Self-Esteem and Satisfaction with Social Relationships across Time

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To appear in: Journal of Personality and Social Psychology

Accepted date: October 4 2020

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The present study was registered on the Open Science Framework at https://osf.io/ngv3y/. Scripts and other materials are provided on the Open Science Framework page at https://osf.io/yz2c4/.

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De Moor, E. L., Denissen, J. J. A., Emons, W. H. M., Bleidorn, W., Luhmann, M., Orth, U., & Chung, J. M. (in press). Self-esteem and satisfaction with social relationships across time. *Journal of Personality and Social Psychology*.

ACKNOWLEDGEMENTS

We would like to thank Charles Driver for sharing his insights about continuous time modeling, which we hope has helped us better convey the conceptual idea of the technique to readers. We also want to thank Terrence Jorgensen for thinking along with us on the issue of model specification in measurement invariance tests on the lavaan help forum.

Abstract

Research on the longitudinal association between self-esteem and satisfaction with social relationships led to ambiguous conclusions regarding the temporal order and strength of this relation. Existing studies have examined this association across intervals ranging from days to years, leaving it unclear as to what extent differences in timing may explain differences across studies. In the present study, we used continuous time structural equation models to examine cross-lagged relations between the constructs (i.e., CT-SEM), and also distinguished between-person differences from within-person processes (i.e., RI-CT-SEM). We analyzed 10 years of annual data from the Longitudinal Internet Studies of the Social Sciences (LISS; N = 14,741). When using CT-SEM, we found a bidirectional positive relation between self-esteem and satisfaction with social relationships, with larger effects over longer intervals. When using RI-CT-SEM, we found the largest effects of self-esteem and satisfaction with social relationships across intervals of one year, with smaller effect sizes at both shorter and longer intervals. Additionally, the effect of fluctuations in people's satisfaction with social relationships on fluctuations in their self-esteem was greater than the reverse effect. Our results highlight the importance of considering time when examining the relation between self-esteem and interpersonal outcomes, and likely psychological constructs in general.

Keywords: self-esteem; relationship satisfaction; continuous time modeling; cross-lagged panel model; random-intercept cross-lagged panel model

Self-Esteem and Satisfaction with Social Relationships across Time

A large body of literature has highlighted the relevance of both self-esteem and social relationships for success in various life domains (e.g., Orth & Robins, 2014; Orth, Robins, & Widaman, 2012; Cohen, 2004). The link between self-esteem and relationship outcomes has been of particular interest to social scientists (Marshall, Parker, Ciarrochi, & Heaven, 2014; Sturaro, Denissen, Van Aken, & Asendorpf, 2008; Van Scheppingen et al., 2018). In particular, high self-esteem has been associated with better relationship quality, including relationship satisfaction, suggesting that seeing oneself as a person of worth is associated with how satisfied people are in their social relationships with others.

Self-esteem is defined as individuals' subjective evaluations of their abilities and worth as a person (e.g., Coopersmith, 1967; Rosenberg, 1979). Perceptions of social relationships encompass a variety of relationship aspects such as relationship warmth, support and acceptance in the relationship (for a recent overview, see Harris & Orth, 2019). These different aspects are combined in individuals' overall perceptions of their relationship quality (Reis, 2007). Here, we focused on one indicator of relationship quality, individuals' overall satisfaction with their relationships with close others (Fletcher et al., 2000; Karney & Bradbury, 1995).

Despite the great interest in the association between self-esteem and satisfaction with social relationships, at least two important questions regarding their relation remain unanswered. The first question concerns the directionality of the association; that is, whether self-esteem affects satisfaction with social relationships, satisfaction with social relationships affects self-esteem, or whether there is a bidirectional relation between the two. Information regarding the directionality of the association would provide critical hints for the validity of different theoretical perspectives and the mechanisms underlying the association. The second question concerns the timescale (e.g., months, years, decades) at which the association

between these variables unfolds. Specifically, at what timescale do changes in self-esteem affect changes in relationship satisfaction, and changes in satisfaction affect changes in self-esteem? Little is known about the appropriate timescale for examining psychological effects in general, and about the relations between people's self-esteem and their satisfaction with relationships with important others in particular.

The purpose of the present study was to examine how the longitudinal interplay between self-esteem and satisfaction with social relationships differs over time. Specifically, we examined if and how the direction and strength of the association between these two constructs varied as a function of differing time intervals (i.e., from 1 month to 10 years). To address this question, we used data from a nationally representative sample of Dutch adults who provided annual reports of their self-esteem and relationship satisfaction over a period of 10 years. We modeled the data using continuous time models (CTM; Voelkle, Oud, Davidov, & Schmidt, 2012) to examine the extent that the length of intervals between measurements is related to the strength of the association between self-esteem and satisfaction with social relationships. In identifying when the association is largest in magnitude, we hoped to provide insights that might stimulate future research into the mechanisms underlying the links between satisfaction with social relationships and self-esteem.

Theory on Self-Esteem and Social Relationships

Social relationships predict self-esteem. Interpersonal theory (Sullivan, 1953), sociometer theory (Leary & Baumeister, 2000; Leary, Tambor, Terdal, & Downs, 1995), and terror management theory (TMT; Greenberg, Pyszczynski, & Solomon, 1986; Solomon, Greenberg, & Pyszczynski, 1991) propose that the perceived quality of people's social relationships influences their self-esteem. Interpersonal theory and sociometer theory posit that self-esteem is shaped by an individual's appraisal of how they are perceived by others. TMT, in contrast, does not consider self-esteem as an indicator of social fitness, but rather as

serving to alleviate anxiety brought on by the awareness of one's mortality. According to TMT, social relationships can also alleviate distress and fear, pointing to the idea that relationships of better quality are beneficial for people's self-esteem. Taken together, although they arrive at this conclusion in different ways, all three theories suggest that self-esteem is influenced by people's relationships with others.

Self-esteem predicts social relationships. An alternative but not mutually exclusive perspective is that self-esteem is consequential for people's success across a variety of domains, including satisfaction with social relationships (Orth & Robins, 2014), which is often used as a proxy of relationship quality (Fletcher et al., 2000; Karney & Bradbury, 1995). For example, the self-broadcasting perspective (SBP) proposes that individuals express their self-esteem through their social behaviors, which others in turn then observe and react to (Swann, Chang-Schneider, & McClarty, 2007; Zeigler-Hill, Besser, Myers, Southard, & Malkin, 2013). From this perspective, individuals with higher self-esteem should also experience more positive relationships with others. Self-esteem may also predict behavior in relationships, such that those with high levels of self-esteem may engage in more relationship-enhancing behavior, and those with low levels of self-esteem may engage in more relationship-damaging behavior. For instance, an individual with low self-esteem may perceive rejection from a friend and then withdraw from the relationship, reducing interpersonal closeness and ultimately relationship satisfaction (e.g., Murray, Rose, Bellavia, Holmes, & Kusche, 2002).

