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Abstract

Objectives: This study examines the relationship between social engagement and loneliness in female and male autistic children and adolescents in school-based social settings. Secondary aims sought to explore the emergence of loneliness across different age groups and differences in social engagement and loneliness between genders.

Methods: This study conducted an analysis of previously collected data from two multi-site randomized control trials. This study included 58 autistic students (29 females, 29 males) between the ages 6 through 18 years. Female and male participants were matched on age and intelligence quotient. Concurrent mixed methods were used to examine participants' social engagement and loneliness.

Results: Findings revealed a significant relationship between joint engagement and loneliness, such that autistic students reported more loneliness when they were mutually engaged with social groups than when they were isolated or alone. Positive correlations between joint engage and loneliness were identified in elementary-age girls and secondary-age boys, suggesting that being mutually engaged with peers leads to increased loneliness. Negative correlations between parallel and loneliness identified in secondary-age boys suggested that boys in close proximity to peers felt less lonely than boys who were mutually engaged with peers. Qualitative analysis of social behaviors indicated that elementary girls and secondary boys were more likely to be mutually engaged or in close proximity to activities, but they had difficulty sustaining this engagement throughout the entire social period. Secondary girls and elementary boys, on the other hand, were more likely to be solitary and less likely to engage with peer groups.

Conclusion: Study findings highlight the relationship between social engagement and loneliness in school-based autistic populations, and that more engagement itself can lead to more loneliness for younger girls and older boys. The influence of age and gender on engagement and loneliness highlights a need to tailor social interventions to leverage existing social strengths.

Keywords

autism, gender, loneliness, school-age, social behaviors, social engagement, social skills

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Introduction

In schools, social relationships are developed in the classroom, during unstructured social periods, and on the playground through participation in conversations, games, and activities.¹ Successful engagement in these social activities requires children and adolescents to react to quick and nuanced social behaviors, and not all children respond in the same ways. Indeed, most individuals gravitate toward people who are more similar to them in terms of interests

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or activities. Autistic students may be at particular disadvantage in these contexts as they may have fewer individuals who match their interests. Observations of autistic students in school unstructured activities often note that they can be found at the periphery of social groups or isolated relative to their peers,² and they report fewer friendships and greater peer rejection.³⁻⁶ These social differences begin in early childhood and persist into adolescence and adulthood.⁷⁻⁹ However, many autistic children are able to connect to peers, and report to having at least one friend.¹⁰⁻¹² Having a mutual friendship has been associated with greater school satisfaction.¹⁰

Social relationships become increasingly salient and complex throughout development, and in adolescence, self-identity is realized through peer group affiliation.¹³ Despite wanting to fit in, autistic adolescents may have less opportunity to form a peer group. They are noted to spend less time socializing with peers,¹⁴ have smaller peer groups, and are less likely to have reciprocal friendships compared to non-autistic counterparts.¹⁵ Adolescent socialization can be daunting—reading and responding appropriately to often rapid and nuanced social cues across varying situations may be particularly challenging as autistic adolescents navigate the social landscape at school. The cumulative impact of ongoing social difficulties can lead to increased internalizing behaviors, such as anxiety and loneliness.¹⁶ Indeed, autistic adolescents report higher levels of loneliness compared to adolescents with attention deficit hyperactivity disorder (ADHD) and neurotypical peers.^{4,17,18}

Research supports the efficacy of social skills interventions on the social outcomes of autistic children and adolescents.¹⁹ While a considerable body of evidence supports social skills interventions in clinic-based settings,¹⁹⁻²³ autistic participants have demonstrated difficulty with generalizing skills to authentic social environments, like schools.²⁴⁻²⁶ To address this issue, a growing body of research has adapted clinic-based interventions for school settings, which allows researchers to support the development and maintenance of social skills within authentic social environments in part by improving the social environment at school, for example, expanding the types of social activities at school that meet the interests of autistic students, or educating the general school population on respecting differences in social behaviors. Moreover, researchers are better able to measure authentic social outcomes, including improvements in social engagement in real-life settings.

Observation protocols using timed interval recording systems to record the occurrence of participants' social behaviors are commonly used to measure participant outcomes. For example, the Playground Observation of Peer Engagement (POPE)²⁷⁻³² was specifically designed to record the engagement states of the autistic participants and their non-autistic peers during unstructured social periods at school. The POPE has been used to evaluate

levels of social engagement in autistic and non-autistic children and adolescents at school,^{26,28,29,31,33} and to capture more qualitative descriptions of participant behaviors and activities within each engagement state.³⁰ Multiple research studies have used the POPE, or adaptations of the POPE, to measure the social behaviors of autistic and non-autistic participants quantitatively and qualitatively within authentic social settings.^{26-29,31-33}

