

Gene–environment interactions and their impact on the development of personality traits

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Abstract

Although there is good reason to suspect that gene–environment interactions (GxE) contribute to the development of personality, there is relatively little research on this topic to date. This review examines available studies of GxE in personality, focusing specifically on the personality traits of negative emotionality (the propensity to experience aversive mood states) and impulsivity (difficulty inhibiting the expression of affect or impulse). Extant studies of impulsivity yield conflicting results, and thus do not allow for any clear conclusions. However, parenting does appear to hold promise as a moderator of genetic influences on negative emotionality. In particular, genetic influences appear to make important contributions to negative emotionality, but only in the absence of a negative parent–child relationship. By contrast, poor parenting appears to increase negative emotionality in offspring, regardless of the child's genetic predispositions. Such findings represent an exciting, if somewhat unexpected, advance in the field, and highlight a clear need for additional research on this topic.

Keywords gene–environment interplay; GxE; impulsivity; negative emotionality; personality

Introduction

Personality has a profound impact on human life experiences, including the development of psychopathology. Indeed, there is now convincing evidence that specific personality traits precede the development of most forms of adult psychopathology, while also serving to differentiate between disorders.^{1,2} High levels of negative emotionality (NEM – the propensity to experience aversive mood states) predict the future development of all common forms of psychopathology (affective, anxiety, substance dependence, and antisocial personality disorders), suggesting that NEM may function as a general risk factor for both internalizing and externalizing psychopathology. High levels of impulsivity (IMP – difficulty inhibiting the expression of affect or impulse), by contrast, appear to uniquely predict only the externalizing spectrum of disorders, thereby differentiating them from the internalizing affective and anxiety disorders.¹ Moreover, there is growing evidence that NEM and IMP share genes with psychopathology. For example, Krueger and colleagues³ found

evidence that IMP shares most of its genes with the broader externalizing spectrum of psychopathology. Similarly, a recent meta-analysis concluded that the serotonin transporter gene (*5HTTLPR*) accounts for 10% of the phenotypic variance in amygdala activation (a key element of NEM and several forms of psychopathology).⁴

Gene–environment interactions

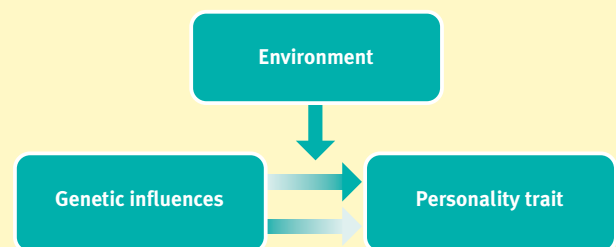
The origins of NEM and IMP are thus a critical avenue of research for the field of psychiatry. With this goal in mind, the present review explores the origins of NEM and IMP, with a particular focus on gene–environment interactions (GxE) (Figure 1). GxE are defined as the moderation of genetic predispositions by environmental experience, such that particular environmental experiences alter subsequent genetic expression. Despite this relatively simple definition, the actual manifestation of GxE is proving to be more complicated than originally assumed. For example, it is typically assumed that ‘bad’ environments activate genetic risk, whereas ‘good’ environments suppress genetic risk. However, it is equally likely that deleterious environments may serve to de-activate the expression of otherwise protective genetic influences. Alternatively, it may be that genetic risk is best expressed in the absence of environmental risk. In the latter case, it may be that more extreme or unfavourable conditions act as ‘environmental main effects’, effectively suppressing the otherwise normal expression of genetic influences.^{5–7}

No matter what the manifestation of GxE, they are a logical contributor to personality.⁸ In particular, both NEM and IMP are approximately 50% heritable, a key point given that GxE are generally contained with the genetic proportion of variance in classical decompositions of variance (see Purcell⁹ for a discussion of this point). Accordingly, this reasonably high estimate of genetic influences need not solely index genetic ‘main effects’ but can also be taken as evidence of possible GxE.

