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How is Anxiety Related to Math Performance in Young Students? A Longitudinal Study of
Grade 2 to Grade 3 Children.

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Abstract

Both general and math-specific anxiety are related to proficiency in mathematics. However, it is not clear when math anxiety arises in young children, nor how it relates to early math performance. This study therefore investigated the early association between math anxiety and math performance in Grades 2 and 3, by accounting for general anxiety and by further inspecting the prevalent directionality of this anxiety-performance link. Results revealed that this link was significant in Grade 3, with a prevalent direction from math anxiety to performance, rather than the reverse. Longitudinal analyses also showed an indirect effect of math anxiety in Grade 2 on subsequent math performance in Grade 3. Overall, these findings highlight the importance of monitoring anxiety from the early stages of schooling in order to promote proficient academic performance.

Keywords: math anxiety, general anxiety, math performance, math precursors, early assessment

How is Anxiety Related to Math Performance in Young Students? A Longitudinal Study of Grade 2 to Grade 3 Children.

Basic mathematical skills are regularly used in everyday life, and their deficiency affects both employment opportunities and socio-emotional wellbeing (e.g., McCloskey, 2007). As adulthood math competence is the end result of the math skills acquired early in life, many studies have sought to identify the factors responsible for math difficulties in children.

Research in the field is mainly focused on those cognitive abilities that underpin math learning, and are potentially impaired in individuals with math difficulties (e.g., Fuchs et al., 2010; Passolunghi, Cargnelutti, & Pastore, 2014). Conversely, the role of the affective aspects such as anxiety is frequently neglected or underestimated when dealing with young students (e.g., Liew, McTigue, Barrois, & Hughes, 2008). Our study was aimed at filling this gap, by longitudinally investigating the relation between both general and math-specific anxiety and math performance in children from Grade 2 through Grade 3.

Anxiety and its Relation With Academic and Math Performance

General anxiety.

Anxiety, broadly defined as a disproportional and dysfunctional response to a situation perceived as threatening, is already present in preschool children with a prevalence of around 10% (Egger & Angold, 2006). Even though many factors may moderate the interplay between anxiety and performance in the academic context, the negative consequences of anxiety alone are proven, with particularly damaging effects in children with learning difficulties, typically more anxious than their normally achieving peers (Fisher, Allen, & Kose, 1996).

This trend was observed not simply when referring to test anxiety, a subtype of anxiety experienced in testing situations (see Hembree, 1990), but also to general anxiety. These findings outline how academic performance can also be affected by trait dispositions of the individual, such as general anxiety, and not merely by factors tightly associated with the academic context.

Math anxiety.

Math anxiety is a distinct subtype of anxiety which can be experienced even in absence of both general and test anxiety (Hembree, 1990). It is defined as a negative emotional response occurring in situations involving math, and can produce stress and avoidance behavior (Ashcraft & Ridley, 2005). Math anxiety is not infrequent, and recent data report it to be experienced at a high degree by approximately 17% of the population (Ashcraft & Moore, 2009). Its effects tend to endure over time also causing repercussions on work choices (Ma & Xu, 2004).

The negative relation between math anxiety and math achievement has been largely proved, with high levels of anxiety demonstrated to be linked to low performance (e.g., Faust, Ashcraft, & Fleck, 1996; Ma & Xu, 2004). However, math anxiety is typically monitored from middle school onward, and assumed to interfere with the execution of complex arithmetic operations (e.g., Faust et al., 1996). Math anxiety has been therefore imputed to cause an *affective drop*, meaning a decline in performance attributable to its presence rather than to inadequate competence (e.g., Ashcraft & Moore, 2009).

Nevertheless, alternative accounts are also plausible. Math anxiety may be interpreted as the result—rather than the cause—of negative math experiences, poor attainment, and failures (Ma & Xu, 2004). Math anxiety, actually, may be simultaneously both the cause and consequence of limited performance (e.g., Ashcraft & Moore, 2009).

Math anxiety in young children.

