

ARTICLE

Friend influence and susceptibility to influence on emotions towards math: The role of adolescent temperament

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Abstract

Background and Aims: Peer relationships during adolescence play an important role in shaping academic outcomes. The present study examined friend influences on emotions towards math, as well as the role of temperament in these influences.

Sample: The sample consisted of 350 Finnish students (mean age 13.29 years; 64% girls) who were involved in stable friendship dyads from fall to spring of Grade 7.

Methods: In this two-wave study, information on adolescents' temperament (i.e., negative emotionality, extraversion, effortful control) and on seven emotions towards math (i.e., enjoyment, hope, pride, anger, anxiety, shame, hopelessness, and boredom) was collected during grade 7. The data were analysed using longitudinal actor-partner interdependence models.

Results: The results showed that friends resembled each other in all the investigated math-related emotions. Furthermore, over and above these initial similarities, friends mutually influenced each other's math-related enjoyment and anger towards math. Students characterized by higher negative emotionality also influenced their friends with lower levels of negative emotionality towards an increase in math-related anger and a lack of effortful control made adolescents more susceptible to friend influence over math-related shame and anxiety.

Conclusion: Our findings demonstrate that friends influence each other over time in math-related enjoyment

Noona Kiuru¹ and Dawn DeLay Shared first authorship.

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and frustration. Furthermore, high negative emotionality may make adolescents more influential over their friends' math-related anger and a lack of effortful control may make adolescents more susceptible to friend influence over math-related shame and anxiety. Thus, the current findings have implications for how peer relations may impact individual outcomes in mathematics, for better or worse.

KEY WORDS

achievement emotions, adolescence, mathematics, peer influence, temperament

INTRODUCTION

Peer relationships play an important role in shaping adolescent academic outcomes (Fulgini et al., 2001; Steenberghs et al., 2023; Valiente et al., 2020). Peer interactions can motivate and encourage academic success or become sources of discouragement and distraction from learning (Crosnoe et al., 2008; Wentzel, 2017). Similarly, emotions associated with learning tasks may promote or hinder academic success (Pekrun, 2017). While peer interactions impact all aspects of the learning environment, mathematics education may be particularly susceptible to the types of learning fears and anxieties that could benefit from supportive peer interactions in the classroom (Foley et al., 2017; Leaper, 2015; Robnett, 2013). Indeed, previous research demonstrates that positive peer interactions in the classroom may influence mathematics success (DeLay et al., 2015). Success in mathematics during adolescence is, in turn, associated with subsequent academic and career outcomes (Lazaraides & Watt, 2015), demonstrating the longer-term impact of early experiences with mathematics. The goal of this study is to investigate the influence of peers on a variety of achievement-related emotions across one school year. Furthermore, we aim to better understand how the temperamental characteristics of youth may open or close the door to peer influence over achievement-related emotions. The findings of will inform our understanding of the possible impact of adolescent peer relationships in influencing achievement-related emotional outcomes.

Student achievement emotions and peer relations

The current study is based on the ideas of the control-value theory of achievement emotions (see Pekrun, 2006, 2017). Many different types of achievement-related emotions are housed under this theory, such as enjoyment, frustration, and boredom as examples of activity emotions, and hope, pride, anxiety, hopelessness, shame, and anger defined as outcome emotions. Finally, the theory holds that control and value are central to the achievement-related emotional arousal that, in turn, impacts academic success or failure outcomes.

The control-value theory of achievement emotions (Pekrun, 2006, 2017) also addresses the issues of antecedents for achievement-related emotional outcomes. For example, these antecedents may be found at both the individual level (e.g., individual characteristics of the target child) and the social level (e.g., peer group characteristics and influences of the target child). During adolescence individuals have an intensified need to be accepted by their peers and, thus, peers become an increasingly important socialization agent for academic behaviours and attitudes (Altermatt & Pomerantz, 2003; Fulgini et al., 2001; Laursen & Veenstra, 2021; Steenberghs et al., 2023). The process of peer influence occurs when peers exert influence on students' academic development across time, resulting in increased similarity among peers (see also Delay et al., 2015).

Most previous research on peer influences has focused on the role of friendships in amplifying different problem behaviours (for a review, see Dishion & Tipsord, 2011; Fuligni & Eccles, 1993; Laursen & Veenstra, 2021). However, contagion and spread of emotions between friends are equally plausible and have received increased attention during the past decade. Accordingly, peer influences have been found to operate in depressive symptoms (Kiuru et al., 2012; Stevens & Prinstein, 2005), school engagement (Kindermann, 2008; Steenberghs et al., 2023), and happiness (van Workum et al., 2013). Although there is some evidence to suggest that friends resemble each other in achievement emotions and that achievement emotions of friends may predict adolescents' subsequent achievement (Reindl et al., 2018), only little is known about the extent of emotion transmission between friends.