Empirical Research on Self-Esteem and Satisfaction With Social Relationships

Despite several theoretical accounts generating different hypotheses about the nature of the link between self-esteem and social relationships, researchers have traditionally examined the two constructs cross-sectionally, making it difficult to infer the directionality of this relation (e.g., Shackelford, 2001; Voss, Markiewicz, & Doyle, 1999). Fortunately,

longitudinal research on the relation between self-esteem and social relationships has increased. A recent meta-analysis aggregated data from 42 longitudinal studies on self-esteem and various indicators of social relationships (e.g., attachment security, popularity, time spent with a relationship partner, perceptions of social rejection), concluding that there is a reciprocal, albeit weak association between them (Harris & Orth, 2019).

We identified 9 recent articles containing 11 different studies that have specifically focused on the unidirectional or bidirectional longitudinal links between self-esteem and different indicators of relationship quality (e.g., closeness, intimacy, and support), including relationship satisfaction, in non-clinical adolescent and adult samples (see Table S1 for an overview of the studies and study details). The overall pattern of findings indicates that the association between self-esteem and social relationships is often but not always statistically significant. Some studies show evidence for bidirectional associations (e.g., Mund et al., 2015; Mund & Nestler, 2019), whereas other studies indicate unidirectional effects of self-esteem on social relationships (Orth et al., 2012; Marshall et al., 2014), and still others suggest unidirectional effects of social relationships on self-esteem (Denissen, Penke, Schmitt, & Van Aken, 2008; Erol & Orth, 2014; Schaffhuser, Wagner, Lüdtke, & Allemand, 2014; Sturaro et al., 2008). Our review suggests that significance of the relation between self-esteem and social relationships does not differ based on how the relationship variable (i.e., quality versus satisfaction more specifically) was operationalized, or which specific relationships were examined (i.e., relationship with romantic partner versus social relationships in general).

One important aspect in which previous studies differ is in the length of intervals between their measurement occasions (i.e., from intervals of 1 day to 6 years). Design choices in these studies may have been determined by resources, convention, and convenience in the absence of a clear theoretical rationale concerning the timescale of the examined effects. By

putting the findings of multiple studies on a timeline, we may approximate a picture of how these effects change in strength across different time intervals. This picture indicates that the bidirectional effects of self-esteem and satisfaction with social relationships have often been found in intervals shorter than 2 years, but not for very short intervals, such as a 1-day interval. Therefore, one tentative conclusion from these studies is that the effects were more often significant for intermediate time intervals. For example, in two studies, researchers found that self-esteem predicted relationship satisfaction and relationship satisfaction predicted self-esteem over the course of 3 assessments that were separated by 1-year intervals (Mund et al., 2015, Study 2; Mund & Nestler, 2019). In another study, researchers found support for bidirectional linkages between self-esteem and relationship satisfaction across a 2-year interval (Schaffhuser et al., 2014). Although the available studies provide different snapshots of the link between self-esteem and satisfaction with social relationships, they do not provide systematic insights into how the effects increase or decrease (or even change in directionality) as a function of the time interval over which effects are observed.

Considering The Role of Timing of Measurements

The literature on self-esteem has treated self-esteem both as a state, and as a trait (e.g., Conley, 1984; Wagner, Lüdtke, & Trautwein, 2016). Although theoretical accounts of self-esteem (e.g., sociometer theory, TMT) focus on the process or state components of self-esteem, empirical research has also examined these theories at a trait level. Like other personality constructs, global self-esteem shows relatively stable differences between individuals across the life course (Kuster & Orth, 2013; Trzesniewski, Donnellan, & Robins, 2003), but also considerable fluctuations within individuals across time (e.g., Donnellan, Kenny, Trzesniewski, Lucas, & Conger, 2012). Relationship satisfaction is generally thought to be more malleable than self-esteem (e.g., Neyer & Asendorpf, 2001), due to the fact that relationships are not only dependent on the person, but also on the environment. For example,

relationship satisfaction may decrease because the other person in the relationship is no longer committed to it, regardless of the person's own behavior or attitude. However, the empirical evidence on the stability of social relationships variables is mixed (e.g., Harris & Orth, 2019; Orth et al., 2012). This might be the case because in addition to being malleable to environmental influences, perceptions of social relationships in part reflect stable tendencies (Branje, Van Aken, & Van Lieshout, 2002; Sarason, Pierce, & Sarason, 1990).

In the present study, we examined the role of timing in the association between self-esteem and satisfaction with social relationships. Specifically, we investigated how the association changes as a function of the length of the interval between measurements. It is likely that examining the association between self-esteem and satisfaction with social relationships may yield a different picture of the underlying phenomenon, depending on the level of analysis (i.e., trait differences between persons versus state fluctuations within persons) and the time intervals between measurements.

The emphasis on selecting appropriate intervals between measurement occasions in order to detect an effect of one variable on another is not new (Gollob & Reichardt, 1987). Yet, very little research has examined the timing of psychological effects in longitudinal survey studies (e.g., Dormann & Griffin, 2015). This small but growing literature has focused on the importance of timing in personality development following major life events (Luhmann, Orth, Specht, Kandler, & Lucas, 2014) and in theoretical work on how short-term personality processes can impact longer-term personality development (Baumert et al., 2017; Wrzus & Roberts, 2017). Furthermore, there is methodological work examining optimal methods of considering time using longitudinal data (Wagner, Lüdtke, & Voelkle, 2019). This research is a much needed development for gaining a better understanding of the role of time and timing in psychological phenomena.

Empirical work examining the role of time has for instance focused on the bidirectional relation between personality and health (Mueller, Wagner, Smith, Voelkle, & Gerstorf, 2018). In this study, individuals' changes in neuroticism and extraversion predicted changes in physical functioning and vision most strongly across intervals of two years. In another study that focused on the co-development of self-esteem between heterosexual romantic partners, the researchers found that changes in self-esteem of husbands predicted changes in wives' self-esteem (Wagner, Voelkle, Hoppmann, Luszcz, & Gerstorf, 2018). As in the study by Mueller et al. (2018), these effects appeared strongest across intervals of two years. These studies have advanced our understanding of personality and self-esteem processes more generally, but they have not specifically considered the role of timing in the context of the association between self-esteem and satisfaction with social relationships. In the current study, we take initial steps toward this endeavor by analyzing the links between self-esteem and relationship satisfaction over different time intervals within the same sample. One benefit of using the same sample instead of comparing results across samples is that the effect of time can be examined without the confounding influence of between-study differences in sample characteristics, sample size, and measures.

