The Equal Environment Assumption in Twin Studies of Political Traits: Social Confounds and Suggested Remedies

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Acknowledgements: Our thanks to Christa McDermott for her assistance with an early draft of this article and to Stanley Feldman, Pete Hatemi, M. Kent Jennings, Laura Klem, Nicky Newton, Leon Porter, Perry Silverschanz, Abby Stewart, Laura Stoker, Jennifer Talarico, Cynthia Torges, David Winter, Nick Winter, and the anonymous reviewers for their advice, comments, and suggestions.

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ABSTRACT

While twin studies of political characteristics are being published at a rapid rate, there remains confusion regarding the tenability of the *equal environment assumption* (EEA) on which such studies depend. Building on literatures in behavioral genetics, psychology, and political science, this article discusses in detail two specific mechanisms – social contact and identification between twins – that may introduce EEA violations, leading to inflated heritability estimates in political twin studies. In addition to offering a critical perspective, this work offers a constructive approach to the study of genetic and environmental influences on political characteristics by discussing explicit measures of potential environmental confounds and statistical tests that utilize such measures, with the goal of improving inferences drawn from twin study designs.

In May 2005, the *American Political Science Review* published an analysis of twins' political ideologies by Alford, Funk, and Hibbing, who argued that much of the variance in political ideology was attributable to genetic variation. While scholars in behavioral genetics had published similar findings in years previous (e.g., see Martin, Eaves, Heath, Jardine, Feingold, & Eysenck 1986), it was Alford et al.'s study that greatly excited the field of political science and quickly spurred additional interest in twin studies. Since 2005, twin studies investigating the heritability of political partisanship, political ideology and attitudes, and voting behavior have been published at a rapid pace (e.g., Eaves & Hatemi 2008; Fowler, Baker, & Dawes 2008; Fowler & Schreiber 2008; Hatemi, Alford, Hibbing, Martin, & Eaves 2008; Hatemi, Funk, Medland, Maes, Silberg, Martin, & Eaves 2009; Hatemi, Medland, & Eaves 2009; Hatemi, Medland, Morley, Heath, & Martin 2007; Settle, Dawes, & Fowler 2009; Hatemi, Hibbing, Medland, Keller, Alford, Smith, Martin, & Eaves 2010).

While this research agenda has produced important evidence of genetic influence on political characteristics, most published work on the heritability of political traits continues to avoid tests of the critical *equal environments assumption* (EEA). Scholars agree that the EEA does not always hold in twin studies, potentially leading to inflated estimates of genetic influence (e.g., see Beckwith & Morris 2008; Charney 2008; Horwitz, Videon, Schmitz, & Davis 2003; Keller, Medland, Duncan, Hatemi, Neale, Maes, & Eaves 2009; Lewontin, Rose, & Kamin 1984; Moore 2001; Rutter 2006). The present study seeks to contribute to the literature on the equal environment assumption in several specific ways.

First, this article focuses on the implications of EEA violations with respect to political attitudes and behaviors specifically. As twin study researchers have argued (e.g., Medland & Hatemi 2009), it is essential for critiques of the equal environment assumption to demonstrate

not only that the EEA is violated, but that it is violated with respect to the dependent variables under study. Recent criticisms of the EEA in political science (Beckwith & Morris 2008; Charney 2008), as well as responses to those criticisms (Alford, Funk, & Hibbing 2008a; Alford, Funk, & Hibbing 2008b), have not concentrated on the "trait-relevant" equal environment assumption, i.e., the EEA with respect to politics. Two specific "politically relevant" EEA violations are discussed in detail in this article: greater social contact and greater psychological identification among monozygotic (MZ), as compared to dizygotic (DZ), twins.

Second, this article parses recent arguments and empirical claims made by twin study researchers regarding the EEA. Twin researchers interested in the heritability of political characteristics have published a number of responses to critiques of the equal environment assumption, including empirical work meant to address some of the concerns raised. These recent responses and related empirical work deserve further attention and are discussed below.

Third, and finally, this work discusses measures of co-twins' social environments and personal relationships and provides an overview of empirical approaches to testing, and correcting, specific EEA violations using such measures. This approach is intended to be constructive and aims to improve the reliability of twin-based heritability studies.

Overview of the Twin Study Method

Below, the most essential features of the twin study method are explained in order to clarify the import and implications of the equal environment assumption. More detailed explications of the twin study methodology are available elsewhere (e.g., Medland & Hatemi 2009; Plomin 2004; Purcell 2008).

While twin study methodology has incorporated increasingly sophisticated statistical modeling techniques in recent decades (Medland & Hatemi 2009), its underlying logic is quite

simple. Variation in observed human characteristics (or phenotypes) is attributed to two broad factors – variation in genes and variation in the environment. Environmental variation is subdivided into two categories: "shared" and "unshared." The shared environment consists of non-genetic influences that create similarity across persons. While it is commonly assumed that those influences that cause similarity are "shared" by the affected individuals (e.g., attending the same college), technically, even disparate environmental factors (e.g., attending different colleges) that happen to lead individuals to become more similar are considered part of the "shared environment." The unshared environment is just the opposite, consisting of non-genetic influences that create differences across persons. Again, while it is commonly assumed that environmental influences that cause difference are "unshared" by the affected individuals (e.g., being treated differently by parents), similar environmental factors that happen to push individuals in different directions are also considered the "unshared environment" (e.g., the same parental lecture interpreted differently) (Alford et al. 2005; Alford & Hibbing 2008; Schaffner 2006; Turkheimer 2006).

Twins are relevant to investigations into heritability because they provide a natural experiment in genetic variation. MZ, or "identical," twins (those from one fertilized egg) share all of their segregating genes, and DZ, or "fraternal," twins (from two fertilized eggs) share on average half of their segregating genes, the same as any two non-twin biological siblings. Segregating genes have allelic variation and are linked to individual differences (Rutter 2006). Heritability estimates are calculated based on the extent to which MZ co-twin similarity with respect to a trait exceeds DZ co-twin similarity. Estimates of "shared" and "unshared" environment are also calculated from twin data.

Studies that compare the similarity of MZ and DZ twins in this fashion in order to estimate the extent to which phenotypic variation is attributable to genetic and environmental influence are using what is referred to as a classical twin design (see Medland & Hatemi 2009). Most classical twin studies carried out in recent years use structural equation modeling (SEM) within a maximum likelihood (ML) framework (Medland & Hatemi 2009). This approach combines measurement models, which link observed variables to latent variables via a confirmatory factor model, with simultaneous equations, which link variables to one another in a causal fashion. An optimization procedure minimizes the discrepancy between the structure of the data and that of the model estimates (Kaplan 2009). Normally, "narrow" heritability – the proportion of phenotypic variance explained by additive genetic effects – is calculated. (Broad heritability refers to the proportion of phenotypic variance attributable to all genetic effects, including gene x gene interactions (Purcell 2008).)

The basic logic underlying SEM twin studies is identical to the earliest twin studies, in which twins' correlations for a trait of interest were inserted into a series of simple equations (Purcell 2008; Schaffner 2006). This method – used by Alford et al. (2005) – calculates narrow heritability. Note that the key terms are squared because they represent the proportion of variance explained.

- $r_{MZ} = h^2 + c^2$ represents the contributions of genes (h^2) and shared environment (c^2) to trait correlations between members of MZ pairs in a sample.
- $r_{DZ} = h^2/2 + c^2$ represents the contributions of genes and shared environment to trait correlations between members of DZ pairs in a sample.
- To obtain the equation for heritability, researchers subtract the DZ from the MZ correlation, isolating the genetic effect by eliminating the presumably equivalent shared environment

effects on each type of pair's correlation: $r_{MZ} - r_{DZ} = (h^2 + c^2) - (h^2/2 + c^2)$. After simplifying, one arrives at the equation: $\mathbf{h^2 = 2(r_{MZ} - r_{DZ})}$.