Adolescent temperament and peer influence in achievement emotions

Adolescence is a developmental period during which adolescents undergo multiple changes in themselves and their social environment (e.g., Denham et al., 2009). It has been assumed that adolescent temperamental characteristics may play a role in the outcomes associated with this developmental period (Sanson et al., 2004), and these assumptions have been supported by vast empirical research demonstrating the associations between temperament and socioemotional, academic, and school-related well-being (e.g., de Haan et al., 2013; Hirvonen et al., 2018; Zhou et al., 2010).

The current study is largely guided by the developmental model of temperament by Rothbart and colleagues (e.g., Rothbart, 2011; Rothbart et al., 2001). In this model, temperament is seen as constitutionally rooted individual differences in reactivity as well as in the self-regulation processes modulating this reactivity. It is also suggested that extraversion, negative emotionality, and effortful control are the three broader dimensions of temperament that drive behavioural and emotional outcomes. *Extraversion* is characterized by characteristics of positive emotionality and the types of approach behaviours that allow youth to be comfortable with new people and when engaging in new behaviours. *Negative emotionality* is characterized by characteristics that make individual more susceptible to negative environmental cues and more likely to dwell on intense negative feelings with facing disappointment. Finally, *effortful control* is characterized by the forms of self-regulation that will allow adolescents to maintain attention as well as to control their behavioural and affective responses.

The onset and progression of the types of achievement-related emotions that have been demonstrated to impact academic success and failure may also be driven by both temperamental features of the target child (see also Leikoinen et al., 2019) or perhaps by these same characteristics existing in influential peer relationships. Based on Rothbart's model (e.g., Rothbart, 2011; Rothbart et al., 2001) it may be that the more reactive aspects of temperament (e.g., extraversion, negative emotionality) make some individuals more influential over their peers' achievement-related emotional outcomes. The model suggests that higher levels of extraversion are likely to make individuals more approachable and pleasant to be around in the academic setting. Thus, it is likely the case that individuals high in extraversion may have a positive influence towards better peer achievement-related emotional outcomes. In contrast, the model suggests that higher levels of negative reactivity may make individuals more disruptive and less pleasant to be around in the academic setting. Thus, individuals high in negative reactivity may have a negative influence towards worsened peer achievement-related emotional outcomes (see also Belsky & Pluess, 2009). Although the ideas presented here related to the intersection of peer influence and individual temperament have not been empirically tested, they are not only supported by theory but also by individual-level analyses linking temperament to achievement-related emotional outcomes (e.g., Lahdelma et al., 2021; Leikoinen et al., 2019).

Furthermore, individual characteristics in self-regulative aspects of temperament, such as effortful control, may serve to either create susceptibilities to or defences against, these forms of social influence. The Rothbart model suggests that higher levels of effortful control are likely to make individuals less susceptible to peer influence. This is assumed to be because those with heightened levels of effortful control are more likely to maintain focus from the external distractors, such as peer behaviours and

social pressures. These ideas are supported by empirical research demonstrating the power of effortful control in predicting positive attention related outcomes, social-developmental outcomes, and academic success outcomes (Lonigan & Vasey, 2009; Moran et al., 2013; Valiente et al., 2010). Although no empirical evidence has directly assessed how differing levels of reactive emotionality and effortful control within peer relationship dyads will direct the processes of peer influence on academic-related emotional outcomes, we do know that individual levels of emotional reactivity and effortful control predict individual outcomes associated with academic success (e.g., Lonigan & Vasey, 2009; Moran et al., 2013; Valiente et al., 2010). There is also some evidence to suggest that high negative emotionality is related to attentional bias to threat stimuli, but only when accompanied by low effortful control (Lonigan & Vasey, 2009).

THE CURRENT STUDY

The broad goal of the current two-wave study is not only to understand *if* there is evidence of peer influence on achievement emotions during early adolescence but also to take these ideas one step further by beginning to understand *how* and *for whom* this influence is likely to occur. Thus, as a first step we will assess whether there is any evidence of peer influence over achievement-related emotional outcomes within one school year. Then, as a next step, we will begin to investigate how individual temperamental characteristics may drive the influence process for achievement-related emotional outcomes. Specific research questions and related hypotheses follow.

1. Do adolescent friends influence each other's emotions towards mathematics (i.e., enjoyment, hope, pride, anger, anxiety, shame, hopelessness, and boredom)? Concerning this research question, we predict that friends will influence each other's emotions in mathematics (Hypothesis 1; see also, DeLay et al., 2015; Valiente et al., 2020).
2. Do reactive aspects of adolescent temperament (i.e., extraversion, negative emotionality) contribute to transmission of math-related emotions between friends? Concerning this research question, we predict that extraversion will promote transmission of positive math-related emotions (e.g., enjoyment) and that negative emotionality will promote transmission of negative math-related emotions (e.g., anger) between friends (Hypothesis 2; see also Rothbart, 2011).
3. Does the level of adolescents' effortful control (i.e., self-regulative dimension of temperament) moderate their susceptibility to the influence of their friends on emotions towards mathematics? Concerning this research question, we expect that low effortful control increases adolescents' susceptibility to their peers' influence, especially on negative achievement emotions (Hypothesis 3; Lonigan & Vasey, 2009).

