

## Mediated Disposition–Environment Transactions: The DAE Model

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*Abstract:* We propose a new model of personality development, the disposition–adaptation–environment (DAE) model. It is based on the assumption that two types of individual characteristics can be distinguished: Dispositions make up the relatively stable core of personality at a particular age, and adaptations are the joint outcome of effects of dispositions and environmental characteristics and mediate transactions between dispositions and environments. Whereas distinctions between dispositions and adaptations have been drawn before, the DAE model is unique in that it (i) entails testable hypotheses whether individual characteristics are adaptations or dispositions, (ii) is based on quasi-causal cross-lagged effects, (iii) assigns adaptations a functional role as longitudinal mediators of disposition–environment transaction, and (iv) is developmentally sensitive. We illustrate application of the DAE model with a three-wave longitudinal study of 1118 adolescents who were observed from the first to the third year in middle school, using the Big Five as dispositions, conduct and self-esteem with peers as adaptations, and peer acceptance and rejection as the environmental measures. Hypotheses-driven and exploratory analyses were combined to yield both safe conclusions and novel hypotheses. We compare the model with other models of personality development and discuss extensions that include stable genetic and socio-economic effects. Copyright © 2017 European Association of Personality Psychology

**Key words:** characteristic adaptation; basic disposition; environment; peer relationships; longitudinal mediation

Research on personality development has been mainly cross-sectional in the early years, describing personality differences at different ages, comparing personality between different age groups, or searching for personality antecedents based on retrospective reports. Beginning in the 1960s, longitudinal studies entered the field and allowed for studies of long-term personality stability, the long-term prediction of personality, and the long-term prediction of developmental outcomes from early personality.

Much of this research is driven by causal questions about long-term transactions between personality traits and environmental characteristics (Laceulle & van Aken, in press; Specht et al., 2014). Both traits and environments are assumed to show high short-term stability but also long-term change. Do early between-children environmental differences cause later personality differences between them (socialization effects)? Do early personality differences cause later environmental differences (selection effects)? Researchers were urged, however, not to touch issues of causality because these studies were mostly based on correlation or

regression models where hidden confounders may be responsible for the observed effects.

More recently, however, this strict policy was somewhat relaxed. Rutter (2007) made a strong point about the usefulness of quasi-experimental designs (e.g. Neyer & Asendorpf, 2001, for a quasi-experimental study of the effect of the first stable partnership on personality). Causal effects in non-experimental studies were systematically discussed by Foster (2010) for developmental research and by Lee (2012) for personality research. Hudson and Fraley (2015) used an intervention design to study whether personality traits can be changed in a non-clinical sample if people choose to change them. These are all examples that researchers are beginning to embrace the concept of causality in an area where it is difficult to experimentally manipulate the main units of analysis: characteristics of personality and the person-specific environment.

In this spirit of moving personality research closer to causal questions, we propose a new approach to causal effects in the long-term transaction between personality traits and enduring environmental characteristics, the *disposition–adaptation–environment* (DAE) model. This model is a differentiation of transactional models of personality development where between-person differences in the proximal environment are explained by processes of personality-driven selection, modification, or evocation; and between-person differences in personality are explained by environment-driven socialization processes (see the discussion of transactional models by Bandura, 1978; Caspi,

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1998; Magnusson, 1990; Roberts, 2006; Sameroff, 1983). The differentiation concerns the personality part where two types of traits are distinguished: dispositions and adaptations. Dispositions make up the relatively stable core of personality at a particular age, and adaptations are the joint outcome of effects of dispositions and environmental characteristics, and mediate transactions between dispositions and environments. They are at the interface of personality and environment. As in all transactional models primarily concerned with the long-term development of personality, the DAE model does not address short-term processes where fluctuations in situations are linked with fluctuations in behaviours or experiences.

Whereas similar distinctions between dispositions and adaptations have been drawn before for theoretical or descriptive purposes (Kandler, Zimmermann, & McAdams, 2014), the DAE model assigns adaptations a possible *functional* role as mediators of longitudinal effects of the environment on dispositions and/or vice versa and is developmentally sensitive because it allows for age-related changes in the quasi-causal relations. For example, an adaptation may become a disposition through self-stabilizing processes (particularly early in life) or increasing personality–environment fit after a transition into a new environment, and a disposition may become an adaptation through destabilizing processes (particularly late in life) or decreased personality–environment fit after a transition into a new environment.

To provide an example, self-esteem differentiates over childhood from a domain-unspecific feeling of grandiose self-worth into domain-specific facets of self-esteem. This differentiation is driven by experiences in each domain (Harter, 1998) and results in adaptations. For some domains such as academic self-concept and physical self-concept, it has been shown that these adaptations show reciprocal transactions with achievement (Marsh, Gerlach, Trautwein, Lüdtke, & Brettschneider, 2007; Marsh & Martin, 2011). The various domain-specific self-concepts, in turn, transact with global self-esteem over late childhood and adolescence due to processes of generalization, compensation, and self-stabilization (Harter, 1998), resulting in the relatively stable trait of global self-esteem in young adulthood (Robins & Trzesniewski, 2005).

First, we outline the key elements of the model. Second, we describe the DAE model and how it can be applied to personality development. Third, we illustrate its application with a three-wave longitudinal study in adolescence. Fourth, we discuss the DAE model and its similarities and differences to other theoretical approaches that link personality with environments. Finally, we discuss expansions of the model that include stabilizing constants for dispositions and/or environments.

### Dispositions, adaptations, and environments

We distinguish between short-term fluctuations of *unstable units* (states and situations) around a person-specific constant or short-term trend, and long-term change of *stable units* (traits and environments). States are observed behaviours including reports of experiences that typically refer to a day or

a few assessments during a day; situations are situational characteristics that also typically refer to a day or a few assessments during a day. Daily reports or experience sampling studies of the enactments of traits, mood, and situational characteristics show retest reliabilities for a single assessment typically ranging from .20 to .40 (Epstein, 1979; Fleeson & Gallagher, 2009; Sherman, Rauthmann, Brown, Serfass, & Jones, 2015). To be on the safe side, we use .50 as an upper limit of retest reliability for unstable units. The DAE model is *not* concerned with unstable units; it is concerned with stable units: traits and environments.

Traits refer to relatively stable tendencies to show particular behaviours including reports of experiences over a period of one month. Therefore, they can be assessed with observed aggregated states within one month, retrospective reports of behaviours or experiences during the last month, self-descriptions of one's stable characteristics, or ability tests that show high short-term retest stability. This trait concept is broad, including abilities, attitudes, beliefs, coping styles, interests, motives, parenting styles, personal goals, personal values, self-concept (including self-narratives), and self-esteem (e.g. all personality units of the neo-socioanalytical model, Roberts & Wood, 2006, and not only what these authors called traits). In models of personality development that include states (e.g. the sociogenomic model of personality, Roberts & Jackson, 2008), continuous states fit our trait concept.

We use one month as a criterion for sufficient aggregation because observational studies of daily states typically show increases of retest reliability over 2–4 weeks and then reach an asymptote (Epstein, 1979; Fleeson, 2001; Fleeson & Gallagher, 2009; Sherman et al., 2015). Aggregation over longer observation intervals such as three months may already confound trait measurement with true trait change. To set traits apart from states, we assume a lower limit of .50 for the one-month retest reliability for traits, although many traits show a much higher retest reliability (e.g. in a meta-analysis of the retest reliabilities up to one month for the Big Five traits, the mean reliability ranged from .78 to .85; Gnambs, 2014).

Environmental characteristics (for brevity henceforward called environments) refer to relatively stable exposures to particular situations over a period of one month. Therefore, they can be assessed with observed aggregated situations or retrospective reports of situations during the last month or one's stable environment (note our strictly parallel description of traits and environments). To set them apart from situations, we assume a lower limit of .50 for the one-month retest reliability also for environmental characteristics. Whereas traits and states are often distinguished (e.g. Fleeson, 2001; Nezlek, 2007; Spielberger, 1972; Steyer, Schmitt, & Eid, 1999), a parallel distinction between situations and environments in terms of the chronic exposure to situations is rare (but see Asendorpf, 1996, in press; Bolger & Schilling, 1991; Neyer & Asendorpf, 2018).

Our concept of environment refers to the proximal environment (the microsystem in the environmental classification by Bronfenbrenner, 1977). Similar to our concept of traits, it is broad, including all traits of members of one's social

network (Asendorpf, in press). The time criterion of one month is consistent with the time criterion for these traits and the fact that aggregation of daily situational characteristics across time shows a similar increase in retest reliability as compared with states (Sherman et al., 2015). This concept of environment is also consistent with the concept of environmental effects in behavioural genetics (Plomin, DeFries, Knopik, & Neiderhiser, 2013) and research in risk and resilience (Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2007) where the concept of environment also refers to relatively stable contextual exposure.

Within traits, we distinguish between dispositions and adaptations. Traditionally, dispositions are conceived of as more stable 'core' traits, and adaptations as more malleable 'surface' traits that are the result of adaptations to the environment (see Kandler et al., 2014, for a review). Typical examples for dispositions are the Big Five traits (John & Srivastava, 1999); typical examples of adaptations are attitudes, personal values, beliefs, personal goals, interests, and the self-concept (McCrae & Costa, 1999). As the review by Kandler et al. (2014) shows, similar but non-identical distinctions have been proposed in the past (e.g. basic tendencies vs. characteristic adaptations, McCrae & Costa, 1996, 1999; core vs. surface characteristics, Asendorpf & van Aken, 2003a; dispositional traits vs. characteristic adaptations, McAdams & Pals, 2006).

