (1994). This method has been used in several studies to test the presence of rGE and GxE with an epidemiological twin design (Brendgen et al., 2009; Jaffee et al., 2005; Wichers et al., 2009). Each twin pair was represented in the data set twice, with each twin serving as “the target twin” and also as the other twin’s “co-twin”. For each target twin, genetic risk for social reticence was computed as a function of (a) zygosity and (b) the presence or absence of social reticence in the co-twin. To represent presence or absence of reticent behavior, the twins’ observed social reticence in the MV task was dichotomized using the 75th percentile as the cutoff. The 75th percentile was chosen as a cutoff (a) because a similar cut-off has been used in previous studies on social withdrawal (Booth-LaForce & Oxford, 2008; Coplan, Girardi, Findlay, & Frohlick, 2007) and (b) because it ensured sufficient sample size at the different levels of the genetic risk factor.

Children whose social reticence score was at or above the 75th percentile value of the sample distribution were considered as being socially reticent. Children whose social reticence

score was below the 75th percentile value of the sample distribution were considered as not being reticent. The presence or absence of social reticence in the co-twin was then combined with information on the pair's zygosity into an index of genetic risk for reticent behavior. Hence, the target twin's genetic risk for reticent behavior was considered to be highest when he or she was part of an MZ pair and when reticent behavior was present in the co-twin. The target twin's genetic risk for reticent behavior was somewhat lower when he or she was part of a DZ pair and when reticent behavior was present in the co-twin. The target twin's genetic risk for social reticence was even lower when he or she was part of a DZ pair and when the co-twin was not reticent. Finally, the target twin's genetic risk for social reticence was lowest when he or she was part of an MZ pair and when the co-twin was not reticent. The number of boys and girls at each level of genetic risk for social reticence is provided in Table 1. It is important to note that the genetic risk index is intended to be understood within a behavioral genetic design and does not mean that MZ twins are more likely to develop socially reticent behavior than DZ twins.

For the logic of the ordinal genetic risk index, it was important to ensure that MZ and DZ twins did not differ in regard to their friends' and non-friends' behaviors. Generalized estimating equations (GEE) were performed with the Statistical Package for the Social Sciences (SPSS) v.19 software (Norusis, 2011). The analyses revealed no differences between MZ and DZ twins for their friend's reticent behavior (*ß* = .07, *SE* = .10, *p* = .47), the male non-friend's reticent behavior (*ß* = .06, *SE* = .10, *p* = .54), the female non-friend's reticent behavior (*ß* = -.09, *SE* = .09, *p* = .37), the friend's dominant behavior (*ß* =.03 , *SE* = .09, *p* = .74), the male non-friend's dominant behavior (*ß* = .13, *SE* = .10, *p* = .18) and the female non-friend's dominant behavior (*ß* = -.17, *SE* = .10, *p* = .09).

Assessment of Gene-Environment Correlations (rGE)

Multilevel regression analyses (see further details below) were performed to assess a) rGE between the twins' genetic risk for social reticence and their friends' and non-friends' reticent and dominant behavior and b) the moderating role of child sex in the link between twins' genetic risk for social reticence and their friends', as well as non-friends' behaviors. The results showed a small positive association between the twin's genetic risk for social reticence and his/her friend's reticent behavior, revealing a significant rGE (*ß* = .09, *SE* = .04, *p* = .05). However, there was no association between the twin's genetic risk for social reticence and his/her friend's dominant behavior (*ß* = .05, *SE* = .05, *p* = .32). Regarding non-friends' behaviors, there was no significant association between the twin's genetic risk for social reticence and the male non-friend's social reticence (*ß* = -.06, *SE* = .05, *p* = .17) or dominance (*ß* = .09, *SE* = .05, *p* = .32) There was also no significant association between the twin's genetic risk for social reticence and the female non-friend's social reticence (*ß* = -.03, *SE* = .05, *p* = .48). However, a significant positive rGE emerged between the twin's genetic risk for social reticence and the female non-friend's dominant behavior (*ß* = .10, *SE* = .05, *p* = .03). The lack of moderation by the twin's sex suggested that none of these associations significantly differed for girls and boys.