- The shared environment statistic is calculated by returning to the first equation and moving the terms around: $\mathbf{c^2 = r_{MZ} - h^2}$ (or, alternatively, $\mathbf{c^2 = 2r_{DZ} - r_{MZ}}$).
- Because all trait variance is attributable to genes, shared environment, or unshared environment, one can calculate the unshared environment statistic (e^2) in the following way: $h^2 + c^2 + e^2 = 1$, and therefore $\mathbf{e^2 = 1 - h^2 - c^2}$ *or* $\mathbf{e^2 = 1 - r_{MZ}}$.

Notice the importance of assuming that shared environment (c^2) is equally relevant to MZ and DZ co-twin trait similarity. Because $c^2_{MZ} = c^2_{DZ}$, these terms cancel out when subtracting r_{DZ} from r_{MZ}. If $c^2_{MZ} > c^2_{DZ}$, that is, if MZ correlations for a trait are larger than DZ correlations in part due to greater environmental effects, then heritability calculations are overestimated and shared environmental influences are underestimated.

To see more clearly why this is the case, imagine a small amount of environmental error has crept into the relevant MZ and DZ trait correlations: $c^2_{MZ} = .3$ but $c^2_{DZ} = .2$. (The environmental error is the difference between c^2_{MZ} and c^2_{DZ}, i.e., .1.) Next, subtract the r_{DZ} equation from the r_{MZ} equation: $r_{MZ} - r_{DZ} = (h^2 + .3) - (h^2/2 + .2)$. Subtract, and then multiply both sides by 2 to simplify, and one sees that the $2(r_{MZ} - r_{DZ})$ formula, which is supposed to equal h^2, actually equals $h^2 + .2$. The distortion, here an inflation in heritability of 20% of the 0 to 100 scale, is great because any error associated with the twin trait correlations is doubled. Then insert this into the shared environment equation: $c^2 = r_{MZ} - (h^2 + .2)$. Just as the heritability statistic is inflated, the shared environment statistic is deflated. Figure 1 illustrates the impact of various amounts of environmental error on heritability and shared environment estimates.

[Figure 1 here]

But how often is $c^2_{MZ} > c^2_{DZ}$ in studies of political traits? This question is examined next.

Violations of the Equal Environment Assumption

Classical twin studies rely on the critical assumption that $c^2_{MZ} = c^2_{DZ}$, i.e., the *equal environment assumption*. It is assumed that "the effect of genetics is measurably distinct for MZ and DZ twins, while the effect of the environment is either equivalent or at least randomly distributed around equivalence." This assumption "is crucial to everything that follows from twin research" (Alford et al. 2005, 155). In other words, the EEA stipulates that MZ and DZ twin pairs either must experience similar environments on average or, if differences exist, those differences must be irrelevant to the trait being studied. While it is widely recognized that MZ and DZ twins' environments are not equivalent, the implications for this lack of environmental equivalence differ depending on the trait under examination (e.g., Alford et al. 2008a). Below, it is argued that political characteristics are likely candidates for bias caused by unequal environmental effects among MZ and DZ twins, focusing on studies of twins raised together rather than apart. (The former type of study is most common, and all twin studies published to date in political science journals have been of twins raised together.)

The Impact of Social Influence and Identity on Political Traits

This section presents the argument that MZ twins' social environments are more similar than DZs', that MZ co-twins identify with one another more strongly than do DZs, and that both of these phenomena likely increase MZ twins' political similarity disproportionately. Most of the evidence drawn on in this section comes from general population studies in the social sciences. While some might argue that evidence drawn from the general population is not relevant to twins, an important assumption of twin studies is that the etiology of the trait under study is the same for twins and nontwins (Kendler 1983). Just as the factors that shape the political traits of

twins ought to be the same for the general population, the factors that shape political traits in the general population ought to be the same for twins.

There is little question that MZ twins share a more similar social environment than DZ twins. MZ twins tend to share more similar friends (Cronk, Slutske, Madden, Bucholz, Reich, & Heath 2002; Horwitz, Videon, Schmitz, & Davis 2003; Kendler & Gardner 1998; Kringlen 1967; Rende, Slomkowski, Lloyd-Richardson, & Niaura 2005), are more likely to go out together (Kendler & Gardner 1998), and are more likely to be placed in the same classroom at school (Cronk et al. 2002; Morris-Yates, Andrews, Howie, & Henderson 1990). One rough proxy measure for exposure to similar environmental influences is how much time twins spend together. MZ twins spend more time together as children than DZ twins on average (Horwitz et al. 2003; Kendler & Gardner 1998; Morris-Yates et al. 1990; Rende et al. 2005) and are in greater contact with one another as adults (Heller, O'Connell, Roberts, Allen, Knapp, Steele, & Silove 1988; Kaprio, Koskenvuo, Langinvainio, Romanov, Sarna, & Rose 1987; Rose, Koskenvuo, Kaprio, Sarna, & Langinvainio 1988). MZ twins are also more likely to consider themselves to be "inseparable" as children and adults (Kringlen 1967).

Evidence from social science literatures on interpersonal influence, social networks, and political socialization demonstrates that citizens' social environments influence their political beliefs and behaviors. Because MZ co-twins' social environments tend to be more similar than those of DZ co-twins, the social environment likely contributes more to MZ co-twins' political concordance than to DZs' political concordance.

Many studies report a relationship between the political preferences of individuals' peers and their own preferences. Scholars of social networks have demonstrated that vote choice and partisanship are influenced by citizens' discussion networks (Beck 2002; Beck, Dalton, Greene,

& Huckfeldt 2002; Huckfeldt & Sprague 1991, 1995; Huckfeldt, Johnson, & Sprague 2004; Kenny 1994, 1998). Early voting scholars made a strong case for peer influence over political preferences as well (Berelson, Lazarsfeld, & McPhee 1954; Campbell, Converse, Miller, & Stokes 1960; Katz & Lazarsfeld 1955; Lazarsfeld, Berelson, & Gaudet 1944). Studies that draw on longitudinal evidence better isolate social influence as a cause of political similarity. Stoker and Jennings (2005) found that married couples' political views grow more similar over time. Another study found that attending an especially liberal college causes political views to shift dramatically in the liberal direction compared to similarly situated participants at less liberal colleges (Alwin, Cohen, & Newcomb 1991). Finally, Walsh (2004) observed peer groups developing shared interpretations of politics over time.

Social contacts are also important with respect to political participation. People who are asked to vote, or otherwise recruited into activism, are much more likely to do so than those who are not asked (Burns, Schlozman, & Verba 2001; McAdam 1986; Rosenstone & Hansen 1993). The effects of social networks appear to be just as relevant to political participation as they are to political preferences (Kenny 1992; Nickerson 2008). Nickerson's experimental study is particularly persuasive; he finds that voting behavior is "contagious," specifically, contacting individuals with a get-out-the-vote message not only makes them more likely to vote, but also makes members of their household more likely to vote.

The above research on political influence is relevant to influence *between* co-twins as well as to influence in response to outside social influences (friends, etc.). MZ co-twins, who spend more time together on average than do DZ co-twins, constitute a more important part of one another's social environment and, therefore, ought to influence one another's political views and behaviors more. In addition, those who enjoy closer relationships are more likely than others

to talk politics (Mutz 2006), and frequency of contact between political discussants makes political influence more likely (Kenny 1998).