In order to distinguish dispositions from adaptations, some authors use criteria such as the level of long-term stability and heritability (higher for dispositions) or causal influence or genetic influence over development (dispositions cause adaptations; genetic influence on adaptations is fully mediated by the genetic variance in dispositions). However, the review of related empirical findings in adulthood by Kandler et al. (2014) shows that there is only weak evidence that specific traits can be considered dispositions rather than adaptations and vice versa according to these criteria. The evidence seems to be stronger for self-related traits than for attitudes and motives, but this difference varies by criterion; the literature is not clear about which is a sufficient set of criteria for the distinction, and most criteria are not sufficiently clearly operationalized (e.g. is a disattenuated five-year rank-order stability of .90, .80, or .70 required for a disposition, and should the same minimum stability apply to all ages?).

We agree with the conclusion by Kandler et al. (2014) that the findings of their review 'call into serious question the labelling of some sets of constructs as either core or surface characteristics of personality' (p. 231). Nevertheless we believe that a distinction between dispositions and adaptations can be useful from a *functional* perspective on environment–disposition transactions: Adaptations may *mediate* the socialization and selection effects involved in these transactions. Therefore, we choose a different approach. We propose three empirically testable criteria for distinguishing dispositions from adaptations that can be tested for any triple consisting of a specific environmental characteristic, a specific measure of an adaptation, and a specific measure of a disposition. Thus the distinction between adaptations and dispositions is conditional on environments.

The three criteria are (i) the adaptation is co-influenced by both the disposition and the environment, (ii) the disposition influences the adaptation more strongly than do vice versa, and (iii) the adaptation longitudinally mediates influences of the disposition on the environment or vice versa. In addition we assume that the roles of adaptation and dispositions may change over the lifespan (e.g. early adaptations may later become dispositions). The three criteria require that influences and longitudinal mediation are operationalized such that they can be empirically determined. We propose that influences and longitudinal mediation are measured using long-term cross-lagged effects as explained in the next section.

### Cross-lagged effects and longitudinal mediation

Cross-lagged analysis estimates the causal effect of a predictor at T1 on an outcome at T2 with the regression of the outcome on the earlier predictor, controlling for the outcome at T1 (cross-lagged effect; see Gollob & Reichardt, 1987, for the merits and limits of this approach). If in addition the roles of predictor and outcome are reversed, the two causal directions are disentangled, and the result can be interpreted in terms of a lead–lag relationship (Finkel, 1995; Little, 2013). The cross-lagged effects are still subject to the hidden confounder problem of all regression analyses and thus should be considered *quasi-causal* effects (Shadish, Cook, & Campbell, 2002), also called Granger causality in econometrics (Granger, 1969).

Many research strands on the long-term transaction between environmental characteristics and personality traits used the cross-lagged approach: consumed media content and aggressiveness (see review by Krahé, 2014), quality of social relationships and personality (see review by Neyer, Mund, Zimmermann, & Wrzus, 2014), parenting and child temperament (see review by Kiff, Lengua, & Zalewski, 2011), or repeated life events and personality (Specht et al., 2014); see also the review of environment–personality transaction by Laceulle and van Aken (in press).

Recently cross-lagged analysis has been criticized with the argument that it confounds between-person and within-person differences along with the remedy that all constant between-person differences should be controlled (e.g. Hamaker, Kuiper, & Grasman, 2015). As Asendorpf, Denissen, Klimstra, and Lüdtke (2017) have pointed out, such a control can be appropriate for intensive longitudinal studies over short periods of a few weeks when no changes in personality traits and enduring environmental characteristics are expected (see also West, Ryu, Kwok, & Cham, 2011). But controlling for all constant between-person differences in studies of the *long-term* transaction between traits and environments discards the baby with the bathwater because all causal effects based on the constant part of the predictor are lost in the remaining cross-lagged effects. The constant part of the predictor can be correlated with the constant part of the environment, but this correlation is silent about the direction of causality, which was the main reason to use cross-lagged analysis in the first place. This drastic reduction dismisses an important part of socialization effects of

environments on traits and of selection effects of traits on environments. Instead, Asendorpf et al. (2017) proposed to leave the full between-person variation intact in studies of long-term personality development.

Cross-lagged models can be expanded to *longitudinal* mediation models where the cross-lagged effects of a predictor at T1 on a mediator at T2, and of the mediator at T2 on an outcome at T3 are simultaneously assessed. Similar to cross-sectional mediation, the product of these two cross-lagged effects is the mediation effect, and the remaining direct path from the predictor to the outcome tests whether mediation is partial or complete (see, for a general discussion, Cole & Maxwell, 2003; and for an application to environment–personality transactions, Reitz, Motti-Stefanidi, & Asendorpf, 2016).

Because it rests on two bivariate cross-lagged analyses, longitudinal mediation is able to distinguish between the two possible directions of mediation between two variables. In contrast, cross-sectional mediation relies on concurrent regressions and therefore cannot disentangle the two directions of mediation between two variables. Also, cross-sectional mediation may fail to detect mediations of longitudinal effects that longitudinal mediation can recover (Maxwell, Cole, & Mitchell, 2011). Longitudinal mediation has also limits that can lead to biased results. Like bivariate cross-lagged analysis, the paths from predictor to mediator and from mediator to outcome in a longitudinal mediation model can be biased by confounders, and the spacing of the assessments can be too short or too long to capture the causal effects (Gollob & Reichardt, 1987). No mediation method is perfect, but longitudinal mediation is closer to the actual causal processes than is cross-sectional mediation.

### The DAE model

We propose a general causal model of personality development based on the distinction between dispositions and adaptations, the DAE model. The building blocks of the model are *DAE triples*. Each triple consists of one disposition, one adaptation, and one environment characteristic; it is assumed that the disposition and the adaptation, and the adaptation and the environment are causally linked, but not necessarily the disposition and the environment. If the disposition is causally linked with the environment, it is assumed that this link is partly explained by the adaptation. These assumptions can be empirically tested using cross-lagged and longitudinal mediation models.

The DAE model itself does not attempt to explain personality development. Instead, the model provides a flexible, general framework for *testing of and searching for explanations* of observed developmental changes in dispositions, adaptations, and environments. Hypothetical links derived from the literature between dispositional, adaptational, and environmental measures can be tested guided by the model. In addition, it is of heuristic value by guiding the search for mechanisms that might explain transactions between dispositions and environments by searching for context-specific adaptations that mediate between them.

For example, studies of the social investment principle that selection and socialization effects in personality–environment transactions correspond to each other (see for an early review Lodi-Smith & Roberts, 2007, and mixed evidence for work environments provided by Denissen, Ulferfs, Lüdtke, Muck, & Gerstorf, 2014) can be enriched with adaptations that mediate the selection and or socialization effects. For example, how do jobs demanding openness to new experiences such as music composer increase openness if one stays in these jobs (Denissen et al., 2014)? Is it through the adaptation of listening to a wide variety of music?

Three exploratory strategies can be distinguished: D-strategy, A-strategy, and E-strategy. The D-strategy starts with a disposition (e.g. openness) and searches for environment characteristics that may be linked to the disposition (in the case of openness this might be, for example, the cultural diversity of members of one's social network or the diversity of consumed media). This search for environment characteristics should be guided by both existing theory and empirical findings. For each disposition–environment link, adaptations are selected that most likely mediate the link, again guided by both theory and empirical findings. In the case of openness and cultural diversity of network members, such an adaptation might be prejudice against particular cultures. In this case, theories and related empirical findings about the development of prejudice and its effect on social relationships should be used.

Similarly, the A-strategy starts with an adaptation and searches for associated dispositions and environment characteristics, and the E-strategy starts with an environment characteristic and searches for associated dispositions and adaptations. Because of our broad concept of traits and environments, the theories and empirical findings that are used for these strategies are highly diverse and only restricted by the types of traits and environments under investigation.

All strategies can lead to the same triples, but depending on the concrete research questions, one strategy is more suited than another one because the research focus often provides a natural starting point. For example, personality psychologists interested in the development of the Big Five traits best choose the D-strategy because they focus on dispositions, developmental psychologists interested in risk and resilience best choose the A-strategy because they focus on how people fulfil developmental or acculturative tasks in the context of environmental risks, and psychologists interested in the role of families or peer groups in personality development best choose the E-strategy because they focus on environments.

Once a DAE triple has been determined, it is tested whether the triple fits the DAE model. This test requires a three-wave longitudinal study of the disposition, the adaptation, and the environment (for some hypotheses, only two time points are required; but in order to increase the robustness of the results, we recommend at least three assessments). Because the DAE model concerns personality development, spacing of the assessments should be reasonably wide to capture causal effects (typically one year apart). The optimal spacing depends on the concrete DAE triple and age range under investigation. Based on these data, the three hypotheses in Table 1 are tested.

Table 1. DAE hypotheses for a DAE triple

H1	Co-influence of <i>D</i> and <i>E</i> on <i>A</i>	$D \rightarrow A, E \rightarrow A$
H2	Causal dominance of <i>D</i> over <i>A</i>	$D \rightarrow A > A \rightarrow D$
H3	<i>A</i> is longitudinal mediator	$D \rightarrow A \rightarrow E, E \rightarrow A \rightarrow D$

Note: *D*, disposition; *A*, adaptation; *E*, environmental characteristic.  
 $\rightarrow$  indicates a cross-lagged effect;  $\rightarrow$  a significant cross-lagged effect.