Continuous Time Models

In the present study, we used continuous time modeling (CTM; Voelkle & Oud, 2013; Voelkle et al., 2012) to examine the association between self-esteem and satisfaction with social relationships. A primary assumption in CTM is that the autoregressive (i.e., stability of the constructs over time) and cross-lagged (i.e., predictive effect of one construct on another) processes are continuous in time. That is, applied to the present focus CTM assumes that people always have a certain level of self-esteem, regardless of whether they are reporting it or not, and similarly, that this level of self-esteem influences their satisfaction with their social relationships at any time, regardless of the actual measurement occasions. This means

that by using CTM, we assume that self-esteem and satisfaction with social relationships influence each other continuously. The observable effects of this continuous process can then be measured at any interval, providing different snapshots of the process.

As discussed above, the direction and magnitude of the observed effects may be different for specific snapshots depending on the given time intervals, thus yielding different results from traditional models (Voelkle & Oud, 2013; Voelkle et al., 2012). Traditional models look at only one time interval and therefore base their estimation on this one interval. Furthermore, coefficients from these models are typically estimated under the assumption that all measurements are taken at equidistant time points. In contrast, CTM uses all information available to calculate estimates of the continuous autoregressive and cross-lagged effects, and does not require measurement occasions to be evenly spaced apart. The continuous effects are instantaneous changes from one moment to the next, and are referred to as *drift* within the CTM framework. Estimates of the parameters describing the continuous effects (i.e., *drift parameters*) can then be used to derive discrete (i.e., time-specific) coefficients of the auto-correlations and cross-lagged correlations for any particular time interval of interest. Therefore, CTM uses information about the underlying effect to estimate effects at specific intervals. In contrast, traditional models calculate effects for specific intervals directly, and therefore only provide estimates that apply to one particular time interval. Using CTM, we can thus examine the size of the effects at different time intervals and develop a more nuanced understanding of the relation between self-esteem and satisfaction with social relationships as it evolves over time.

Another feature of CTM is that effects can be modeled by combining between- and within-person effects (i.e., similar to a cross-lagged panel model, with a fixed intercept) or specifying within-person effects (i.e., random-intercept cross-lagged panel model; Hamaker, Kuiper, & Grasman, 2015). A cross-lagged panel model CTM allows for an examination of

the directionality of effects and indicates whether individual differences in one variable (e.g., scoring high on self-esteem compared to others in the sample) are predictive of individual differences in that same variable or in a different variable at a later time point. However, cross-lagged panel models do not distinguish between-person and within-person variance, leaving it unclear as to whether effects play out at the level of stable differences between individuals, or via temporary changes within them. Adding a random intercept to the cross-lagged panel model CTM allows for the delineation of these between-person differences from within-person changes. This latter source of variance indicates whether temporary deviations from one's own trait level (i.e., scoring differently on a self-esteem measure than how they do on average) predict temporary deviations from the mean in the same or a different variable at a later time point. Therefore, this model may be used to study how self-esteem and satisfaction with social relationships affect each other within an individual.

Because the random-intercept cross-lagged panel model CTM is more specific with regard to where the variance is coming from, researchers have argued that it is a more informative and accurate model for examining effects over time (Hamaker et al., 2015; Wagner et al., 2019). However, both models have different statistical properties and advantages (e.g., the random-intercept cross-lagged panel model tends to show better model fit whereas the cross-lagged panel model produces more consistent effects; Orth, Clark, Donnellan, & Robins, 2020). Moreover, both models provide useful information to understand the nature of psychological effects. In fact, examining the association of self-esteem and satisfaction with social relationships in both models may be important, as one previous study on psychological effects reported different findings depending on the model used (Hudson, Lucas, & Donnellan, 2019). Specifically, the authors of this study found a bidirectional link between health and well-being using a cross-lagged panel model, but only few links, and with no discernable pattern, using random-intercept cross-lagged panel models,

indicating that relations between constructs may differ depending on whether the focus is on between- and within-person variance, or only on within-person variance.

In summary, CTM produces models that allow for the identification of the time interval(s) at which effects are most pronounced. As such, it allows us to answer questions about the timing of effects that traditional models that are based on only one time interval cannot. Answers to these questions help us to contextualize the findings of past research, to refine longitudinal study designs for future research on the links between self-esteem and relationship outcomes, and to shed light on potential underlying mechanisms.

Current Study

In the current study, we investigated the temporal order and strength of the relation between self-esteem and satisfaction with social relationships as a function of time between measurement occasions. We examined the reciprocal links between these two constructs in a large, nationally representative sample of Dutch adults over a period of 10 years and used a continuous time modeling approach to calculate the continuous processes underlying these links, before estimating the discrete effects across different time intervals.

Specifically, we examined whether the direction and size of the cross-lagged effects between self-esteem and relationship satisfaction differed across different time intervals. Consistent with past research, we hypothesized that individual differences in self-esteem are positively related to subsequent differences in satisfaction with social relationships, and differences in satisfaction with social relationships positively related to later differences in self-esteem. Although the findings from previous studies on self-esteem and relationship quality (see Table S1) suggest a pattern of larger effects in studies with intermediate time intervals (i.e., intervals of 1 or 2 years between measurements), this pattern is dependent on the study design choices of those previous studies. Therefore, we examined the association between self-esteem and satisfaction with social relationships across a range of intervals. In

addition, as a robustness check at the request of reviewers, we examined the association between self-esteem and romantic relationship satisfaction. In doing so, we tested whether the general results hold for a domain-specific type of relationship satisfaction. The research questions, hypotheses, and initial analytical plan of the present study were pre-registered at https://osf.io/ngv3y/.

Method

Participants

We analyzed data from the Longitudinal Internet Studies of the Social Sciences (LISS) panel, administered by CentERdata (Tilburg University, the Netherlands). At any time, the LISS panel consists of 5,000 households, with a total of over 7,000 individuals. The LISS panel is based on a true probability sample of households drawn from the Dutch population register, thus forming a nationally representative sample of the population. To contextualize our findings, it is useful to note that the Netherlands is a relatively non-religious country (Becker & Vink, 1994) that is characterized by high levels of individualism (*Sociaal en Cultureel Planbureau*, 2000) and long-term orientation (Hofstede & Minkov, 2010).