MZ twins' environments are not equivalent to DZs' in yet another way, less often discussed by researchers. Due in large part to their nearly identical appearance, MZ twins highly identify with one another, much more so than do DZ twins. The issue is especially evident when MZ twins are young:

> [I]dentity is a much greater problem for the identical twin. He recognizes his twin in the mirror before he recognizes himself and is several months behind the non-identical twin in recognizing his own mirror image….He takes longer to say "I" and "me" and more often answers to his twin's name (Sandbank 1999, 169).

Strong identification, and occasional identity confusion, continues into adulthood (Jackson 1960; Joseph 2004; Kringlen 1967). Even as adults, identical twins report sometimes looking in the mirror and believing it is their co-twin looking back (Sandbank 1999).

This strong sense of identification with one's co-twin is reinforced by the way others treat MZ twins. MZ twin pairs are often treated "as a unit" or as "two of a kind" by parents (Kringlen 1967; Morris-Yates et al. 1990). When they are young, MZ twins' peers often act as if the two co-twins are interchangeable (Sandbank 1999). Even if peers wish to tell MZ twins apart, they often fail; MZ twins are much more often confused for one another by others than DZ twins (Kringlen 1967; Matheny, Wilson, & Dolan 1976). In fact, confusing co-twins for one another is so common among people who interact with MZs that questions regarding identity confusion are frequently used by twin researchers as an inexpensive and fairly reliable determination of zygosity (Cronk et al. 2002; Kendler, Neale, Kessler, Heath, & Eaves 1993). Finally, young

MZs' unique similarity of experience is emphasized by the fact that many parents dress them alike (Cronk et al. 2002; Kringlen 1967; Morris-Yates et al. 1990).

This sense of identification tends to lead to a stronger interpersonal bond between MZ co-twins. MZ twins report being closer emotionally and more attached to one another than DZ twins (LaBuda, Svikis, & Pickens 1997; Segal 2000). DZ twins' level of closeness is more like ordinary siblings compared to MZs (Kringlen 1967). MZ twins are more likely than DZs to name their co-twin as the family member who they would miss the most if he or she died and, indeed, are more grief-stricken on average when their co-twin dies (Segal 2000). This close bond may also explain why MZ twins spend much more time together compared to DZs.

In the general population, identity and closeness (as well as related variables such as respect and trust) make interpersonal influence over political attitudes more likely (Berelson et al. 1954; Campbell et al. 1960; Fiske 2004; Kenny 1994; Lazarsfeld et al. 1944; Turner 1991; Walsh 2004). Controlled experiments offer the best evidence for this causal relationship. Such studies have found that greater identification makes conformity among peers more likely with respect to social and political attitudes and behaviors (e.g., Abrams, Wetherell, Cochrane, Hogg, & Turner 1990; Clark & Maass 1998; Cohen 2003; Green & Gerber 2008; Wood, Pool, Leck, & Purvis 1996). *Why* might closeness or shared identity increase conformity? Turner (1991) and Walsh (2004) argue that those who are like us in many respects also serve as good models regarding what types of opinions we should hold. Other researchers suggest that emotions motivate conformity because it is emotionally uncomfortable to disagree with peers (Asch 1951; Elliot & Devine 1994; Festinger 1957; Matz & Wood 2005; Noelle-Neuman 1993).

Thus, the greater identification and closeness of MZ twins may cause them to engage in more interpersonal influence over one another's political attitudes and behaviors than DZ twins,

resulting in inflated heritability estimates. Simply put, MZs are more likely to try to persuade their twin, and are more likely to be persuaded *by* their twin. Some have referred to such effects as special "sibling effects," whereas others have labeled them as part of the familial environment (Carey 1986, 337-8). Whatever one's nomenclature, this identity-driven effect is expected to occur over and above the influence of increased contact between MZ co-twins, and the effect of contact may even increase as identification and closeness increase.

Psychological research on MZ twins suggests that MZ pairs' closer relationship indeed leads to more mutual influence in general compared to DZ twins (Ainslie 1997; Jackson 1960; Sandbank 1999). Many twins, but more often MZs, develop "secret languages" and sometimes communicate only with one another, especially when young (Sandbank 1999). MZs are more likely to experience "folie à deux," symptoms of a mental illness that are socially transmitted from one person to another (Jackson 1960). Ainslie (1997) gives an example of an identical twin in his study whose tendency to conform to his co-twin even affected the interview process. The twin says, "[W]e answered questions pretty much the same….[I]f you ask us something, we put our ideas together into one, rather than each of us coming up with our own answers" (79).

In summary, this article has discussed social scientific research demonstrating that social interaction and identification with others shapes a person's political attitudes and behaviors. Because MZ twins share a more similar social environment and identify more strongly with one another, their political trait concordances may be proportionally more influenced by the "shared environment" than DZ twins' concordances on average. Where this is the case, heritability statistics will be inflated and shared environment statistics deflated all else equal, as demonstrated in the *Overview of the Twin Study Method* section above and in Figure 1.

Note that the preceding discussion on peer influence and co-twin identification does not exhaust potential sources of EEA violations. For example, MZ twins are also more likely to share experiences that are less social in nature than those discussed above (e.g., media exposure; crime victimization). This multifaceted subject is ripe for future research. In addition, some have argued that more similar treatment of MZ co-twins relative to DZ co-twins by parents, teachers, and peers directly causes MZ twins to have more similar characteristics (e.g., Charney 2008; Joseph 2004). However, with respect to parental treatment in particular, research suggests that differential treatment of MZ and DZ pairs does not substantially affect personality characteristics (e.g., see Loehlin & Nichols 1976). But also see Beckwith and Morris (2008) for a critique of research on parental treatment.

Behavioral Genetics Research on the EEA Relevant to Politics

This section describes evidence from the behavioral genetics literature on the equal environment assumption as it pertains to the results of twin studies of political traits.

Several studies of twins have found positive correlations between co-twin contact and political traits, thus suggesting that the EEA is violated to some extent. Lykken, McGue, Bouchard, & Tellegen (1990) report a moderate, positive relationship between co-twins' amount of contact with one another and a measure of traditionalism among MZ twins; the concordance of MZ co-twins in "daily" contact was 42% higher than MZs "seldom" in contact (X^2 test of traditionalism across contact: $p = .018$). Martin, Eaves, Heath, Jardine, Feingold, & Eysenck (1986) report positive correlations between approximately 4000 twin pairs' level of contact at the time of interview and similarity with respect to conservatism (females $r = .08$, males $r = .14$). Finally, Posner, Baker, Heath, & Martin (1996) find contact to be positively correlated with similarity in conservatism ($r \approx .15$); a longitudinal analysis to isolate contact as a cause of

similarity – as opposed to similarity as a cause of contact – finds a significant result for MZ females and a near-significant result for MZ males (p. 129, Table III). Given that MZ twins are normally in greater contact with one another than DZ twins, the consistent positive relationship between contact and political similarity suggests that heritabilities derived from twin studies of political traits are at least partly inflated.

Smith, Alford, Hatemi, Funk, and Hibbing (2010) conduct a twin study to estimate the effect of genes and the environment on political ideology with, and without, environmental controls. Their estimate for the heritability of political ideology drops 5 percentage points when controlling for co-twins' shared environment as children and amount of communication as adults (although the best-fitting model in their study does not include the environmental controls).