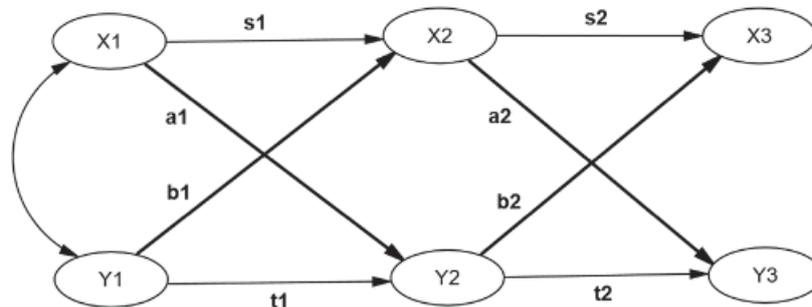
The co-influence hypothesis tests with cross-lagged analysis whether the adaptation is significantly predicted by the disposition and the environmental measure. The causal priority hypothesis tests with cross-lagged analysis whether the influence of the disposition on the adaptation is stronger than is vice versa. No causal priority of the environment over the adaptation is assumed to allow for effects of adaptations on the environment (selection and manipulation of environments that fit to one's personality, and evocation of others' responses that reinforce one's traits; Buss, 1987; Roberts, Wood, & Caspi, 2008). In such cases, bi-directional influences between adaptations and environments occur where the effects of the adaptations on the environment can be even stronger than do vice versa.

The mediation hypothesis tests whether the adaptation longitudinally mediates the dispositional effect on the

environmental measure or vice versa. Searching for and finding such mediations set the DAE approach apart from traditional analyses of personality–environment transactions, and the identification of such mediations moves the causal analysis of personality development a step further. Because different adaptations can show opposite mediational effects between the same disposition and the same environmental measure, direct effects between dispositions and environments are not a necessary requirement for such mediations (see also the discussions of mediation by MacKinnon, Fairchild, & Fritz, 2007, and Rucker, Preacher, Tormala, & Petty, 2011). However, because the effect sizes of mediations are the product of the effect sizes of the two paths on which they rest, each path should show a sufficiently large effect.

Each hypothesis can be tested with a structural equation model (SEM) (Figure 1). Because the tests of the co-influence and the mediation hypothesis involve cross-lagged path coefficients, it is important to control for the unreliability of the measures by using latent variables with multiple indicators whenever this is possible (Cole & Maxwell, 2003). If the time distance between the assessments is large, measurement equivalence across time should be tested in terms of equal factor loadings of the indicators across time (Cole & Maxwell, 2003). Because longitudinal mediation

Panel 1: SEM for H1 and H2



Panel 2: SEM for H3

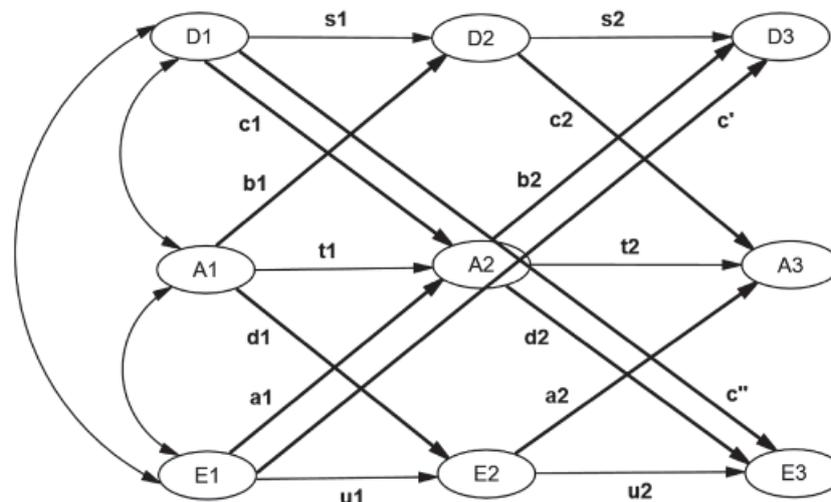


Figure 1. Structural equation models (SEMs) for testing the disposition–adaptation–environment hypotheses. Manifest variables, stabilities from T1 to T3, and correlations between measurement-specific errors across waves and between residuals within waves are not shown.

requires three waves of assessment, DAE models should also be tested with at least three waves. Figure 1 shows the two types of SEMs used in tests of univariate DAE models. For the DAE hypothesis 1,  $Y$  is the adaptation  $A$  and  $X$  is either the environment  $E$  or the disposition  $D$ ; for hypothesis 2,  $Y$  is the adaptation  $A$  and  $X$  is the disposition  $D$ .

Figure 1 shows that the DAE hypotheses 1 and 2 are tested two times within a three-wave study (one time for the first two waves and another time for the last two waves). Similarly, each longitudinal mediation can be tested with two products of path coefficients (e.g.  $a_1b_2$  and  $a_2b_1$  for the mediation of the effect of  $E_1$  on  $D_3$ ). This makes sense only if one can assume stationarity of the model (i.e. regressions with the same letter are equal). Stationarity can be tested by comparing a model with equal auto-lagged and cross-lagged regressions across the retest intervals with an unrestricted model; if the fit of the stationary model is not worse than the fit of the unrestricted model, stationarity can be assumed. Stationary models not only are more parsimonious but also provide more robust estimates of the cross-lagged parameters because unsystematic error is reduced through averaging.

Because mediation effects are the product of two path coefficients, their significance should be tested using robust methods such as robust standard errors or bootstrapping (MacKinnon et al., 2007; Rucker et al., 2011). Selective attrition effects can be controlled with full information maximum likelihood estimation. Compared with cross-sectional studies, shared method variance is a smaller problem for tests of the DAE model because the cross-lagged coefficients control for concurrent correlations that fully include concurrent shared method variance. Thus, the higher the stability of the predicted variable, the better concurrent shared method variance is controlled for. Shared method variance can become a problem however if the stability of the predicted variable is low or if shared method variance is changing over time.

It is important to point out that alternative models that simply correlate changes in traits with synchronic changes in environments are not able to distinguish between the directions of causality (see Allemand & Martin, 2016, for a review of such models). The same restriction applies to models where changes in traits are regressed on changes in environments or vice versa. If one wants to disentangle the direction of causality in predictions of changes in one variable from changes in another variable, a viable method is predicting *subsequent* changes from *preceding* changes (see Mund & Neyer, 2014, for personality–relationship transactions).

In principle, these univariate DAE models can be extended to multivariate ( $k, l, m$ ) DAE models where cross-lagged relations between  $k$  dispositions,  $l$  adaptations, and  $m$  environmental characteristics are studied. In these cases, the influence of all dispositional or environmental measures on an adaptation and the influences of all adaptations on a disposition can be studied, in terms of both unique and overall contributions. Similarly, longitudinal mediations can be studied with multiple mediator models where both the unique contributions of each mediator and the total mediation effect by all mediators are determined (Preacher & Hayes, 2008; the methods described there can be easily adapted to longitudinal multiple mediation).

However, if the dispositional, adaptational, or environmental measures show substantial concurrent correlations, the unique cross-lagged effects based on them are threatened by suppressor effects even more than in ordinary multiple regression because each cross-lagged effect is controlled for all other direct effects *and* all other indirect effects such that substantive interpretations of the unique cross-lagged effects are difficult. More viable is the alternative strategy of interpreting each triple one by one in a multivariate DAE model. In this case, alpha inflation due to the many statistical tests has to be controlled with procedures such as stepwise Bonferroni correction. We illustrate the use of a multivariate DAE model with the following empirical example.

### Empirical illustration

We illustrate use of a (5, 2, 2) DAE model (5 dispositions, 2 adaptations, 2 environmental measures) with a three-wave longitudinal study of 1118 adolescents who were observed from the first to the third year in middle school. Following a D-strategy, we first chose the self-reported Big Five traits as dispositions. We chose peer acceptance and rejection as the environmental measures because concurrent correlations between the Big Five and peer relationships have been well established for children and adolescents (van Aken & Asendorpf, in press), detailed sociometric data on adolescents' status in the classroom were available, and the data on sociometric status were based on peer reports that did not share method variance with the self-reported dispositions. One's social status in the peer group is neither a trait because it does not assess regularities in one's behaviour nor a relationship characteristic because it does not refer to a specific dyad; it is a measure of the environment because sociometric peer status shows a high short-term retest reliability (Cillessen & Marks, 2011).

Given these choices of dispositions and the environmental measures, which adaptations may mediate them? Reviews that link peer relationships with personality in childhood and adolescence often refer to mild behavioural problems as possible mediators, namely, externalizing problems (mainly aggressiveness and conduct problems) and internalizing problems (low self-esteem, loneliness, and depression) (Achenbach & Edelbrock, 1981). Because we consider here the full range of inter-individual differences, we prefer the terms externalizing and internalizing *tendencies*.