Even if we assume the link between math anxiety and math performance to be bidirectional, the onset of this relation is still almost unexplored. Until recently, only a handful of studies involved children before Grade 5. Moreover, outcomes about students during the first grades of primary school are divergent: It is not clear how and when math anxiety arises, and, more importantly, when it becomes relevant to math performance. Some authors have indeed failed to find an early relation between math anxiety and performance. Among them, Thomas and Dowker (2000) hypothesized an age-dependent relation between the two variables, expected to surface after the age of 9. Krinzinger, Kaufmann, and Willmes (2009) instead proposed the link to possibly emerge only in individuals with extremely high math anxiety concomitant with very pronounced math difficulties.

On the other hand, evidence has also been found for a significant link between math anxiety and math proficiency in the first stages of schooling. Wu and colleagues (Wu, Barth, Amin, Malceme, & Menon, 2012; Wu, Willcutt, Escovar, & Menon, 2014) observed that math anxiety predicted performance in Grades 2 and 3 even when controlling for general anxiety, and that some math domains (e.g., those involving reasoning) were more affected than others. The effects of math anxiety were also detected in other studies, with other constructs also proposed to moderate the relation between anxiety and performance (e.g. Harari, Vukovic, & Bailey, 2013; Jameson, 2014).

Current Study

Given the sparse and contradicting findings on the issue, our research was aimed at shedding light on the relation between anxiety and math proficiency in the early primary grades. Our first purpose was to verify whether math anxiety in particular can impact math performance even in young children, and whether a possible reciprocal influence exists. We collected data from children attending Grade 2 and subsequently Grade 3, attempting to define both concurrent and developmental patterns.

Overall, this study advances prior works in several ways. First, in contrast to Wu and colleagues (2012, 2014), we explored the interplay between math anxiety and performance by means of path analyses, with longitudinal models aimed at shedding light on the causal pathways and prevalent directionality of this link. Second, expanding upon Krinzinger and colleagues (2009), we also evaluated the role of general anxiety (as in Wu et al., 2012, 2014), in order to see whether math anxiety is independent from it, and uniquely linked to math performance even in early schooling. Further, in contrast to past research in which only computation was assessed (Krinzinger et al., 2009; Thomas & Dowker, 2000), we tested diverse math skills relevant to the early primary school curriculum, in order to achieve a more global and robust index of math competence.

In summary, our hypotheses were that math anxiety, independently from general anxiety, could impact math proficiency very early, with significant negative effects traceable even in Grade 2. Regarding the directionality of the link, we expected math anxiety at this stage to already be both the cause and consequence of low math performance.

Method

Participants

Two hundred and three children attending Grade 2 were recruited for the study. Children attended 10 different classes across six primary schools in Northeastern Italy. These schools were located in urban non-disadvantaged areas and were attended mostly by children from middle-income families. From the initial sample, three children were excluded because of neurological diseases, and two for atypical ages for their grade. The resulting sample included 198 children (105 males; mean age = 7 years 7 months).

Of this sample, 80 children (48 males; mean age = 8 years 4 months) were also included in the testing phase in Grade 3. The remaining students did not participate because of not-renewed school consent.

Procedure

The study took place at two different time points: the second term of Grade 2 (April-May) and first term of Grade 3 (December). The investigated constructs (general anxiety, math anxiety, and math competence) were assessed collectively and on different days within the same week, by randomly alternating the order of the tasks.

Self-rating questionnaires were used to assess general and math anxiety. Teachers' ratings of children's general anxiety were also collected. This measure was taken to check for potential discrepancies with the ratings given by children of their affective states. This was done purposely because general anxiety, contrary to math anxiety, lacks specificity (i.e., it can be experienced in several contexts and can be determined by different stressors), thus resulting in less reliable self-evaluations by young students (White, Oswald, Ollendick, & Scahill, 2009).

Measures

Anxiety.

General anxiety.

Depression and Anxiety in Youth Scale (DAYS, Newcomer, Barenbaum, & Bryant, 1994; Italian ed., 1995). This questionnaire was developed for youths from 6 years of age onward. Concerning the self-rating scale (hereafter *Anxiety-Self*), we partly modified the original version by removing or reformulating some items in order to make it more suitable for younger children (e.g., the sentence "I want to kill myself." was removed). The administered scale resulted in eight items with four response options: *never*, *sometimes*, *often*, and *always*. Scoring ranged from 0 (*never*) to 3 (*always*). The maximum score was 24 points.