Social comparison

Systematic observation of social engagement within the naturalistic social environment is important because a growing body of research indicates that many autistic individuals use camouflaging to gain peer acceptance.^{34,35} Given that the very nature of camouflage is to blend in, it can be difficult for an observer to detect social camouflaging or the social challenges of autistic youth without a systematic observation protocol. During social interactions, individuals mask autistic behaviors through social imitation and suppressing autistic characteristics.³⁶ Camouflaging to fit in requires (a) an awareness of the extent to which one's own behaviors deviate from the behaviors endorsed by the desired peer group and (b) the ability to observe and imitate the behaviors of others. A benefit of camouflaging for some individuals is access to social opportunities and friendships—individuals who act like their desired peer group are more likely to be accepted. Reported more frequently, though, is that camouflaging is exhausting and can lead to increased anxiety, depression, and a feeling of a lost identity.^{34,37}

Similar to camouflaging, self-reports of loneliness also involve social comparison between oneself and a desired peer group. Feeling lonely likely requires an individual to have knowledge of their desired versus actual friendships and an understanding of their own standing within their social milieu. Some reports indicate that autistic students are at increased risk of peer victimization and bullying and feel the need to camouflage to fit in, creating a great deal of stress on the individual.^{10,37} After a time, a pattern of repeated rejection and victimization may contribute to the development of loneliness.³⁸ Alternatively, loneliness may occur later for autistic students due to an accumulation of many negative social interactions.^{9,38} For example, child age affects whether children report loneliness at school. In separate studies, 7- to 9-year-old autistic students did not endorse loneliness at school,² whereas autistic adolescents reported more loneliness than classmates of the same age.^{3,7,39,40} These findings suggest there may be developmental changes in the way autistic students understand or feel loneliness.

Gender differences in social interactions

Socially constructed gender norms influence the environment in which autistic students socialize.^{34,41} Autistic

students tend to socialize in same-sex peer groups,^{34,42,43} and the social characteristics of female groups in elementary school appear more conducive to camouflaging social challenges compared to male groups.³⁴ Autistic girls' fly-under-the-radar appearance is partly due to their increased likelihood of camouflaging their autistic characteristics.^{44–50} Girls' use of social imitation to fit in makes it easier to blend into the female social landscape.^{38,50} For example, a mixed-methods study found that when elementary children with and without autism socialized at school, autistic girls tended to move in and out of groups, vacillating between being mutually engaged in a group and being alone, while autistic boys tended to wander alone. Autistic girls used compensatory behaviors, such as close proximity and fluid movements, to hide their challenges and to look like non-autistic girls. In contrast, the social behaviors of elementary boys tended to be activity-focused (i.e. structured games with rules), which made it more difficult for autistic boys to mask their social challenges.³² While autistic boys and girls both experience social difficulties at school, there are quantitative (i.e. time spent in joint engage versus solitary) and qualitative (i.e. social activity) differences in their experiences.

Gender differences in social behaviors persist through adolescence. In general, girls evince greater social motivation and desire for friendships than boys,⁵¹ and female friendships have greater closeness and companionship.⁵¹ In 2013, Kuo et al.⁵² found that when adolescent autistic boys socialized, they tended to engage in passive activities like watching television or playing computer games. Autistic adolescent girls were more likely to engage in active social activities, like talking with friends. As female friendships become more intimate in adolescence,⁹ autistic girls may be particularly impacted relative to autistic boys because the central tenets of female friendship map onto the core challenges of autism. Autistic adolescent girls have reported difficulty fitting into female groups due to subtle non-verbal communication styles and relational aggression among non-autistic peers. This may be partially explained by difficulty interpreting implicit social rules in neurotypical female groups.^{53,54} The complexity of female adolescent relationships may lead to camouflage fatigue, making it difficult to sustain effective camouflaging behaviors and leading autistic girls to avoid social interactions altogether.

Research aims

There is substantial research examining social engagement and internalizing behaviors (i.e. loneliness) in autistic children and adolescents. However, most of these studies have been conducted in clinical settings, and less is known about the interaction of social engagement and loneliness within the school context. This study seeks to address this gap in the literature by examining (1) the relationship between social engagement and loneliness in autistic

children and adolescents, (2) the emergence of loneliness across different age groups, and 3) gender differences in social engagement and loneliness.

We hypothesized that higher rates of loneliness would be correlated with increased solitary behavior and that higher loneliness scores would be correlated with increasing age. Finally, the final research objective sought to explore social engagement quantitatively and qualitatively in relation to loneliness in autistic girls and boys.

Methods

The research aims were examined using a secondary exploratory analysis of pre-collected data, in which the data were initially collected during two large multi-site randomized control trials.^{30,38} In the original studies, autistic students participated in social skills interventions across four sites. After the initial assessment to determine eligibility, qualitative and quantitative data were collected on school campuses using surveys and systematic observations. The quantitative and qualitative data (i.e. baseline data collected prior to the start of the intervention) collected in these prior studies were reexamined to address this study's research questions.