The effects of adolescent gender and initial levels of mathematics abilities were controlled in the current study. This is because we know that boys and girls may face different sorts of pressure and influence on mathematics-related outcomes (e.g., Leaper, 2015) and because we know that individuals with heightened mathematics abilities at the onset may also have few vulnerabilities to social disruptions, or external influences, on mathematics-related outcomes (e.g., Foley et al., 2017).

METHOD

Participants

This study is part of a broader longitudinal study that follows a community sample of Finnish students across the transition from primary school to lower secondary school. The students were recruited from central Finland. This study focused on a sample of 350 (225 girls, 125 boys) adolescents

in stable, reciprocated, same-sex friendship dyads during the first year of lower secondary school (i.e., grade 7).

The participants' age ranged from 12 to 14 years (mean = 13.29 years; $SD = .33$), and native language was Finnish in 98% of cases. Most participants lived with both parents in one household (76%) or alternated between their mother and father (10%). In turn, 14% of students lived with only one parent, in blended families, or with somebody else. Four per cent of the mothers and 8% of the fathers reported no vocational education after comprehensive school; 28% of the mothers and 42% of the fathers had completed vocational upper secondary school; 39% of the mothers and 28% of the fathers had completed vocational post-secondary college; and 29% of the mothers and 22% of the fathers had a Master's degree or higher educational level.

Procedure

The original sample consisted of 841 students who participated in the study in Grade 7. Parent consent and child assent were required for participation. All the tests and questionnaires were administered by trained research assistants during normal school days through pen/pencil and paper assessments. The procedures were in accordance with the principles of the Helsinki Declaration on research with human subjects. The research plan of the project was approved by the Human Sciences Ethics Committee of the University of Jyväskylä.

From the original 841 participants, this study focused on the 350 students who were involved in stable, reciprocated friendship dyads during grade 7 (i.e., from fall to spring of the school year). Girls were overrepresented compared to boys among the students who had reciprocal stable friendships in their school class ($\chi^2(1) = 23.34, p < .001$, Cramer $V = .17$). Otherwise, there were no differences in any demographic or study variables between those with and those without stable reciprocated friends (all $ps > .05$).

Measures

Peer nominations

Friendships were assessed in the fall and spring of grade 7 by using a sociometric nomination procedure (Bukowski et al., 2012; Kiuru et al., 2015). Adolescents were asked to nominate up to six rank-ordered classmates with whom they most like spending time during breaks. *Friends* were defined as students who reciprocated preferred affiliate nominations. *Stable friends* were defined as dyads in which the same students reciprocated nominations at both time points (Bagwell et al., 1998). Some participants had more than one stable same-sex friendship. In this case, preference was given to highest rank friendships and every adolescent was included only in one friendship dyad (see also Delay et al., 2015).

Achievement emotions in mathematics

Students' achievement emotions concerning mathematics were measured in the fall and spring of grade 7 with the Finnish version of the Achievement Emotions Questionnaire (AEQ; Pekrun et al., 2011; for validity in the Finnish sample, see Sainio et al., 2021), which was adapted for school age students. The students rated their achievement emotions (enjoyment, hope, pride, anger, anxiety, shame, hopelessness, and boredom) regarding learning, attending classes, and test situations in math on a five-point Likert-type scale (1 = *I disagree*; 5 = *I agree*). The Cronbach's alpha reliabilities were above $>.70$.

Adolescent temperament

The adolescents' temperament was reported by parents in grade 6 using the Finnish version of the Early Adolescent Temperament Questionnaire (Revised) (EATQ-R) (Capaldi & Rothbart, 1992; Ellis & Rothbart, 2001; for the validity in the Finnish sample, see Kiuru et al., 2019). The 56 statements of the questionnaire were designed to measure broader dimensions of temperament, namely, effortful control, negative emotionality, and extraversion. Mean scores for effortful control ($\alpha = .80$), negative emotionality ($\alpha = .84$), and extraversion ($\alpha = .74$) were calculated. These data were used for the second set of analyses to define within-dyad differences in temperament.

Control variables

Adolescent biological sex (1 = girl, 2 = boy) and math skills were included as the covariates in the analyses. Gender was self-reported, and math skills were assessed with the Basic Arithmetic Test (see also Räsänen et al., 2009). The test contains tasks of addition, subtraction, multiplication, and division. The students were asked to do mental calculations and write their answers on the test paper. The test has 28 tasks (e.g., $527 + 31 = ?$; $15 - ? = 9$; $12 \times 28 = ?$), starting with easier tasks and getting more difficult throughout. The time limit for completing the test was 3 min. Students received one point for each correct answer, the maximum possible score thus being 28. The Cronbach's alpha reliability for the scale was .82.