In the LISS panel, participants fill out a questionnaire of 15 to 30 minutes each month on the internet. Participants were provided with a computer and internet access if they could otherwise not participate. Although the total sample of the LISS panel consists of roughly 7,000 individuals at any given time, the overall sample size of the present study is larger because our data spanned 10 years. To counter dropout, replenishment participants were periodically added to the sample, resulting in a total of 14,741 respondents, 7,962 (54%) of whom were female (see Table S5 of the Online Supplementary Material for a full overview of the descriptive statistics such as age and gender distribution for each year). Due to the study design in which new participants were added across the course of the study, our data have a high percentage of missingness on the variables of interest (61% across all waves). When

comparing groups, we found that individuals with relatively lower levels of missingness (i.e., less than 61% missing) generally reported higher self-esteem ($t(11{,}801) = 5.55$, $p < .001$, Cohen's $d = .10$) and satisfaction with social relationships ($t(12{,}468) = 2.28$, $p = .022$, Cohen's $d = .04$), than individuals with relatively higher levels of missingness (i.e., more than 61% missing). There were no gender differences between the groups ($t(13{,}003) = 0.79$, $p = .429$). This indicates that individuals who completed more questionnaires were more positive about their self-esteem and their social relationships than individuals who completed less questionnaires. However, the effect sizes of these differences were small, suggesting that potential bias due to different degrees of missingness was not a serious concern in the present study.

Study Design

The current study included data from the first 10 years of the LISS panel (2008-2017)[1]. Surveys about participants' self-esteem and satisfaction with social relationships are part of the core modules of the panel and, as such, were administered every year (though not always in the full sample: participants sometimes skipped a yearly self-esteem measure, though at varying time points depending on the year in which they entered the survey). The exception was 2016, when self-esteem data were not collected. It is important to note that our primary constructs of interest, self-esteem and satisfaction with social relationships, were assessed at different times depending on the assessment year. For example, in 2008, self-esteem was assessed in May, and satisfaction with social relationships was assessed in April (see Table S2 of the Supplementary Online Material [SOM] for a detailed description of the longitudinal design). Ethical approval for questionnaire research is not required in the

[1] Data from the LISS panel have been used in many prior studies (for a complete overview, see https://www.dataarchive.lissdata.nl/publications). Several published studies have used the self-esteem measure from the LISS data (Bleidorn & Schwaba, 2018; Bleidorn, Schwaba, Denissen, & Hopwood, *in press*; Gnambs, Scharl, & Schroeders, 2018). However, these studies have not focused on the associations between self-esteem and satisfaction with social relationships, which is the focus of the present research.

Netherlands for topics which are not considered intrusive, and therefore was not obtained for the LISS panel data[2].

Measures

Self-esteem. Self-esteem was measured using the 10-item Rosenberg Self-Esteem Scale (RSE; Rosenberg, 1965), a widely used measure of self-esteem (Donnellan, Trzesniewski, & Robins, 2015). An example of an item in the RSE is, "I feel that I'm a person of worth, at least on an equal basis with others". Participants rated the extent to which they agreed with each statement on a 7-point scale, ranging from 1 (*totally disagree*) to 7 (*totally agree*). Five negatively worded items were reverse-coded. For the current study, the items were assigned to three parcels that were then used as manifest indicators of self-esteem (for item assignment to parcels, see p. 9 of the SOM), with high scores indicating higher levels of self-esteem. In the current study, coefficient alpha ranged from .88 to .92 across the waves.

Satisfaction with social relationships. Satisfaction with social relationships was measured using a single item, "How satisfied are you with your social contacts?" Participants rated the extent to which they agreed with the item on a 10-point scale, ranging from 0 (*entirely dissatisfied*) to 10 (*entirely satisfied*). A similar one-item measure of satisfaction with social relationships has been used in previous research (Pederesen et al., 2016; Bonsang & van Soest, 2012; Delmelle, Haslauer, & Prinz, 2013).

Statistical Analyses

Continuous Time Structural Equation Model. We analyzed the data using CTM within the structural equation modeling framework (Voelkle & Oud, 2013; Voelkle et al., 2012). As mentioned previously, a major strength of CTM is that it makes it possible to examine the association between variables as a function of the time interval, even when the

[2] Because we made use of data from the LISS database, we do not have the rights to share the data or study materials with others (we direct the interested reader to the LISS website: https://www.lissdata.nl/). *R* scripts for calculating the descriptive statistics, conducting data preparation, and for our analyses are provided on the project OSF page at https://osf.io/yz2c4/.

constructs were not measured at those specific intervals (Voelkle & Oud, 2013). Therefore, it allows us to answer research questions regarding timing that traditional models such as regular cross-lagged panel models do not, because estimates of CTM are not dependent on the actual measurement intervals and can be examined across intervals of differing lengths. An additional advantage of CTM compared to traditional models is its ability to handle fluctuating intervals between measurements (Oud & Voelkle, 2014). CTM makes use of all available data instead of only the data available for that specific interval.

An important assumption underlying CTM estimation is that of stationarity, which means that the underlying processes should be the same at equal measurement intervals regardless of when the measurements were actually taken (e.g., 1-year interval between Wave 2 and 3, or Wave 8 and 9; Voelkle et al., 2012). In the present study, we believe the stationarity assumption is justified given that the sample was heterogeneous with regard to age and other demographic characteristics, minimizing the possibility that the sample as a whole was influenced by specific events or developmental factors (i.e., factors that would disrupt the stationary processes such as the transition to working life; see e.g., Cole & Maxwell, 2003; Kenny, 1979). Unfortunately, in the present research it was not possible to formally test this assumption, but closer examination of the standard deviations (Table S5, SD_{range} = [0.96-1.11] for self-esteem and [1.53-1.69] for satisfaction with social relationships), and the within-wave correlations (Table S6, r_{range} = [.23-.35]) of self-esteem and satisfaction with social relationships suggested that these coefficients were quite stable across different time points. This provides some support for our assumption that the data were driven by stationary processes.

Using CTM, we estimated a cross-lagged panel model CTM (i.e., CT-SEM) and an extension of this model, the random-intercept cross-lagged panel model CTM (RI-CT-SEM). The CT-SEM examines effects of individual differences in one variable at one point in time

on individual differences in another variable at a later point in time. As in a regular cross-lagged panel model, estimates from the CT-SEM reflect a combination of between-person and within-person effects. In this model, the cross-lagged relations between the variables of interest include variability from people in the sample differing in their initial standing on the variables of interest, as well as variability from people changing on the variables of interest over time. Autoregressive effects represent the relative stability of individual differences over time. Cross-lagged effects represent the degree to which rank-order in one variable predicts changes in the rank-order of another variable at a later point in time.