Externalizing tendencies are mainly linked to peer rejection (being rejected by peers) and internalizing tendencies to low peer acceptance (not being accepted by peers; Bukowski, Laursen, & Rubin, in press; Hymel, Rubin, Rowden, & LeMare, 1990; Rubin, Bukowski, & Parker, 2006). Rejection and low acceptance are related but not the same because of neglected members of a peer group who are neither accepted nor rejected, and controversial members who are both accepted by one subgroup and rejected by another subgroup (Cillessen, Schwartz, & Mayeux, 2011; Coie, Dodge, & Coppotelli, 1982). Although most of the empirical evidence for these links stems from correlational studies, some studies using experimental groups and intervention designs showed evidence for both directions, from peer relationships to

Table 2. Externalizing–internalizing hypotheses

Dispositions		Adaptations		Environment
Concurrent correlations				
Extraversion, emotional stability	–	Internalizing	–	Peer acceptance
Agreeableness, conscientiousness	–	Externalizing	+	Peer rejection
DAE model				
Extraversion, emotional stability	➔	Internalizing	←	Peer acceptance
	←		➔	
Agreeableness, conscientiousness	➔	Externalizing	←+	Peer rejection
	←		➔+	

Note: ➔, ← necessary effects; ← optional effects.

externalizing/internalizing tendencies and vice versa (Rubin et al., 2006). Therefore, we expected bi-directional effects between peer non-acceptance and internalizing tendencies, and peer rejection and externalizing tendencies.

In terms of the Big Five model of personality, externalizing problems are mainly linked to low agreeableness and low conscientiousness, and internalizing problems to low extraversion and low emotional stability (Asendorpf & van Aken, 2003b; Van Leeuwen, Mervielde, De Clercq, & De Fruyt, 2007). Therefore, links of externalizing problems to the undercontrolled personality type characterized by low agreeableness and low conscientiousness, and internalizing problems to the overcontrolled personality type characterized by low extraversion and low emotional stability are expected and were repeatedly shown (Asendorpf, Borkenau, Ostendorf, & van Aken, 2001; Asendorpf & van Aken, 1999; Caspi, 1998; Meeus, Van de Schoot, Klimstra, & Branje, 2011). Cross-lagged studies of the direction of effects between these personality traits and externalizing/internalizing tendencies are rare. Klimstra et al. (2010) found mainly bi-directional effects over adolescence between the Big Five and externalizing and internalizing tendencies, whereas Mezquita et al. (2015) found effects from neuroticism to internalizing and from agreeableness and conscientiousness to externalizing tendencies but only one reverse effect (from externalizing to conscientiousness). Therefore, we expected a bi-directional pattern with stronger influences from the Big Five to externalizing/internalizing than vice versa.

Finally, a review of relations between the Big Five personality traits and peer relationships showed the strongest concurrent correlations of peer acceptance with extraversion and emotional stability, and of bullying and peer rejection with low agreeableness and low conscientiousness (van Aken & Asendorpf, in press). Furthermore, three cross-lagged studies in adolescence and emerging adulthood showed that extraversion predicted more support from peers, more closeness to peers, and selecting more friends; neuroticism predicted insecurity with peers; agreeableness predicted being more selected as a friend by peers; and both agreeableness and conscientiousness predicted less conflict with peers; the reverse effects were not found (Asendorpf & Wilpers, 1998; Parker, Lüdtke, Trautwein, & Roberts, 2012; Selfhout et al., 2010). Therefore, we expected positive effects from extraversion and emotional stability on peer acceptance, and negative effects from agreeableness and conscientiousness on peer rejection.

Putting these pieces together, we expected effects of extraversion and emotional stability on peer acceptance that are mediated by low internalizing tendencies, and of low agreeableness and low conscientiousness on peer rejection that are mediated by externalizing tendencies. Reverse effects were expected for low peer acceptance on internalizing tendencies, and peer rejection on externalizing tendencies, whereas effects from externalizing or internalizing tendencies on the Big Five were expected to be weaker than effects of the Big Five on these tendencies (see Table 2 for a summary of these externalizing/internalizing hypotheses).

The externalizing/internalizing hypotheses are compatible with a (4, 2, 2) DAE model where the effects of extraversion and emotional stability on peer acceptance are mediated by low internalizing tendencies, and the effects of agreeableness and conscientiousness on low peer rejection are mediated by low externalizing tendencies; expectations for the reverse mediations were conditional on effects from internalizing/externalizing tendencies to personality. If the remaining disposition openness is added for exploratory purposes, this results in a (5, 2, 2) DAE model.

## METHOD

### Sample

The initial sample consisted of adolescent students living in neighbourhoods with a high proportion of immigrant families in Athens, Greece, that were assessed after the first trimester in secondary school early in 2013. Assessed were 1118 students who attended 57 secondary-school grade 1 classes in 14 schools (age  $M = 12.6$  years,  $SD = 0.57$ ; 53% male). The sample was reassessed one year later (attrition rate 8%) and two years later (additional attrition rate also 8%).<sup>1</sup>

<sup>1</sup>A detailed description of the initial sample, also in terms of ethnic composition, is provided by Motti-Stefanidi and Asendorpf (2017). Sample selection was based on school classrooms and included all students of a classroom. In this earlier publication, one school of the present study was not included for better comparison with an earlier cohort such that the sample size was smaller; the present study used the full sample and additionally wave 2 and wave 3 of the study. As the data were recently assessed (assessment and cross-checking of the data were finished in 2015), we do not wish to provide open access to the data before 2020 in order to give a publication preference to the collaborators in the project.

## Measures

The following measures were assessed in all waves with identical procedures. The dispositional measures assessed the Big Five, the adaptational measures externalizing and internalizing problems, and the environmental measures being accepted or rejected by the classmates. The scores of externalizing and internalizing were reversed such that all relations were expected to be positive except for those involving peer rejection.

### Dispositions

The Big Five personality factors were self-rated on translated versions of German eight-item scales developed by Asendorpf and van Aken (1999) for *Extraversion*, *Emotional Stability*, *Agreeableness*, *Conscientiousness*, and *Openness to Experience*. Each item consisted of two bipolar adjectives that were rated on a 5-point scale (see Asendorpf & van Aken, 2003b, and Supplement S1, for English translations of the items). These Big Five scales were used in previous research in a different sample of adolescents by Motti-Stefanidi and Asendorpf (2012). As in the earlier study, the internal consistencies were relatively low but acceptable given the broad Big Five factors ( $\alpha$ 's above .63 in all three waves; see Supplement S2 for details).

### Adaptations

Externalizing tendencies were rated by the Greek language teacher in the student's classroom on six items, each rated on a 5-point scale, ranging from 1 = *not at all* to 5 = *very much*. The items assessed the degree to which the student was aggressive towards peers or disturbed the class (see Supplement S1 for English translations of the items). The items were reversely coded such that high scores indicate *Conduct*. This scale was used in previous research on a different sample of adolescents by Motti-Stefanidi, Asendorpf, and Masten (2012) and Motti-Stefanidi and Asendorpf (2017). As in earlier studies, the internal consistencies of the scale were high ( $\alpha$ 's above .87 in all three waves; see Supplement S2 for details).

Internalizing tendencies were self-rated on six items of the Strengths and Difficulties Questionnaire (Goodman, Meltzer, & Bailey, 1998) and two items assessing fearful and preoccupied attachment to peers based on the attachment classification of Bartholomew and Horowitz (1991) (see Supplement S1 for English translations of the items). Because the items were rated on different response scales, they were  $z$ -transformed in the full sample. The common core of the items can be seen as a negative evaluation of one's relations with peers (negative self-esteem with peers). The items were reversely coded such that high scores indicate *self-esteem with peers*. The internal consistencies of the scale were sufficiently high ( $\alpha$ 's above .62 in all three waves; see Supplement S2 for details).

### Environmental measures

*Sociometric peer acceptance/rejection* was assessed with the sociometric procedure used by Coie et al. (1982). In each wave, all students in each classroom were asked to write down the names of up to three classmates they liked most and three classmates they liked least. Peer acceptance/rejection was measured for each student in terms of the percentage of all nominating classmates who positively/negatively nominated him or her. These scores could range from 0% to 100%. They control for the number of nominating classmates (i.e. the opportunity to be nominated). These measures were used in previous research on a different sample of adolescents by Asendorpf and Motti-Stefanidi (in press).

## RESULTS

### Descriptive statistics

The means, standard deviations, and intercorrelations of the DAE variables in wave 1 and their stabilities across waves are reported in Table 3. The relatively high correlations among the Big Five, particularly among emotional stability, agreeableness, and conscientiousness (second-order factor

Table 3. Means, standard deviations, and intercorrelations of the variables in wave 1, and their stabilities between waves 1, 2, and 3

Variable (judge)	<i>M</i>	<i>SD</i>	Intercorrelations												Stabilities							
			ES		AG		CO		OP		CON		SEP		PA		PR		<i>r</i> <sub>12</sub>	<i>r</i> <sub>23</sub>	<i>r</i> <sub>13</sub>	
			<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>						
Extraversion (S)	EX	3.58	0.68	.33	.001	.38	.001	.25	.001	.43	.001	.06	.075	.40	.001	.17	.001	-.09	.005	.39	.48	.38
Emotional stability (S)	ES	3.58	0.71			.52	.001	.53	.001	.43	.001	.09	.007	.40	.001	.10	.002	-.12	.001	.44	.49	.39
Agreeableness (S)	AG	3.68	0.65					.59	.001	.44	.001	.21	.001	.30	.001	.10	.001	-.13	.001	.47	.46	.41
Conscientiousness (S)	CO	3.58	0.66							.53	.001	.19	.001	.30	.001	.06	.042	-.07	.027	.49	.53	.41
Openness (S)	OP	3.73	0.67									.16	.001	.36	.001	.14	.001	-.14	.001	.47	.52	.47
Conduct (T)	CON	4.34	0.88											.13	.001	.12	.001	-.26	.001	.39	.46	.33
Self-esteem with peers (S)	SEP	-0.01	0.54													.21	.001	-.19	.001	.47	.58	.45
Peer acceptance (P)	PA	0.16	0.12															-.30	.001	.44	.52	.36
Peer rejection (P)	PR	0.14	0.14																	.50	.59	.47

Note:  $N > 1029$  for each variable. Correlations  $r$  are Pearson correlations (significances  $p$  two-tailed). All stabilities are significant at  $p < .001$ . Shaded cells refer to the externalizing/internalizing hypotheses.