Participants

Previously collected data from 58 autistic students from elementary (grade 1–5; $n=40$) and secondary school (grade 6–12; $n=18$) ranging from 6 to 18 years of age ($M=9.79$, $SD=3.61$; elementary ($M=7.58$, $SD=0.90$); secondary ($M=14.71$, $SD=2.16$)) were analyzed in this study. Data were collected from August 2009 through 2012 (elementary), and January 2010 through 2012 (adolescent). Participants had a confirmed diagnosis of autism (Autism Diagnostic Observation Schedule (ADOS))⁵⁵ without intellectual disability (intelligence quotient (IQ) ≥ 67 ; confirmed by the Stanford–Binet Intelligence Scales, Fifth Edition (SB-5)) and were educated in a general education classroom for a minimum of 80% of the school day. The participants were Black/African American (8.3%), White/Caucasian (48.3%), Hispanic/Latinx (11.7%), Asian (22.0%), Mixed Race (8.5%), and did not disclose (1.7%). Descriptive statistics included the mean score on the social communication and stereotyped behaviors/restricted interests domains on the ADOS, the mean abbreviated IQ score on the SB-5, and social communication scores from the Social Communication Questionnaire (see Table 1). Parents indicated participant gender prior to the administration of the diagnostic and cognitive measures.

Males significantly outnumbered females in the original data sets. As such, all autistic female participants were included in this study ($n=29$). Males were randomly selected from the larger male pool and were matched to girls on age and IQ ($n=29$). Independent samples t tests

Table 1. Participant descriptive statistics: mean scores and standard deviations for age, IQ, and ADOS*.

	<i>n</i>	Age	IQ	ADOS SA	ADOS RRB	ADOS OT	ADOS CSS
All	58	9.79 (3.61)	92.19 (18.27)	10.60 (4.39)	10.60 (4.39)	13.39 (5.41)	7.28 (2.31)
Male	29	9.78 (3.60)	92.76 (17.47)	10.61 (4.39)	2.89 (2.20)	13.50 (5.53)	7.32 (2.23)
Female	29	9.80 (3.69)	91.62 (19.33)	10.59 (4.46)	2.69 (1.65)	13.28 (5.38)	7.24 (2.42)
Elementary age	40	7.58 (0.90)	91.30 (19.27)	10.08 (4.32)	2.80 (2.09)	12.88 (5.47)	7.15 (2.33)
Secondary age	18	14.71 (2.16)	94.17 (16.16)	12.94 (6.31)	2.76 (1.52)	14.59 (5.22)	7.59 (2.29)

IQ: intelligence quotient; ADOS: Autism Diagnostic Observation Schedule.

*ADOS variables include Social Affect (SA), Restricted and Repetitive Behavior (RRB), Overall Total (OT), and Calibrated Severity Scores (CSS).

comparing differences in autism severity and demographic variables show no statistically significant differences between female and male participants.

Measures

ADOS. The ADOS⁵⁵ was used to confirm the diagnosis of autism. All ADOS administrators were research reliable. The ADOS is a standardized, semi-structured play-based assessment of autistic symptoms. The ADOS algorithms for the domains of Social Affect and Restricted and Repetitive Behavior were assessed. Items within each domain were scored based on a 3-point scale (0=no impairment to 2=marked impairment) and summed. The ADOS has excellent reliability for distinguishing between children with and without autism. We administered module 3 to elementary, middle, and high school students ($n=54$) due to the level of language ability in the original randomized controlled trials (RCTs). We administered module 4 to older high school students ($n=4$). To account for differences between modules, the ADOS calibrated severity scores are reported.⁵⁶

SB-5. The SB-5⁵⁷ is a standardized test that measures intelligence and cognitive abilities in children and adults. For this study, an IQ score is determined from an abbreviated version using two subtests, yielding an abbreviated, non-verbal, and verbal IQ score. The abbreviated IQ scores are highly correlated with full-scale IQ scores.

Loneliness Rating Scale. The Loneliness Rating Scale⁵⁸ is a standardized 24-item self-report questionnaire measuring children's global feelings of loneliness. The child receives a loneliness score for 16 items rating their loneliness on a 5-point scale (1=not true at all to 5=always true) on statements, such as "I have nobody to talk to" and "I feel alone"). The remaining eight items are filler items that cover hobbies and interests. The summation of items yields a total loneliness score. The higher the score, the higher the rating of loneliness. In 1984, Asher et al. reported high internal consistency (Cronbach's $\alpha=.90$). The Loneliness Rating Scale has been reported as an effective tool for measuring the loneliness construct in autistic students^{5,59} and has a high internal consistency for this population.³

