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Understanding Heritability in the Context of Reading Ability and Instruction

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Abstract

In this paper, we discuss what heritability is and how it is measured, and explain why estimates of heritability are not always the same in different scientific papers. After providing this foundational knowledge, we bust some common myths about heritability. We end with discussing how teachers can use their knowledge about heritability in their own practice.

The challenging task faced by every reading teacher is to ensure that all students, despite coming into school with a wide variety of pre-reading levels, leave as competent readers. This task is complicated because learning to read is more difficult for some students than others for a variety of reasons—including if a student has family members who also had trouble learning to read. Students from families with a parent or sibling with dyslexia are about four times more likely to also have dyslexia than other students (Snowling & Melby-Lervaag, 2016). This is because parents pass genes related to reading ability to their children. Many years of research has pointed to the importance of genes to our development, including our reading ability.

A common misconception about the role of genes in our development is that they predetermine all our future outcomes. As it happens, hearing the words *genetic, heritability*, or *inherited* can often mislead teachers into a sense of instructional resignation—the false notion that instruction will not make a difference in a student's progress through school. For reading ability, this would mean that each student's genes would predetermine if they become a proficient reader or if they will struggle with reading—regardless of the instruction they receive. In truth, the role genes play in reading development is not that simple. Reading ability does not rest solely on genes inherited from one's family; a family's environmental influences play a part too. For example, some students may have problems learning to read because they were not exposed to language-rich word play when they are young. Others may have success with reading because their caregivers often engaged in shared, dialogic read-alouds (i.e., actively involving children in talking about a story while reading).

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We know that genes and environments exert influence on each other. Genes are shaped by environments and environments are shaped by genes. We also know that providing evidence-based reading instruction strengthens students' abilities, no matter their genes or home literacy environments. In fact, even with a family history of reading difficulties, most students can still be taught how to read through targeted and evidence-based reading instruction. It is important for educators to understand the roles that genes and the environment play in reading development so that they may combine this understanding with knowledge of a student's family reading history to inform their teaching practice, if this history is available.

People differ from each other in skills and characteristics, and in research we refer to these differences as *individual differences*. The how and why of these individual differences, including individual differences in reading ability, are attributable to nature (i.e., genes) *and* nurture (i.e., the environment)—not either/or, but both. The role genes play in our development is not simple. While nature sets the range of potential for each person's ability, the eventual ability within this range is determined by nurture/environment. This concept is easily illustrated by looking at a characteristic with obvious individual differences, such as height. Based on their genes, each person has a potential height span, but their environment determines how tall each person will eventually be. For example, take two children with the same potential height span of 5'5" – 5'8". One child grows up eating a healthy diet and reaches the maximum potential of 5'8". The second child, however, grows up malnourished, and the inadequate diet results in a lower height of 5'5". The same interplay between nature and nurture exists in reading ability. Each child has a predisposition of reading ability, but in order to reach their full potential, children need to be exposed to "healthy" environments, such as shared, dialogic read-alouds and targeted, evidence-based reading instruction. The role teachers have is critical in ensuring that children reach their maximum potential.

In the scientific literature, *heritability* is the numerical representation of the amount of individual differences in a skill or characteristic that can be explained by nature, or genes. Educators are likely acquainted with the idea of nature and nurture, may have heard the term heritability before, and may even be aware of specific findings from the scientific literature, such as reading comprehension ability shows a heritability of just over 50% (Little et al., 2017). However, educators may still be unsure about the actual meaning of the term heritability and what it has to do with their own reading instruction. In this paper, we will start by discussing what heritability is and how it is measured, and then explain why estimates of heritability are not always the same in different scientific papers. After providing this foundational knowledge, we will disprove some common myths about heritability. We will end with discussing how educators can use their knowledge about heritability in their own practice.

What Is Heritability and How Is It Estimated?

Any reading teacher will have noticed that students differ in their reading ability. As we mentioned above, one part of these differences is a result of the environment students grew up in (including their home, school, and previous reading instruction), and the other part is a result of their genes. The numerical representation of the influence of genes on our individual differences is called *heritability*. Heritability estimates range from 0.0 to 1.0. An estimate of 0.0 means that none of the individual differences are associated with differences in genes. Conversely, an estimate of 1.0 means that all of the individual differences are associated with differences in genes. Whatever portion of the reading skill is not due to heritability is then a result of the environment.

