Box 1
Key Points for Longitudinal Modeling.

It is important to match a theory of change with design and statistical model to assess change. (p. 4)
Models with two time points cannot provide estimates of within-person change. (p. 5, 15 − 16)
All longitudinal findings are bounded by the start and endpoints of analyses, the selection of temporal intervals, and by the number of time points in analyses (p. 6, 13, 21)
Standardizing *within* a time point actually *removes* time trends from longitudinal data. (p. 9)
It is important to carefully consider the psychometric properties of measures as they are administered over time. (p. 9–10)
"Stability" over time can reflect many things, only some of which mean a lack of change. (p. 14)
Difference scores can be reasonable estimates of change unless the measures have low reliability or high stability over time. (p. 15)
It is important to consider between person variability in repeated measures as a potential confound in auto-regressive models. (p. 18)
Multilevel and latent growth curve models are very similar, but have different strengths and weaknesses. (p. 19)
The intercept in a growth curve model represents the level of an outcome at one time point, and does not have to be the starting point of data collection. (p. 22)
Varying the intercept can provide different estimates of covariances among growth parameters, and will change the estimates of lower-order growth parameters when time is non-linear (e.g. quadratic, cubic). (p. 22 −23)
It is important to interpret all growth model parameters in the context of all others. (p. 25)
It is helpful to describe not only average growth (e.g. intercept and slope means), but variances in the growth parameters. (p. 25)
A non-significant effect of time (i.e. no average growth) does not preclude individual differences in growth (i.e. slope variances or random effect). (p. 26 − 27)
It is important to graph the estimated models of change against the observed data to gain greater insight into your models. (p. 25)
Requiring significant variation in slopes (i.e. random effects) prior to testing *a-priori* hypotheses about predictors of variation may result in under-powered hypothesis tests. (p. 28)
It is important to avoid reifying class solutions from mixture models because numerous methodological factors can influence the number and shape of classes that are found. (p. 32)
It is important to avoid relying on rules of thumb for model fit, and to consider that plausible alternative models may also fit the data well. (p. 36)

Box 2
Considering developmental peaks.

One example of matching theory to design is the search for developmental "peaks". That is, researchers are often interested when, on average, children, adolescents or adults are expected to show maximum levels of some construct, such as reward sensitivity (Braams et al., 2015), cognitive control (Ordaz et al., 2013), or cortical thickness (Walhovd et al., 2016), before those levels begin to decline. Assuming the phenomena is already measured at the correct time scale, peaks may be examined in a number of ways. Average developmental peaks may be discerned from cross-sectional studies with multiple age-cohorts, as has been done with sensation seeking and "self-regulation" (Steinberg et al., 2017). Longitudinal studies may go further by also estimating individual differences in the timing of those peaks, as well as factors that impact individual differences in that timing. Because the functional form of a peak may approximate quadratic growth, splines, or piecewise growth, longitudinal studies hoping to identify individual differences in the timing of developmental peaks require at least four and preferably five repeated observations from most individuals to be properly identified (Bollen and Curran, 2006). Moreover, it is important to include confidence intervals in any peak estimates to characterize the (un)certainty of such peaks.

unfolds as relatively smooth increases or decreases over time. For example, empirical data indicate that cortical thickness decreases roughly 1% per year during adolescence (Tamnes et al., 2017). Conversely, transformational change, where new abilities or characteristics emerge in relatively rapid transitions, or stability-maintenance processes (e.g., homeostatic systems) are less studied. To match developmental theory with the appropriate statistical model, multiple types of change processes, as well as multiple forms of those processes (such as linear, exponential, sigmoidal or spline), should be considered (Ram and Grimm, 2015). See Box 2 for one example of some challenges in matching theory with statistical models. Moreover, change can be assessed in terms of multiple indices (Roberts and Mroczek, 2008), including mean-level change, rank-order consistency (e.g., relative ordering of individuals over time), structural consistency (e.g., similar factor structures across time), and inter-individual differences in intra-individual change (individual differences in within-person change).

Theories about the forms of change should be supported by a theory about the processes that produce change. For example, neurodevelopmental theories attempt to explain developmental changes in risk taking and impulsivity based on the development of the pre-frontal cortex and subcortical structures including the striatum and amygdala (e.g., Casey and Caudle, 2013; Romeo, 2013). Many developmental models have yet to appear in the developmental neuroimaging literature, such as transactional models, bioecological models, or developmental cascade models (e.g., Bronfenbrenner, 1977; Masten and Cicchetti, 2010). For example, "coercion theory" is a transactional model positing that negative parental responses to child misbehavior can be negatively reinforced by the elimination of misbehavior, while accidentally positively reinforcing the misbehavior through the provision of attention (Dishion et al., 1992). Through this cycle of reinforcement, each behavior escalates over time, leading to increasingly maladaptive behaviors by both parents and children (Dishion et al., 1992; Granic and Patterson, 2006). Drawing upon a strong theory that explains how individual differences might emerge over time provides a critical foundation for longitudinal research.

2.2. Design a study to assess change

The next step is to design a study to reflect the theory of change. This includes decisions related to the timing, frequency, and spacing of observations in a longitudinal study. For example, researchers may measure cortical thickness annually across adolescence because it is