The RI-CT-SEM partials out stable between-person effects (i.e., trait effects), thus allowing for an examination of within-person processes. In this model, people's initial standing on the variables of interest is modeled by a stable trait factor. Therefore, autoregressive effects reflect the extent to which deviation from an individual's trait level at one time point predicts changes in the deviation in the same variable at a later time point. The cross-lagged effects reflect the degree to which deviation from the individual's mean in one variable predicts change in the deviation from an individual's mean in another variable at a later point in time. Figure S1 in the SOM illustrates the CT-SEM and RI-CT-SEM model that were tested in the current study for the relation between self-esteem and satisfaction with social relationships.

Continuous effects. In CTM, continuous autoregressive and cross-lagged effects are modeled using a drift matrix. As described above, the drift parameters represent continuous processes that take place within very small time intervals. The drift matrix is a first step in the estimation process, in which CTM uses all available data to estimate the continuous autoregressive and cross-lagged relationships between the variables of interest that most

closely fit the data. The resulting four drift parameters (two autoregressive and two cross-lagged) can be thought of as the speed of change at time point t.[3]

Discrete effects. As is customary in CTM, we converted the drift parameters to estimates of discrete (i.e., time-specific) autoregressive and cross-lagged effects that can be used to evaluate the effect of one variable on itself (e.g., the effect of self-esteem at one time point on self-esteem at a later time point), or the effect of one variable on another variable for specific time intervals (e.g., one month, six months, one year, etc.). These coefficients are presented as unstandardized and standardized regression coefficients, and show the predicted strength of the effects as if they were measured at these specific intervals (Driver, Voelkle, & Oud, 2017). Therefore, the discrete coefficients resulting from the CTM have the same interpretation as those from a traditional cross-lagged panel model or random-intercept cross-lagged panel model.

Data analytic strategy. To determine whether participants responded to the items the same way across waves and to ensure that we can meaningfully examine the association between the variables across time, we first tested whether the self-esteem measure (i.e., the RSE) was invariant across assessments using the *lavaan* package (Rosseel, 2012) in R, version 3.4.3 (R Core Team, 2017). We used parcels rather than single items to decrease model complexity, and randomly assigned the ten RSE items to three parcels (Little, Rhemtulla, Gibson, & Schoemann, 2013; for item assignment see p. 9 of the SOM). Because there was a substantial amount of missing data in some waves (68% on the RSE across all waves), we were only able to test invariance for waves that had data coverage overlap with all

[3] Because the drift parameters are limiting values for infinitely small time intervals and logarithmically related to interval-specific autoregressive and cross-lagged effects, their exact interpretation is far from trivial (for a more thorough discussion see Kuiper and Ryan, 2018). However, in general, the closer the value of the drift parameter to 0, the more stable the process is, or the weaker the cross-lagged effect. Furthermore, drift parameters for the auto-regressive effects in stationary processes are typically negative indicating that the association between subsequent time points weakens as the time interval grows (Newsom, 2005). The sign of the drift parameters for the cross-lagged effects depends on the direction of the effect.

other waves, which resulted in the exclusion of data from 2010 (for which there was no overlap with several other waves) and 2016 (in which the RSE was not administered). Results from these analyses provided evidence for strict invariance, indicating that the results of our analyses could be meaningfully interpreted and that the parcels could be used as indicators of a latent variable for self-esteem in our primary analyses (see SOM, pp. 9–10 for a detailed description of these tests).

We then estimated the CTMs using the R package *ctsem* (Driver & Voelkle, 2017; Driver et al., 2017). To handle the influx of panel members across the duration of the 10 waves of data used for this study, we realigned each participant's data so that their first measurement was at Time Point 0 and their next measurements were measured in relation to this time point (e.g., if their first measurement of either self-esteem or satisfaction with social relationships was in May 2008, their second measurement in February 2009 would be at 9 months). This adjusted timeline was used in the CTM analyses. Within the CTM framework, variables can be modeled using either the observed variable (manifest sum or average score) or a latent variable for which the individual items or parcels are the indicators. In line with our measurement invariance tests, we used a latent variable approach, using the item parcels as indicators for self-esteem. Satisfaction with social relationships was entered as a single manifest indicator of an underlying latent variable in the analyses (Driver et al., 2017).

An alpha level of .05 was used to determine the significance of the effects found with the CTMs. To examine whether the autoregressive and cross-lagged effects of self-esteem and satisfaction with social relationships significantly differed between constructs, we also fitted a CT-SEM and RI-CT-SEM model with equality constraints on the autoregressive or cross-lagged paths in the drift matrix. Model comparison was done using deviancy tests on -2 Log-Likelihood statistics (Δ-2LL) and change in Akaike's information criteria (ΔAIC). If the constrained model fit significantly worse, as determined by a significant change in -2LL in

combination with a change of more than 4 in the AIC compared to the unconstrained model (for recommendations, see Long, 2012), the effects were determined to be different from each other. Due to several statistical and practical reasons, our final analysis plan deviated from the one outlined in our registration (https://osf.io/ngv3y/)[4]. Table 2 shows a complete overview of the deviations from our pre-registration and the reasons for these deviations.

Table 2. Deviations of the final study from the registration

Registered plan	Deviation	Reason for deviation
Examination of bidirectional links between self-esteem and two types of social relationship variables: satisfaction with social relationships and number of close others	The analysis with number of close others as social relationship variable were left out of the manuscript	The model for number of close others did not converge, potentially due to the censored discrete nature of the variable in combination with high numbers of missingness (i.e., 68% for self-esteem, 56% for satisfaction with social relationships) and the weak data structure (i.e., large variation in the actual length in intervals between measurements).
Use of data from the LISS panel from 2008-2015	Use of data from the LISS panel from 2008-2017	The 2017 data were not yet available at the initial planning of this manuscript.
Test moderation effects of personality and sex using median split and multiple group continuous time modeling	Moderation analyses were left out of the manuscript	Several of the subgroup analyses (i.e., conscientiousness and neuroticism) provided out-of-range estimates. As these problems could not be solved, we decided to leave out the moderation analyses.
Perform a CFA on the self-esteem items, to decide whether or not we could use a	Performed a CFA on parcel scores for the self-esteem items	We used parcels for measurement invariance testing due to the large number of parameters that would otherwise have to be estimated

[4] Table 2 shows the changes that we made to the analysis plan, and indicates that many were due to statistical issues that we had not foreseen when we planned our pre-registration. As a result, the use of the pre-registration for the present study – and subsequent registrations of our deviations – may best be seen as a transparent research log for the reader rather than a plan that was successfully carried out.

latent variable for self-esteem in our CTM	across 10 waves (i.e., for ten items instead of three parcels). This approach was extended to the CFA test for consistency.