A common way for researchers to estimate how much of the differences between people is explained by heritability and by the environment is by doing a twin study. In a twin study, researchers collect data from both identical and fraternal twins. Twins are ideal for estimating heritability because they share a large portion of their environment, including home environment, classrooms, and the prenatal environment. However, the two types of twins are different when it comes to their genes. Identical twins come from one fertilized egg and, as a result, share 100% of the genes. Fraternal twins come from two fertilized eggs, and, like any other sibling pair, share around 50% of their genes. This key difference in the percentage of genes twin types share, combined with the common environment experienced by both types of twins, creates a natural way for researchers to estimate how much of the individual differences in reading ability is explained by heritability versus environmental factors.

Figure 1 demonstrates the idea behind a twin study. In the figure, the reading fluency scores of several identical and fraternal twin pairs have been plotted on a graph. The scores of identical twins (on the left) are more concentrated together than the more scattered scores of fraternal twins (on the right). This implies that identical twins are more similar in their reading fluency than fraternal twins. Since both kinds of twins have the same kind of environmental input, but identical twins share all their genes whereas fraternal twins share only half their genes on average, any greater similarity between identical twins compared to fraternal twins must be driven by genes. It is also possible that identical and fraternal twins are equally similar to each other. This would show up in a graph as similarly scattered scores. If identical and fraternal twins are similarly alike in reading fluency, environment would more likely be the cause. Since both kinds of twins share a home and school environment, their common environmental influences determine their similarity on a reading skill.

What Causes Differences in Heritability Estimates?

The way popular and social media talks about heritability estimates may make it seem as if they are the same for everyone, but this is not the case. Heritability estimates are actually specific to the twin sample included in a particular study. For example, a study that included a twin sample from Colorado reported the heritability estimate of decoding skills as .71 (Gayan & Olson, 2001). That is, in this sample of twins, 71% of the individual differences in decoding skills were likely due to differences in genes. However, a different study from the Western Reserve Reading Project that included a twin sample mostly living in Ohio, had a heritability estimate of decoding skills of .49 (Petrill et al., 2006). This is almost a 20% difference in the estimated influence of genes between these two studies. This does not mean that decoding skills for twins in Colorado are more influenced by genes than for twins in Ohio. There are various reasons why heritability estimates can be different across studies, and, in order to interpret what a heritability estimate means, it is important to consider the factors that can influence the values of heritability.

To determine if a characteristic can explain individual differences in reading ability, students need to differ on that characteristic. For instance, if we needed to figure out whether student age could explain differences in reading scores, we would need a sample that included students of different ages. The same is true when we are estimating the influence of genes or the environment; there need to be differences in the genes and environments of the sample of students in order to determine whether they influence a given characteristic.

If the environment is highly similar for all students in a sample, it cannot account for individual differences. For example, imagine a study involving twins living in the same neighborhood, receiving reading instruction from the same curriculum, and being read to daily for the same amount of time. Since there is little difference in their environmental input, this cannot be the source of individual differences. Because all individual differences in a characteristic are due to a *combination* of genes and environment, if the environment is so similar in a sample that it cannot contribute to individual differences, then the only source of individual differences must be due to genes. This leads to a low estimate of environmental influences. Consequently, the heritability estimate will be high. The opposite is true as well. If there is little variation in genes (say we were able to find 100 students with the same genetic make-up), any variation in their reading skills would be completely attributable to their environments. In other words, if the environmental estimate is low, heritability is necessarily high, and vice versa.