Main Analyses: Analytical Rationale

Using SPSS v.19 software, multilevel regressions were performed for the analysis of our hierarchically structured data. In a two-level model, a hierarchy consists of lower-level observations (i.e. level 1) nested within higher-level observations (i.e. level 2). In the context of the present study, each individual twin is nested within a sibling pair. In the present study, the level 1 unit of analysis thus represents each individual twin, whereas the level 2 unit of analysis represents each individual sibling pair. The level 1 variance estimates describe the degree to which twins within a pair differ from each other (i.e. within-pair variance), whereas the level 2

variance estimates indicate the degree to which twin pairs differ from one another (i.e. between-pair variance) with respect to the dependent variable. Child-specific predictors were included in the multi-level regression analyses as fixed effects. The fixed effect estimates provide information about the unique link between each predictor (i.e. the twin's sex and genetic risk for social reticence and the friend's and non-friends' behaviors) and the dependent variable (i.e. the twin's social reticence). To control for the overlap between peers' social dominance and reticence when predicting twin's social reticence, the two behaviors were regressed on each other (separately for friends', male non-friends' and female non-friends' behaviors) and the residuals were used as predictors in all analyses. To minimize problems due to multicollinearity and to facilitate interpretability of the regression parameters, all of the study variables except sex were z-standardized prior to creating interaction terms.

Two sets of consecutive models were estimated where each subsequent model was compared to the preceding one to evaluate whether the inclusion of additional predictors provided a better fit to the data. Goodness of fit for each model was evaluated based on the –2log likelihood estimate and a likelihood ratio test was used to evaluate the difference in fit between subsequent models.

Main Analyses Results: Predictive Effects of Friend's and Non-friends' Social Reticence

Table 2 presents the results from the first set of multilevel analyses, which assessed the unique predictive effect of the friend's and the non-friends' social reticence on the twin's social reticence. The first model tested was an unconditional model, without including any predictors, which provided preliminary information about the total within-pair (i.e. level 1) and between-pair (i.e. level 2) variance of reticent behavior. In the second model, the twin's sex and genetic risk for social reticence, as well as friend's reticence and male and female non-friends' reticence

were added to the equation as fixed effects. Inclusion of these predictors resulted in a significantly improved model fit compared to the previous model (Likelihood Ratio Difference = 34.8 (5), $p < .001$). Specifically, genetic risk for social reticence was positively associated with observed social reticence (*ß* = .20, *SE* = .04, $p < .001$). The friend's reticence was also positively associated with the twin's reticent behavior (*ß* = .21, *SE* = .04, $p < .001$). In contrast, the male non-friend's reticence was negatively associated with the twin's reticent behavior, albeit only with a statistical trend (*ß* = -.08, *SE* =.04, $p = .06$). No association emerged between the female non-friend's reticence and the twin's reticent behavior, however (*ß* = -.01, *SE* = .04, $p = .90$).

In the third model, six two-way interaction terms were added: "friend's reticent behavior * genetic risk", "friend's reticent behavior * twin's sex", "male non-friend's reticent behavior * genetic risk", "male non-friend's reticent behavior * twin's sex", "female non-friend's reticent behavior * genetic risk" and "female non-friend's reticent behavior * twin's sex". These interactions served to test whether the effects of the friend's and the non-friends' reticent behaviors on the twin's observed reticent behavior were moderated by the twin's genetic risk or sex. Results showed a significant interaction effect between the friend's reticent behavior and the twin's sex (*ß* = -.19, *SE* = .09, $p = .03$). Probing of this interaction revealed that the friend's reticence predicted the twin's reticent behavior more strongly for girls (*ß* = .31, *SE* = .06, $p < .001$) than for boys (*ß* = .12, *SE* = .06, $p = .05$). Results also showed a significant interaction between the male non-friend's reticent behavior and the twin's genetic risk (*ß* = -.11, *SE* = .05, $p = .02$). To illustrate this interaction, we examined the link between the male non-friend's reticent behavior and the twin's genetic risk for two sample cases: when the twin's genetic risk was very high and when it was very low. The results for these sample cases revealed that, for twins at highest genetic risk for social reticence, the male non-friend's reticent behavior was negatively associated with the twin's own

observed reticent behavior (*ß* = -.28, *SE* = .10, *p* = .01). However, for twins at lowest genetic risk for social reticence, the male non-friend's reticent behavior was not associated with the twin's observed reticent behavior (*ß* = -.01, *SE* = .07, *p* = .83). No other significant interactions emerged. Moreover, three-way interactions were tested and were also found to be non-significant (not shown in Tables 2 and 3 for parsimony).