Social engagement measure. The original studies^{27,33} used a systematic observation protocol to record participant behavior during recess and lunch in elementary school and during break and lunch in secondary school. The study by Kasari et al.^{27,31} assessed elementary school-age children using the POPE. The study by Dean et al.³³ and Oti et al.⁶⁰ used the Teen Observation of Peer Interaction (TOPI), an adaptation of the POPE, to observe middle and high school students. Both observation protocols use interval coding to code the presence or absence of predominant engagement states during authentic social settings. Quantitative engagement state codes were established during the live POPE and TOPI observation intervals. In addition, brief field notes record student social activities, peers or peer groups, and affect. An example of qualitative field notes would read "JE" (joint engage), "Playing handball with three boys," "Happy," or "S" (solitary), "wandering the yard alone," "neutral affect." Trained observers, who were research assistants or doctoral students in special education, human development and psychology, or education programs, rated the social engagement of autistic students for two 10- to 15-min observation periods. For the POPE, each interval was 1 min, and coders were trained to observe for 40 s and code for 20 s. TOPI intervals were longer. Coders observed for 1 min and 30 s and coded for 30 s. All coders were trained to reliability criteria of greater than .85 ($K \geq .85$) on playground and classroom observations. We measured reliability between coders for 20% of the sessions; kappa reliability was consistently above .80.

Social engagement scores are the proportion of the total number of observation intervals that a child endorsed each engagement state. For example, a child who was mutually involved in an activity with other children for 8 out of 15 intervals would have a joint engage score of .53. Social engagement was coded as being *solitary* (isolated and not interacting with other students), *parallel* (near other students, but not socially interacting), or *joint engage* (mutually involved in a social activity with one or more peers).

Procedure

Upon completing the consent procedures (parent consent and child assent) in the original studies,^{30,36} participant diagnosis of autism was confirmed, and cognitive testing

Table 2. Mean scores and standard deviations of loneliness, solitary, parallel, and joint engage.

	Loneliness	Solitary	Parallel	Joint engage
All	40.43 (17.44)	42.12 (36.80)	17.82 (25.30)	32.89 (33.35)
Female	36.43 (13.33)	42.12 (36.80)	16.72 (23.61)	36.39 (35.09)
Male	43.80 (19.91)	41.98 (37.70)	18.95 (27.33)	29.26 (31.66)
Elementary	41.46 (18.80)	42.84 (35.35)	12.96 (21.21)	33.71 (31.38)
Secondary	38.83 (15.46)	40.56 (40.80)	28.33 (30.53)	31.11 (38.18)
Elementary				
Female	35.83 (14.14)	38.77 (35.15)	16.26 (27.18)	38.27 (35.02)
Male	45.69 (21.11)	47.12 (35.99)	9.50 (12.03)	28.91 (27.14)
Secondary				
Female	37.22 (12.95)	50.00 (40.62)	17.78 (13.94)	32.22 (37.01)
Male	40.44 (18.28)	31.11 (41.06)	38.89 (39.19)	30.00 (41.53)

was conducted (see measures above). Eligible participants completed the Loneliness Rating Scale.⁵⁸ Social engagement data were collected at school. All students were observed 2 times during unstructured social periods at school (e.g. lunchtime, snack, or recess) for 10 to 15 min per observation period.

Analysis

Quantitative and qualitative data were analyzed using concomitant mixed methods (QUAN + QUAL) to examine the relationship between social engagement (solitary, parallel, joint engage) and loneliness in autistic males and females in elementary and secondary grades. Descriptive statistics, multiple regression analysis, and correlation analyses were used to examine quantitative relationships and to identify between-group differences (male and female; elementary and secondary; higher and lower social engagement), and model fit was evaluated for all models. Bonferroni adjustment for multiple testing was employed, and tests that survived the Bonferroni adjustment were denoted with an asterisk in the results section.

A comparative case study analysis of qualitative field notes was used to examine salient social activities within elementary and secondary male and female groups. The first two authors read through all qualitative field notes and established preliminary codes. After establishing and reaching a consensus on preliminary codes, each person coded independently. Twenty-five percent of the data were double coded. Interrater reliability was assessed using intraclass correlation coefficient (ICC), and coders maintained a strong coding consistency (ICC = .96). Discrepancies were resolved through consensus. The coding procedure occurred as follows. First, we used line-by-line coding of field notes at the individual level to identify participant activities during each 1-min interval. Coders were blind to the age and gender of the participant. Next, we disaggregated field notes by engagement state (solitary, parallel, and joint engage), age, and gender. Then, to determine primary activities, we calculated the frequency that

each primary activity occurred within each group (male and female) and engagement state (joint engage, parallel, and solitary). The number of participants exhibiting behaviors and the total number of intervals in each engagement state were also calculated. Finally, we compared primary activities across cases.

Qualitative and quantitative data analyses were integrated to provide a more detailed description of what joint engage, parallel, and solitary behaviors looked like during authentic social periods and to identify behavioral characteristics that may provide insight into the relationships between engagement and loneliness. This methodology has been used in prior studies,³² and the acknowledgment of behavioral characteristics enabled the observer to identify discrete social behaviors that relate to the participants' engagement.

Results

Descriptive statistics of the primary outcome variables are shown in Table 1. Independent samples *t* tests found no significant gender or age category differences on the descriptive variables. As such, descriptive variables were not included in the following statistical models.