Because few EEA studies have looked at political characteristics, this article also discusses tests of the equal environment assumption with respect to personality traits and psychopathology. It is important to discuss these studies for two reasons. First, twin researchers of political traits have defended the EEA within the context of their political studies by citing findings from the general EEA literature. In the course of so doing, they have claimed that this literature has shown the EEA to hold up overall (Alford et al. 2005; Fowler et al. 2008; Hatemi et al. 2008; Hatemi, Medland, & Eaves 2009). Second, personality traits and psychopathologies, traits commonly investigated in EEA studies, while not political, are often politically relevant. Twin study researchers agree, arguing that interpersonal variation in personality traits and psychopathologies (e.g., anxious tendencies) explain some of the observed variation in political traits in the population (Alford et al. 2005; Fowler et al. 2008; Oxley, Smith, Alford, Hibbing, Miller, Scalora, Hatemi, & Hibbing 2008). Thus, violations of the EEA with respect to these traits would likely also be manifest in studies of explicitly political traits.

Studies of personality and psychopathology have shown estimates of genetic contributions to trait variance to drop when environmental confounds were controlled. Researchers have found that taking into account the unequal environments of MZ and DZ twins substantially reduces the amount of trait variance attributable to genetic variance with respect to anxiety and depression (Clifford, Hopper, Fulker, & Murray 1984; Horwitz et al. 2003); the reduction in genetic contribution is more modest in a study of achievement (Lykken et al. 1990) and another study of emotional and behavioral disorders (Cronk et al. 2002).

EEA violations for a particular trait can be identified without conducting a full twin study. As in the "political" EEA tests above, scholars need only demonstrate that measures of possible environmental confounds (such as time spent together or twin closeness) are correlated with co-twin similarity on the traits under study, controlling for zygosity (Medland & Hatemi 2009). Assuming MZ twin pairs' environments are more similar and/or their bond stronger (as is usually the case), such studies test whether a twin study conducted with those data would arrive at inflated heritabilities all else equal. Along these lines, researchers have shown twin contact and other measures of environmental confounds to be associated with twins' similarity with respect to personality traits, such as extraversion and neuroticism (Rose & Kaprio 1988; Rose et al. 1988) and psychological problems, such as depression and anxiety (Morris-Yates et al. 1990). Finally, Scarr and Carter-Saltzman (1979, 532) found that fraternal twins who believed that they were identical had more similar personalities than fraternals who correctly perceived their zygosity (although see the discussion below regarding studies of "miscategorized" twins).

The above studies focus on measures of environmental confounds among twins during childhood and adulthood; however, researchers are increasingly investigating the potential for the pre-natal environment to cause inflated heritability statistics. The environmental similarity of

MZ twins begins in the womb. Approximately two-thirds of MZ twins share a chorion (a membrane which forms the embryonic part of the placenta), whereas DZ twins almost never do (Prescott, Johnson, & McArdle 1999; Sokol, Moore, Rose, Williams, Reed, & Christian 1995). Researchers have found chorion status – whether twin pairs did, or did not, share a chorion in their mother's womb – to be associated with a variety of personality differences (Sokol et al. 1995), as well as psychiatric symptoms (Davis, Phelps, & Bracha 1995; Wichers, Danckaerts, Van Gestel, Derom, Vlietink, & van Os 2002) and intelligence (Jacobs, Van Gestel, Derom, Thiery, Vernon, Derom,& Vlietinck 2001).

It is important to note that not all researchers who have investigated EEA violations with respect to personality and psychopathology have found compelling evidence of violations. Hur (2007) finds chorion type to have a negligible impact on prosocial behavior. A number of studies that have directly measured environmental similarities between MZ and DZ co-twins have found null results or violations for only a small percentage of traits examined (Hettema, Neale, & Kendler 1995; Kendler, Heath, Martin, & Eaves 1986; Kendler, Neale, Kessler, Heath, & Eaves 1992a, 1992b, 1992c). Finally, studies that have examined "miscategorized" twins have tended to find that when zygosity is misperceived by parents or twins themselves (i.e., DZ twins believe themselves to be MZ or vice versa), twins' traits seem to be largely unaffected, suggesting that dissimilar treatment and/or co-twin identification based on MZ or DZ status does not threaten the EEA (Kendler, Neale, Kessler, Heath, and Eaves 1993; Scarr and Carter-Saltzman 1979; Xian, Scherrer, Eisen, True, Heath, Goldberg, Lyons, and Tsuang 2000). This said, there are important methodological limitations to miscategorized (or misperceived) zygosity studies, including low statistical power due to small samples of miscategorized twins (e.g., Scarr and Carter-Saltzman

1979; Kendler et al. 1993) and researcher error in determining "true" zygosity. See Beckwith and Morris (2008) for criticisms of such studies.

Taken as a whole, however, there is reason to be concerned about EEA violations with respect to studies of political traits and related personality characteristics. Twin researchers have given a confusing impression of this literature, as when Medland and Hatemi write, "[N]o EEA violations have been reported for intelligence, personality, or political preferences" (2009, 199). The violations may sometimes be modest, but they ought not be overlooked.

Further, twin studies of political traits may arrive at heritability statistics that are more inflated than the EEA literature suggests. Many of the studies that test the equal environment assumption examine just one environmental confound – often measured with just one variable – at a time. For example, Martin et al. (1986) correlate the amount of contact between twins at the time of interview with their dependent measure (ideology) and, when a small relationship is found, declare the EEA to be only marginally violated. Yet, the "shared environment" measure in this study appears to be a single item, not a reliable scale; further, it excludes important potential environmental confounds, such as how much time twins spent together as children, as well as whether the twins share the same social network as adults and how closely they identify with one another. The result is an error-prone measure of the target construct and a limited assessment of the confounding influence of environmental differences between MZ and DZ twins. Twin researchers emphasize that any observable effect of genetic inheritance on behavior is likely the result of many genes working together, and twin studies allow them to test for such aggregate effects. However, tests of the EEA often proceed as if just one type of environmental effect is responsible for EEA violations when many of the ways in which MZ twins' environments differ from DZs' likely together inflate heritability estimates.

Arguments and Evidence Regarding the EEA in Political Science Journals

Twin study researchers who study political traits have addressed the equal environment assumption issue at length in various articles. In this section, many of the specific arguments and evidence put forward in defense of the EEA are discussed.

Problematic EEA Tests and Corrections

Several teams of authors claim to test the EEA in their studies of political characteristics (and claim to find no violation) or to correct for EEA violations but have not in fact done so.

First, two sets of authors – Fowler et al. (2008) and Settle et al. (2009) – suggest they have tested the equal environment assumption with respect to political traits. (These authors refer to the EEA as the "Comparable Environments Assumption.") However, the main test used in these studies (e.g., see p. 237, Table 1, in Fowler et al.) is not a test of the EEA. Rather, the authors provide evidence supporting what Medland and Hatemi (2009) call homogeneity assumptions, ensuring that no differences in the means and variances of the dependent variables, related variables, or important demographic variables (e.g., education, income) exist between the subsample of all MZ twins and the subsample of all DZ twins. If such differences exist, the results of a statistical analysis may be biased; however, these specific biases have little to do with the equal environment assumption. Why? First, most of the measures examined are not measures of the environment (e.g., Settle et al. examine basic demographic and political variables, including gender, age, education, and political ideology). Second, and more important, most of the measures examined are not measures of co-twin environmental similarity or closeness. This difference is key. It is statistically possible for MZ twins in a sample to be, on average, equivalent to DZ twins in a sample on a typical demographic variable, while, at the same time, *members of MZ pairs are more similar to one another* on that variable than *members of DZ*

pairs. For example, consider a hypothetical dataset with four MZ pairs and four DZ pairs who have been asked whether or not they attended college. The means and variances for the samples of MZ twins and DZ twins will be equivalent if four MZs attended college and four MZs did not attend college, and if four DZs attended college and four DZs did not attend college. Yet, this dataset with comparable means and variances could reveal that MZ pairs were completely concordant for college attendance (two MZ pairs went to college and two MZ pairs did not), whereas none of the DZ pairs were concordant for college attendance. (This example is used because education appears in both the Fowler et al. and Settle et al. articles; college attendance is not endorsed as a measure of the environment in this article.) By way of contrast, tests of the EEA seek to assess, as a first step, whether MZ co-twins share a more similar environment or a closer relationship than DZ co-twins (e.g., are MZ co-twins in the sample in closer contact than DZ co-twins in the sample on average?); the second step, discussed elsewhere, is to examine whether variation in that similarity is related to the dependent variable (e.g., are the political attitudes of co-twins in close contact more similar to one another than those of more distant co-twins?). The AddHealth database used in the Fowler et al. (2008) study includes a variety of measures of co-twin shared environment which could be of use in future tests for EEA violations.