Main Analyses Results: Predictive Effects of Friend's and Non-friends' Social Dominance

Table 3 presents the results from the second set of multilevel analyses, which assessed the unique predictive effect of the friend's and the non-friends' social dominance on the twin's observed social reticence. The first model tested was again an unconditional model, without including any predictors. In the second model, the twin's sex and genetic risk for social reticence, as well as the friend's and the male and female non-friends' dominant behaviors were added to the equation. Inclusion of these predictors resulted in a significantly improved model fit compared to the previous model (Likelihood Ratio Difference = 81.6 (5), $p < .001$). As before, the twin's genetic risk for social reticence was positively associated with the twin's reticent behavior (*ß* = .19, *SE* = .04, $p < .001$). Moreover, the twin's social reticence was positively associated with his/her friend's dominance (*ß* = .20, *SE* = .05, $p < .001$), as well as with the dominance of the male non-friend (*ß* = .31, *SE* = .05, $p < .001$) and of the female non-friend (*ß* = .36, *SE* = .05, $p < .001$).

In the third model, six two-ways interaction terms were included: "friend's dominant behavior * genetic risk", "friend's dominant behavior * twin's sex", "male non-friend's dominant behavior * genetic risk", "male non-friend's dominant behavior * twin's sex", "female non-friend's dominant behavior * genetic risk" and "female non-friend's dominant behavior * twin's sex". However, no significant two-ways interactions emerged. Moreover, three-way interactions of the

friend's and the non-friends' dominant behaviors with the twin's genetic risk and sex were tested and were also found to be non-significant (not shown in Tables 2 and 3 for parsimony).

Additional analyses were performed to examine whether the additive and interactive effects of the friend's behaviors on children's social reticence varied depending on whether the friendship was reciprocal or not. No moderating effects of friendship reciprocity were found. We also reran the analyses excluding twins with non-reciprocal friends. These analyses yielded the same results as when twins with non-reciprocal friends were included, with the exception of one interaction (sex * friend's reticent behavior), which only showed a statistical trend.

Discussion

Using an observational competitive situation for a limited resource, the first objective of the present study was to examine the unique effects of friends' and non-friends' reticent and dominant behaviors on children's social reticence. The second objective was to examine potential rGE and GxE in the link between children's genetic disposition, friends' and non-friends' behaviors on children's social reticence. The third objective was to investigate potential sex moderation of the observed pattern of results.

Friends' Behaviors and Children's Social Reticence

Preschool children genetically vulnerable for social reticence were more likely to exhibit reticent behavior in the competitive situation. This result is in line with previous studies with older children and young adolescents suggesting that reticent youth seem to withdraw instead of facing the challenge in difficult social situations (Gazelle & Druhen, 2009; Gazelle & Rudolph, 2004; Wichmann et al., 2004). The results also showed a positive association between twins' genetic disposition for social reticence and their friend's reticent behavior, supporting the hypothesis of a rGE. This finding may be indicative of an active selection process whereby

children with a genetic disposition for social reticence may deliberately choose friends with similar behavioral characteristics. It is also possible that reticent children affiliate with reticent peers by default rather than by choice, either because they are ignored as potential friends by other more extrovert peers (i.e. a possible evocative rGE) or because their equally reticent parents, who have passed along their genetic make-up to their child, shape their child's friendship relations (i.e. a possible passive rGE). In any case, the affiliation with reticent friends seems to decrease the benefits of friendship involvement (Rubin et al., 2006). Indeed, after controlling for genetic risk, the results showed that their friend's reticent behavior predicted a higher level of children's own social reticence.

Reticent children seem to use avoidant strategies to deal with social challenges (Wichmann et al., 2004). Hence, exposure to reticent friends may foster children's use of withdrawn strategies via social learning mechanisms such as social imitation. However, the association between their friend's reticent behavior and children's own social reticence was stronger for girls than for boys. This finding supports the view that, in difficult social situations, boys and girls may differ in their way of behaving with friends. Compared to girls, boys are more competitive and confrontational in interaction with their friends (Brendgen, Markiewicz, Doyle, & Bukowski, 2001; Hartup, 1989). Hence, girls may imitate to a greater extent their friend's avoidant behavior because they may not want to appear as taking advantage of their friend's social reticence. In contrast, boys may imitate to a lesser extent their friend's reticent behavior because they are more competitive and concerned about their status in the peer group than their female counterparts (Berndt, 1981). Moreover, because peer-related consequences are greater for socially withdrawn boys than for socially withdrawn girls, boys may be even less likely to imitate their reticent male friend's behavior (Coplan et al., 2004).