Social engagement and loneliness

Mean scores and standard deviations of outcome variables are presented in Table 2. The majority of time was spent in solitary (overall 42.12%), parallel (overall 17.82%), and joint engage (overall 32.89%). We evaluated two-way and three-way interactions of age category by gender by engagement states (i.e. solitary, parallel, and joint engage) on loneliness. None of the two-way or three-way interactions were statistically significant and were removed from the models. Tests of main effects with loneliness as the outcome variable, gender (female versus male) and age category (elementary versus secondary) as fixed factors, and engagement state (solitary, parallel, or joint engage) as the covariate. The main effect of solitary on loneliness was

not significant ($F(1,36)=0.483, p=.491, \omega^2=0.005$) after adjusting for age and gender. There was a significant main effect of parallel on loneliness ($F(1,41)=7.62, p=.01^*, \omega^2=0.16$), where higher parallel engagement is associated with decreased loneliness. There was a significant effect of joint engage on loneliness ($F(1,41)=6.793, p=.031, \omega^2=0.142$), where students who are more jointly engaged report greater loneliness. There was a significant main effect of gender ($F(1,41)=3.944, p=.054, \omega^2=0.088$), where male students with greater joint engagement report higher levels of loneliness.

We then separated the data by age category (elementary and secondary) and conducted follow-up two-way interaction analyses to test the effect of gender and engagement state (parallel, joint engage, or solitary) on loneliness. Main effects of solitary on loneliness were not significant in elementary age ($F(1,24)=0.167, p=.686, \omega^2=.007$) or secondary age ($F(1,15)=0.706, p=.414, \omega^2=0.05$). Main effects of parallel in the elementary-age category were not significant, ($F(1,24)=3.95, p=.120, \omega^2=0.098$), but were significant in the secondary-age category ($F(1,15)=5.23, p=.259, \omega^2=0.12$). There is a significant interaction effect of gender and joint engagement on loneliness in secondary students ($F(1,14)=5.36, p=.036, \omega^2=0.28$), suggesting a difference in the association between joint engage and loneliness in boys and girls. Secondary boys with higher joint engagement have increased loneliness, whereas the effect is more diminished among girls.

We used correlation analysis to further explore the relationship between engagement (solitary, parallel, joint engage) and loneliness within each subgroup (elementary female and male; secondary female and male). Because of the small sample size in the secondary-age group, we conducted a visual analysis of scatter plot data to confirm outcomes were not driven by outliers. Bivariate correlation analysis findings revealed there were no significant correlations between loneliness and solitary among both elementary and secondary students. There was a significant negative correlation between loneliness and parallel for all participants and the male sample. Finally, there was a positive correlation between loneliness and joint engage for the total sample, secondary males and elementary females (see Table 3).

Social profiles

Qualitative analysis was used to increase our understanding of the quantitative findings, particularly with regard to actual observations at school, and to further explore qualitative group differences that may influence engagement and loneliness. Qualitative results revealed similarities and differences in social behaviors across groups and engagement states. The top three salient activities within each group and in each engagement state are presented in Table 4. Salient activities were determined by the proportion of participants endorsing the activity and the overall

Table 3. Loneliness correlations.

	Solitary	Parallel	Joint engage
All	-.11	-.35*	.38*
Female	-.17	-.29	.41
Male	-.08	-.44*	.39
Elementary age	-.04	-.31	.15
Secondary age	-.23	-.43	.59**
Elementary age			
Female	-.28	-.32	.64*
Male	.03	-.40	.01
Secondary age			
Female	-.40	-.27	.15
Male	-.34	-.59	.89**

*Correlation is significant at the 0.05 level (two-tailed).

**Correlation is significant at the 0.01 level (two-tailed).

time that participants engaged in the activity during the observation interval. It is possible for participants to have engaged in more than one salient activity, and this overlap will result in percentage scores above 100. Results indicate the number of participants within each group who were observed in each engagement state. A representative example of the social engagement of participants for each case is presented.

Elementary female. In the elementary female group, solitary ($n=17$) and joint engage ($n=16$) were the most salient engagement states. Among the 17 girls who spent at least 1 min in solitary, they spent 47.06% of their solitary time wandering, followed by playing by themselves with a ball (35.29%) and jump rope or hula hoop (23.53%). Among the 17 elementary girls who spent at least 1 min in parallel, they spent 41.18% of their parallel time eating near peers, followed by wandering near social groups (35.29%) and sitting/standing near social groups (29.41%). Of the 16 elementary girls who spent at least 1 min in joint engage, they spent 75% of their joint engage time talking, followed by unstructured play (e.g. digging in sand; 37.5%), walking around with a peer, but not talking (18.75%).

Elementary female

- S Digging in a sandbox. Briefly interacts with two boys, then goes back to digging alone.
- S Digging and calls to another boy but boy does not respond
- JE Digging with a girl and talking
- JE Digging and talking with the same girl
- S Digging alone

JE: joint engage.