GxE studies: latent versus molecular

That said, there is relatively little evidence to date of GxE in personality (Tables 1 and 2). Available studies of NEM and IMP, at both the latent and molecular levels of analysis, will be reviewed

Schematic of a gene–environment interaction affecting personality traits



Environmental experiences (risky or protective) serve to enhance (arrow with progressively more colour) or suppress (arrow with progressively less colour) genetic influences on personality traits

Figure 1

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Extant studies of gene–environment interactions in negative emotionality

Reference	N	Gene	Environment	Significant GxE? If so, how?
Krueger <i>et al.</i> ¹⁰	2320	Aggregate	Mutual regard between parent and child	Yes; genetic influences expressed most strongly in presence of high mutual regard
Krueger <i>et al.</i> ¹⁰	2320	Aggregate	Parent–child conflict	Yes; genetic influences expressed most in the presence of low parent–child conflict
Jang <i>et al.</i> ¹¹	326	Aggregate	Family conflict	Yes; genetic influences expressed most in presence of low family conflict
Jang <i>et al.</i> ¹¹	540	Aggregate	Maternal overindulgence	Yes; genetic influences expressed most in presence of maternal overindulgence
Kendler <i>et al.</i> ¹²	1914	Aggregate	Family dysfunction	No, but trend was somewhat consistent with pattern above

GxE, gene–environment interactions.

Note: 'Aggregate' indicates that the study examined genetic influences inferred from comparison of family members with different degrees of genetic relatedness (i.e. twins), but did not examine specific genes.

Table 1

in turn. As most readers will be familiar only with molecular GxE, it is worth taking a moment to clarify the distinction: latent or biometric analyses centre on environmental moderation of latent or inferred genetic risk, calculated via comparisons of resemblance among relatives with varying degrees of genetic similarity.⁹ Molecular analyses, by contrast, focus on environmental moderation of the expression of directly measured genes.¹⁷ Each approach has significant advantages and disadvantages.¹⁸ Because latent genetic influences comprise the aggregate of all genetic influences on the trait in question, environmental moderators of latent genetic influences are likely to represent particularly potent GxE.¹⁸ Moreover, the absence of latent GxE strongly suggests that molecular GxE contribute little, if any, meaningful genetic variance to the trait in question. Even so, there are limits to this approach, most notably that latent genetic risk reflects statistical signals from susceptibility loci¹⁸ but reveals nothing about the number or location of genes involved, and thus has limited direct biological relevance. Molecular GxE research circumvents the descriptive nature of latent genetic risk, as genes are measured directly. However, most molecular GxE work to date has focused on the moderation of a single polymorphism within a given candidate gene, and is thus so specific that it probably represents only a very small part of the overall causal pathway in complex biobehavioural phenomena (such as personality). Even more troubling, a recent simulation study indicated that, because of well known pathologies of scale, regression can induce what appear to be significant molecular GxE, even when none is present in the underlying liability of the disorder.¹⁹ Given this, the present review places more interpretative emphasis on latent GxE studies (although available molecular studies are also presented).

Impact of GxE on negative emotionality

Studies of GxE in NEM are presented in Table 1. The largest and most rigorous study of GxE in personality has been conducted by Krueger and colleagues.¹⁰ They examined whether and how positive and negative aspects of parenting moderated aggregate

(latent) genetic influences on personality in an epidemiologically based sample of 1160 twin pairs (or 2320 twins). Results were striking: aggregate genetic influences on NEM were most pronounced when the parent–child relationship was characterized by either high levels of mutual regard or by low levels of parent–child conflict (even though mean levels of NEM were *lower* in these same individuals). In other words, genetic influences were necessary to develop NEM in the presence of a *positive* parent–child relationship. By contrast, there were minimal genetic influences in those exposed to poor parenting; instead, poor parenting appeared to increase offspring NEM *regardless of the child's genetic predispositions*. Such findings are provocative, as they (seemingly paradoxically) imply that genetic influences on NEM are more pronounced for those with lower levels of the trait.

Importantly, the results of Krueger *et al.*¹⁰ replicate those of another study: Jang *et al.*¹¹ found that as levels of family conflict increase, genetic influences on emotional instability (a construct very similar to NEM) decrease to near-zero levels, dropping from 87% to 14% of the variance. They then found a similar pattern of effects for maternal overindulgence in a different twin sample. In short, results again suggested that genetic influences are most important for those not at environmental risk. Although the consistency of these findings across three independent samples is certainly impressive, at least one study found no evidence of genetic moderation. Kendler and colleagues¹² examined whether family dysfunction moderated the impact of genetic influences on neuroticism (NEM as assessed via the Big Five). They again found that NEM increased with increasing levels of family dysfunction. However, results revealed little, if any, evidence of genetic moderation (although the pattern of effects was in the expected direction).

