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Developmental behavioral genetics research on school achievement is missing vulnerable children, to our detriment

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Abstract

Gene–environment processes tell us how genetic predispositions and environments work together to influence children in schools. One type of gene–environment process that has been extensively studied using behavioral genetics methods is a gene-by-environment interaction. A gene-by-environment interaction shows us when the effect of your context on a phenotype differs depending on your genetic predispositions, or vice versa, when the effect of your genetic predispositions on a phenotype differs depending on your context. Developmental behavioral geneticists interested in children's school achievement have examined many different contexts within the gene-by-environment interaction model, including contexts measured from within children's home and school environments. However, this work has been overwhelmingly focused on WEIRD samples children, leaving us with non-inclusive scientific evidence. This can lead to detrimental outcomes when we overgeneralize this non-inclusive scientific evidence to racialized groups. We conclude with a call to include racialized children in more research samples.

Introduction

The U.S. Census Bureau predicts that within this generation the non-White proportion of the population will shift to more than 50% (Frey, 2020). These data point to the need to consider how to better support this diverse population, including children in schools, and their variety of needs. The field of behavioral genetics, and the subfield of developmental behavioral genetics—which focus on understanding genetic and environmental contributions to individual differences in a developmental context, especially with children—is often at the forefront of research on developmental mechanisms involved in school achievement. Unfortunately, these fields have not mirrored the U.S. population changes with research participants. This is problematic as we know that racialized and vulnerable students often experience different developmental contexts which also differentially impact school

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achievement (e.g., Garcia Coll et al., 1996). In this paper we will focus on developmental behavioral genetics research using twin studies on children's school achievement outlining ways that this research can be more inclusive to benefit racialized students.

Like many areas of behavioral science (e.g., Syed et al., 2018), much of the evidence from twin studies on school achievement has been built using samples that are predominantly White (e.g., see the meta-analytic sample of Tucker-Drob & Bates, 2016). This leads us to conclude that behavioral geneticists do not have data on the full spectrum of experiences that children encounter, and that the current findings overwhelmingly reflect what White children experience. In addition, some (see Harden and Koellinger, 2020) have argued that behavioral genetics studies should be more inclusive of racialized groups and vulnerable populations to uncover how this research can better serve these groups while remaining vigilant in not misapplying the results of behavioral genetics research to these groups.

We argue that by failing to recruit racialized research participants, we are exacerbating existing vulnerabilities, especially if those who have the greatest risk of struggling in school (largely due to social/environmental factors) continue to be excluded. We are also missing a scientific opportunity to understand the full range of environmental risks that lead to school achievement vulnerabilities as well as the range of environmental supports that contribute to better achievement. To discuss this in greater detail we will examine previous research on developmental behavioral genetics, considering how the limited forms of racial/ethnic inclusion miss an opportunity to use science to better support our most vulnerable students. We will also consider how the process of gene-by-environment interaction provides clues for where we can better support students to improve achievement.

Developmental Behavioral Genetics and School Achievement

The evidence built to date with existing twin samples shows that both genetic predispositions (i.e., nature) and environments (i.e., nurture) influence individual differences in children's school achievement (see meta-analysis, de Zeeuw et al., 2015). Typically, it is found that genetic influences account for just over half of the variance in school achievement, with small differences depending on how school achievement is measured (e.g., 73% for word reading, 57% for mathematics; de Zeeuw et al., 2015). Although these estimates of genetic influences on individual differences (i.e., "heritability") in school achievement, are high, they are not perfect, showing that individual differences are also shaped by environmental features. Indeed, what is not accounted for by genetic influences is necessarily accounted for by environmental influences. Finally, it is important to remember that estimates of genetic and environmental influences are sample specific, representing snapshots of the experiences of that sample at that time (see van Dijk et al., 2021, for a review of what the concept of heritability does and does not represent).

The idea that genetic and environmental influences can differ based on the experiences of a sample is rooted in a concept called a gene-by-environment interaction (e.g., Purcell, 2002; note, this is not the only way that genetic predispositions and environments are linked together across development, e.g., Johnson, 2007, but it is our focus here). A gene-by-environment interaction shows us when the effect of a context on a phenotype differs

depending on your genetic predispositions, or vice versa, when the effect of your genetic predisposition on a phenotype differs depending on your context. Next, we consider what previous work on gene-by-environment interactions have shown pertaining to differences in children's school achievement.