Secondary female. Solitary was the most salient engagement state in the secondary female group ($n=7$). Among the seven secondary girls in solitary, all girls (100.00%) spent some portion of the observation interval eating and

Table 4. Number (n^*) of participants** in each group and percentage scores of the salient activities in each state.

		Solitary		Parallel		Joint engage	
Female	Elementary	Activities	Girls ($n = 17$)	Activities	Girls ($n = 17$)	Activities	Girls ($n = 16$)
		Wandering	47.06	Eating	41.18	Talking	75
		Ball play	35.29	Wandering	35.29	Unstructured play	37.5
		Hula hoop/Jump rope	12.09	Sitting/Standing	29.41	Walking	18.75
	Secondary	Activities	Girls ($n = 7$)	Activities	Girls ($n = 6$)	Activities	Girls ($n = 4$)
		Eating	100	Eating	100	Talking	100
Wandering		100	Standing/Sitting	50	-	-	
	Classroom	71.43	Classroom	16.67	-	-	
Male	Elementary	Activities	Boys ($n = 19$)	Activities	Boys ($n = 12$)	Activities	Boys ($n = 12$)
		Wandering	68.42	Wandering	64	Talking	83.33
		Ball	36.84	Play structure	64	Play structure	41.67
		Standing/Sitting	31.58	Near group	12	Game	41.67
	Secondary	Activities	Boys ($n = 4$)	Activities	Boys ($n = 6$)	Activities	Boys ($n = 6$)
		Eating	75	Eating	83.33	Talking	100
		Adult	33.33	Computer	50	-	-
		Computer game	33.33	Classroom	25.74	-	-

* n = the total participants within each group who spent a minimum of one 1-min interval in the engagement state.

**Participants may have engaged in more than one of the salient activities during the observation interval, making some percentages greater than 100.

wandering, and 71.43% of these girls stayed in a classroom (eating while reading or studying). Of the six girls in parallel, 100% were eating, 29.41% were sitting or standing near peers, or 16.67% were in a classroom engaging in an activity near peers. The only jointly engaged activity endorsed by secondary girls is talking (100.00%).

Secondary female

- JE Standing at the end of line. Tries to initiate conversation with two girls. They respond briefly. Lots of talking after conversation was initiated.
- JE Still in line with other girls, actively engaged in conversation with other two girls. Mostly they are all looking at each other.
- P Leaves the girls' group and gets a lunch tray. Tries to sit, seems unsure where to sit (no peer asks her to join), so eats standing up. Watching their table eat. Then sits down alone at a desk facing the wall at the end of interval.
- S Eats alone at a desk (not lunch table) against the wall. Does not face toward the lunchroom. Does not look at other kids at all.
- S Eats alone at a desk. Look around once or twice during the interval but not more than 50% of the time.

JE: joint engage.

Elementary male. In the elementary male group, solitary was the most salient state ($n = 19$). Salient solitary activities include wandering (68.42%), solitary ball play (36.84%), and sitting/standing (31.58%). Among the 12 elementary boys who spent at least 1 min in parallel, the salient parallel activities include wandering (64.00%), play structure (64.00%), and hovering near the periphery of a group (12.00%). Among the 12 elementary boys in joint engage,

salient joint engage activities include talking (83.33%), play structure (41.67%), and games with rules (41.67%).

Elementary male

- S Plays alone on bridge (play structure)
- S Brief conversation with peer and adult; becomes frustrated
- S Plays alone in tunnel (play structure)
- S Plays alone, then asks people to play fortune teller
- JE Brief conversation with peers and adult

JE: joint engage.

Secondary male. In the secondary male group, the most salient states were parallel ($n = 6$) and joint engage ($n = 6$). Among the four secondary males in solitary ($n = 4$), individuals were eating (75%), with an adult (33.33%), or playing a computer game (33.33%). Among the six secondary males in parallel, individuals were eating (83.33%), playing on the computer (50%), or reading or watching a movie in a classroom (25.24%). In joint engage, talking was the only activity (100.00%).

Secondary male

- S Eating by himself (four intervals)
- JE Eating lunch together with one male peer (also has autism). Conversation.
- P Eating lunch together. Peer initiation, conversation. Target initiates (does not lead to conversation). A majority of the intervals are parallel.
- P Eating lunch with a peer. Target responds and later initiates. No conversation.
- P Eating lunch with a peer. Occasionally look at each other.

JE: joint engage.

Discussion

This study used mixed methods to examine the relationship between social engagement (solitary, joint engage, parallel) and loneliness in autistic children and adolescents, and the emergence of loneliness across different age groups. Secondary aims sought to explore possible gender differences in the relationship between social engagement and loneliness. Results indicated a greater time in joint engage, and not solitary, was significantly associated with loneliness. Age was associated with parallel, such that secondary students hanging out near groups had lower loneliness scores. The effects of age and gender were evident, such that elementary-age girls and secondary-age boys with greater joint engage also reported greater loneliness than their opposite-gender counterparts. Differences in the qualitative features of joint engagement, parallel, and solitary among girls and boys highlight differing gender-related engagement profiles.