The scale for teachers (hereafter *Anxiety-Observed*) was kept in the original version and includes seven statements (e. g., “He/she easily changes his/her mood.”) with a dichotomous response modality (*true* or *false*). Responses indicating the presence of an anxiety symptom were scored 1 point, or otherwise 0 points. The maximum score was 7 points.

Math anxiety.

Scale for Early Math Anxiety (SEMA, translated and adapted from Wu & Menon, 2012). This questionnaire includes 20 items requiring children to imagine either having to solve a given math problem (e. g., “What time will it be in 20 minutes?”), or to be experiencing common situations occurring during math lessons (e.g., “Your teacher gives you a bunch of subtraction problems to work on.”). In both cases children have to indicate the level of nervousness they would feel if these conditions were truly happening.

This version provided four instead of the original five response options: *not nervous at all*, *a little nervous*, *somewhat nervous*, and *very nervous*. The choice was supported by pilot studies showing pupils’ difficulty in selecting between five different response options. Each response was scored 0 (*not nervous at all*) to 3 (*very nervous*) points, giving a maximum score of 60 points.

Math skills.

Written computation. This test was developed in two versions, one for each grade, by referring to the corresponding math textbooks. Both versions are comprised of 16 arithmetic computations to be solved within 10 minutes (additions and subtractions for Grade 2, all operations for Grade 3). In both versions, each correct solution received 1 point, giving a maximum of 16 points.

Word problems (from Giovanardi Rossi & Malaguti, 1994). This test requires children to solve, within 15 minutes, six word problem questions for Grade 2 (additions and

subtractions), and eight for Grade 3 (all operations). Up to 1.5 points were assigned for each correct answer (1 point for the correct set out of the expression to be solved, plus 0.5 if also the computation procedure was correctly executed). The maximum score was 9 points for Grade 2, and 12 points for Grade 3.

MAT-2 (from Amoretti, Bazzini, Pesci, & Reggiani, 2007). We administered the module *Number*, including a wide spectrum of tasks to be performed within 20 minutes. The module consists of 11 tasks for Grade 2 (e.g., ranking numbers from the smallest, decomposing numbers), and 13 tasks for Grade 3 (e.g., writing down numbers in the rank of thousands, solving problems involving the concepts of expenses and profits). Each exercise correctly solved was scored 1 point, with a maximum score of 11 points for Grade 2, and 13 points for Grade 3.

Data Analysis

Main statistical analyses were conducted by *PAW Statistics 21*. AMOS 21 package was used to perform path analyses. Missing data were imputed using a stochastic procedure, and Maximum Likelihood approach was adopted for model estimation. A bias-corrected bootstrap procedure with 2,000 re-samples was run to estimate confidence intervals for direct, indirect, and total effects.

Pertaining to general anxiety, Anxiety-Self and Anxiety-Observed scores were treated separately, being mildly correlated with each other and, more importantly, differentially correlated with the other variables (see Table 1). Concerning math performance, we computed a unique composite score for each grade, named Math, by averaging the scores of Written computation, Word problems, and MAT-2.

Path models were first estimated independently for each grade to test the impact of anxiety on concurrent math performance. The link causal ordering was instead inspected in the longitudinal models including both assessment times. For the definition of the

longitudinal relations, we tested different models with alternative directionality solutions. All the models were estimated with each variable in Grade 2 expected to predict the correspondent in Grade 3, and by taking general anxiety as a covariate, to control for its non-specific effects on Math.

In detail, Anxiety-Observed in Grades 2 and 3 was hypothesized to be linked to correspondent math performance (in Grades 2 and 3, respectively). Despite a bidirectionality possibly being observed in the relation between general anxiety and Math, preliminary analyses confirmed that the statistical fit systematically favored models with general anxiety predicting Math, rather than the reverse. Moreover, given that Anxiety-Self was not strongly correlated to any other measure, except for SEMA, we retained only Anxiety-Observed, in order to reduce the model complexity.

Alternative model comparison.