Contrary to our hypotheses, children with dominant friends did not seem to enjoy any advantages from the presence of their friend in the MV situation. It was expected that preschool children would be less inhibited in the presence of a dominant friend, perhaps by being able to take advantage of their friend's privileged access to the resource. However, their friend's dominance was positively related to children's social reticence, independently of their genetic disposition for such behavior. This result is in line with previous findings that reticent middle schoolers use avoidant strategies in familiar peer situations, even in contexts involving friends (Gazelle & Druhen, 2009). Indeed, socially withdrawn children and early adolescents are more inhibited and less competitive with their friends when compared to other friendship dyads (Schneider, 1999, 2009). Withdrawn children's friendships may be less helpful than other friendships (Rubin et al., 2006) and dominant friends may function similarly to overprotective parents (Rubin, Cheah, & Fox, 2001) by doing everything themselves instead of teaching reticent children helpful strategies, therefore unintentionally undermining reticent children's initiative when competing. It is also possible that dominant children deliberately take advantage of others' - even of their friends'- submissive behavior in order to gain access to a desired resource.

Non-Friends' Behaviors on Children's Social Reticence

Children's reticent behavior was also predicted by the behavior of the non-friends that were present in the competitive situation. Specifically, children were less reticent when non-friends showed high levels of social reticence in the competitive situation, and this was particularly true for children who are genetically vulnerable for social reticence. This GxE supports the notion that children's reticent behavior may be the result of an interaction between the children's predisposition for this behavior and the characteristics of a specific social situation (Gazelle et al., 2005). In a less challenging and menacing environment, the expression of

children's disposition for social reticence may thus be reduced. However, this GxE was only true with respect to male non-friends' reticent behavior. This result is in line with previous studies showing that social withdrawal is less normative and accepted for boys, who therefore suffer more peer-related consequences than reticent girls (Coplan et al., 2004). Reticent children may therefore have been more inclined, to some extent, to take advantage of a male non-friends' reticent behavior because this behavior may be less normative and easier to have power over.

Children were also more reticent when non-friends were highly dominant, independently of their genetic disposition. This result is in line with previous studies on social dominance in the MV Situation (Charlesworth & LaFreniere, 1983; LaFreniere & Charlesworth, 1987). These studies showed that less dominant children tend to retreat instead of compete when confronted with dominant familiar peers. However, non-friends' dominance may also have occurred in part as a reaction to the target children's reticence. In line with this notion, our findings indicated a significant rGE between children's genetic disposition for social reticence and female non-friends' dominant behavior. Specifically, female non-friends were more dominant when interacting with children who were genetically vulnerable for social reticence. This result strongly suggests an evocative rGE: children with a genetic predisposition for social reticence seemed to elicit dominance in their female non-friends classmates. In contrast, male non-friends seemed to be more dominant as soon as the target children were reticent, even if the target children did not have a stable genetic disposition for social reticence. Competition and confrontation are less normative for girls than for boys, particularly when interacting with friends (Brendgen et al., 2001; Hartup, 1989). Girls may therefore be more inclined to take advantage of another child's social reticence if they are not friends with that child and if the child has a consistent tendency for social reticence. Since the female non-friends were in the same class as

the target child, they knew about the child's disposition for social reticence and may therefore have been more inclined to take advantage of that "vulnerability" in the competitive situation.

Strengths, Limitations, and Conclusions

The present study has a number of positive features. It is the first to use a genetically informed design to assess gene-environment interplay in the link between peers' behaviors and children's social reticence. Moreover, the use of an observational task in a relatively naturalistic play situation increased the ecological validity of the study. A further asset is a careful consideration of the social context by distinguishing between friends' and non-friends' behaviors, as well as potential moderating effects of child sex.