Even so, the above studies are collectively consistent with some GxE on NEM (albeit not in the direction some might initially have predicted): genetic influences are expressed more in the presence of positive parent–child/familial relationships, but are expressed only minimally in the presence of negative relationships – a pattern that holds despite the fact that mean levels

Extant studies of gene–environment interactions in impulsivity

Reference	N	Gene	Environment	Significant GxE? If so, how?
Krueger <i>et al.</i> ¹⁰	2320	Aggregate	Mutual regard between parent and child	No
Krueger <i>et al.</i> ¹⁰	2320	Aggregate	Parent–child conflict	No
Boomsma <i>et al.</i> ¹³	3948	Aggregate	Raised in religious household	Yes; genetic influences (especially in males) expressed most in absence of religious upbringing
Sheese <i>et al.</i> ¹⁴	45	<i>DRD4</i>	Parenting quality	Yes; long <i>DRD4</i> allele predicted increased IMP in presence of low parenting quality
Keltikangas-Järvinen <i>et al.</i> ¹⁵	92	<i>DRD4</i>	Hostile childhood environment	Yes; short <i>DRD4</i> allele predicted increased IMP in presence of hostile childhood environment
Lahti <i>et al.</i> ¹⁶	150	<i>DRD4</i>	Frequency of paternal drunkenness	Yes; short <i>DRD4</i> allele predicted increased IMP in presence of frequent paternal drunkenness

GxE, gene–environment interactions; IMP, impulsivity.

Note: 'Aggregate' indicates that the study examined genetic influences inferred from comparison of family members with different degrees of genetic relatedness (i.e. twins), but did not examine specific genes.

Table 2

of NEM are significantly higher in the latter. In short, it appears that less favourable parenting/familial experiences may act as 'environmental main effects', serving to increase NEM regardless of genetic risk.

Impact of GxE on impulsivity

Studies of GxE in IMP are presented in Table 2. As seen there, results for IMP are more mixed and far less consistent than those for NEM. Krueger and colleagues¹⁰ found no consistent evidence that parent–child relationships (either positive or negative) moderated genetic influences on impulsivity. Such findings thus suggest that parenting may not serve to moderate genetic influences on IMP, or, if it does, it accounts for a trivial proportion of genetic variance. Given this, it is surprising that two molecular studies have identified GxE for IMP in which parenting/the childhood environment moderated the impact of a particular polymorphism. Sheese *et al.*¹⁴ examined whether observed parenting quality interacted with the variable nucleotide tandem repeat dopamine receptor D₄ (*DRD4*) to predict mother-reported temperamental sensation seeking (which includes IMP) in a sample of 45 toddlers. (The focus on *DRD4* was appropriate given the often-studied, but not always replicated, association between *DRD4* and IMP.²⁰) They found that the *DRD4* long or seven-repeat allele predicted increased toddler IMP, but only in the presence of lower parenting quality. Keltikangas-Järvinen and co-workers¹⁵ also found evidence that a hostile childhood environment interacted with the *DRD4* polymorphism to predict novelty seeking (a construct very similar to IMP) in a sample of 92 children. Importantly, however, they found that the childhood environment interacted with the short (or two- to five-repeat allele) to predict increases in IMP.

The above findings are collectively quite difficult to understand. Results suggest that parenting/the family environment (1) does not moderate genetic influences on IMP, (2) moderates the impact of the long (but not the short) allele within the *DRD4* gene on IMP, and (3) moderates the impact of the short (but not

the long) allele within the *DRD4* gene on IMP. The contradictory molecular findings are especially troubling. Such findings could be the result of the very small sample sizes examined in these studies. Specifically, because single genes are unlikely to have large effects on complex phenotypes such as personality, very large samples are needed reliably to detect specific genetic effects. That said, these results may also reflect the latent results of Krueger *et al.*,¹⁰ which suggest little to no GxE for IMP. Should these results be correct, contradictory and/or null results would be expected.

Despite these less-than-promising results for parenting/the family environment, other environmental experiences may still moderate genetic influences on IMP. Boomsma *et al.*¹³ found evidence that aggregate genetic influences on IMP were weaker when the individual had been raised in a religious family. Alternately, Lahti and colleagues¹⁶ found that the short *DRD4* allele interacted with frequency of paternal drunkenness to predict increased IMP, although, again, the sample was quite small by molecular genetic standards ($n = 150$). In short, there may yet be important GxE underlying IMP. However, the environmental experience in question may involve something besides parenting.

Summary

Extant research suggests that GxE may affect the development of personality. However, currently available results are too few (and for impulsivity, too conflictual) for any firm conclusions to be drawn. Even so, parenting holds promise as a moderator of genetic influences on negative emotionality. However, genetic influences appear to make important contributions to NEM only in the absence of a negative parent–child relationship, whereas poor parenting increases offspring NEM regardless of the child's genetic predispositions. Such findings represent an exciting, if somewhat unexpected, advance in our understanding of the origins of NEM, and highlight a clear need for additional research on this topic. ♦

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FURTHER READING

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