Taking the constraints on the model definition described in the data analysis section, we compared five alternative models in which we tested the relation between SEMA and Math in both causal orderings, and by defining these links as concurrent within each wave, longitudinal, and cross-lagged. In detail, the following models were compared: a) Model 3.1 (anxiety-driven model), in which SEMA in Grades 2 and 3 (hereafter, SEMA_2 and SEMA_3) concurrently predicted Math scores in Grades 2 and 3 (hereafter, Math_2 and Math_3), respectively; b) Model 3.2 (performance-driven model), in which the reverse paths were tested; c) Model 3.3 (mixed model), with Math_2 predicting SEMA_2, and SEMA_3 predicting Math_3; d) Model 3.4, which tested the reverse mixed solution; e) Model 3.5 (cross-lagged model), in which SEMA_2 predicted Math_3, via direct effect, and Math_2 predicted SEMA_3, directly as well, with no concurrent relations admitted from SEMA to Math within each grade. In all the tested models, both SEMA_2 and Math_2 were allowed to longitudinally predict the corresponding variable in Grade 3.

As the models were non-nested, the traditional approach for model comparison based on the chi-square difference value was not applicable. Therefore, model comparison was based on direct comparison of indices, such as AIC and BIC, with lower values indicating better fit (according to Raftery, 1995, BIC differences $\Delta < 2$, between 2 and 6, and > 6 indicate respectively weak, moderate, and strong evidence in favor of the model with the lowest values).

Although the fit indices were from acceptable to good for all the tested models (for details, see Supplemental Table 1 in Supplementary Materials), Models 3.1 and Model 3.3 displayed a better fit as compared to Model 3.2 and Model 3.4 ($\Delta AICs$ and $\Delta BICs > 4$). Model 3.5, in which only cross-lagged paths were admitted, globally showed the worst fit. Importantly, none of the cross-lagged paths directly linking SEMA and Math of consecutive grades were significant. In sum, Model 3.1 and Model 3.3 should be retained as the best-fitting and more parsimonious models.

Results

Descriptive statistics, reliability measures and correlations are reported in Table 1.

(Table 1 about here)

The path analysis results are described below. We reported the final models we chose on the basis of their robustness from both the theoretical and statistical viewpoints.

Cross-Sectional Path Models

Concerning the Grade 2 assessment, we reported the full model entailing the links for all anxiety measures to math performance. This model, termed Model 1 (Figure 1(a); see Supplementary Table 2 for details), explained 8% of Math variance with a good statistical fit: $CMIN = 0.07$, $df=1$, $CMIN/df = 0.07$, $p = .80$, $CFI = 1.000$, $NFI = .999$, $TLI = 1.141$, $RMSEA < .001$, $AIC = 18.08$, $BIC = 47.71$.

(Figure 1 about here)

Anxiety-Observed appeared as the only variable directly and negatively accounting for math performance ($\beta = -.26, p < .001$). SEMA did not predict Math significantly ($\beta = -.12, p = .10$), nor Anxiety-Self ($\beta = .06, p = .38$), whose indirect effect via Anxiety-Observed was however significant (mean = $-.09$, 95% CI = $[-.02, -.17]$).

Concerning the Grade 3 assessment, the relations between the inspected variables are represented in Model 2 (Figure 1(b) and Supplementary Table 3). As the model is saturated, we report only AIC and BIC values as fit indices: AIC = 18.00, BIC = 39.44.

Anxiety measures explained 27% of variance in Math, and it significantly concurred with both Anxiety-Observed and SEMA ($\beta = -.45, p < .001$, and $\beta = -.29, p < .01$, respectively). Although Anxiety-Self did not act on Math directly ($\beta = .10, p = .18$), it yielded a significant indirect effect through Anxiety-Observed (mean = $-.17$, 95% CI = $[-.05, -.33]$).

Longitudinal Path Models

We report data on the selected longitudinal models. Model 3.1 is illustrated in Figure 2(a) (with related values in Supplementary Table 4). Anxiety-Observed was a significant predictor of concurrent Math, stronger in Grade 2 ($\beta = -.36, p < .001$) than in Grade 3 ($\beta = -.16, p = .04$). With regard to SEMA, its relation to Math was significant in Grade 3 ($\beta = -.21, p < .01$), but not in Grade 2 ($\beta = -.16, p = .12$). However, bootstrap analysis showed that SEMA_2 significantly predicted Math_3 indirectly via Math_2 and SEMA_3 (mean = $-.23$, 95% CI $[-.07, -.38]$).