Our study also has several limitations that need to be considered when interpreting the results. First, this study did not measure specific genes and used an ordinal scale of genetic risk. This scale, which has been used in several studies (Brendgen et al., 2009; Jaffee et al., 2005; Wichers et al., 2009), allows representing overall genetic risk as an 'observed' variable in the analyses. It thus affords greater statistical power to test complex hypotheses of GxE involving multiple predictors than other quantitative approaches such as SEM based genetic modeling (Ottman, 1994). Moreover, simple effects analysis based on the ordinal genetic risk scale yield findings that are comparable to those obtained from latent univariate genetic (ACE) models (Brendgen et al., 2013; Jaffee et al., 2005). Nevertheless, as previously mentioned, it is important to note that the genetic risk index has to be understood strictly within the context of a quantitative genetic design and cannot be interpreted in an absolute sense. It is also important to keep in mind that this scale only provides a relatively rough approximation of genetic risk and may underestimate to some the extent the relative contribution of genetic effects when compared to findings based on latent genetic ACE modeling. The results should therefore be interpreted

with caution and need to be replicated with larger samples using latent quantitative as well as molecular genetic analyses. Second, although rather naturalistic, the generalizability of the MV situation is limited. It was a snapshot of children's behavior in a very specific situation. Moreover, in the MV task, there was a potential overlap between different subtypes of social withdrawal. Solitary unoccupied behavior, as a component of social reticence, was observed when children were wandering in the periphery of the social scene. However, it is possible that some of this behavior also represented a lack of interest in social interactions (i.e. *social disinterest*) instead of an approach-avoidance conflict (i.e. *social reticence*). Third, the non-friends present in the play situation were neutral in terms of their affiliative closeness with the target children and the target children's friends. The presence of peers that are direct enemies in a competitive situation may exacerbate the association between non-friends' behaviors and children's social reticence, as well as the role of children's friends' behavior in this context. It should also be kept in mind that the external validity of the study is limited given the age composition of the sample. Indeed, the pattern of results may differ at different age periods. In this study, the results did not support the hypothesis that dominant friends may be useful to reticent preschool children in a difficult social situation. However, since friendships become less egoistic and more based on mutual support as children mature (Selman, 1981), dominant friends may be more helpful to reticent children in middle or late childhood.

In a related vein, friendship quality was also not considered in the present study, yet the presence of dominant friends may be beneficial only if the friendship quality is strong. Reciprocity of the friendship did not moderate the link between their friend's dominance and children's reticent behaviors. However, some studies have shown that, even when they are reciprocal, the friendships of reticent children and early adolescents seem to be less close than

those of other children (Rubin et al., 2006; Schneider, 2009), which may explain to some extent why reticent children in our study did not benefit from their friend's social dominance. Nevertheless, further studies should investigate the role of friendship quality in the association between friends' behavior and children's social reticence, as well as potential age differences in this context. Finally, it should be mentioned that sample attrition may have affected at least to some extent the findings of the present study. Although the participants did not differ from nonparticipants in regard to socio-family background or early childhood temperament, the nonparticipants may be different from the children participating in the MV situation on other non-measured variables such as behavioral and social characteristics.

Despite these limitations, the present study offers new insights into the complex interplay between children's genetic disposition and the peer environment in explaining social reticence. The results support the notion that reticent behavior is a function of a child's inherent characteristics and the social context. In that regard, the present findings corroborate the growing literature on a selection process, which may occur as early as kindergarten, whereby children with a genetic disposition for social reticence may deliberately choose friends with similar behavioral characteristics. However, even affiliation with non-reticent friends does not necessarily seem to be beneficial for socially reticent children, at least not when they face socially challenging situations. Together, our findings suggest that established intervention programs aimed at helping socially reticent children should not only target children's own behavior but also include children's friends, whose behavior may otherwise reinforce reticent children's psychosocial difficulties. In this context, social skills training with target children and their friends may not only need to focus on decreasing anxiety and reticence but also on improving the friendship relation and reducing overcontrolling behavior in dominant friends.

References

Berndt, T. J. (1981). Effects of friendship on prosocial intentions and behavior. *Child Development, 52,* 636-643.

Boivin, M., Hymel, S., & Bukowski, W. M. (1995). The roles of social withdrawal, peer rejection, and victimization by peers in predicting loneliness and depressed mood in childhood. *Development and Psychopathology, 7,* 765-785.

Booth-LaForce, C., & Oxford, M. L. (2008). Trajectories of social withdrawal from grades 1 to 6: Prediction from early parenting, attachment, and temperament. *Developmental Psychology, 44*(5), 1298-1313.