S, self; T, teacher; P, peer judgement.

alpha; Digman, 1997), and between extraversion and openness (beta), are not uncommon for self-ratings of early adolescents (Soto, John, Gosling, & Potter, 2008); they suggest that there may be collinearity problems in models including all Big Five measures. The correlations between the adaptations and between the environmental measures were low, assuring discriminant validity. The stabilities were similarly high for all variables, tended to increase with increasing age, and tended to slightly decrease with increasing retest interval, which suggests true differential change over the two years of observation. The remaining *Ms*, *SDs*, and correlations can be found in Supplement S2 and S3.

The wave 1 correlations relevant for the externalizing/internalizing hypotheses are shaded in Table 3. They are consistent with these hypotheses (Table 2) if one takes into account that the correlations between the dispositions and self-esteem are inflated owing to shared method variance. It should be noted however that the correlations can be affected by unreliability of the assessments as well as by systematic attrition effects if they involve assessments in wave 2 or wave 3. Therefore, they should be considered as only preliminary evidence for the externalizing/internalizing hypotheses.

#### Direction of effects, significance testing, and suppressor effects

Table 3 and Supplement S3 provide strong evidence that the correlations between the DAE variables are consistent with the social desirability of their high scores. All significant correlations in these tables were positive except those relating peer rejection to another variable, which were all negative (no exception among the 290 significant correlations). This fully consistent pattern clearly justifies the general use of one-tailed hypotheses for all effects. In addition, significant regressions in the following analyses that do not conform to this pattern are suppressor effects and can be therefore easily recognized.

#### Measurement equivalence and stationarity

Following recommendations by Finkel (1995) for cross-lagged models and by Cole and Maxwell (2003) for longitudinal mediation, we assured measurement equivalence and stationarity across time using a latent variable approach if possible (see Reitz et al., 2016, for a similar approach to a different sample). Each disposition and adaptation was implemented as a latent variable with two item parcels that were constructed using the item-to-construct balance parcelling technique (Little, Cunningham, Shahar, & Widaman, 2002); the assignment of the items to the parcels is shown in Supplement S1. These parcels correlated above .48 for each latent variable for each wave of the study, and the split-half reliabilities of the scales based on the parcels were at least .63 for all three waves (see Supplement S2 for details). The measurement errors of a parcel were allowed to correlate across waves in order to capture parcel-specific stability (Marsh & Hau, 1996). Measurement equivalence for the latent

variables was assured by constraining the factor loadings of the parcels to be equal across time.<sup>2</sup> The two sociometric measures were included as manifest variables because they consisted of only one manifest variable. The reliability of the sociometric measures can be assumed to be high because they were based on many nominators, and the short-term retest reliability of sociometric measures is high (Cillessen & Marks, 2011).

Stationarity was assured by constraining for each DAE variable the auto-regressions and for each DAE pair the cross-lagged regressions to be equal across the two intervals, T12 and T23. Finally, preliminary analyses only of the auto-regressive structure (refer to succeeding discussions) showed that the lag2 (T1–T3) auto-regressions were significant for all DAE variables. Therefore, they were included in all models. MPLUS 7.0 (Muthén & Muthén, 1998–2012) was used for all SEM analyses.

Whether the equivalence and stationarity assumptions fitted the data was tested both for relative and for absolute fit as follows. The fit of an unrestricted (5, 2, 2) DAE model with the five dispositions, the two adaptations, and the two environmental variables was compared with the fit of a restricted model where the factor loadings, the auto-regressions, and the cross-lagged regressions were constrained to be identical across the two time intervals T12 and T23 (see Supplement S4 for the MPLUS syntax of the restricted model).

The restricted model had 51 degrees of freedom more than the unrestricted model has (14 for factor loadings, 9 for auto-regressions, and 28 for cross-lagged regressions). Both the unrestricted and restricted models converged without problems. The relative fit of the restricted model was not worse than the fit of the unrestricted model, both in terms of  $\chi^2$ ,  $\Delta\chi^2(51) = 48.48$ ,  $p = .574$ , and in terms of comparative fit index (CFI) ( $\Delta\text{CFI} = 0.001$ ). The absolute fit of the restricted model was also good, root mean square error of approximation (RMSEA) = 0.026, 95% CI = [0.024, 0.028]; CFI = 0.961. Because all models used in the following analyses were sub-models of the (5, 2, 2) DAE model, they were based on the restricted version (henceforward called stationary models). The advantage of these stationary models is not only their higher parsimony and ease of interpretation but also the reduction of the *SEs* of the stationary parameters because each one is based on two or three parameters of the unrestricted model.

#### Multivariate versus univariate DAE models

Whereas the test of the stationary model was based on a multivariate (5, 2, 2) DAE model with multiple dispositions, adaptations, and environmental measures, we used in all further analyses univariate (1, 1, 1) DAE models, or sub-models of them, because we focused on the lagged effects of each measure, not on the unique lagged effects controlling for other measures of the same type (D, A, or E measures). These unique effects can be misleading if the measures show

<sup>2</sup>In the present case, the loading of only the second parcel has to be constrained because the loading of the first parcel was fixed to 1 anyway.

Table 4. Auto-regressions and cross-lagged effects between the DAE variables

Variables <i>X</i>	Auto-regressions $X \rightarrow X$				Conduct <i>Y</i>						Self-esteem with peers <i>Y</i>					
	$T \rightarrow T + 1$		$T1 \rightarrow T3$		$r_{XY}$		$X \rightarrow Y$		$Y \rightarrow X$		$r_{XY}$		$X \rightarrow Y$		$Y \rightarrow X$	
	$\beta$	<i>p</i>	$\beta$	<i>p</i>	<i>r</i>	<i>p</i>	$\beta$	<i>p</i>	$\beta$	<i>p</i>	<i>r</i>	<i>p</i>	$\beta$	<i>p</i>	$\beta$	<i>p</i>
Extraversion	.478	.001	.219	.001	.048	.288	<b>.063</b>	<b>.006</b>	.014	.416	.579	.001	-.053	.234	<b>.209</b>	<b>.001</b>
Emotional stability	.555	.001	.151	.007	.106	.032	<b>.064</b>	<b>.067</b>	-.020	.502	.588	.001	.018	.672	<b>.084</b>	<b>.060</b>
Agreeableness	.561	.001	.171	.006	.267	.001	<b>.125</b>	<b>.001</b>	.042	.142	.453	.001	.022	.526	.053	.155
Conscientiousness	.636	.001	.115	.069	.204	.001	<b>.119</b>	<b>.001</b>	.027	.219	.455	.001	-.026	.463	.004	.918
Openness	.584	.001	.220	.001	.197	.001	<b>.102</b>	<b>.008</b>	.022	.315	.533	.001	-.059	.139	<b>.087</b>	<b>.036</b>
Peer acceptance	.450	.001	.155	.001	.100	.001	<b>.048</b>	<b>.003</b>	<b>.042</b>	<b>.045</b>	.261	.001	<b>.048</b>	<b>.051</b>	<b>.097</b>	<b>.001</b>
Peer rejection	.487	.001	.229	.001	-.264	.001	<b>-.141</b>	<b>.001</b>	<b>-.064</b>	<b>.010</b>	-.226	.001	<b>-.047</b>	<b>.098</b>	<b>-.078</b>	<b>.009</b>
Conduct	.423	.001	.210	.001												
Self-esteem with peers	.631	.001	.185	.003												

Note:  $N = 1118$ . The standardized regression coefficients  $\beta$  and the initial correlations  $r$  were estimated with stationary auto-regressive or cross-lagged models with robust standard errors (MLR estimation); significances (two-tailed) refer to the unstandardized solution. Significant cross-lagged effects (one-tailed) are marked in bold. Shaded cells refer to the externalizing/internalizing hypotheses.

relatively high intercorrelations as in the case of the Big Five measures (Table 3). Indeed, the DA part of the (5, 2, 2) DAE model showed mostly non-significant cross-lagged effects and evidence of suppressor effects.

### Auto-regressive structure

A first set of analyses investigated the auto-regressive structure for each DAE variable assuming stationarity. The auto-regressions between subsequent waves (lag1 effects) and the auto-regression from wave 1 to wave 3 (lag2 effects) are reported in Table 4.<sup>3</sup> For conscientiousness and openness, the significances could not be computed owing to a problem with the lag2 stability of the first parcel's measurement error; fixing it to zero solved the problem. For all analyses, RMSEA < 0.05 and CFI > 0.95. Although the lag1 regressions were much higher than the lag2 regressions, the latter were at least marginally significant. They indicate a dampened decrease of stability (stability from wave 1 to wave 3 was higher than expected from the two 1-year stabilities; e.g. Little, 2013).