Second, in an analysis not reported in detail, Alford, Funk, and Hibbing (2008a, 322) re-estimate their 2005 findings, reporting that they account for the equal environment assumption. They write:

> [W]e have also empirically estimated heritability while accounting for the EEA. To do so, we have re-estimated our findings from the Virginia 30K sample using more sophisticated structural equation models that account for shared environmental

> influences from other family relationships—namely parents and non-twin siblings….The findings support our original claims that genetics accounts for at least 40 percent of the variance in ideological orientations.

Such nuclear twin family designs, at least as described, do not correct for a violated EEA. They can model a special "twin effect" of the environment on DZ co-twin trait similarity; such an effect exists if DZ co-twins are more similar to one another than ordinary siblings (both DZ twins and ordinary sibs share 50% of their segregating genes on average). However, this effect is not directly relevant to the possible greater impact of the shared environment among MZ co-twins relative to DZ co-twins. In addition, while it is true that the inclusion of additional types of family members in a study of heritability will make environmental error specifically associated with twins relatively less influential on study outcomes, data from non-twin family members also suffer from environmental confounds. In fact, family designs may make matters worse in that biological similarity (e.g., comparing full to half-siblings) may be even further confounded with environmental similarity (e.g., full siblings are more likely to live in the same household than half-siblings). This said, estimating a special twin effect has advantages. It allows researchers to refine their estimates of environmental effects. Also, as Medland and Hatemi (2009, 199) argue, estimating this effect can provide evidence regarding whether an EEA violation may be present. If DZ co-twins are more similar to one another than ordinary siblings, this is likely due to the fact that DZs share a more similar environment and have a closer relationship than ordinary sibs. Given that MZ co-twins spend *more* time together and have a *closer* relationship than DZs on average, a DZ effect suggests an even greater (hidden) one for MZs. A recent study of the heritability of political attitudes reports just such a twin effect (Hatemi, Alford, Hibbing, Keller, Martin, Medland, & Eaves 2007).

Third, and finally, Hatemi, Funk, et al. (2009) examine heritability from a developmental perspective, finding that the heritability of political attitudes emerges only in adulthood. Because heritability is zero during childhood and adolescence, the authors conclude that the equal environment assumption cannot be violated prior to adulthood. This finding does not challenge the arguments and evidence presented here. Just as high heritability is not *prima facie* evidence that the EEA has been violated, low heritability is not *prima facie* evidence that the EEA is valid. The authors rightly argue that parental influence is especially strong while children are living at home. This particular environmental influence in the home could be strong enough to overwhelm any bias introduced by the more similar social environments and greater closeness of MZ co-twins relative to DZ co-twins. Once MZ and DZ pairs leave home, however, parental influence is likely to dissipate while, at the same time, disparities in the two twin types' environmental similarity and closeness should increase on average. The most salient example of this is the fact that, as adults, MZ co-twins are more likely to cohabitate than DZ co-twins. Thus, the specific violations of the EEA on which this article focuses may be greatest among adult twins. This may explain in part why Hatemi et al. find that same-sex DZ correlations for political attitudes are under half those of MZs among 21-25 year-old twins who no longer live at home (r = .229 and .577, respectively). In contrast, among 21-25 year-old twins who continue to live at home, MZ and DZ correlations are almost equivalent, the same pattern seen among younger study participants.

The Impact of MZ Co-Twin Contact

In defense of the EEA, twin researchers argue that the significant amount of time that MZ co-twins spend together does not inflate heritability estimates. For example, Alford et al. (2005, 155) argue that the relationship between co-twin contact and ideological similarity tends to be

negative, not positive. However, in the key study cited (Martin et al. 1986; also see above), Alford et al. have the relationship backward; Martin et al. find the relationship between frequency of contact and co-twin similarity to be *positive*, although small (p. 4367). Both Alford et al. (2005) and Fowler et al. (2008) also write that available evidence indicates that MZ twins become more similar to one another as they age, even as their environments become increasingly different (i.e., as they leave home, marry, etc.). However, this is not the case in the cited work (Bouchard & McGue 2003) or in other studies (Hatemi et al. 2008). Finally, Alford et al. write that MZ twins reared together "are often less likely to share behavioral traits with their twins than are MZ twins reared apart" (2005, 155). However, the dominant trend in the cited article (Bouchard & McGue 2003) is for "raised together" MZ pairs (MZTs) to be more similar than "raised apart" pairs (MZAs). Rose and Kaprio (1990) review three studies of MZA/MZT twins found through population registries, which do not suffer from the self-selection bias of volunteer studies. They find MZAs were more similar than MZTs for all measured personality traits.

A more common argument in defense of the EEA is to suggest that it is twins' – especially MZ twins' – political similarity that leads to increased contact, not the other way around (e.g., Alford et al. 2008b; Fowler et al. 2008). Although more similar individuals choose to spend more time in one another's company, the causal arrow runs in the other direction too. Multi-wave twin studies exploring the direction of these effects demonstrate that the causal arrow points both ways, with perhaps contact more often leading to similarity (Kaprio, Koskenvuo, & Rose 1990; Rose, Kaprio, Williams, Viken, & Obremski 1990). A multi-wave study by Posner et al. (1996) on political ideology is sometimes cited as evidence that the causal arrow runs only from similarity to contact (e.g., see Fowler et al. 2008; Hatemi et al. 2007; Settle et al. 2009); however, the key cross-lagged regression results presented by Posner et al. in Table

III (p. 129) support contact as a cause of similarity over the reverse causal story. Lykken et al. (1990) are also often cited as offering evidence that similarity causes contact, not vice versa, but these authors draw on cross-sectional, not longitudinal, data. Finally, while Alford et al. (2008b) write that political science studies overwhelmingly suggest that the contact / similarity association exists in the general population because "birds of a feather flock together," longitudinal and experimental evidence shows that contact also leads to political similarity (e.g. see Alwin et al. 1991; Nickerson 2008; Stoker & Jennings 2005).

Another version of the "similarity causes contact" argument is that similar *genes* (mediated by trait similarity) are responsible for high rates of contact among MZ twins. It is likely true that MZ co-twins spend more time with one another than DZ co-twins in part because they share similar genes, but this does not imply that contact has no effect on trait similarity. A simple test of whether genetic similarity explains the association between co-twin trait similarity and contact *in toto* is whether there is a positive relationship between these variables among MZ twins; a correlation between level of contact and trait similarity among MZ co-twins, who share the same genetic code, cannot be due to similar genes. Many studies have found a positive association between contact and similarity among MZ co-twins (Clifford et al. 1984; Cronk et al. 2002; Heller et al. 1988; Kaprio et al. 1990; Lykken et al. 1990; Morris-Yates et al. 1990; Rose & Kaprio 1988; Rose et al. 1988).