Plan of analysis

Longitudinal Actor-Partner Interdependence Model (APIM) analyses were conducted within a path analysis framework (see also Kenny et al., 2006) using the Mplus statistical package with FIML estimation and robust standard errors (Version 8.4; Muthén & Muthén, 1998–2021). First, indistinguishable dyad APIM analyses were carried out for stable friendships between two time points (350 adolescents in 175 dyads). Figure 1 illustrates the longitudinal APIMs of indistinguishable dyads for math-related achievement emotions with two waves of data. Our particular interest was in the partner effects, that is, whether friends explain some unique variance of each other's later achievement emotions. Reciprocal friend dyads are a classic example of indistinguishable dyads, that is, there are no meaningful differences that can be used to distinguish (or differentiate) two members of a friendship dyad (see also Kenny et al., 2006). Consequently, the covariance structure and correlations were constrained to be equal between friend 1 and friend 2. In other words, the resulting model is invariant between indistinguishable friends (friend 1 and friend 2).

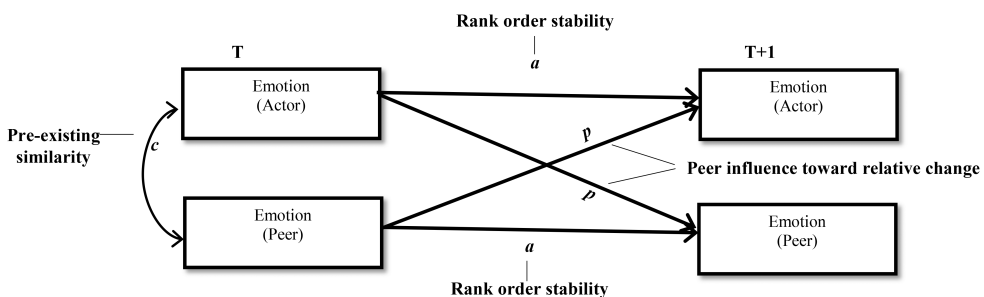


FIGURE 1 Theoretical model to test peer influence in math-related achievement emotions among indistinguishable dyads.

Second, distinguishable dyad APIM analyses were carried out for stable friendship dyads that were distinguishable in regard to extraversion ($n = 116$ consisting of 58 dyads, $d = 2.22$ for distinguishability between dyads) and negative emotionality ($n = 150$ consisting of 75 dyads; $d = 2.21$ for distinguishability between dyads). The fact that friendship dyads were distinguishable in regards to temperament refers to the relative difference between the members of the same friendship dyad in terms of their temperament. Figure 2 illustrates the longitudinal APIMs for distinguishable dyads as a function of high and low levels of extraversion and high and low levels of negative emotionality as they impact the direction and strength of friend influence on math-related achievement emotions with two waves of data.

In both models, correlations between partners in the first wave (c , pre-existing similarity) were included in the model. Also, residuals in the second wave are allowed to be correlated. Paths (a) are actor paths that represent the longitudinal stability for each partner on achievement emotions. Paths (p) are partner paths that represent the influence that each partner has over the other. Because the model controls for the actor's previous level of achievement emotion, partner paths represent influence over change in achievement emotion between the two time points. The effects of adolescent gender and level of math skills were controlled for in all the analyses.

RESULTS

Descriptive statistics for the study variables are found in Table 1.

Indistinguishable dyad APIM analyses for achievement emotions in mathematics

The results of APIM analyses for indistinguishable friendship dyads showed that peer influence paths (p , Figure 1) were significant for two out of eight emotions, that is, for math enjoyment ($\beta = .11$, $SE = .04$, $p = .006$) and for math-related anger ($\beta = .10$, $SE = .05$, $p = .048$), when controlling for the rank-order stability effects and the effects of covariates (i.e., gender, math skills). In other words, friends were influenced by each other both in enjoyment and anger in math. However, no peer influence was detected in math-related hope, anxiety, boredom, hopelessness, pride, and shame (all p s $> .05$). In addition, initial similarity (c , Figure 1), that is the correlation between partners' emotions in the fall of the seventh grade, was statistically significant in five out of eight math-related emotions: r for hope = .23 ($p = .005$), r for enjoyment = .23 ($p = .008$), r for boredom = .26 ($p = .001$), r for hopelessness = .20 ($p = .01$), and r for pride = .16 ($p = .035$). By contrast, no initial similarity between friends (c , Figure 1) was found in anxiety ($r = .09$, $p = .26$), shame ($r = .05$, $p = .51$), and anger ($r = .13$, $p = .08$).