### Initial correlations and cross-lagged effects

The initial correlations and cross-lagged effects between *D* and *A*, and between *E* and *A*, were analysed with  $7 \times 2 = 14$  stationary cross-lagged (1, 1) DAE sub-models. The structural part of these models is shown in Figure 1, panel 1 (*X* has to be replaced by *D* or *E*, and *Y* by *A*). The results are reported in Table 4. They are the building blocks for the tests of the externalizing/internalizing and the DAE hypotheses and therefore described in later sections. For all analyses, RMSEA < 0.05 and CFI > 0.95. No evidence for suppressor effects was found.

<sup>3</sup>The standardized paths of identical unstandardized paths in a stationary model can vary depending on the SDs of the involved variables; we report the mean of the standardized paths for auto-regressions and cross-lagged effects.

### Longitudinal mediation effects

The indirect effects from a disposition at T1 to an environmental variable at T3 via an adaptation at T2 and vice versa were tested within stationary (1, 1, 1) DAE models (see Figure 1, panel 2, and Supplement S4 for the MPLUS syntax). The unstandardized indirect effect from *D* to *E* via *M* is the product of the unstandardized cross-lagged effects from *D* to *M* and from *M* to *E* and measures the extent to which *M* longitudinally mediates the effect from *D* to *E*, and vice versa. The product of the standardized cross-lagged effects is a useful measure of effect size (MacKinnon et al., 2007). Because most cross-lagged effect sizes in the present study were below .10, the longitudinal mediation effect sizes are expected to be below .01. Following recommendations in the recent literature on mediation, we did not test full versus partial mediation (significance of the direct paths from *D* at T1 to *E* at T3 and vice versa) because of the low statistical power of this test (Rucker et al., 2011). Nevertheless these paths can provide important information because if they are significant, they suggest that adaptations not included in the study may mediate between *D* and *E*.

The results are presented in Table 5. For all analyses, RMSEA < 0.05 and CFI > 0.95. No evidence for suppressor effects was found. Among the 80 tests, four significant (one-tailed) longitudinal mediation effects and six significant direct effects were found, mostly concerning effects from dispositions to the environment. The tests are sometimes related to each other (e.g. if a mediation through adaptation *A* is significant and a parallel mediation through adaptation *A'* is close to zero, a significant direct path in the latter mediation model is expected because it contains the former mediation). Also the mediation tests make only sense if the two involved cross-lagged paths have a sufficiently large effect. We interpret the findings displayed in Table 5 in the following sections.

### Externalizing/internalizing hypotheses

The results on the externalizing/internalizing hypotheses are first discussed for externalizing and then for internalizing.

Table 5. Results for longitudinal mediation

DAE triple			H3							
			$D \rightarrow A \rightarrow E$		$D \rightarrow E^1$		$E \rightarrow A \rightarrow D$		$E \rightarrow D^1$	
D	A	E	$\beta$	$p$	$\beta$	$p$	$\beta$	$p$	$\beta$	$p$
EX	CON	PA	.002	.103	<b>.123</b>	<b>.003</b>	.000	.679	<b>.085</b>	<b>.012</b>
EX	CON	PR	-.003	.113	-.006	.851	-.001	.673	.022	.547
EX	SEP	PA	<b>-.005</b>	<b>.201</b>	<b>.103</b>	<b>.006</b>	<b>.009</b>	<b>.071</b>	.044	.146
EX	SEP	PR	.005	.232	.016	.639	-.008	.162	.051	.125
ES	CON	PA	.001	.299	.020	.537	.000	.930	.011	.743
ES	CON	PR	-.003	.175	-.024	.540	.001	.773	-.020	.570
ES	SEP	PA	<b>.002</b>	<b>.486</b>	<b>.033</b>	<b>.377</b>	<b>.004</b>	<b>.187</b>	<b>.006</b>	<b>.874</b>
ES	SEP	PR	-.002	.414	.032	.363	-.004	.193	-.009	.797
AG	CON	PA	.004	.113	.014	.730	.001	.270	.025	.457
AG	CON	PR	<b>-.006</b>	<b>.022</b>	-.004	.915	-.005	.114	.018	.615
AG	SEP	PA	.002	.574	.001	.989	.003	.234	.014	.672
AG	SEP	PR	-.002	.552	.011	.737	-.002	.321	.012	.723
CO	CON	PA	.002	.374	.024	.449	.000	.594	.022	.434
CO	CON	PR	<b>-.005</b>	<b>.022</b>	.013	.676	-.004	.185	-.025	.493
CO	SEP	PA	-.002	.621	.005	.896	.002	.921	.020	.518
CO	SEP	PR	.001	.626	.032	.313	.000	.945	-.033	.286
OP	CON	PA	.002	.496	<b>.134</b>	<b>.001</b>	.000	.574	.036	.222
OP	CON	PR	<b>-.005</b>	<b>.038</b>	.049	.125	-.003	.325	-.002	.954
OP	SEP	PA	-.005	.171	<b>.115</b>	<b>.002</b>	.004	.130	.019	.525
OP	SEP	PR	.005	.179	<b>.065</b>	<b>.057</b>	-.004	.159	.012	.716

Note:  $N = 1118$ . The  $\beta$ s are standardized indirect effects in stationary cross-lagged models with robust standard errors (MLR estimation); their significances refer to the unstandardized solution. All significances are two-tailed. One-tailed significant effects are marked in bold. Shaded cells refer to the externalizing/internalizing hypotheses.

EX, extraversion; ES, emotional stability; AG, agreeableness; CO, conscientiousness; OP, openness; CON, conduct; SEP, self-esteem with peers; PA, peer acceptance; PR, peer rejection.

<sup>1</sup>Remaining path after controlling for mediation.

<sup>2</sup>Direction of effect opposite to prediction.

As expected, agreeableness and conscientiousness predicted conduct, and conduct negatively predicted peer rejection (Table 4). Also as expected, the effects of agreeableness and conscientiousness on peer rejection were longitudinally mediated by conduct; the remaining direct effects from agreeableness or conscientiousness on peer rejection were non-significant (Table 5). Concerning the reverse direction, peer rejection negatively predicted conduct, whereas no evidence for effects of conduct on agreeableness or conscientiousness was found (Table 4). In line with the lack of these effects, conduct did not mediate the effects of peer rejection on the Big Five; also, no direct effects were found from peer rejection to the Big Five. Thus, the externalizing/internalizing hypotheses were fully confirmed for externalizing tendencies.

In addition to these expected effects, openness also predicted conduct with similar strength, and conduct mediated the effects of openness on peer rejection, with no reverse effects. Thus, openness showed the same pattern as agreeableness and conscientiousness regarding conduct and externalizing tendencies. In addition, two significant effects from extraversion and emotional stability to conduct were found that were however somewhat weaker than the ones for the other Big Five and did not lead to significant mediation effects. Together, the hypotheses for externalizing were

fully confirmed, and an additional effect of openness on peer rejection via conduct was found.

As expected, self-esteem with peers predicted peer acceptance, but the expected dispositional effects on internalizing were not found. Neither extraversion nor emotional stability predicted self-esteem with peers (Table 4). Therefore, self-esteem with peers was not a mediator of extraversion or emotional stability effects on peer acceptance, and significant direct paths from extraversion to peer acceptance suggested that extraversion had effects on peer acceptance but not via the two measured adaptations. Self-esteem with peers was also not predicted from other dispositions.

Instead, the effects from peer acceptance to dispositions via self-esteem with peers were significant. Peer acceptance predicted self-esteem with peers, and self-esteem with peers predicted both extraversion and emotional stability and served as a mediator of the effect from peer acceptance to extraversion (but not for emotional stability). Again, openness showed similar effects to extraversion as it was predicted from self-esteem with peers. However, self-esteem with peers did not mediate the effect of peer acceptance on openness; significant direct paths suggested that peer acceptance predicted openness but not via the two measured adaptations. Together, the hypotheses concerning self-esteem with peers were not confirmed, whereas links in both directions between extraversion (but not emotional stability) and peer acceptance were found. Additional effects of openness on peer acceptance and from self-esteem with peers on openness were also found.

An implicit assumption of the externalizing hypothesis is that effects of agreeableness and conscientiousness on conduct are stronger than are effects of the other Big Five dispositions. We tested this assumption with a (4, 1) DA stationary model, with agreeableness or conscientiousness, and extraversion, emotional stability, and openness as the dispositions, and conduct as the adaptation. Thus, the agreeableness or the conscientiousness effect on conduct tested the unique contributions of these dispositions on conduct, controlling for the effects of extraversion, emotional stability, and openness. One-tailed tests confirmed this assumption for agreeableness,  $\beta = .099$ ,  $p = .012$ , and marginally for conscientiousness,  $\beta = .082$ ,  $p = .057$ . The effects of extraversion and emotional stability on self-esteem with peers showed not even marginal unique effects, which is not surprising because the simple cross-lagged effects were non-significant (Table 4).

## DAE hypotheses

Alternatively the results can be interpreted based on a systematic exploratory strategy that is based on the three DAE hypotheses and takes alpha inflation owing to the many involved statistical tests into account using stepwise Bonferroni correction.