Brendgen, M. (2012). Genetics and Peer Relations: A Review. *Journal of Research on Adolescence, 22*(3), 419-437.

Brendgen, M., Markiewicz, D., Doyle, A. B., & Bukowski, W. M. (2001). The relations between friendship quality, ranked friendship preference and adolescents' behavior with their friends. *Merrill-Palmer Quarterly, 47,* 395-415.

Brendgen, M., Vitaro, F., Boivin, M., Girard, A., Bukowski, W. M., Dionne, G., . . . Pérusse, D. (2009). Gene–environment interplay between peer rejection and depressive behavior in children. *Journal of Child Psychology and Psychiatry, 50,* 1009–1017.

Brendgen, M., Vitaro, F., Bukowski, W. M., Dionne, G., Tremblay, R. E., & Boivin, M. (2013). Can Friends Protect Genetically Vulnerable Children From Depression? *Development and Psychopathology, 25,* 277-289.

Burgess, K. B., Wojslawowicz, J. C., Rubin, K. H., Rose-Krasnor, L., & Booth-LaForce, C. (2006). Social information processing and coping strategies of shy/withdrawn and

aggressive children: Does friendship matter? *Child Development, 77*(2), 371-383. doi: 10.1111/j.1467-8624.2006.00876.x

Charlesworth, W. R., & LaFreniere, P. J. (1983). Dominance, friendship, and resource utilization in preschool children's groups. *Ethology and Sociobiology, 4*(3), 175-186.

Chen, X., Cen, G., Li, D., & He, Y. (2005). Social Functioning and Adjustment in Chinese Children: The Imprint of Historical Time. *Child Development, 76*(1), 182-195

Coplan, R. J., Girardi, A., Findlay, L. C., & Frohlick, S. L. (2007). Understanding solitude: Young children's attitudes and responses toward hypothetical socially withdrawn peers. *Social Development, 16*(3), 390-409.

Coplan, R. J., Prakash, K., O'Neil, K., & Armer, A. (2004). Do you "want" to play? Distinguishing between conflicted shyness and social disinterest in early childhood. *Developmental Psychology, 40*(2), 244-258.

Coplan, R. J., Rubin, K. H., Fox, N. A., Calkins, S. D., & Stewart, S. L. (1994). Being alone, playing alone, acting alone: Distinguish among reticence and passive and active solitude in young children. *Child Development, 65*, 129-137.

Falconer, D. S. (1989). *Introduction to quantitative genetics*. Essex, England: Longman Scientific and Technical.

Forget-Dubois, N., Perusse, D., Turecki, G., Girard, A., Billette, J.-M., Rouleau, G., . . . Tremblay, R. E. (2003). Diagnosing zygosity in infant twins: Physical similarity, genotyping, and chorionicity. *Twin Research, 6*, 479-485.

Fox, N. A., Nichols, K. E., Henderson, H. A., Rubin, K. H., Schmidt, L., Hamer, D., . . . Pine, D. S. (2005). Evidence for a Gene-Environment Interaction in Predicting Behavioral Inhibition in Middle Childhood. *Psychological Science, 16*(12), 921-926.

Gazelle, H. (2006). Class climate moderates peer relations and emotional adjustment in children with an early history of anxious solitude: A child × environment model. *Developmental Psychology, 42*(6), 1179-1192. doi: 10.1037/0012-1649.42.6.1179

Gazelle, H., & Druhen, M. J. (2009). Anxious solitude and peer exclusion predict social helplessness, upset affect, and vagal regulation in response to behavioral rejection by a friend. *Developmental Psychology, 45*, 1077-1096.

Gazelle, H., & Ladd, G. W. (2003). Anxious solitude and peer exclusion: A diathesis-stress model of internalizing trajectories in childhood. *Child Development, 74*(1), 257-278.

Gazelle, H., Putallaz, M., Li, Y., Grimes, C. L., Kupersmidt, J. B., & Coie, J. D. (2005). Anxious solitude across contexts: Girls' interactions with familiar and unfamiliar peers. *Child Development, 76*(1), 227-246. doi: 10.1111/j.1467-8624.2005.00841.x

Gazelle, H., & Rudolph, K. D. (2004). Moving toward and away from the world: Social approach and avoidance trajectories in anxious solitary youth. *Child Development, 75*(3), 829-849.