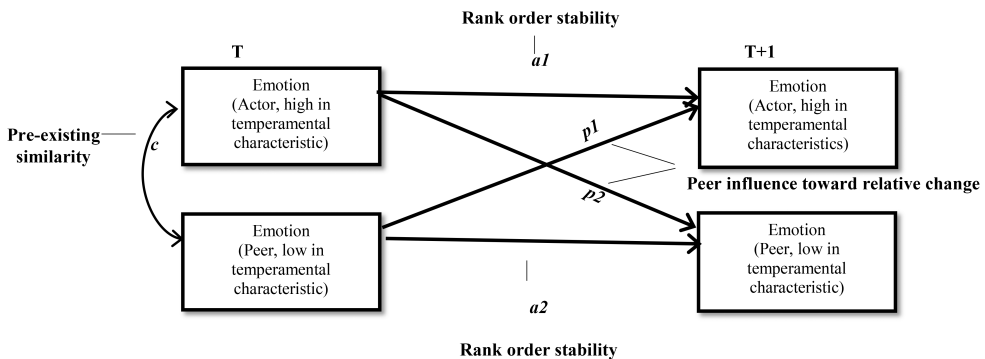


FIGURE 2 Theoretical model to test peer influence in math-related achievement emotions for distinguishable dyads in regard to temperament.

TABLE 1 Means and standard deviations of the study variables ($N = 350$).

	M	SD	Range of scale
Math enjoyment (gr7, fall)	3.35	.94	1–5
Math enjoyment (gr7, spring)	3.03	.96	1–5
Math hope (gr7, fall)	3.84	.82	1–5
Math hope (gr7, spring)	3.52	.91	1–5
Math pride (gr7, fall)	3.61	.93	1–5
Math pride (gr7, spring)	3.37	.97	1–5
Math anger (gr7, fall)	1.56	.63	1–5
Math anger (gr7, spring)	1.89	.79	1–5
Math anxiety (gr7, fall)	1.67	.77	1–5
Math anxiety (gr7, spring)	1.95	.87	1–5
Math shame (gr7, fall)	1.54	.74	1–5
Math shame (gr7, spring)	1.77	.81	1–5
Math hopelessness (gr7, fall)	1.53	.78	1–5
Math hopelessness (gr7, spring)	1.88	.94	1–5
Math boredom (gr7 fall)	1.85	.99	1–5
Math boredom (gr7, spring)	2.31	1.11	1–5
Negative emotionality	2.24	.49	1–5
Extraversion	3.47	.65	1–5
Effortful control	3.66	.53	1–5
Math skills	15.45	3.56	0–28
Gender (1 = girl, 2 = boy)	1.36	.48	1–2

Note: gr7, 7th grade.

Distinguishable dyad APIM analyses for achievement emotions in mathematics

Distinguished on negative emotionality

The results revealed differential peer influence in math-related anger for friends distinguished on the basis of negative emotionality. Higher negative emotionality friends influenced their lower negative emotionality friends towards an increase in math-related anger ($p2$ path: $\beta = .18$, $SE = .09$, $p = .05$), whereas lower negative emotionality friends did not influence their higher negative emotionality friends in math-related anger ($p1$ path: $\beta = .09$, $SE = .10$, $p = .48$).

Next, the regulative dimension of temperament, that is, effortful control was tested as a moderator of the effects of reactive dimensions of temperament on peer influence. The results showed that the interaction effects of adolescent effortful control and peer influence effect of friends with high negative emotionality were statistically significant when predicting math-related anxiety ($\beta = -.24$, $SE = .08$, $p = .002$) and math-related shame ($\beta = -.25$, $SE = .08$, $p = .001$) of adolescents with lower negative emotionality. In other words, the level of adolescents' effortful control moderated their susceptibility to be influenced by their higher negative emotionality friends in regard to anxiety and shame (Figure 3 for anxiety and Figure 4 for shame). Specifically, low effortful control increased adolescents' susceptibility to detrimental peer influence towards an increase in anxiety and shame in mathematics. By contrast, if the level of adolescents' effortful control was high no peer influence from high negative emotionality friends was found.