Perhaps anticipating such evidence, twin researchers put forward another important argument with respect to contact and similarity: If MZ twins are in greater contact than DZs due to their greater physical similarity, and if this contact creates political or personality trait similarity, a comprehensive model still has genes as the prime mover (Alford et al. 2008b). It is reasonable to believe the premise that identical twins' identical DNA is an important cause of

their close relationship and shared social environment. The precise mechanism for this link is complicated. A closer relationship likely develops because of cultural norms regarding MZ twins (i.e., that they ought to be a unit), because MZ co-twins look so similar (to themselves and others), and because MZ twins have more similar personality traits. However, this causal story is not interchangeable with the models proposed by twin study researchers of political traits.

Such researchers have argued that genes determine political directionality. Alford et al. write, "[G]enes influence people's outlooks and personalities, and it is these broad features that then predispose individuals toward suites of specific attitudes" (2005, 164), such as conservatism versus liberalism (Alford et al. 2005) or political participation versus apathy (Fowler et al. 2008). These genetic effects on political traits are mediated by personality traits (Alford et al. 2005; Fowler et al. 2008) and other individual differences, such as a tendency to be intense or apathetic (Hatemi et al. 2008). To illustrate: suites of genes may cause individuals to become more (or less) "open to experience," and, then, that "openness to experience" may cause individuals to become more (or less) liberal, at least in certain political contexts, such as the contemporary United States. Biology, while not completely deterministic, can be said to strongly bias individuals in one direction or the other. The influence of the environment is mainly seen, then, when it pushes against "type" (Alford et al. 2005, 165).

The arguments presented in this article differ from the above accounts of genetic influence in important ways. First, consider that twins' opinions will be more likely to converge the more time they spend together (and with similar others) and the greater their closeness. The argument, here, is that the greater conformity and more similar peer socialization of MZ co-twins can be traced to the generic fact of identity (e.g., their awareness of their identical DNA), not the content of that identity. In other words, opinion convergence stemming from identity or

similarity often is divorced from the content of opinions; it will occur on the left or right, and, of course, with respect to nonpolitical opinions too (e.g., dress, music, sports). Understanding the genetic origins of these convergence effects perhaps advances our understanding of the general phenomena of socialization and conformity, but it does not advance the goal of understanding the extent to which genes code for specific political phenotypes. Second, it is acknowledged that MZ twins sometimes select into similar environments (e.g., choose similar friends) because specific personality characteristics (e.g., openness to experience) cause both of them to be attracted to the same types of environments (e.g., liberal friends) that are ultimately politically influential. Environmental effects in this case may be linked to specific genes; however, the genetic effects depend on the environment for their expression. That is, in this instance, without the environmental experience, there is no attitudinal or behavioral change. Twin studies of political traits would be more informative if these *environmentally contingent* genetic effects were parceled out of heritability coefficients. This does not mean hiding them in the "shared environment" statistic; they can be modeled and estimated explicitly.

When thinking about how to classify such effects, it may be helpful to recall the original *raison d'etre* of twin studies. In 1869, Galton published *Hereditary Genius*, claiming that genius "ran in families." The major problem with this study is the assumption that similar achievement levels among family members were entirely due to shared heredity and that environmental factors associated with social class and cultural transmission within the family were irrelevant. Twin studies were introduced to address this flaw: To control for the effects of social class, socialization, and other environmental factors that tend to co-vary among biological relatives, one can compare individuals with known differences in heredity and an assumed equivalence in their environment, i.e., MZ and DZ twins. However, if those individuals who are more

biologically related (MZ twins) share a more similar social environment than those who are less biologically related (DZ twins), then the analysis moves back to square one. Twin studies are supposed to disentangle the effects of the environment and biology, but, if the equal environment assumption is violated, they cannot fully succeed in doing so.

Converging Evidence for Genetic Effects?

Twin researchers interested in political traits often describe a variety of other genetically informative study designs for which, they argue, the EEA is not an issue and whose evidence they say converges with evidence of substantial genetic effects in their own studies. For example, Alford et al. (2005) contend that general population adoption studies, in which adopted children are compared to their adoptive parents as well as their biological parents, offer evidence that corroborates that of classical twin studies. Such studies do have fewer environmental confounds; however, adoption studies tend to find lower heritabilities than twin studies (Collins, Maccoby, Steinberg, Hetherington, & Bornstein 2000; Prescott et al. 1999), despite the fact that decreased environmental variation among adopting parents' households will tend to inflate heritability estimates and decrease environmental effects (Nisbett 2009; Rutter 2006). Studies of twins "raised apart," which have reported heritability coefficients on par with "raised together" studies, have been described as far superior to raised-together studies (Alford et al. 2005, 155); however, such studies have various methodological limitations, including the fact that "raised apart" MZ twins tend to be reared in similar environments, often by close relatives, and often have a great deal of contact despite their separation (Charney 2008; Joseph 2004; Moore 2001). Finally, a recent heritability study which avoids the equal environment assumption by using non-twin siblings' exact genetic similarities to estimate genetic contribution to trait variance (Visscher, Medland, Ferreira, Morley, Zhu, Cornes, Montgomery, & Martin 2006) and which converges

with twin study estimates (Alford et al. 2008b; Hatemi, Medland, & Eaves 2009) is not an ideal comparison to twin studies of political characteristics because it focuses on height. Height is not subject to the same types of environmental confounds as political ideology or participation or related personality traits; therefore, twin study findings for height are more likely to provide accurate heritability estimates.

Recommendations

The arguments and literature discussed thus far provide reason for researchers to conduct EEA tests in studies of political traits, with particular attention paid to differences in social contact, social environment, and identification between MZ and DZ co-twins. By establishing that the EEA *is* upheld in their studies or, if it is not, by correcting for EEA violations, scholars will generate more reliable estimates of genetic (and environmental) influence and establish greater confidence in their results. Controlling for environmental confounds is unlikely to reduce heritability statistics to zero in twin studies of political traits; however, heritability estimates may diminish.

Below, methods of testing and, if necessary, correcting for a violated EEA are explained. Measures of environmental confounds that have been incorporated into past data collection efforts and may be incorporated into future data collection efforts are also discussed.

Testing and Controlling for Environmental Confounds

Various tests of the EEA have been described by Kendler (1983) (also see Medland and Hatemi 2009, p. 199, who provide a succinct summary). Each method involves efforts to identify whether there exists an effect of the unequal environments of MZ and DZ twins on the traits under study. The best tests involve direct measures of these environmental factors, rather than proxy variables (such as the misperception of zygosity status). Given the importance of social

influence dynamics to twin studies, researchers might most fruitfully examine the time that co-twins spend together, identification and/or the closeness of their relationship, as well as the similarity of co-twins' social networks (in childhood and adulthood for all three).

The simplest approach is to calculate Pearson correlations for the degree of co-twins' shared environment (e.g., amount of co-twin contact, proportion of shared friends, similarity of treatment by parents/peers) or other environmental confound (e.g., level of co-twin identification or attachment) and the trait similarity of each pair, for MZ and DZ twins separately. (A combined analysis confounds the much greater genetic similarity of MZ twins with their greater degree of environmental similarity and closeness.) Assuming that MZ twins in the sample exhibit a greater degree of environmental similarity according to the measures examined – as they normally do – a statistically significant relationship is evidence that the EEA is violated and that researchers should control for that confound.

The method to control for environmental confounds depends on whether heritability is estimated using the simple equations described above, often referred to as "Falconer equations," or structural equation modeling. With the Falconer equations, the sample is first segmented according to suspected environmental confounds, e.g., dividing the sample into twins with low, medium, and high levels of contact. Next, heritability statistics are calculated for each subgroup, and then the heritability statistics are pooled (see Lykken et al. 1990). The point is to drain the heritability estimate of the influence of the environmental confound by holding it constant.