Goldsmith, H. H. (1991). A zygosity questionnaire for young twins: A research note. *Behavior Genetics, 21*, 257-269.

Goodwin, R. D., Fergusson, D. M., & Horwood, L. J. (2004). Early/withdrawn behaviours predict later internalising disorders. *Journal of Child Psychology and Psychiatry, 45*(4), 874-883.

Green, V. A., & Cillessen, A. H. N. (2008). Achievement versus maintenance of control in six-year-old children's interactions with peers: an observational study. *Educational Psychology, 28*(2), 161-180.

Guimond, F. A., Brendgen, M., Forget-Dubois, N., Dionne, G., Vitaro, F., Tremblay, R. E., & Boivin, M. (2012). Associations of mother's and father's parenting practices with children's observed social reticence in a competitive situation: A monozygotic twin difference study. *Journal of Abnormal Child Psychology, 40*, 391-402.

Hartup, W. W. (1989). Behavioral manifestations of children's friendships. In T. J. Berndt & G. W. Ladd (Eds.), *Peer relationships in child development* (pp. 46-70). New-York: John Wiley & Sons.

Hawley, H. H. (2002). Social dominance and prosocial and coercive strategies of resource control in preschoolers. *International Journal of Behavioral Development, 26*(2), 167-176.

Hocksta, R. A., Bartels, M., Hudziak, J. J., Van Beijsterveldt, T. C. E. M., & Boomsma, D. I. (2008). Genetic and environmental influences on the stability of withdrawn behaviour in children: a longitudinal, multi-informant twin study. *Behavior Genetics, 38*, 447-461.

Jaffee, S. R., Caspi, A., Moffitt, T. E., Dodge, K., Rutter, M., Taylor, A., & Tully, L. A. (2005). Nature × nurture: Genetic vulnerabilities interact with physical maltreatment to promote conduct problems. *Development and Psychopathology, 17*(1), 67-84.

Ladd, G. W. (2006). Peer rejection, aggressive or withdrawn behavior, and psychological maladjustment from ages 5 to 12: An examination of four predictive models. *Child Development, 77*(4), 822-846.

LaFreniere, P. J., & Charlesworth, W. R. (1987). Effects of friendship and dominance status on preschooler's resource utilization in a cooperative/competitive situation. *International Journal of Behavioral Development, 10*(3), 345-358.

Norusis, M. J. (2011). *IBM SPSS Statistics 19 Guide to Data Analysis*: Addison Wesley.

Ottman, R. (1994). Epidemiologic analysis of gene-environment interaction in twins. *Genetic Epidemiology, 11*(1), 75-86. doi: 10.1002/gepi.1370110108

Parke, R. D., & Buriel, R. (2007). Socialization in the Family: Ethnic and Ecological Perspectives *Handbook of Child Psychology*: John Wiley & Sons, Inc.

Plusquellec, P., François, N., Boivin, M., Pérusse, D., & Tremblay, R. E. (2007). Dominance among unfamiliar peers starts in infacy. *Infant Mental Health Journal, 28*(3), 324-343.

Polderman, T. J. C., Posthuma, D., De Sonneville, L. M. J., Verhulst, F. C., & Boomsma, D. I. (2005). Genetic analyses of teacher ratings of problem behavior in 5-year-old twins. *Twin Research and Human Genetics, 9*(1), 122-130.

Rubin, K. H., Burgess, K. B., & Hastings, P. D. (2002). Stability and social-behavioral consequences of toddlers' inhibited temperament and parenting behaviors. *Child Development, 73*(2), 483-495.

Rubin, K. H., Cheah, C. S. L., & Fox, N. (2001). Emotion regulation, parenting and display of social reticence in preschoolers. *Early Education & Development, 12*(1), 97 - 115.

Rubin, K. H., Wojslawowicz, J. C., Rose-Krasnor, L., Booth-LaForce, C., & Burgess, K. B. (2006). The best friendships of shy/withdrawn children: Prevalence, stability, and relationship quality. *Journal of Abnormal Child Psychology, 34*(2), 143-157.

Rutter, M., Moffitt, T. E., & Caspi, A. (2006). Gene–environment interplay and psychopathology: Multiple varieties but real effects. *Journal of Child Psychology and Psychiatry, 47*(3-4), 226-261.