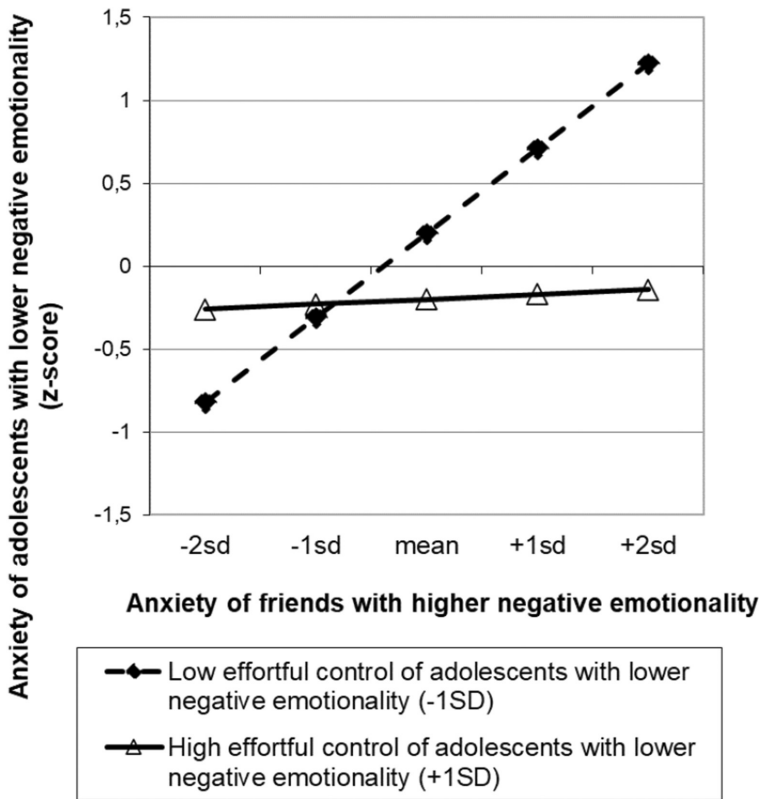


FIGURE 3 Adolescent's own effortful control as a moderator of susceptibility to peer influence of higher negative emotionality friends in math-related anxiety.

Distinguished on extraversion

No evidence of differential peer influence in any of math-related emotions for friends distinguished on the basis of extraversion was detected and effortful control did not moderate these effects.

DISCUSSION

Peer relationships during adolescence play an important role in shaping academic outcomes (Valiente et al., 2020). Yet, very little is known about the influences of peers on achievement-related emotions and about the role of adolescent temperament in these influences. Our findings demonstrate that friends influenced each other in math-related enjoyment and frustration over time. Furthermore, adolescents with high negative emotionality were more influential over their friends' math-related anger, whereas a lack of effortful control made adolescents more susceptible to friend influence over math-related shame and anxiety.

Friend similarities and friend influences in achievement emotions

Our results provide new knowledge regarding the role of emotional transmission between friends. First, it was demonstrated that the results are partly in line with Hypothesis 1 (see also, DeLay et al., 2015;

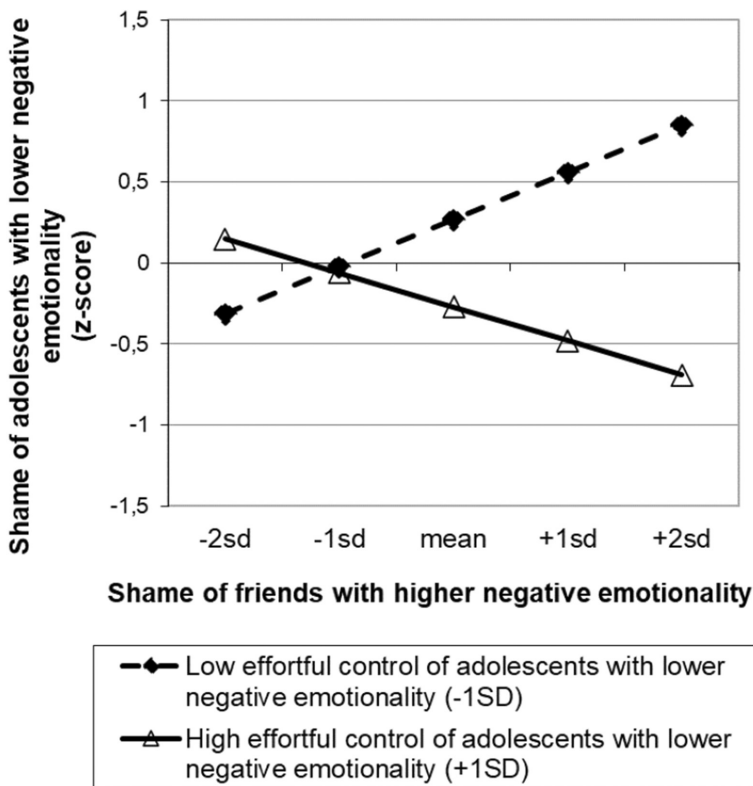


FIGURE 4 Adolescent's own effortful control as a moderator of susceptibility to peer influence of higher negative emotionality friends in math-related shame.

Valiente et al., 2020), suggesting that, over and above friends' initial similarities, friends mutually influenced one another's math-related enjoyment and anger within one school year. As far as we know, our study is first to report such effects.

There are several possible explanations for the findings. First, feelings of enjoyment and anger may be transferred between friends by emotional contagion (see also Coviello et al., 2014; Reindl et al., 2018; van Workum et al., 2013). According to the emotional contagion theory (Hatfield et al., 1993, 1994) individuals automatically mimic and synchronize the emotional expressions of others. The intention to mimic the emotions of one another is more likely to develop between friends because the empathy created by exhibiting the same emotions strengthens intimate friendships (see also Reindl et al., 2018). As a result, the counterpart feels understood by their friend. In addition, adolescents may synchronize with their friends' feelings of enjoyment and anger without mimicking their expressions. Merely observing friend's expression of joy and enjoyment or anger and frustration may also be sufficient to induce positive or negative achievement emotions, because observing a friend's expressions may produce similar brain responses as personally expressing emotions (Parkinson, 2011; Van Workum et al., 2013). Other possible mechanisms involved in peer influence relate to opportunities to have positive or negative academic experiences with friends (Wang et al., 2018). Friends are an important source of social and emotional support, resulting in joys and sorrows being shared and opportunities for information exchange (Bandura, 1986; Ryan et al., 2019). Adolescents can perceive the emotional reactions of their best friends also through verbal expressions, such as "Math is fun" (cf. Hatfield et al., 1994), and information about emotional experiences can be an important source for perceiving another person's emotion (Reindl et al., 2018; Wild et al., 1997).