### DAE hypothesis 1: co-influence of D and E on A

Table 4 indicates that conduct was at least marginally predicted by all dispositions and was significantly predicted by both peer rejection and peer acceptance. In contrast, self-esteem with peers was predicted by both peer acceptance

and rejection but not by any of the dispositions. Thus, one conclusion for DAE hypothesis 1 is that it was significantly supported except for the missing effects from the dispositions on self-esteem with peers. However, this conclusion is not safe because of the possible alpha inflation due to the  $5 + 5 + 2 \times 2 = 14$  statistical tests. Therefore, we applied a stepwise Bonferroni correction procedure. All effects with  $p < .10/14$  were kept (five tests), the remaining nine effects were tested for  $p < .10/9$ , and so on. This correction resulted in a final critical  $p$  value of .0125. The resulting pattern confirmed hypothesis 1 in six of the seven cases for conduct but in no instance for self-esteem with peers.

#### *DAE hypothesis 2: causal dominance of D over A*

Hypothesis 2 was tested by comparing the fit of stationary (1, 1) DA models with the same models where the cross-lagged effects between  $D$  and  $A$  were constrained to be equal (10 tests). As expected and in line with Table 4, the effects from the dispositions to conduct were stronger than the opposite effects (in each case,  $\Delta\chi^2(1) > 3.81$ ,  $p < .026$ , one-tailed), whereas hypothesis 2 was not confirmed for self-esteem with peers. Instead, Table 4 suggests that self-esteem with peers predicted extraversion and openness more strongly than do vice versa (opposite to Hypothesis 2), which was confirmed,  $\Delta\chi^2(1) > 7.39$ ,  $p < .007$ , two-tailed. After stepwise Bonferroni correction for the 10 tests, only the expected dominance of agreeableness and conscientiousness over conduct was confirmed.

#### *DAE hypothesis 3: A is longitudinal mediator*

Hypothesis 3 was tested in three steps. First, only those mediations were considered where the paths to and from the mediator were significant. Including one-tailed significances, this approach resulted in 10 possible mediations from  $D$  via conduct to  $E$ , and in six possible mediations from  $E$  via self-esteem with peers to extraversion, emotional stability, or openness (Table 4). To control for alpha inflation due to the 16 cases, a stepwise Bonferroni procedure resulted in a critical  $p$  value of .011. This correction resulted in four possible mediations from  $D$  to  $E$ . Three of them were significant (agreeableness, conscientiousness, and openness via conduct on peer rejection), whereas the possible mediation from extraversion via conduct to peer rejection did not reach significance (Table 5). The bottom line is that conduct mediated the effects of three dispositions on peer rejection (agreeableness, conscientiousness, and openness), whereas self-esteem with peers was not a mediator between peer acceptance/rejection and the Big Five.

### Summary

Taken together, both analysis strategies resulted in the same conclusion. The data for conduct supported both the externalizing part of the externalizing/internalizing hypothesis and two of the three DAE hypotheses; only the causal dominance of all of the Big Five over conduct could not be clearly shown. In contrast, the hypotheses for self-esteem with peers were not supported because it was not predicted by any of the Big Five; instead, self-esteem with peers

predicted extraversion and openness more strongly than do vice versa. Unexpectedly, openness showed relatively strong effects on conduct and both peer acceptance and rejection.

### DISCUSSION

This empirical illustration shows how a multivariate DAE model can be used for testing substantive hypotheses about personality development, for exploring additional quasi-causal effects among traits and environments, and for an empirical evaluation of the question whether particular traits functioned as dispositions or as adaptations for the given environments.

In the present case, the hypothesis-driven and the exploratory strategies resulted in the same conclusions. The externalizing hypothesis that agreeableness and conscientiousness influence conduct in the classroom, which, in turn, influences peer rejection, was fully supported by the cross-lagged effects, and conduct served as a longitudinal mediator for the effects of agreeableness and conscientiousness on peer rejection. As the dispositions were self-rated, conduct was teacher rated, and peer rejection was based on peer nominations; these effects were not even partly based on shared method variance.

In contrast, the internalizing hypothesis that extraversion and emotional stability influence self-esteem with peers, which, in turn, influences peer acceptance, was not supported because self-esteem with peers influenced extraversion and marginally also emotional stability rather than do vice versa. Extraversion (but not emotional stability) showed a direct effect on peer acceptance (but not on peer rejection) after controlling for the mediating role of self-esteem with peers or conduct, which showed that extraversion might have evoked peer acceptance through other adaptations such as actively approaching peers and establishing friendship with them (see Selfhout et al., 2010, for supporting evidence).

In terms of the DAE hypotheses, conduct was co-influenced by agreeableness and conscientiousness, and by peer rejection; agreeableness and conscientiousness showed the expected causal dominance over conduct; and conduct served as a longitudinal mediator between agreeableness and conscientiousness and peer rejection. Thus, agreeableness and conscientiousness were supported as dispositions, and conduct as an adaptation, for peer rejection. Peer acceptance influenced self-esteem with peers, but self-esteem with peers did not mediate the effects of agreeableness and conscientiousness on peer acceptance because of a relatively weak effect of conduct on peer acceptance.

In contrast, self-esteem with peers showed an unexpected causal dominance over extraversion and was not influenced by emotional stability. Therefore, self-esteem with peers is not an adaptation within the logic of the DAE model. Instead, it may be better viewed as a disposition already in adolescence. This view is consistent with the well-supported finding of a causal dominance of general self-esteem over non-clinical depression (Sowislo & Orth, 2013). Thus, the roles of conduct and self-esteem with peers were completely different with regard to the Big Five traits. The concurrent correlations

between the Big Five and self-esteem with peers were relatively high (Table 3), which might be easily misinterpreted as effects of the Big Five on self-esteem. Instead, they were due to shared method variance and some influences of self-esteem with peers on the Big Five (Table 4). Thus this case nicely shows how important it can be to disentangle the direction of effects in personality development and how careful one has to be before one assigns the role of disposition versus adaptation to specific traits. The DAE model assists this task.

Finally, openness showed relatively strong concurrent correlations with peer acceptance and peer rejection that were inconsistent with the review of the literature by van Aken and Asendorpf (in press) where openness showed the fewest associations with peer relationships among the Big Five traits. The longitudinal mediation analyses showed a direct effect of openness on peer acceptance, and an effect on peer rejection that was mediated by conduct. We attribute these unexpected openness effects to the fact that two-thirds of the sample were immigrant students of the second or first generation who came from diverse cultures of origin (see Motti-Stefanidi & Asendorpf, 2017, for details).

In such a culturally diverse context, openness may be helpful to navigate between the different cultures and form positive cross-ethnic relationships, which would explain the direct effect on peer acceptance. The effect on peer rejection through conduct may be similarly explained by a negative effect of openness on prejudice, which leads to less aggression against peers of other ethnicity, which, in turn, leads to less rejection by them. These *post hoc* interpretations can be evaluated in detail with the current data, but such analyses are outside the scope of this article.

## GENERAL DISCUSSION

The DAE model is a refinement of transactional models of personality development as it specifies certain traits as dispositions and other traits as adaptations to a particular environmental context and assigns adaptations a functional role as mediators between dispositions and environments. Whereas similar distinctions between dispositions and adaptations have been drawn before for theoretical or descriptive purposes (Kandler et al., 2014), the DAE model is unique in that it (i) entails *testable hypotheses* whether individual characteristics are adaptations for a given disposition, environment, and age range; (ii) requires *quasi-causal* effects (cross-lagged effects); (iii) includes transactions between environment and adaptations but also between adaptations and dispositions (thus *within-person dynamics*); (iv) assigns adaptations a possible *functional* role as mediators of longitudinal effects of the environment on dispositions and/or vice versa, thereby moving personality–environment transactional models a step further to explanation; and (v) is *developmentally sensitive* because it allows for age-related changes in the quasi-causal relations, exemplified with the development of domain-specific and global self-esteem in the introductory section. The two-year observation period in the present study was too short to study such changes, but over longer time periods, changes in the quasi-causal relations would be

captured by the DAE model in terms of non-stationary cross-lagged relations.

The DAE model does not assume that individual characteristics can be classified as dispositional or adaptational based on content, breadth, or heritability. Instead, classification is gradual and relies on a key asymmetry of causal influence: *D* influences *A* more than vice versa does. Thus, everything else being equal, influences of *D* on *E* are more likely than vice versa are. Although this asymmetry seems to imply that selection effects are preferred to socialization effects, this is only true for univariate DAE models. If multiple adaptations are included, different adaptations might exert only small influences on a disposition that however might cumulate resulting in a relatively larger total effect.

As the empirical illustration shows, the DAE model can be useful both in the case of its confirmation and in the case of its rejection. If a DAE triple fits the DAE model well as in the case of the externalizing hypothesis, we have learned more about the transactions of agreeableness and conscientiousness with peer relationships than if we would have relied only on concurrent correlations and cross-lagged effects between the Big Five and peer relationships. If a DAE triple unexpectedly does not fit the DAE model as in the case of the internalizing hypothesis, the analysis of where violations occurred and where not informs us about alternative mechanisms that might explain the socialization or selection effects that were found.

The DAE model sets the stakes high for decisions whether personality traits fit the roles of dispositions or adaptations with regard to a particular environment and age range because it requires significant cross-lagged effects (when testing co-influence), significant differences between cross-lagged effects (when testing causal dominance), and significant products of cross-lagged effects (when testing longitudinal mediation). These high stakes are a consequence of taking causality seriously, which requires not only time lags between all three variables in a mediation model but also controlling the preceding status of the mediator and the outcome. The illustrative example suggests that the stakes are not set too high if adequate DAE triples are chosen and a sufficiently large sample is studied.