Robustness Analyses. At the request of reviewers, we computed additional CTMs to examine the robustness of our primary findings. These analyses were also registered on the Open Science Framework page of the project prior to conducting the analyses. First, we tested a model in which we replaced satisfaction with social relationships with a measure of romantic relationship satisfaction to examine the extent to which our findings generalize to domain-specific types of relationship satisfaction. Second, in order to examine whether the peak in the size of cross-lagged effects across intervals was affected by the annual spacing of the actual measurements in the data, we conducted a sensitivity analysis in which we only included data that was separated by a 2-year measurement for every participant. As the actual intervals between measurements differed in length (e.g., 1 year, 3 years), we could only select a subset of the assessments for each of the participants.

Finally, at the request of reviewers, we fitted our models to data from another sample, to examine whether our findings were generalizable to other populations. For these analyses, we used data from the first 10 waves of the German Family Panel, 2008/2009-2017/2018 (PAIRFAM, release 10.0; Brüderl et al., 2019, for a detailed description of the study see Huinink et al., 2011)[5]. The PAIRFAM study is an ongoing longitudinal study focused on romantic partnership and family dynamics in which participants are assessed annually, and is funded by the German Research Foundation (DFG). PAIRFAM consisted of 12,402 individuals at the beginning of the study, 51.4% of which were female and with a mean age of 26.3 years-old (*SD* = 8.3). In contrast to LISS, the sample was not replenished to counter

[5] Data from the PAIRFAM panel are only available on request and as such, we do not have the rights to share these data or the study materials with others (but we direct the reader to the PAIRFAM website: https://www.pairfam.de/en/). *R* scripts on this dataset are available with the other scripts at https://osf.io/yz2c4/.

attrition. In the PAIRFAM study, self-esteem was measured with three items that were based on the Rosenberg Self-Esteem Scale (an example item is "I like myself just the way I am", other items are provided on p. 12 of the SOM) and was measured on a scale from 1 [*not at all*] to 5 [*absolutely*]. Satisfaction with social relationships was measured with one item ("How satisfied are you with the following domains of your life? – Friends, social contacts" on a scale from 0 [*very dissatisfied*] to 10 [*very satisfied*]).

In contrast to our main analyses, the measurement model of self-esteem did not fit acceptably for this sample from the PAIRFAM study[6]. Because issues of measurement can impact the estimation of the continuous time models using the construct, we report the measurement invariance tests and further PAIRFAM continuous time model analyses in the SOM (see p. 17 for the measurement invariance tests and pp. 32-40 for the further analyses).

Results

Descriptive Statistics

For self-esteem, the means ranged from 5.31 to 5.66 (on a scale from 1 to 7) and the standard deviations from 0.97 to 1.11 across waves. For satisfaction with social relationships, the means ranged from 7.26 and 7.34 (on a scale from 1 to 10), and the standard deviations from 1.53 and 1.69 (see Table S5 of the SOM for a full overview of the descriptive statistics and correlations for each year). This suggests that on average, participants reported relatively high (i.e., above the mid-point of the scale) levels for both self-esteem and satisfaction with social relationships. The zero-order correlations between self-esteem and satisfaction with social relationships were generally between .25 and .35 across waves (see Table S6), indicating a small to medium positive relation between the two constructs.

[6] This is in contrast to the measurement checks reported in a PAIRFAM Technical Paper by Sonntag, Neyer, and Schubach (2015), which demonstrated good fit for the measurement model. When examining these differences, we found several discrepancies in the way the models were specified (see Table S3 for an overview), most notable of which is the test of longitudinal (present study) versus multi-group (Technical Paper) measurement invariance tests. These differences in model specification may have contributed to the difference in fit.

Continuous Time Structural Equation Model

Calculating the gradient. To examine the association between self-esteem and satisfaction with social relationships across time, we first estimated the continuous process underlying these links. Table 3 shows the estimated drift matrix. Due to the large sample size of the study and the scaling of the variables, confidence intervals showed extremely small values. As described above, the drift parameters describe instantaneous change and are not linked to any real-world interval between measurements. Therefore, to identify autoregressive and cross-lagged effects and to make inferences regarding these effects, they have to be transformed into discrete coefficients.

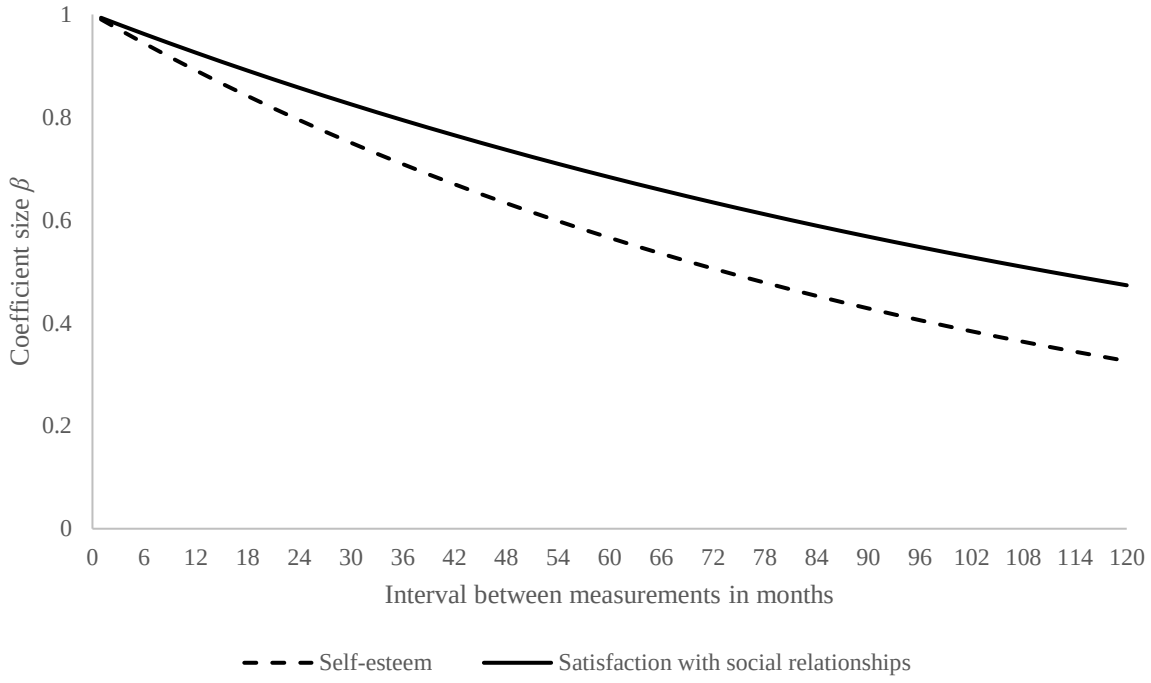
Table 3. Continuous and discrete parameter estimates of self-esteem and satisfaction with social relationships of the CT-SEM.