Although friends resembled each other also in math-related hope, boredom, hopelessness, and pride, there were no longitudinal friend influence effects on these emotions. One explanation for

this relates to the fact that enjoyment and anger are classified as basic emotions (Ekman, 1992; Ekman & Cordano, 2011; Izard, 1992) that have unique and universally recognized facial expressions. With respect to observational processes and visibility of emotions, the other investigated emotions are not classified as basic emotions and may therefore be harder to observe in others, resulting in weaker emotion contagion. The present study was also conducted after the transition to lower secondary school when school-based friendships are reorganized. It is then possible that friends had not yet developed such close, trustful, and intimate connections that they would have extensively shared experiences of one another's more private and less visible emotions regarding math learning (see also Reindl et al., 2018).

The role of adolescent temperament in friend influence and susceptibility to influence

It has also been suggested that there are individual differences in emotion transmission, with some individuals being more prone to emotion transmission than others (Aunola et al., 2015; Larson & Almeida, 1999). Although it has been suggested that some adolescents are more vulnerable to environmental effects (e.g., peer influence) than others due to their temperamental features (Belsky & Pluess, 2009), to our knowledge no other previous studies have examined the role of temperament in friend influences in achievement emotions. Consequently, we next examined adolescent reactive temperament (i.e., extraversion and negative emotionality) to assess its role in determining *who influences whom* on emotions towards math.

The results supported Hypothesis 2 partly (see also Rothbart, 2011) by showing that friends' relatively higher negative emotionality contributed to the transmission of math-related emotions between friends. In particular, high negative emotionality adolescents influenced their friends with lower levels of negative emotionality towards an increase in math-related anger. There was, however, no evidence to suggest that negative emotionality had an impact on peer influence for less visible and observable negative achievement emotions. Similarly, in contrast to hypothesis 2 (Rothbart, 2011), extraversion played no role in the transmission of any of the investigated positive emotions (enjoyment, hope, pride). Overall, the results suggest that negative emotionality is a stronger contributor of negative emotion transmission between friends than extraversion is for positive emotion transmission between friends.

One explanation for this finding relates to the threshold, intensity, and duration of emotional reactions that is characteristic of adolescents with high negative emotionality (see also Hirvonen et al., 2019). Negative emotionality makes individuals more susceptible to negative environmental cues and more likely to dwell on intense negative feelings, such as anger and frustration when facing disappointment and interruptions (Rothbart, 2011). These emotional reactions are likely also shown in interactions with friends and this might explain why math-related anger and frustration experienced by adolescents with higher negative emotionality tend to transfer to their friends. In turn, no emotional contagion (see also Coviello et al., 2014; Reindl et al., 2018; van Workum et al., 2013) was observed from adolescents with lower negative emotionality to their friends.

Finally, we examined the role of relative differences in the self-regulative aspect of temperament (i.e., effortful control) regarding *who is susceptible to friend influence* in math-related emotions. The results were partly in line with our Hypothesis 3 (Lonigan & Vasey, 2009) stating that lower levels of effortful control made adolescents more susceptible to influence on math-related shame and anxiety when their friends had higher levels of negative emotionality. There was, however, no evidence that relative differences in effortful control had any impact on susceptibility to influence in other emotions. Our results broaden previous literature on adolescent problem behaviour that has shown a stronger association between friend deviance and delinquent behaviour for those adolescents who are more vulnerable to rewards and less likely to inhibit and regulate their emotions and behaviour (Dishion & Connell, 2006; Gardner et al., 2008; Goodnight et al., 2006). In turn, adolescents with high levels of self-regulation have shown to be less vulnerable to peer influences to engage in problem behaviour. At the same time,

it is notable that not all previous studies have been able to demonstrate the moderating role of self-regulation in the association between friendship and the development of external problem behaviour (e.g., Franken et al., 2016).

Our results suggest that high levels of temperamental self-regulation (i.e., effortful control) may make adolescents less susceptible to the influence of their more reactively influential peers on achievement-related emotional outcomes. By contrast, if individuals have lower levels of effortful control, they seem to be more susceptible to peer influence on emotions, especially regarding math-related anxiety and shame that are considered less observable and internal emotions. One additional mechanism underlying our findings is co-rumination or the excessive discussion of negative math-related experiences, challenges, and failures between friends (see also Rose, 2002; Schwartz-Mette & Rose, 2012; Stevens & Prinstein, 2005) that might increase the likelihood of transmission of anxiety and shame from adolescents with higher negative emotionality to their friends with relatively lower effortful control. Lower effortful control which is related to difficulties in emotion regulation may make adolescents particularly sensitive to “catch” their friends' anxiety and shame.