The relationship between joint engage and loneliness was significant for elementary-age girls and secondary-age boys. Compared to elementary boys, elementary-age girls had higher joint engage and lower solitary scores. Yet a closer inspection of field notes suggests that joint engage was not sustained throughout the observation period. Elementary girls vacillated between joint engage and solitary, without sustaining mutual engagement with peers. These findings corroborate the work of Dean et al.,³² in which autistic girls were able to blend into the female social landscape at school by emulating the social behaviors of non-autistic girls.^{32,49,54} Non-autistic girls tend to fluidly move from activity to activity and from peer to peer throughout the duration of recess or other social periods while maintaining joint engagement throughout the observation period.³² Autistic elementary-age girls emulate the fluidity of non-autistic female groups but appear to have difficulty sustaining joint engagement. The relative strength of elementary autistic girls is that they seem to intuitively understand the mechanics of entering social situations. However, missing or misunderstanding nuanced behaviors within social interactions may have led to unsuccessful conversation maintenance. Through a camouflage lens, elementary girls endorsed camouflage *assimilation*,^{34,35} in which girls enacted social behaviors to look like their non-autistic female peers. Within social interactions, however, elementary girls did not appear to endorse camouflage *compensation*^{34,35}—more complex skills necessary to evince the social interactions styles of their non-autistic peers.³⁷ This may also provide a partial explanation for the lack of benefit of parallel on loneliness for elementary girls. Close proximity to non-autistic peer groups is representative of elementary girls' ongoing efforts to join groups and maintain joint engagement. For elementary autistic girls, being on the outside of a group denotes their social difficulties with staying jointly engaged throughout the social period.

Alternatively, they may not have sustained joint engage because of the cognitive load required to socialize at that level. Instead, it may be easier and possibly more satisfying for them to flit between engagement states. It should be noted in this sample, however, adolescent girls spent more time in solitary than in joint engage or parallel. Girls' tendency toward solitary may reflect an increased pressure to fit in and make friends during a developmental stage when social interaction demands become increasingly nuanced and intimate.^{37,61} This finding suggests that, even though camouflaging has been shown to help autistic girls make friends,³⁸ after years of camouflaging to maintain joint engage in female peer groups, autistic adolescent girls may find being alone without camouflaging is less lonely than hiding aspects of their identity to fit in Ryan et al.¹¹ and Halsall et al.³⁷ Future intervention studies should include strengths-based approaches to leverage girls' innate ability to enter social group dynamics and include peer (e.g. peer-mediated interventions⁶ and school personnel training^{27,29}) to help to build a social environment that is supportive and accepting of autistic girls.

The significant effect of parallel on loneliness suggests a benefit of being in close proximity to peers for autistic individuals. Being near peers but not mutually engaged may help reduce cognitive demand and subsequent social stressors indicative of trying to follow rapidly paced social conversations while trying to fit in. Thus, being near peers may be satisfying because it allows autistic individuals to feel socially connected.⁶¹ Qualitative results show a salient parallel activity was eating lunch—participants ate near peers without being actively involved in the conversation. Given that social eating is a universal social bonding activity,⁶² autistic students may benefit from targeted interventions that support social engagement during mealtime. For example, the Remaking Recess intervention^{30,63} uses lunchtime to support social engagement in elementary children. Interventionists facilitate social opportunities between students with and without autism in the school cafeteria by helping autistic students enter peer groups and providing conversation starters to scaffold social conversations. In secondary settings, mealtime social interventions outside of the cafeteria can provide a safe space for autistic students to connect with school personnel and peers. For example, Miles et al.⁶¹ interviewed nine adolescent autistic females about their social experiences in mainstream settings. Participants benefited from adult-facilitated lunchtime clubs, in which girls socialized with a small group of peers in a classroom or in other quiet space on campus.

Significant correlations between joint engage and loneliness and parallel and loneliness were evident in the secondary male sample. Secondary males placed themselves in proximity to peers or peer groups but had difficulties sustaining mutual engagement in shared activities and conversations. This may be due in part to widely accepted gender differences in play among boys and girls. Elementary

boys tend to engage in rough and tumble play and games with rules throughout the duration of recess, and elementary autistic boys have an increased likelihood of being in solitary and not playing the game.^{32,64} As a result, autistic adolescent boys enter secondary school with a smaller social repertoire than typically developing boys, and therefore, being in parallel may feel less overwhelming than joint engage. These findings corroborate qualitative studies in which adolescent autistic boys have expressed difficulty with navigating group dynamics.^{49,65,66} Increased proximity suggests an increased social motivation relative to elementary boys and secondary girls. Yet, significant loneliness scores suggest an awareness of one's actual versus desired relationships, which can increase social stress.^{24,67} Thus, the comparison of one's sense of social competency in the context of desired peer relationships can lead to negative self-evaluations^{13,65} and increased emotional symptoms and reputational concerns.⁶⁵ In contrast, if the adolescent boys in our study exhibited high rates of solitary behavior in elementary school, then the hesitancy to enter and sustain social interactions may be due to a lack of experience with reciprocal joint engagement with peers. Thus, limited joint engagement and subsequent loneliness may be the result of limited opportunities to practice the salient joint engage behavior—conversations.