Gene-by-Environment Interaction and School Achievement

Twin researchers interested in children's school achievement have examined many different types of contexts within different gene-by-environment interaction models, including contexts measured from within children's home and school environments. For example, in a sample of early elementary school students, Taylor et al. (2010) found that classroom quality, measured by average annual gains in reading across the students in a classroom, moderated the influence of genetics on reading ability. Genetic influences on reading skill were stronger when classroom quality was high and were weaker when classroom quality was low. These results were mirrored when the twins were followed up in adolescence (Taylor et al., 2020). This work suggests that when classroom quality is lower, there is more overall variability in individual differences in reading outcomes, and this variability was attributed to the environment and not genetics.

This pattern of moderation aligns with a bioecological model of development (also called the Scarr-Rowe effect), which proposes that *supportive* environmental contexts (e.g., higher classroom quality) enhance genetic propensity, and that *poorer* environmental contexts inhibit genetic potential (Bronfenbrenner & Ceci, 1994). The idea behind this effect is that exposure to social disadvantage is associated with a restriction of opportunities which then leads to the suppression of genetically driven individual differences. Haughbrook et al. (2017) investigated the role of school quality on early reading skills. School quality grades, a letter "grade" determined by school-level student performance on a state reading assessment and assigned by the state department of education, are assumed to represent broad aspects of the school climate. In this paper, genetic and environmental influences on reading skills were estimated separately across schools who received an "A" grade versus those that did not get an A, and then compared. Moderation analyses suggested that school quality had some effect, with students in the highest quality (A) schools showing greater genetic influences on their early literacy scores than students in all 'lower' quality (non-A) schools, again supporting the bioecological model.

Across the literature, consistent statistically significant gene-by-environment interaction effects are not certain and seem to vary by the environments being measured. This includes broader environmental factors, such as nationality. A meta-analysis that examined gene-by-environment interactions across school achievement measures found that U.S. samples tended to find statistically significant gene-by-environment interactions, but non-U.S. Western countries did not, and beyond statistical significance, the effect size of the interaction was larger for U.S. samples than not (Tucker-Drob & Bates, 2016). Supporting the bioecological model framework, the overall pattern of results in the meta-analysis suggested there is less socioeconomic stability in the U.S. versus other non-U.S. Western countries. The meta-analytic data could not speak to the source of that environmental variability, but the authors conjectured that aspects ranging from curriculum choices to

social mobility could be underlying the national differences (and it is likely a combination of many reasons).

Moving beyond just environmental variability, the bioecological model theorizes that environmental disadvantage restricts genetic variation in cognitive ability by limiting opportunities for children to seek out, or receive, educational experiences that match their own genetically influenced traits (Bronfenbrenner & Ceci, 1994). Therefore, closer comparisons of social and educational infrastructures can pinpoint key differences as targets for reform efforts where greater disparities exist. For example, if the wide array of curricula used in the U.S. versus countries that use a national curriculum (e.g., the U.K.) was the source of the environmental variation that was reducing genetic potential as found in Tucker-Drob & Bates, 2016, then national educational policy change conversations should occur. Some have gone as far as pointing to gene-by-environment interaction models as a non-experimental causal model (Fletcher & Conley, 2013). This would mean that any environment that is found to moderate genetic influences of school achievement would be a good candidate (to explore) for causal conclusions of the effect of that environment on school achievement. Certainly, many gene-by-environment interaction models are correlational and do not allow causative conclusions (and some are prone to problems, van der Sluis et al., 2011, and some are simply wrong and should not be used, e.g., Duncan & Keller, 2011), however they begin to give us evidence to allow us to characterize groups of individuals who may be vulnerable for school difficulties based on environmental factors. Newer approaches to gene-by-environment interaction models, which include using genomic data and randomized controlled trial methods, can help us understand for whom and when an environmental intervention works or what environments matter the most (e.g., Burgoyne et al., 2020; Harden & Koellinger, 2020; Neale et al., 2021). These newer variations of gene-by-environmental interactions are very powerful in understanding the causal role of the environment (e.g., Neale et al., 2021).