We can use this knowledge to explain why two studies have different heritability estimates for the same characteristic. Both geographical location and timing can influence the similarity of environments. The high heritability estimate for the Colorado twins implies that, compared to the Ohio twins, the environmental influences on their decoding skills (e.g., demographics, instruction, access to books) must have been more similar. Additionally, the twins' decoding skills across the two samples were measured in different calendar years. Most of the Ohio twins were measured after a national reading initiative might have led to more standardization in reading instruction. As a result of this increased curriculum uniformity, the role of the environment in the Ohio sample's decoding skills may have been decreased leading to a higher heritability estimate. In contrast, most of the Colorado twins were measured before the start of this national initiative. The higher variability in reading instruction (i.e., the environment) may have led to the lower estimate of heritability for the Colorado twins.

Because heritability estimates provide a snapshot of genetic influences at the time of measurement, they are also dependent on the age of the twins in a sample. Differences in genes may become more or less able to explain individual differences in reading ability as students grow older. Thus, heritability estimates can change over time. This can be a result of the environment becoming more similar over time. For example, phonics instruction usually diminishes in the upper elementary grades. While phonics instruction may still vary widely across classrooms in the early elementary years, there are likely only small differences in classroom phonics instruction for older students. This will make individual differences in decoding skills seem more related to genes as students progress through elementary school.

This idea is supported by research showing that heritability estimates for a range of reading skills such as reading comprehension (Little et al., 2017), oral reading fluency (Hart et al., 2013), and word reading (Logan et al., 2013), increase across the elementary grades. To illustrate the potential influences of age on heritability estimates, we will come back to the differences between the Colorado twins and Ohio twins mentioned earlier. The Colorado twins were 8 to 20 years old, whereas the Ohio twins were 4 to 8 years old, making the Colorado twins older on average and representing a wider range of ages. If phonics instruction is typically offered early in elementary school, most of the Colorado twins would not have received phonics instruction anymore, and thus have more similar phonics environments. The different heritability estimates found for the samples could be because the twin samples were measured at different ages that receive different instruction.

If two studies have different heritability estimates, which estimate should we consider more accurate? The answer is: neither and both. A single heritability estimate on its own does not provide any indication of which possible environmental factors played a role in the differences of a characteristic. Multiple heritability estimates can be informative through comparison and provide useful information about the environmental and individual characteristics of the samples from which they were derived. For example, a higher heritability estimate for the Colorado twins compared to the Ohio twins tells us that the individuals in the Colorado twin sample have more equitable environments. Heritability estimates can also be combined to give a global overview. When applying this approach across many twin samples, scientists have found that *both* nature and nurture matter to almost the same extent for reading ability (Little et al., 2017).

Heritability Myths

A few of you may have raised your eyebrows in response to reading that the heritability of decoding in the Colorado sample was 71%. A common reaction to the relatively high estimates of heritability for reading outcomes is a sense of discouragement: If such a large part of individual differences in reading is related to genes, what good can instruction really do? Doesn’t this mean that students coming into school at risk for reading problems will always stay at risk, no matter how hard a teacher tries? The answer to this question is unequivocally: No! The most notable misinterpretations of heritability are that (a) heritability represents a fixed, irreversible characteristic, (b) that heritability provides us with information about the scores of the sample, (c) that heritability predicts how a specific student will perform, and (d) that heritability can explain differences in performance between groups of students. The paragraphs that follow will directly address and disprove these common misinterpretations.

Misinterpretation 1: heritability as a fixed characteristic.

Even if estimates of heritability for reading skills are high, this does *not* mean the specific skill is fixed and cannot be influenced by the environment, including through instruction. As we mentioned in the previous section, heritability estimates are specific to a particular study sample, including their environment and their individual characteristics. Accordingly, heritability estimates represent a snapshot of a statistical reality—but not potential ability. Just because something is genetic (i.e., heritable), it does not mean the outcome is determined. For example, even the devastating cognitive deficits that can result from the genetic disorder Phenylketonuria (PKU) can be completely avoided by changing a child's diet. In other words, by changing the child's environment, in this case represented by their dietary input, the effects of the PKU gene are completely avoided.