Of course, proceeding in this way does not allow calculations of the effect sizes of confounds and, more important, limits the number of control variables. With structural equation models, one can enter several measured environmental confounds as covariates. Suspected environmental confounds can also be modeled from the start, simultaneously testing the EEA

and controlling for possible confounds. Figure 2, an amended version of an ACE model presented in Hatemi et al. (2008), offers an illustrative example.

[Figure 2 here]

P1 and P2 represent the phenotypes of twin 1 and twin 2 in each pair. A is the additive genetic component, C is the shared environment component, and E includes both unique environment and any measurement error. The double-headed arrow drawn between A_1 and A_2, labeled 1.0/0.5, represents the fact that MZ co-twins' genetic codes correlate at 1.0, whereas DZ co-twins' correlate at 0.5 on average. The double-headed arrow drawn between C_1 and C_2 represents the equal environment assumption: It is assumed that MZ and DZ co-twins' environments both correlate at 1.0. Unique environment (E_1, E_2) is assumed to be uncorrelated for twin pairs.

Next, four covariates are added to the basic model, based on measures introduced in the next section. The paths from each covariate to P_1 and P_2 are constrained to be equal, meaning that, e.g., the closeness of co-twins' relationship will similarly affect the phenotypes of both twins in a pair. Assuming the twins are interviewed as adults, retrospective measures of the similarity of childhood environment and strength of co-twin relationship ("child") are suggested as well as contemporary measures of co-twin contact ("time"), closeness and shared identity ("close"), and shared social environment ("social"). Each covariate should include several measures of the construct to form a reliable scale. Smith et al. (2010) provide an empirical demonstration with a model similar to the one described here. Researchers may also wish to consider the effects of similar treatment, appearance, and prenatal environment. Prescott et al. (1999) offer a method for correcting bias due to the greater propensity for MZ twins to share a chorion (assuming chorion type is known).

What the added covariates do in the path model is partially relax the equal environment assumption. Heritability, shared environment, and unique environment coefficients are estimated while statistically controlling for these covariates. If the covariates successfully reflect all of the systematic differences in shared environment between MZ and DZ twin pairs, the problem of MZ twins having, on average, a more similar environment and sharing a closer relationship to one another is solved. At the same time, the model allows the researcher to estimate the extent to which shared childhood environment, time spent together, co-twin closeness, shared social environment, and any other environmental covariate influence the trait under study. Estimates of A (heritability) will be reduced if, and only if: a) there are systematic differences in the means of the covariates (e.g., the extent to which co-twins in each pair have similar friends) between MZ and DZ twins, and b) the covariates influence the trait under study.

If the coefficients on the paths that link the covariates and the twins' phenotypes are statistically significant, the researcher should retain these controls because the EEA is violated. Researchers should test for model fit by comparing the full model with the baseline model (without the four environmental covariates). This ensures that the combined effect of environmental confounds is tested, just as classic twin studies test for the combined effect of genes. Researchers may wish to add covariances between A and the environmental measures in order to test whether measured environment is partly a function of inherited characteristics.

Recommended Measures

Datasets utilized in political twin studies often include at least some measures of possible environmental confounds among twins. This said, most do not include measures of all the environmental confounds that may cause EEA violations in twin studies of political traits. Table 1 presents twenty questions that measure various aspects of the environment that likely differ for

MZ and DZ twins. The list is intended to guide tests of the EEA in twin studies of political characteristics where these measures, or similar ones, are available. The list is also intended as a guide to future data collection efforts. The measures are divided into four categories: childhood environment / relationship, co-twin contact, co-twin closeness / identity, and shared social environment.

Most of the questions in Table 1 are taken directly from, or are closely based on, several sources: the Minnesota Twins Political Survey (http://www.unl.edu/polphyslab/data.html) and The National Longitudinal Study of Adolescent Health (Add Health), as well as questions reported by Kendler and Gardner (1998), Kringlen (1967), and LaBuda et al. (1997). Three new questions have been added to measure adult twins' similarity in social environment based on similar items that appear elsewhere in the table or that have a high degree of face validity.

[Table 1 here]

The measures in Table 1 have been grouped to suggest possible scales; however, researchers will want to use factor analysis to identify the best scales in their datasets.

When to Test the EEA

Best practices in twin research stipulate that twin study researchers conduct tests of the equal environment assumption (as well as other assumptions of the model) and provide some indication in published work that such tests have been carried out (Medland & Hatemi 2009). The equal environment assumption is not a settled issue (Keller 2010). It is especially important to test for EEA violations where previous work suggests a violation may be present (Kendler, Neale, Kessler, Heath, & Eaves 1994), in new areas of study – e.g., the heritability of political traits – without a history of EEA validation (Matt Keller, personal communication), or when new data are being analyzed.

Instead of testing the EEA in their studies, twin researchers of political traits have tended to cite previous EEA scholarship on non-political traits (e.g. Alford et al. 2005; Fowler et al. 2008; Hatemi et al. 2008; Hatemi, Medland, & Eaves 2009; Settle et al. 2009). This is inconsistent with the argument that any violations of the EEA must be shown to be trait-relevant. If the only violations of the EEA worth paying attention to by scholars of politics are those that matter to political characteristics, then twin researchers of political characteristics should not defend the EEA by citing studies based on non-political traits.

Conclusion

For decades, genes and other biological factors have been ignored by many in the political science community. A flurry of scholarship in the past several years has begun to correct that error by highlighting the overlooked contributions of past bio-politics scholarship and by offering new evidence for genetic influences on political traits.

However, investigations into the heritability of political traits have tended to neglect tests to determine whether the crucial equal environment assumption (EEA) is upheld in their studies. If that assumption is violated, then current scholarship likely overestimates the extent to which genes are responsible for variation in political characteristics, while simultaneously underestimating the environment's role (see *Overview of the Twin Study Method* above; also see Horwitz, Videon, Schmitz, & Davis 2003; Keller, Medland, Duncan, Hatemi, Neale, Maes, & Eaves 2009). Even a very small difference in the extent to which the shared environment influences MZ and DZ co-twin similarity can inflate heritability estimates by 10 to 20 percent and deflate shared environment estimates by the same amount (see Figure 1).

Findings from behavioral genetics overlooked by recent authors interested in the heritability of political characteristics raise concerns about the viability of the EEA in many

studies of political, and related, traits. Social scientific evidence also suggests that the EEA may be suspect in political twin studies because MZ co-twins (compared to DZ co-twins) share a more similar social environment and identify more strongly with one another, leading to disproportionate conformity and similarity in socialization experiences among MZ twins. These routes of social influence highlight previously underappreciated facets of behavior among twins with potentially important implications for twin study estimates. Published commentary on the equal environment assumption in political science has tended to downplay the likelihood that violations of the equal environment assumption occur, and many of the recent empirical efforts carried out to address the equal environment assumption do not directly address the problem.

Going forward, twin researchers interested in politics ought to test and (if necessary) correct for violations of the equal environment assumption in their studies. This article includes an extensive list of questions measuring twins' social environments and relationships that twin researchers and others may use to guide tests for EEA violations as well as future data collection efforts. This article also reviews simple statistical methods for testing for, and correcting, EEA violations. Looking to the future, twin studies of political characteristics that are sensitive to possible violations of the equal environment assumption will provide more accurate estimates of the influence of genes and the environment on political attitudes and behavior.