SantéQuébec, Jetté, M., Desrosiers, H., & Tremblay, R. E. (1998). *"In 2001…I'll be 5 years old!" Survey of 5-month old infants.* Preliminary report of the Longitudinal Study of Child Development in Québec. Bibliothèque Nationale du Québec.

Schneider, B. H. (1999). A multimethod exploration of the friendships of children considered socially withdrawn by their school peers. *Journal of Abnormal Child Psychology, 27*(2), 115-123.

Schneider, B. H. (2009). An observational study of the interactions of socially withdrawn/anxious early adolescents and their friends. *Journal of Child Psychology and Psychiatry, 50*, 799–806.

Selman, R. L. (1981). The child as a friendship philosopher. In S. R. Asher & J. M. Gottman (Eds.), *The development of children's friendship*. Cambridge: Cambridge University Press.

Van Lier, P., Boivin, M., Dionne, G., Vitaro, F., Brendgen, M., Koot, H., . . . Pérusse, D. (2007). Kindergarten children's genetic vulnerabilities interact with friends' aggression to promote physical aggression. *Journal of the American Academy of Child and Adolescent Psychiatry, 46*, 1080-1087.

Wichers, M., Schrijvers, D., Geschwind, N., Jacob, N., Myin-Germeys, I., Thiery, E., . . . van Os, J. (2009). Mechanisms of gene-environment interactions in depression: evidence that genes potentiate multiple sources of adversity. *Psychological Medicine, 39*, 1077-1086.

Wichmann, C., Coplan, R. J., & Daniels, T. (2004). The social cognitions of socially withdrawn children. *Social Development, 13*(3), 377-392.

Table 1

Number of Boys and Girls by Genetic Risk Status

Genetic Risk Status	Boys	Girls	Total
Highest risk (MZ)	40	31	71
High risk (DZ)	18	26	44
Low risk (DZ)	78	68	146
Lowest risk (MZ)	88	117	205

Table 2

Multilevel Analyses Assessing the Effects of Genetic Risk, Friends' and Non-Friends' Reticent Behavior on Twins' Social Reticence

Model	Predictors	Fixed effect	Standard error	Log likelihood (np)	ΔLikelihood ratio (df)
1	Unconditional model			1302.6 (3)	
2	Sex	-.08	.09	1267.8 (8)	34.8*** (5)
	Genetic risk	.20***	.04		
	Friend's reticent behavior	.21***	.04		
	Male non-friend's reticent behavior	-.08^{T}	.04		
	Female non-friend's reticent behavior	-.01	.04		
3	Friend's reticent behavior * genetic risk	-.04	.04	1251.8 (14)	16* (6)
	Friend's reticent behavior * sex	-.19*	.09		
	Male non-friend's reticent behavior * genetic risk	-.11*	.05		
	Male non-friend's reticent behavior * sex	-.02	.09		
	Female non-friend's reticent behavior * genetic risk	-.05	.04		
	Female non-friend's reticent behavior * sex	-.14	.09		

n = 466. Sex is coded 0 = girls, 1 = boys. np = number of parameters, df = degrees of freedom, ^{T} p < .10; * *p* < .05; ** *p* < .01; *** *p* < .001.

Table 3

Multilevel Analyses Assessing the Effects of Genetic Risk, Friends' and Non-Friends' Dominant Behavior on Twins' Social Reticence

Model	Predictors	Fixed effect	Standard error	Log likelihood (np)	ΔLikelihood ratio (df)
1	Unconditional model			1302.6 (3)	
2	Sex	-.03	.08	1221 (8)	81.6*** (5)
	Genetic risk	.19***	.04		
	Friend's dominant behavior	.20***	.05		
	Male non-friend's dominant behavior	.31***	.05		
	Female non-friend's dominant behavior	.36***	.05		
3	Friend's dominant behavior * genetic risk	-.05	.05	1216.9 (14)	4.1 (6)
	Friend's dominant behavior * sex	-.15	.10		
	Male non-friend's dominant behavior * genetic risk	-.04	.05		
	Male non-friend's dominant behavior * sex	-.08	.10		
	Female non-friend's dominant behavior * genetic risk	-.00	.05		
	Female non-friend's dominant behavior * sex	-.07	.10		

n = 466. Sex is coded 0 = girls, 1 = boys. np = number of parameters, df = degrees of freedom, * $p < .05$; ** $p < .01$; *** $p < .001$.