Limited Racial/Ethnic Diversity in Current Behavioral Genetics Approaches

As previously mentioned, most developmental behavioral genetics projects, such as twin projects, are overwhelmingly White. Proving that point, a meta-analysis on the genetic and environmental influences on reading comprehension, which summarized all available published and unpublished developmental behavioral genetics studies, found only 7 of 37 studies included a sample that was not at least 75% White (Little et al., 2017). To make that number worse, these 7 studies were publications from only two samples of all possible twin samples around the world, the National Longitudinal Survey of Youth (NLSY) sample (Rodgers et al., 1994) and the Florida Twin Project on Reading (Taylor et al., 2019). Beyond reading comprehension, Tucker-Drob and Bates (2016) mention one other study, Tucker-Drob et al. (2011), that was nationally representative of the U.S. and therefore the sample was not overwhelmingly White (this sample did not include reading which is why it was not captured by Little et al., 2017). In addition, most of the twin work reviewed in the de Zeeuw et al., 2015 meta-analysis on the genetic and environmental influences on school achievement variables was done on samples that were a majority White. Although not presented in the original article, we revisited the articles included in de Zeeuw et al., 2015 and reviewed the reported race/ethnicity demographics. Of those, only 3/11 studies on

Reading were less than 90% White participants, 2/5 for Reading Comprehension, 0/3 for Mathematics, 0/3 for Language (although one paper did not report demographics and we had to infer based on the sample location and era), 0/3 for Spelling, 0/2 for Educational Attainment. Twin samples with greater racial (and socioeconomic) diversity can show higher estimates of environmental influences than more homogenous samples (see Little et al., 2017). Given so much of the previous twin work is based on homogenous White samples, this would suggest that we do not really know the full story of the genetic and environmental influences on school achievement variables.

There are many reasons we think that developmental behavioral genetics samples have been mostly White. Some are innocuous, such as many larger twin samples come from countries that happen to keep population records, and those countries happen to be overwhelmingly White (e.g., Scandinavian countries). Some reflect the biases of many areas of science, such as most researchers in behavioral genetics tend to be White, and researchers study the populations they know. And some are more disturbing, specifically the historical support by some early behavioral geneticists of the eugenics movement, as well as the results of the field used by some to contribute to scientific racism (see Panofsky et al., 2021, for a recent example). This history has misused racialized participants, excluded them, and rightfully made them hesitant of participating in scientific research (see also Fisher et al., 2020). No matter the reason, almost the entirety of our scientific knowledge on how genetic predispositions and environments interact together on school achievement measures is based on White participants. Therefore, almost all this knowledge does not include the contexts that racialized children experience.

Why Racial/Ethnic Inclusion in Behavioral Genetics Research Matters

The contexts that racialized children experience tend to be unique, especially in the U.S. as such, we focus here on Black and Latino/a children. In terms of positive supports, Black children tend to grow up in homes with parenting styles that encourage general and academic development (Tamis-LeMonda et al., 2008). Moreover, oral language narrative skills are emphasized in the homes of Black children (Gardner-Neblett et al., 2012). In addition, different dialects are often spoken, and those who show more dialect shifting have higher reading comprehension scores (Terry et al., 2016). Latino/a children tend to grow up in homes with multiple languages being spoken which may give them enhanced executive function skills, including the “bilingual advantage” (Carlson & Meltzoff, 2008; Ware et al., 2020). Latino/a children also tend to have parents who emphasize social cohesion, education, and respect (Fuller & García Coll, 2010). Both Black and Latino/a children tend to grow up in homes with regular interaction with extended family caregivers, resulting in rich social networks of adults to support them in their education (Gerstel, 2011). These examples are all drawn from research on Black and Latino/a children and the home context, but similar statements of contextual differences can be made about other non-White children (e.g., Kim, 2021), and contexts such as schools, neighborhoods, and socioeconomic conditions. Outside of positive supports, the contexts around racialized children also tend to include racism, oppression, and segregation, further adding to the unique experiences racialized children in the U.S. experience (Garcia Coll et al., 1996).