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Table 1: Measures of Shared Environment and Co-Twin Relationship

Childhood shared environment / relationship
When you were growing up…. 1. How often did you and your twin: Share the same bedroom at home?[a] 2. How often did you and your twin: Attend the same classes at school?[a] 3. How often did you and your twin: Have the same friends?[a] 4. How often did you and your twin: Dress alike?[a] 5. Were you emotionally closer to your twin than would be usual for ordinary sisters/brothers?[c] 6. Would you say that you and your twin were "inseparable"?[d]
Co-twin contact
1. How old were you when you and your twin first lived apart?[a] 2. How often do you usually see your twin?[a] 3. How often do you usually talk to your twin on the telephone?[a] 4. How often do you usually contact your twin electronically (through text messages, e-mail, Facebook, or other devices)?[a] 5. How far in travel time do you and your twin live from one another?[b] 6. How long has it been since you last talked (in person) with your twin?[e]
Co-twin closeness / shared identity
1. How close do you feel to your twin?[b] 2. How often do you feel love for your twin?[b] 3. How often do you turn to your twin for help when you have personal problems, or problems at school or work?[b] 4. How often do you and your twin quarrel or fight?[b]
Shared social environment
1. How much time do you and your twin spend with the same friend or group of friends?[b] *2. How often do you and your twin go out or attend social events together?* *3. Do you and your twin work for the same company or organization?* *4. Do you and your twin attend the same church, synagogue, or other religious institution?*

a. Minnesota Twins Political Survey

b. AddHealth

c. Kendler and Gardner

d. Kringlen

e. LaBuda

Italicized items are original to this article.

Figure 1

Impact on Twin Study Estimates of Violations of the Trait-Relevant EEA

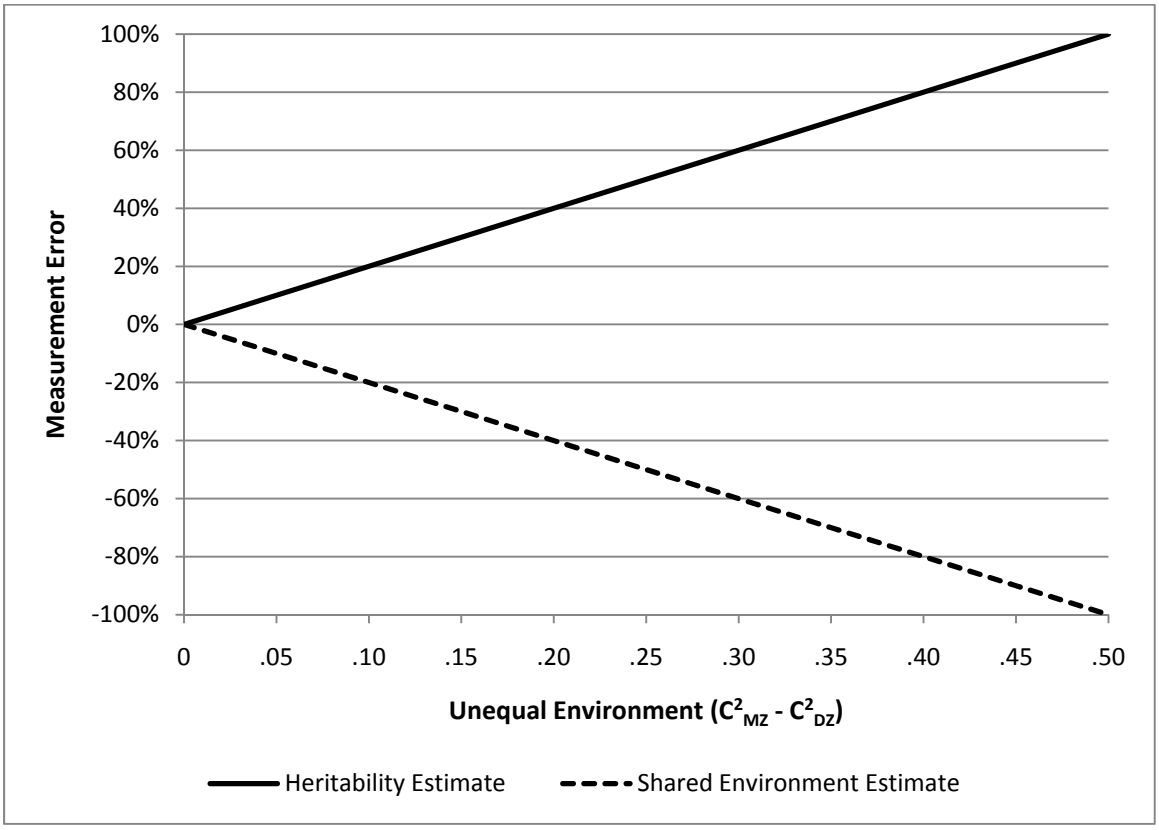
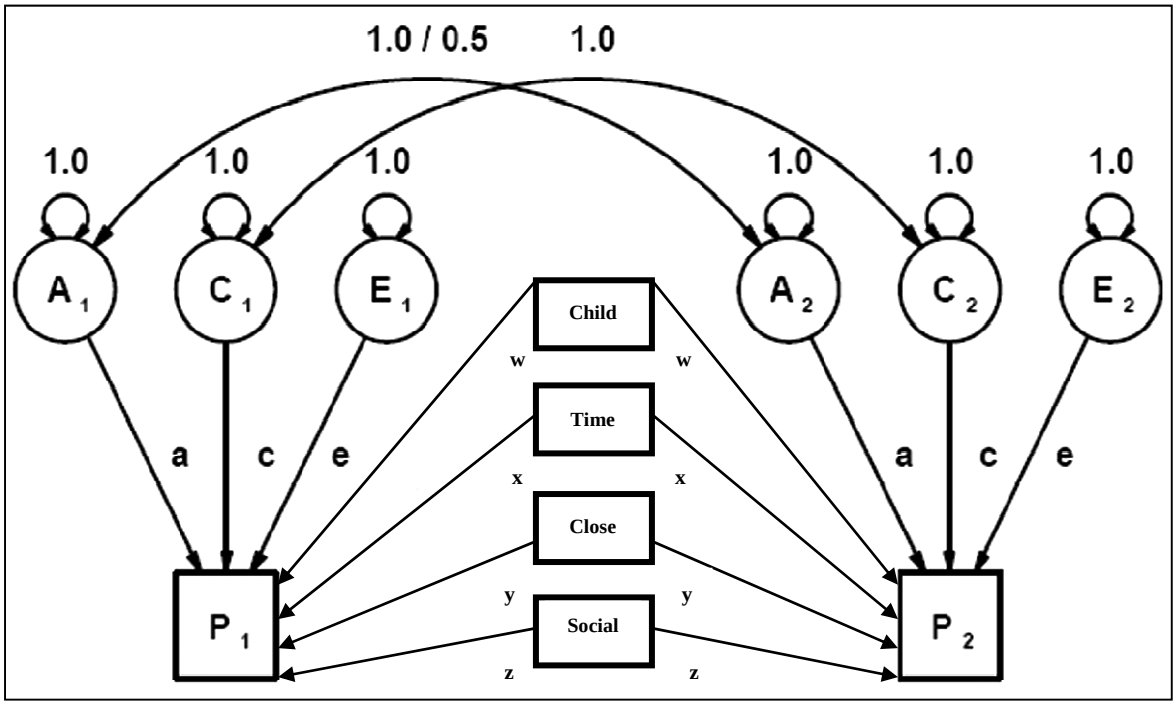


Figure 2

Twin Path Analysis with Environmental Covariates



Note: The original ACE model (without covariates) is taken from Hatemi et al. 2008.