Let's bring this back to reading. The heritability estimates for decoding skills mentioned earlier range from .48 to .71. These estimates imply that student environments can explain around 30–50% of the differences between students in their decoding skills. Since reading instruction is just one part of a student's environment, deterministic thinking would lead one to believe that changing the instruction would not greatly impact students' decoding ability. Scientific research has consistently debunked the concept of genetic determinism for reading, showing that specific interventions targeting phonics can, in fact, significantly improve students' decoding abilities (NICHD, 2000). This finding that interventions help move the needle on children's decoding skills, highlights the important point that heritability is telling us what *is*, not what *can be*. Through empirically-based interventions and instructional inputs, teachers can make a difference in students' reading outcomes, regardless of what heritability estimates say *is*, because we still have the space available for what *can be*.

Misinterpretation 2: heritability informs us of scores of a sample.

A second point to keep in mind is that heritability estimates do not tell us the actual score or ability level of the sample. Heritability is an *estimate* of how much of individual differences result from genetic differences. Even if people collectively increase on a particular skill or characteristic, there will still be individual differences. To illustrate this concept, we can look at the heritability estimates of height. Even though the average height of North American and Australian women increased by almost 5cm from 160.2cm in the 1900s to 165cm in the 1970s, the heritability estimates did not change, staying within a range of .63–.76 (Jelenkovic et al., 2016). This shows that even though there was a significant change in average height estimates with women collectively growing taller (likely due to more nutritious diets), the individual differences around the average height remained the same. Thus, even though all women were taller, some women are just taller or shorter than others.

The same thing happens in reading. Collectively, U.S. fourth graders have increased their average scores on the NAEP reading assessment between 1992 and 2019 (NCES, 2019), but some students still read better than others. The individual differences have remained. Thus, because heritability is aimed at explaining why students differ in reading skills, regardless of the average ability level of the sample, heritability estimates do not change based on the shifts in average ability.

Misinterpretation 3: heritability predicts how a specific student will perform.

A third common misconception about heritability is that it tells us how genes influence the ability of a specific student. For example, in the study of Ohio twins, decoding skills were estimated to have a heritability of .48 (Petrill et al., 2006). This means that around half of the differences in decoding skills of the twins in that particular sample were the result of differences in their genes. However, this estimate does not imply that 48% of the decoding skills of each individual student in the sample are because of their genes. Heritability tells us what is happening, on average, in the sample—not what is happening for each individual within the sample. Instead, some students may have lower heritability contributions and higher environmental contributions and vice versa. When added together and averaged, the differences between students are lost and only the average variability remains.

Misinterpretation 4: heritability can explain differences in performance between groups.

A final, crucial misunderstanding of heritability is the notion that it can explain differences between specific groups of people. This has resulted in the troubling misuse of heritability to claim inferiority of a specific population. Unfortunately, heritability estimates have been, and continue to be, used to claim there are inherent differences between populations based on characteristics such as ethnicity and race. We emphasize the fact that these claims have no empirical basis. As we have discussed in previous sections, heritability only tells us about the sample in a specific study at the time of measurement and no more. It is a snapshot of what is happening on average in a specific study sample. It does not tell us anything about any intrinsic quality of the more general population or any individual within this population. The proliferation of such prejudicial ideas, however, warrants repetition that such claims are erroneous, empirically baseless, and do not abide by the actual properties of heritability estimates.

Final Thoughts

From our account of heritability, you may have gotten the impression that heritability estimates for reading are actually not that useful for educators. We agree that knowing the specific heritability estimates of reading ability probably isn't that useful to teachers in day-to-day classroom instruction. However, from a broader perspective, heritability estimates have practical value. Recent evidence shows that heritability estimates of reading and math difficulties are highly related, meaning that reading difficulties and math difficulties share the same genetic influences (Daucourt et al., 2020). This information may be useful to teachers, as it suggests that a student struggling with reading might also have difficulty with math. Similarly, by knowing that reading difficulties run in families, teachers can keep a closer eye on students from families with a history of struggling to learn to read. This illustrates the point that the broader context of heritability can give teachers valuable insights when it comes to planning and designing instruction and interventions. Admittedly, truly translational work that makes heritability estimates useful for teachers has been lacking, and we hope that more work in this direction will be done soon.