Adolescents with lower effortful control are likely to have challenges in emotion and behaviour regulation during social situations and they may show slower recovery in response to a social threat (Derryberry & Rothbart, 1997; Hirvonen et al., 2019; Rothbart, 2011). The significance of effortful control in the regulation of affect, behaviour, and attention is highlighted in previous research showing that effortful control can moderate the relation between negative affectivity and threat appraisals (Lonigan & Vasey, 2009). Students' ability to monitor and shift their attention away from potential threats and stress-evoking factors can reduce their anxiety and improve their functioning, especially if, without this ability, they would be inclined to have intense, negative reactions when distracted or frustrated (see also Hirvonen et al., 2019). However, as far as we know our study is among the first to show that effortful control plays a moderating role also in the achievement of emotion transmission between friendship dyads.

Strengths, limitations, and future directions

This study provides a novel understanding of the rarely studied topic of friend influences in positive and negative achievement emotions, as well as of the role of temperament in these processes. Further strengths of the study are the longitudinal design and the fact that the reported results held after controlling for initial similarities, as well as student gender and math skills.

However, this study also includes limitations. First, achievement emotions were investigated only in the mathematics domain and via self-reports. Future studies are needed to reveal possible differences between different academic subjects concerning emotion contagion. Self-reports could also be complemented with information from other sources, such as by recording physiological responses. Second, because the closest friendships were defined as stable and reciprocal friendships, we may have underestimated the contributions of peer influences on emotions. Although previous studies indicate that reciprocal peer nominations are comparable to direct measures of friendship (Hartup et al., 1988; see also DeLay et al., 2015), we cannot rule out the possibility that also unilateral friends, unstable friends, and characteristics of broader peer networks might be influential. Hence, our findings can be generalized only to closest friends and future studies are needed to examine possible peer influences at the level of larger networks.

Fourth, in comparison to boys, girls were overrepresented in our sample. Although our results remained after controlling for student biological sex, in future studies it might be worthwhile to use larger samples to examine whether student gender might also moderate some of the investigated mechanisms. Relatedly, it may be necessary to have broader definitions of gender in future research, given the variability youth experience in their understanding of gender and gender identity. Finally, the sample consisted of Finnish adolescents, and we had only two measurement points. In future research, it would be useful to investigate similar mechanisms with longer follow-ups and with samples consisting of different age groups and students from different educational and cultural backgrounds.

CONCLUSION

The current study has implications for the onset and progression of math-related enjoyment and frustration among early adolescents because the findings demonstrate that adolescents develop relationships with similarly minded peers and influence one another over time on math-related emotions. Specifically, high negative emotionality may make adolescents more influential over their friends' math-related anger and a lack of effortful control may make adolescents more susceptible to friend influence over math-related shame and anxiety. Thus, the current findings have implications for how peer relations may impact individual outcomes in mathematics. The results suggest that there are individual differences in how influential and how susceptible adolescents are to peer influences in math-related emotions. By paying attention to patterns of peer interactions and strategically managing peer-interaction partners during learning situations, educators may be able to maximize positive peer influence and prevent, or disrupt, negative influence processes towards increases in math-related fears and anxiety. More specifically, educators can make students aware of the detrimental impact of the influence of peers with negative emotionality. This awareness may help to prevent the cycle of negative forms of peer influence on math-related outcomes. Furthermore, educators can encourage students to pay attention to their susceptibility to peer influence and highlight the importance of students' own individual input in math-related endeavours irrespective of their peers' emotions or spoken attitudes towards math.

AUTHOR CONTRIBUTIONS

Noona Kiuru: Conceptualization; funding acquisition; writing – original draft; investigation; data curation; formal analysis; project administration; writing – review and editing; visualization; methodology. **Dawn DeLay:** Conceptualization; methodology; data curation; formal analysis; investigation; writing – original draft; writing – review and editing. **Katja Tervahartiala:** Writing – review and editing. **Juho Polet:** Writing – review and editing. **Riikka Hirvonen:** Funding acquisition; project administration; conceptualization; data curation; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The datasets generated and/or analysed during the current study are not publicly available due to ethical restrictions but are available from the corresponding author on reasonable request.

ETHICS STATEMENT

This study was conducted in compliance with APA ethical standards. The procedures were in accordance with the principles of the Helsinki Declaration on research with human subjects. The research plan of the project was approved by the Human Sciences Ethics Committee of the University of Jyväskylä.

INFORMED CONSENT

Informed consent to participate and publish the study results was obtained from all the participants of the study.

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