(Figure 2 about here)

Model 3.3 (see Figure 2(b) and Supplementary Table 5) was identical to Model 3.1, except for the path linking Math and SEMA in Grade 2, directed from the former to the latter, with the reverse path in Grade 3. The path from Math_2 to SEMA_2 was slightly stronger

than that of the reverse tested in Model 3.1, even though it only approximated the conventional significance threshold ($\beta = -.19, p = .08$). The link between SEMA_3 and Math_3 was instead significant ($\beta = -.21, p < .01$). Bootstrap analyses also showed a significant indirect impact of SEMA_2 on Math_3, via SEMA_3 (mean = $-.13$, 95% CI [$-.04, -.24$]). In sum, math anxiety and performance in consecutive grades appeared to be related, but only indirectly. Importantly, part of the longitudinal relation between math performance scores in consecutive grades was likely to be a function of related variability in math anxiety.

Discussion

The main purpose of this research project was to uncover whether affective aspects, such as anxiety, can even be precociously related to math proficiency. To date, only a few studies examined math anxiety before Grade 5, with even fewer works adopting a longitudinal perspective (Krinzinger et al., 2009), controlling for the role of general anxiety (Wu et al., 2012, 2014), or including a robust index of math competence. This study adds to existing literature in all these respects by assessing general anxiety, math anxiety, and math proficiency, and by targeting their causal ordering from Grade 2 through 3.

Both general and math anxiety were tested by self-rating questionnaires. General anxiety was further inspected by a questionnaire completed by teachers (Anxiety-Observed). This was done purposefully for general anxiety, which young children find difficult to appraise because of its lack of specificity (see White et al., 2009), and not for math anxiety, which was expected to be more easily self-detected (as also supported by the good reliability indexes). In agreement with this, Anxiety-Observed and Anxiety-Self appeared mildly related (see De Los Reyes & Kazdin, 2005), and presented different correlation patterns. Nonetheless, we judge teachers' ratings to be a reliable measure, as already proven (see

Tripp, Schaughency, & Clarke, 2006). Therefore, it is important to point out that the discussed results about general anxiety are those concerning Anxiety-Observed. However, the issue remains of the suitability of the self-rating scales in measuring some constructs in young students.

Differential Impact of Anxiety in the two Grades

Results from the current study globally highlight the strong negative link between anxiety and math performance. Interestingly, results from the cross-sectional models, designed independently for each grade, show that the combined effect of general and math anxiety on performance was noteworthy and appreciably increased from Grade 2 to 3 (respectively, 8% and 27% of explained variability in math performance).

Nevertheless, whereas general anxiety affected proficiency in both grades, a significant direct role of math anxiety emerged only in Grade 3. These findings suggest that the effect of math anxiety may increase over time (see Thomas & Dowker, 2000), possibly due to the accumulation of negative experience in the discipline. However, we cannot exclude the idea of this relation being strengthened by other factors intervening in Grade 3, such as the increased demands of math tests. According to Stevenson, Hofer, and Randel (2000), this change may also reflect the possibility that the effects of math anxiety may be overwhelmed by other powerful sources of influence at this stage (e.g., teachers' and parents' attitudes, or other general personality aspects).

Irrespective of this, it is important to underline the finding that the effect of math anxiety actually appeared to be independent from that of general anxiety even in Grade 2, suggesting its precocious onset and specificity (Wu et al., 2012, 2014).

Longitudinal Relations

Longitudinal outcomes indicate that math anxiety and performance influence one another, so the link is very likely to be bidirectional (see Ashcraft & Moore, 2009). However,

whereas in Grade 2 the impact of performance on math anxiety was the strongest (despite not yet being statistically significant), the reverse relation emerged in Grade 3. Further, the effect size of math anxiety in Grade 3 was even higher than that of general anxiety. A possible interpretation of these findings is that poor math attainment can firstly boost math anxiety (e.g., Ma & Xu, 2004), which only secondarily harms math performance, in a sort of vicious cycle. Even more importantly, math anxiety in Grade 2 appeared to have a significant impact, though indirect, on determining future math competence. Overall, these findings call for a precocious monitoring of math anxiety, even when it is not yet apparently related to attainment, as the early onset of negative experience towards math is predictive of poorer proficiency over time.