	Drift parameters			Discrete estimates			
Path	Estimate	Standard error	95% CI	1 month	1 year	5 years	10 years
			Autoregressive effects				
SE → SE	-.010	< .001	[-.009638, -.009628]	.990/.990	.891/.891	.566/.566	.326/.326
SR → SR	-.006	< .001	[-.006467, -.006458]	.994/.994	.926/.926	.684/.684	.473/.473
			Cross-lagged effects				
SE → SR	.002	< .001	[.002110, .002123]	.002/.002	.023/.019	.079/.065	.098/.082
SR → SE	.002	< .001	[.002065, .002072]	.002/.002	.023/.027	.077/.093	.096/.116

Note. *-2LL*(122,701) = 301,707.40. Missing data were handled using Full Information Maximum Likelihood estimation.
SE = self-esteem; SR = satisfaction with social relationships. All reported effects were significant at the .05 level. The left part of the table shows the continuous (i.e., time-independent) autoregressive and cross-lagged estimates in the drift matrix. The right part of the table reports the discrete (i.e., time-dependent) unstandardized (first estimate) and standardized (second estimate) effects at intervals of 1 month, and 1, 5, and 10 years.

Stability of self-esteem and satisfaction with social relationships. To ascertain how stable our constructs of interest were over time, we examined the discrete autoregressive effects of self-esteem and satisfaction with social relationships for time intervals ranging from one month to ten years. Figure 1 shows a graphical representation of the probed, discrete autoregressive effects. Table 3 shows the discrete estimates for several intervals, and indicates that both self-esteem and satisfaction with social relationships were highly stable over 1-year intervals. Therefore, individuals reporting high self-esteem and high satisfaction with social relationships were also likely to report high self-esteem and high relationship satisfaction one year later. A model with the autoregressive paths constrained to be equal yielded worse model fit, indicating that satisfaction with social relationships had significantly higher levels of stability than self-esteem (Δ-2LL(1) = 173.9, $p < .001$, ΔAIC = 171.9). This difference was particularly visible across longer intervals (e.g., 10 years).

Figure 1. Autoregressive regression coefficients for self-esteem and satisfaction with social relationships of the CT-SEM.

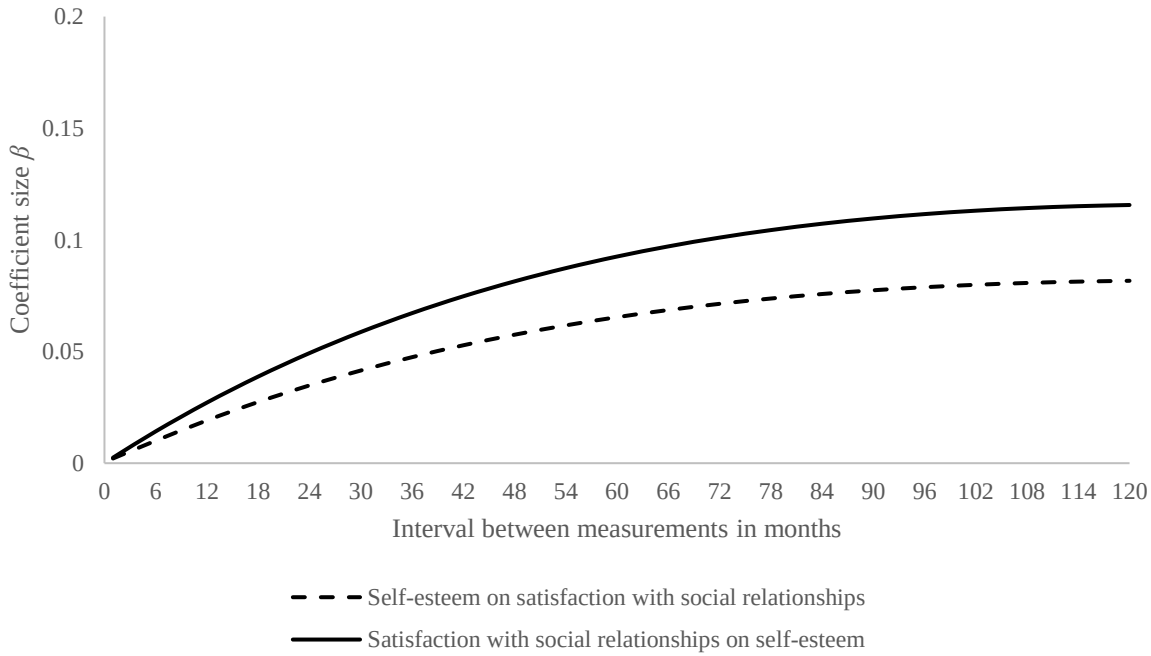


Note. The figure shows the discrete (time-specific) autoregressive estimates of self-esteem (dashed curve) and satisfaction with social relationships (solid curve) at intervals from 1 month to 10 years. The estimates are presented as standardized coefficient β.

Cross-lagged effects of self-esteem and satisfaction with social relationships. We next examined the extent to which individual differences in self-esteem and satisfaction with social relationships predicted later satisfaction with social relationships and self-esteem, respectively. In addition, we investigated at what time interval these effects appeared greatest. Similar to our examination of the autoregressive effects, the continuous cross-lagged effects were probed for intervals between one month and ten years (see Figure 2). A graphical representation of the plotted discrete effects indicated that the effect of satisfaction with social relationships on self-esteem (range of *b* values of the plotted effects = [.002; .096], β_{range} = [.002; .116], $p_{range} < .05$) was descriptively greater than the effect of self-esteem on satisfaction with social relationships (b_{range} = [.002; .098], β_{range} = [.002; .082], $p_{range} < .05$) for all intervals. Constraining the cross-lagged paths to be equal, resulted in significantly worse

fit in terms of the deviancy test (Δ-2LL(1) = 4.6, p = .033) but not in terms of the AIC difference (Δ= 2.5). Therefore, although both effects were statistically significant, they were not significantly different from each other in magnitude when considering the AIC criterion. Moreover, neither effect was particularly large, with all βs ≤ .116.