As we outlined, heritability estimates do not represent genetic determinism, and empirical evidence shows that environmental inputs, like targeted interventions, are effective and important for improving students' reading skills. Thus, high heritability estimates are no reason for instructional resignation. In fact, teachers are fundamental in changing the numerical reality of what *is* into what *can be*. By providing high quality reading instruction and intervention adapted to suit each student's needs, teachers are instrumental in making sure all students reach their full potential, regardless of their genes. Quality instruction and intervention will not eliminate individual differences in reading for students, and a range of abilities will always exist. However, quality instruction and intervention by skilled teachers will continue to be essential to improving the average performance of all students.

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References

Bergen E. van, Snowling MJ, Zeeuw E. L. de, Beijsterveldt C. E. M. van, Dolan CV, & Boomsma DI (2018). Why do children read more? The influence of reading ability on voluntary reading practices. Journal of Child Psychology and Psychiatry, 59(11), 1205–1214. 10.1111/jcpp.12910 [PubMed: 29635740]

Daucourt MC, Erbeli F, Little CW, Haughbrook R, & Hart SA (2020). A meta-analytical review of the genetic and environmental correlations between reading and Attention-Deficit/Hyperactivity Disorder symptoms and reading and math. Scientific Studies of Reading, 24(1), 23–56. 10.1080/10888438.2019.1631827 [PubMed: 32189961]

Gayan J, & Olson RK (2001). Genetic and environmental influences on orthographic and phonological skills in children with reading disabilities. Developmental Neuropsychology, 20(2), 483–507. 10.1207/S15326942DN2002_3 [PubMed: 11892949]

Hart SA, Logan JAR, Soden-Hensler B, Kershaw S, Taylor J, & Schatschneider C (2013). Exploring how nature and nurture affect the development of reading: An analysis of the Florida Twin Project on Reading. Developmental Psychology, 49(10), 1971. 10.1037/a0031348 [PubMed: 23294149]

Jelenkovic A, Hur Y-M, Sund R, Yokoyama Y, Siribaddana SH, Hotopf M, Sumathipala A, Rijsdijk F, Tan Q, Zhang D, Pang Z, Aaltonen S, Heikkilä K, Öncel SY, Aliev F, Rebato E, Tarnoki AD, Tarnoki DL, Christensen K, … Silventoinen K (2016). Genetic and environmental influences on adult human height across birth cohorts from 1886 to 1994. ELife, 5. 10.7554/eLife.20320

Little CW, Haughbrook R, & Hart SA (2017). Cross-study differences in the etiology of reading comprehension: A meta-analytical review of twin studies. Behavior Genetics, 47(1), 52–76. 10.1007/s10519-016-9810-6 [PubMed: 27630039]

Logan JAR, Hart SA, Cutting L, Deater-Deckard K, Schatschneider C, & Petrill S (2013). Reading development in young children: Genetic and environmental influences. Child Development, 84(6). 10.1111/cdev.12104

National Center for Education Statistics, U.S. Department of Education. (2019). The condition of education 2018. (NCES 2018–144). Government Printing Office.

National Institute of Child Health and Human Development (NICHD). (2000). Report of the National Reading Panel: Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction: Reports of the subgroups (NIH 00–4754). Washington DC: U. S. Government Printing Office.

Petrill SA, Deater-Deckard K, Thompson LA, De Thorne LS, & Schatschneider C (2006). Reading skills in early readers: Genetic and shared environmental influences. Journal of Learning Disabilities, 39(1), 48–55. 10.1177/00222194060390010501 [PubMed: 16512082]

Snowling MJ, & Melby-Lervaag M (2016). Oral language deficits in familial dyslexia: A meta-analysis and review. Psychological Bulletin, 142(5), 498. [PubMed: 26727308]

Resources for further reading:

Introductions

http://www.nealelab.is/blog/2017/9/13/heritability-101-what-is-heritability

http://www.nealelab.is/blog/2017/9/13/heritability-201-types-of-heritability-and-how-we-estimate-it

https://kids.frontiersin.org/article/10.3389/frym.2019.00059

http://psych.colorado.edu/~carey/hgss/hgssapplets/heritability/heritability.intro.html

More technical papers

Bishop DVM (2015) The interface between genetics and psychology: Lessons from developmental dyslexia. Proceeding of the Royal Society B. 282:20143139 10.1098/rspb.2014.3139