Limitations of the Study and Implications

Findings from this study leave some questions open, concerning in particular the assessment of affective states in very young students. For this reason, subsequent investigations are necessary to understand whether ratings of young children evaluating their own anxiety are effectively reliable, and how they relate to those collected from significant adults.

Furthermore, results should be corroborated by inspecting the relation between these constructs on larger and more numerically homogeneous samples of participants, especially when dealing with longitudinal data.

Outcomes of the present study are noteworthy in the way they extend previous findings on the onset of the relation between math anxiety and proficiency. By highlighting the strong impact of affective components on academic performance in very young students, these findings are important also from an educational perspective. Promoting successful learning and preventing drawbacks of poor math proficiency is crucial in different aspects of children's present and future life, ranging from occupational opportunities to self-esteem.

Therefore, greater care should be taken to precociously detect and treat not only deficiencies in cognitive math precursors, as traditional approaches do, but also negative affective conditions such as anxiety.

This necessity is corroborated by the limited but interesting data on interventions aimed at increasing math performance through the reduction of math anxiety, even in children with math disabilities (Furner & Duffy, 2002). Students can be provided with simple self-instruction strategies to handle their anxiety, but teachers can also adopt simple strategies, such as creating a serene learning atmosphere, and appraising an achieved goal rather than emphasizing failure: students should not be disparaged in the face of an error, which should be considered as just a normal step along the path leading to successful learning (for recommendations and suggestions, see Furner & Duffy, 2002).

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Table 1

Descriptive Statistics, Reliability Measures, and Intercorrelations Between all Variables

	Descriptive statistics							Intercorrelations											
	Min	Max	Mean	SD	Skewness	Kurtosis	Reliability	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	
1. Computation_2	0.00	16.00	11.65	4.30	-1.04	0.30	.84												
2. Problem solving_2	0.00	9.00	6.61	2.25	-1.21	1.16	.69	.17*											
3. MAT_2	0.00	11.00	7.47	2.25	-0.96	1.54	.74	.32***	.08										
4. Computation_3	0.00	15.00	10.06	2.58	0.17	1.08	.88	.10	-.20**	-.04									
5. Problem solving_3	0.00	12.00	5.65	3.19	0.34	-0.85	.79	<.01	-.20**	-.09	.54***								
6. MAT_3	1.00	11.00	6.13	2.31	0.20	-0.38	.80	-.06	-.30***	-.12	.65***	.60***							
7. Anxiety-Self_2	0.00	20.00	6.89	3.85	0.42	-0.21	.65	.28*	.02	.24*	-.10	-.09	-.07						
8. Anxiety-Observed_2	0.00	7.00	1.47	1.52	1.03	0.61	.65	.21	.46***	.19	-.25*	-.37**	-.26*	.18					
9. SEMA_2	0.00	57.00	14.82	10.57	0.80	0.74	.86	<.01	.04	.61***	-.14	-.22*	-.12	.29**	.01				
10. Anxiety-Self_3	0.00	20.00	7.79	4.69	0.43	-0.58	.84	.13	-.27*	-.12	.26*	.31**	.17	.05	-.35**	-.17			
11. Anxiety-Observed_3	0.00	7.00	1.68	1.82	0.94	0.04	.72	.10	-.27*	-.18	.34**	.35**	.35**	-.03	-.30**	-.18	.43***		
12. SEMA_3	0.00	39.00	12.44	8.83	0.95	0.44	.87	.12	-.24*	-.21	.31**	.31**	.36**	-.11	-.24	-.27*	.38***	.67***	

Note. Min = minimum; Max = maximum; SD = standard deviation; _2 = measure collected in Grade 2; _3 = measure collected in Grade 3.
 * $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$.

Figure 1. Cross-Sectional Models

Figure 1. Standardized solution for cross-sectional models. Anxiety-Obs = Anxiety-Observed; 2 = measure collected in Grade 2; 3 = measure collected in Grade 3. Dashed lines indicate links approaching statistical significance.

Figure 2. Longitudinal Models

Figure 2. Standardized solution for longitudinal models. Anxiety-Obs = Anxiety-Observed; 2 = measure collected in Grade 2; 3 = measure collected in Grade 3. Dashed lines indicate links approaching statistical significance.