There are noteworthy examples of the danger of assuming that data from one narrow group will apply to all individuals. For example, there has been active work to understand the role of growth mindset interventions on school achievement. Influential work suggests that brief growth mindset training in college students will have a positive effect on college achievement (Yeager et al., 2016). Given how easy the intervention is to apply, and the size of the effect, it seems to be an easy policy recommendation to incorporate this intervention for all college students, particularly for first-generation, low income, and racialized students (e.g, Yeager & Walton, 2011; see also Sisk et al., 2018; Yeager et al., 2019). However, it was pointed out that the original participant pools from the original efficacy studies were from selective schools that did not represent the populations of all colleges, and when applied to less selective, more racially diverse colleges, the intervention did not affect college achievement (Brez et al., 2020). Moreover, this highlights the notion that intervention efficacy can be influenced by different environmental factors (e.g., contextual and individual factors like kinds of colleges and students they were implemented with), and their efficacy can also be shifted by where students are in their developmental trajectory. Based on this example, it is not a far leap to say that applying developmental behavioral genetics research done using almost entirely White children to all children will result in incorrect generalizations. At worst, incorrect public policy recommendations will be made based on this limited evidence base. Appropriately, we remind the reader that Tucker-Drob and Bates (2016) ended their paper by saying that “genetically informed research…may provide a unique key to understanding the impact of specific policies on individual differences in intellectual development and school achievement.” The stated end goal of this work was to better understand mechanisms, with the hope to eventually find ways to make policy changes.

Conclusion

Taken together, we argue that gene-by-environment interaction models give us another piece of evidence in our understanding of the sources of vulnerability. Therefore, it is important for future developmental behavioral genetics work to leverage more diverse samples to gain a better understanding of the sources of vulnerability and find better ways to support vulnerable children. This is especially the case in the U.S. context. The U.S. is a remarkable country in many ways, including having substantial socioeconomic variation and racial and ethnic diversity. This coupled with fewer socialized support systems, a history of racialized discrimination, and contemporary sociopolitical turmoil, leads to many reasons why there are substantial school vulnerabilities felt by non-White children. The bioecological theory illustrates that for racialized children in the U.S., vulnerability in school achievement is one manifestation of how they are more likely to grow up in contexts that systematically limit their genetic potential for school success (Bronfenbrenner & Ceci, 1994; see also Garcia Coll et al., 1996).

We strongly believe that racialized children need to be included in developmental behavioral genetics studies. We acknowledge the history of scientific racism and eugenics that some behavioral geneticists have taken part in (see Panofsky, 2021). We also recognize how this history has negatively impacted our science and the ability of our science to be used to serve some of the most vulnerable children. As such, behavioral genetics researchers

must recruit more inclusive and diverse samples. When we do so, we must be careful and thoughtful with how we include racialized children into our samples, including how we treat their data (Birney et al., 2021). We need to be purposely antiracist in our science (Roberts & Rollins, 2020). We are not the first to say that developmental science (Syed et al., 2018), intelligence and achievement research (Holden & Hart, 2021), or behavioral genetics (Oni-Orisan et al., 2021) need to include more racialized participants. Indeed, even the National Institutes of Health issued a request to have more racialized participants (policy announcement NOT-OD-15-102). But we believe it is critically important to say it again, and to say it in the context of us needing to understand the full range of environments that children are experiencing. Only then, will we be truly able to examine the influences of certain vulnerabilities and their role in gene-environment interaction. We cannot understand the causal role of the environment, beyond the genetic confounds (Hart et al., 2021), if we do not measure the full environment. By measuring a narrow range of environmental variance, due to the narrow range of participants we include in our studies, we risk that our data will not reflect the full range of vulnerable students. The point of science is to collect evidence to support human flourishing. Given racialized students in the U.S. are at high risk of not learning fundamental skills such as how to read (see the National Assessment of Educational Progress Nation's Report Card, 2019), our science needs to change. With this information, we could bridge the gap between research and social applications. Until we do, we argue that developmental behavioral genetics research should not be used to make sweeping policy recommendations.

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