Sokolowski HM, & Ansari D (2018). Understanding the effects of education through the lens of biology. Npj Science of Learning, 3(1),1–10. 10.1038/s41539-018-0032-y [PubMed: 30631462]

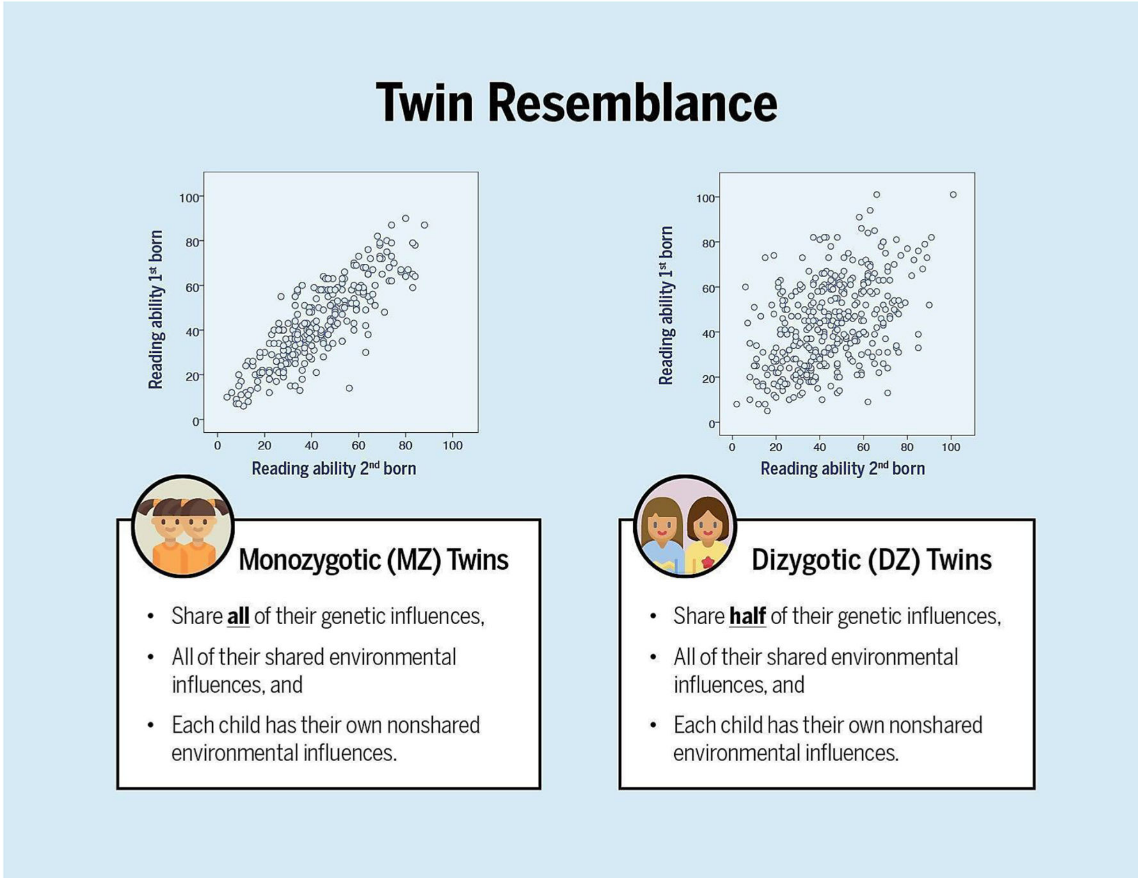

Figure 1. The Logic Behind Twin Research

Note. The scatterplots in this figure show that identical (MZ) twins score more similarly for reading ability than fraternal (DZ) twins. That is, the dots on the graph of MZ twins are closer together than those of DZ twins. This pattern indicates a higher influence of genetics on the individual differences in reading ability. The data represent Grade 2 word level reading fluency test scores and come from van Bergen et al. (2018). Figure by Hart and colleagues (2020), available at https://bit.ly/3k4w2Ji under a CC BY 4.0 license.