Contrary to our hypothesis, the effect of solitary on loneliness was not significant. Some autistic students may be content to spend unstructured social periods alone.⁶⁸ Other autistic individuals may avoid taking social risks and join peer groups that are convenient instead of deliberately seeking out opportunities (e.g. joining clubs or going to school functions) to meet friends with shared interests. Some individuals may want friends, but after experiencing social challenges in elementary school,^{25,41} they may avoid social interactions in secondary school—feeling socially incompetent may feel more lonely than being alone. Interestingly, secondary girls had the highest mean of solitary scores. Qualitative analysis revealed that these girls spent more than twice as many observation intervals in solitary compared to parallel and joint engage. These findings may be due to the association between adolescent identity and peer group affiliation,⁶⁹ if autistic adolescents feel self-conscious about their social challenges, they may hang out on the periphery of social groups without developing intimate connections. Adolescent autistic girls have an increased risk of late diagnosis or, due to camouflaging behaviors, missed access to support services,⁶⁹ and the lack of social support at school may perpetuate social difficulties. The male-to-female ratio of autism^{70,71} may also inadvertently exacerbate social difficulties. When autistic girls gain access to social support, groups are likely to be male dominated, which may interfere with girls developing social skills needed to successfully navigate the female social landscape.³⁷ These findings highlight the historic lack of attention of school personnel to the female autism phenotype and the unique social support needed by autistic

females. Successful camouflaging of social difficulties in elementary school can leave adolescent autistic girls with unmet social needs. Practitioners need to be aware of autistic camouflaging and to be able to identify social strengths and challenges and design social interventions for girls accordingly. Future research needs to examine the impact of group gender dynamics on social and loneliness outcomes.

Limitations

While these data provide important information regarding the relationship between engagement and loneliness, as well as gender and age differences in social engagement and loneliness for autistic students, there are also limitations. First, the study's small sample size may have reduced statistical power to detect effects. Second, cross-sectional data were used to examine the differences between elementary- and secondary-age students. Future studies should include larger sample sizes and longitudinal data to examine the impact of social engagement on camouflaging, loneliness, and mental health outcomes over the course of developmental stages. Finally, the observational data were based on interval coding of engagement states and brief qualitative notes. More detailed observation data of the social interactions (e.g. discourse analysis) should be collected to identify more targeted and granular skills needed in these children and adolescents' social repertoire, specifically addressing the individual needs of different ages and gender groups.

Conclusion

The significant relationship between joint engage and loneliness suggests that autistic students may find that the effort they put forth into fitting in does not yield sustained social engagement, or acceptance into their desired peer groups,^{34,36} because the effort to keep up with social dynamics can be overwhelming. Identified age and gender differences highlight differing intervention needs between girls and boys. The relative strength of elementary-aged girls (their ability to enter peer groups and to maintain some joint engagement) coupled with the increased solitary in adolescent girls highlights a specific need for female oriented social skills support. Girls' joint engagement in elementary school may mask their social challenges and therefore limit their access to social support. Practitioners need to be aware of autistic students' potential to camouflage so that they can provide intervention support accordingly.

The most common joint engage activity among all autistic students, regardless of gender, is conversations. This suggests that autistic students may benefit from in vivo support to help them enter social groups and maintain conversations with their peers.^{6,18} Some social skills interventions have broken down steps of social interactions

to help autistic students practice recognizing and appropriately inserting themselves into social situations. For example, the Children's Friendship Training teaches children how to "slip in" to activities and conversations.⁷² Specifically, it teaches children to decide which groups of peers to join and what they should observe and listen to in these group interactions.

To truly facilitate inclusive practices, school-based social interventions should acknowledge the social skill development needs of neurotypical peers. Peer interventions should build autism awareness by teaching peers to recognize differences in social communication styles and to identify their role in creating social environments in which autistic traits are understood and accepted.^{73–75} Neurotypical peers will benefit from interventions to learn and practice strategies to initiate and maintain social interactions and conversation with autistic peers, as well as strategies to support the inclusion of autistic peers into peer groups and social activities.

Declarations

Ethics approval and consent to participate

The study is an analysis of data previously collected in two different prior studies. The original studies had approval from the university institutional review board to conduct the study. Research personnel followed the Human Subjects Research protocol, and all participants had written parent consent and signed assent to participate in the study.

Consent for publication

The authors have approved the work for publication, have agreed to submit the article, and accept full responsibility for the content of the article.

Author contribution(s)

Michelle Dean: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Writing—original draft; Writing—review & editing.

Ya-Chih Chang: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Writing—original draft; Writing—review & editing.

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