## Breadth and causal functions of the units in DAE models

In principle, DAE models make no assumptions about the breadth of the units (dispositions, adaptations, and environments). Dispositions can be broad traits such as extraversion, facets such as sociability, or behavioural nuances captured by single items ('I like to chat with people'); see Möttus, Kandler, Bleidorn, Riemann, and McCrae (2017). Similarly, environments and related adaptations may be broad (e.g. size of one's social network, perceived potential support from others), domain-specific (e.g. number of opposite-sex friends, self-efficacy with opposite-sex peers), or highly specific (e.g. one's partner's jealousy, one's own tendency to have secret affairs).

We do not assume that broader units show causal unity in terms of the exchangeability of their subunits (Asendorpf,

2016; Möttus, 2016). Instead, we assume with Köhler (1929) that broader units are more than the sum of their parts. If one considers a broad unit as an aggregate of hierarchically organized subunits (e.g. trait–its facets–their nuances), a general principle of system theory (Miller, 1978; von Bertalanffy, 1968) is that there will be emergent properties as one moves from one level to the next higher one due the greater complexity and additional organizing processes at the higher level. Therefore, the relation between a subunit and its higher-order unit is often more than only being entailed in that higher unit. A change in the subunit may or may not cause a change in the higher-order unit through processes of generalization, compensation, or backfire. Consequently, we do not exclude that an adaptation can be a facet of a disposition (e.g. domain-specific self-esteem as a facet of global self-esteem; Marsh, 1993).

The DAE model is based on a linear mediation model of causality and thus may be criticized as conforming to a linear logic that is inadequate for living systems that are better described as self-organizing systems with non-linear regulatory mechanisms at multiple levels (Miller, 1978; von Bertalanffy, 1968). Self-regulation models have been proposed again and again over the years also in personality and social psychology (e.g. Bischof, 1973, 1993; Carver & Scheier, 1981, 2001; Denissen, van Aken, Penke, & Wood, 2013; Geukes, van Zalk, & Back, in press). Although we are generally sympathetic with this view, we also agree with the critique that in psychology, these models often remain mere ‘system talk’ with little consequence for empirical research.

From the perspective of self-regulation models, the DAE model is concerned with long-term shifts in set points for self-regulation, but even highly elaborated models such as the Zurich model of social motivation (Bischof, 1993) are much better in describing information processing and behaviour of one person with a given set point than in describing processes that lead to between-person differences in set point change. Last but not least, often non-linear functions can be well approximated by linear ones. Proponents of self-regulation models would make a strong point if they could show empirically that predictions based on a self-regulation model lead to stronger predictions than do predictions based on more parsimonious linear mediation models such as the DAE model.

### Reflective, formative, and network measurement models

The DAE model is compatible with both reflective and formative models of measurement. Reflective models assume that the manifest indicators are caused by a latent variable such that the latent variable fully explains the true correlations among the indicators; formative models assume that the indicators cause the latent variable (Edwards & Bagozzi, 2000). Formative models describe well cases where the indicators describe alternative constituents of the same variable (e.g. peer acceptance is constituted by the acceptance/non-acceptance of many peers); the constituents may be correlated or not at all. Reflective models describe well cases where the indicators are clearly correlated such that their correlational pattern can be effectively described (e.g. the

correlational pattern between the items of a highly internally consistent conduct scale). Both approaches have pros and cons (Edwards & Bagozzi, 2000).

A third approach to the measurement of traits or environments does not include any latent variable as the causal unit for between-person analysis. Instead, each measured variable is considered a causal unit, and all possible interrelations between the variables are described in terms of a network of relations where the relations are constituted by causal mechanisms (Schmittmann et al., 2013). Although the dynamics of these networks have been mainly discussed from the perspective of within-person variation (occasionally confusing the within-person and between-person perspectives on change, see Asendorpf, 2012; Cramer et al., 2012), between-person differences in within-person network change can be studied too.

With the application of this approach to a DAE model, all measured variables would be described by a large network with three sub-networks corresponding to D, A, and E. The DAE hypotheses would be tested regarding between-person differences in the within-person dynamics mainly of the edges connecting nodes of different sub-networks. In this case, the DAE hypotheses may help to specify changes within the sub-networks that are causally related to changes in the other two sub-networks, reducing the problem of getting lost in too complex relations in the overall network.

### Developmental processes underlying DAE effects

In the last two sections, we have already touched upon possible developmental processes underlying the causal effects described by the DAE model. The two main points to be faced in describing these processes are in our view that the processes describe (i) effects of status on change, not change on change, and (ii) between-person effects, not within-person effects.

Recent models of dynamic personality–environment interaction (PERSOC, Back et al., 2011; the self-regulation model by Denissen et al., 2013; TESSERA, Wrzus & Roberts, 2017; the state process model by Geukes et al., in press) focus on the interaction between states and situations and often describe change processes from a within-person perspective. Whereas the models provide elaborate descriptions of state fluctuations, they are less specific about how between-person differences in chronic situational exposure or recurring states cause between-person changes in chronic situational exposure or recurring states (or, from a systems perspective, changes in set points).

Taking up our illustrative example, how does repeated acceptance by classmates cause increased self-esteem with peers, and ultimately increased global self-esteem? These processes are described by the sociometer theory (Leary & Baumeister, 2000; Reitz et al., 2016), but the sociometer theory does not describe the reverse effects of self-esteem with peers on repeated acceptance by classmates, let alone effects of other environments on other adaptations and dispositions, and vice versa. We are sceptical about attempts to formulate general models for causal mechanisms involved in environment–personality transaction. Because of the high context specificity of these mechanisms, general models have

to rely on highly abstract categories of mechanisms such as associative–reflective or accommodation–assimilation (Wrzus & Roberts, 2017) that do not lead very far when it comes to understanding the concrete mechanisms for concrete environment–personality transactions.

### Expansions of the DAE model by including stabilizing constants

If personality development is studied over a decade or more, the long-term stabilities tend to decrease less than one would expect on the basis of the stabilities over a few years (Fraley & Roberts, 2005; Laceulle, Ormel, Aggen, Neale, & Kendler, 2013). As Asendorpf, van de Schoot, Denissen, and Hutteman (2014) showed, the decelerated decrease is underestimated in studies where substantial attrition occurs such that part of the observed instability is due to sampling error; if attrition is controlled with multiple imputation or full information maximum likelihood, stability shows a more decelerated decrease. Fraley and Roberts (2005) proposed and made plausible with a simulation study that stabilizing effects of constant between-person factors might be responsible for the observed decelerated decrease of stability.

For dispositions, such a constant factor may be genetic differences at conception if one assumes that the effects of the differences are similar all over the lifespan; the effects on the trait differences may decrease with increasing age, but if the decrease is slow enough, it can still exert stabilizing effects on the trait differences. The constant genetic factor might be assessed with a polygenic score, that is, the weighted sum of all (usually extremely small) effects of single-nucleotide polymorphisms on the disposition that were obtained from an earlier large genome-wide association study where the disposition was related to a very large number of potentially associated single-nucleotide polymorphisms. Thus, a polygenic score captures the genetic disposition for an observed disposition (see Belsky et al., 2016, for an application to educational attainment). The polygenic score is time independent and can be added as a stabilizing constant to the disposition part of the DAE model with paths to each assessment of the disposition (see Fraley & Roberts, 2005, for cross-lagged models including a stabilizing constant). Thereby the genetic influence is directly measured, and the model may better fit the longitudinal data.

For environments, such a constant factor may be environmental differences at conception such as the socio-economic status of the family of origin or more specific early environmental risk factors that exert influences on the environment all over the lifespan. They can be added as a time-invariant stabilizing constant to the environment part of the DAE model, allowing for correlations with constant factors for dispositions. Although such an expanded DAE model bears some superficial similarity with bivariate state–trait models where the two constants are defined by a constant latent factor underlying all state and situational assessments (e.g. Hamaker et al., 2015), these state–trait models are not quasi-causal in the trait–state and environment–situation part because causality from the factor to the state/situation assessments would run backwards in time for the first half of the

assessments; also the constant factors can change if the study would be continued. In contrast, all paths in the expanded DAE model envisioned here would have a clear quasi-causal interpretation, the constants are independent of the length of the longitudinal observation, and the constants are independently assessed from the dispositions and environmental measures included in the transaction part of the model.

This expanded model would assume that genetic effects on adaptations are fully explained by genetic effects on dispositions, which is in line with the empirical findings on genetic effects reviewed by Kandler et al. (2014) for traits that they considered as adaptations. Similarly, the model assumes that early environmental effects on dispositions are fully explained by environmental effects on adaptations. Both assumptions are consistent with the logic underlying all DAE models.

### CONCLUSIONS

The DAE model provides a flexible, general framework for testing of and searching for explanations of observed developmental changes in dispositions, adaptations, and environments. Hypothetical links derived from the literature between dispositional, adaptational, and environmental measures can be tested guided by the model. In addition, it is of heuristic value for discovering mechanisms that might explain transactions between dispositions and environments because it can assist the search for context-specific adaptations that mediate between dispositions and environments. The empirical study of personality development has moved in the past from a (more or less genetically informed) socialization perspective to a transactional perspective. The added value of the DAE model to extant models of personality development is that it further refines the transactional perspective by adding adaptations as longitudinal mediators between dispositions and environments and providing clear guidelines how adaptations can be empirically distinguished from dispositions and how the mediation by adaptations can be empirically determined.

### SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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