Figure 2. Cross-lagged regression coefficients of self-esteem on satisfaction with social relationships and of satisfaction with social relationships on self-esteem of the CT-SEM.



Note. The figure shows the discrete (time-specific) autoregressive estimates of self-esteem (dashed curve) and satisfaction with social relationships (solid curve) at intervals from 1 month to 10 years. The estimates are presented as standardized coefficient β.

Random-Intercept Continuous Time Structural Equation Model

Calculating the gradient. To examine whether the association between self-esteem and satisfaction with social relationships was based on differences between individuals or fluctuations within individuals, we extended the CT-SEM by including a random intercept for self-esteem and satisfaction with social relationships, which accounts for stable inter-individual differences at the first time point, and thus represents changes in people's

temporary deviations from their person-specific trait levels. Table 4 shows the estimated drift parameters of the RI-CT-SEM. As in the CT-SEM, the drift matrix describes the continuous relations between self-esteem and satisfaction with social relationships. Importantly, the negative drift of the autoregressive effect parameter appear higher in the RI-CT-SEM than in the CT-SEM, suggesting that in the current model there was less stability over longer time intervals, consistent with the conceptualization of the random effects as temporary deviations from the person-specific overall mean level.

Table 4. Continuous and discrete parameter estimates of self-esteem and satisfaction with social relationships of the RI-CT-SEM.

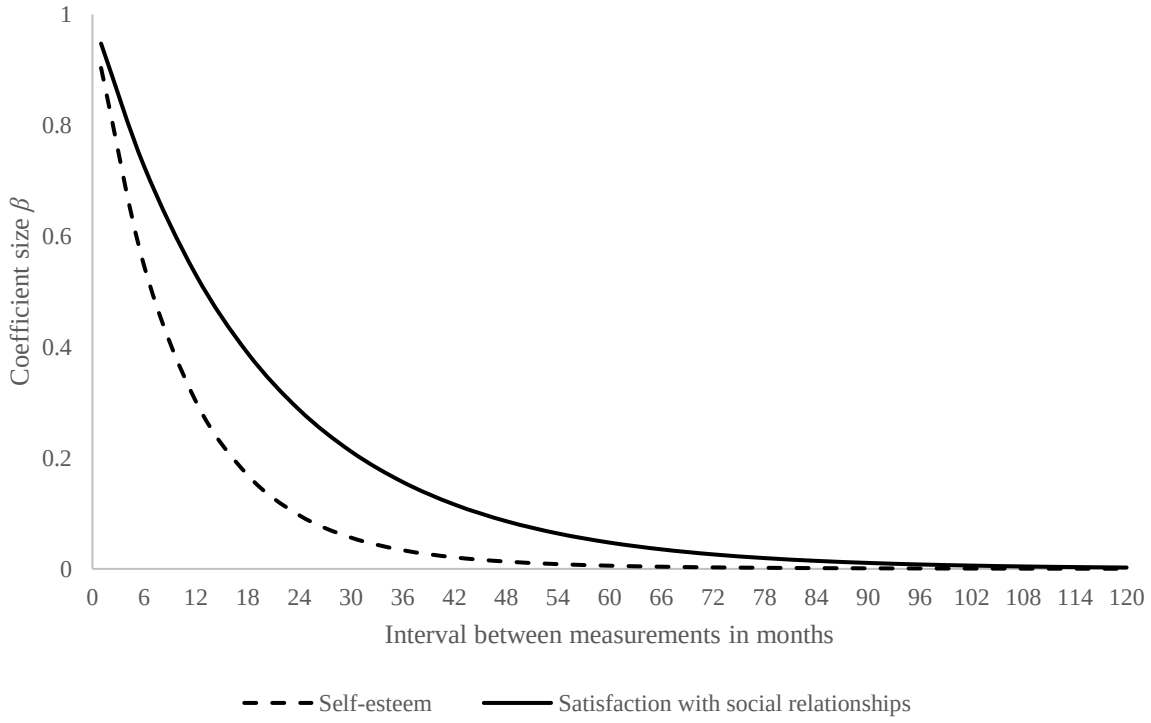
	Drift parameters			Discrete estimates			
Path	Estimate	Standard error	95% CI	1 month	1 year	5 years	10 years
			Autoregressive effects				
SE → SE	-.102	.004	[-.101568 , -.101442]	.904/.904	.302/.302	.006/.006	< .001/<.001
SR → SR	-.054	.004	[-.054078 , -.053959]	.948/.948	.530/.530	.047/.047	.002/.002
			Cross-lagged effects				
SE → SR	.014	.004	[.013673 , .013799]	.013/.011	.066/.057	.012/.010	.001/.001
SR → SE	.017	.003	[.017272 , .017272]	.016/.018	.083/.096	.015/.018	.001/.001

Note. *-2LL*(175,115) = 427,874.00. Missing data were handled using Full Information Maximum Likelihood estimation.
SE = self-esteem; SR = satisfaction with social relationships. All reported effects were significant at the .05 level. The left part of the table shows the continuous (i.e., time-independent) autoregressive and cross-lagged estimates in the drift matrix. The right part of the table reports the discrete (i.e., time-dependent) unstandardized (first estimate) and standardized (second estimate) effects at intervals of 1, 5, and 10 years.

Stability of self-esteem and satisfaction with social relationships. We transformed the drift parameters into discrete coefficients for time intervals from one month to ten years to study the stability of self-esteem and satisfaction with social relationships within individuals (see Figure 3 for a graphical representation of the plotted discrete autoregressive effects).

Table 4 shows the discrete estimates for a selection of intervals. When comparing the results of the RI-CT-SEM to the results of the CT-SEM, we found smaller autoregressive effects after accounting for between-person differences in our variables. As indicated by Table 4, stability was high at shorter intervals, but was markedly low over longer intervals, with temporary deviations in self-esteem and satisfaction with social relationships from people's mean levels only weakly predicting deviations in the same variable after ten years. To examine whether the autoregressive effects of self-esteem and satisfaction with social relationships significantly differed from each other, we tested the model against one where these paths were set equal, which showed that the constrained model showed significantly worse fit (Δ-2LL(1) = 881.9, $p < .001$, ΔAIC = 880.0). Thus, the autoregressive effects for deviations in self-esteem were smaller than the autoregressive effects for deviations in satisfaction with social relationships. The results from the RI-CT-SEM suggest that individuals' temporary deviations in self-esteem and satisfaction with social relationships were only weakly predictive of their deviations at a later time point, although they were slightly more stable in the case of satisfaction with social relationships.

Figure 3. Autoregressive regression coefficients of self-esteem and satisfaction with social relationships of the RI-CT-SEM.

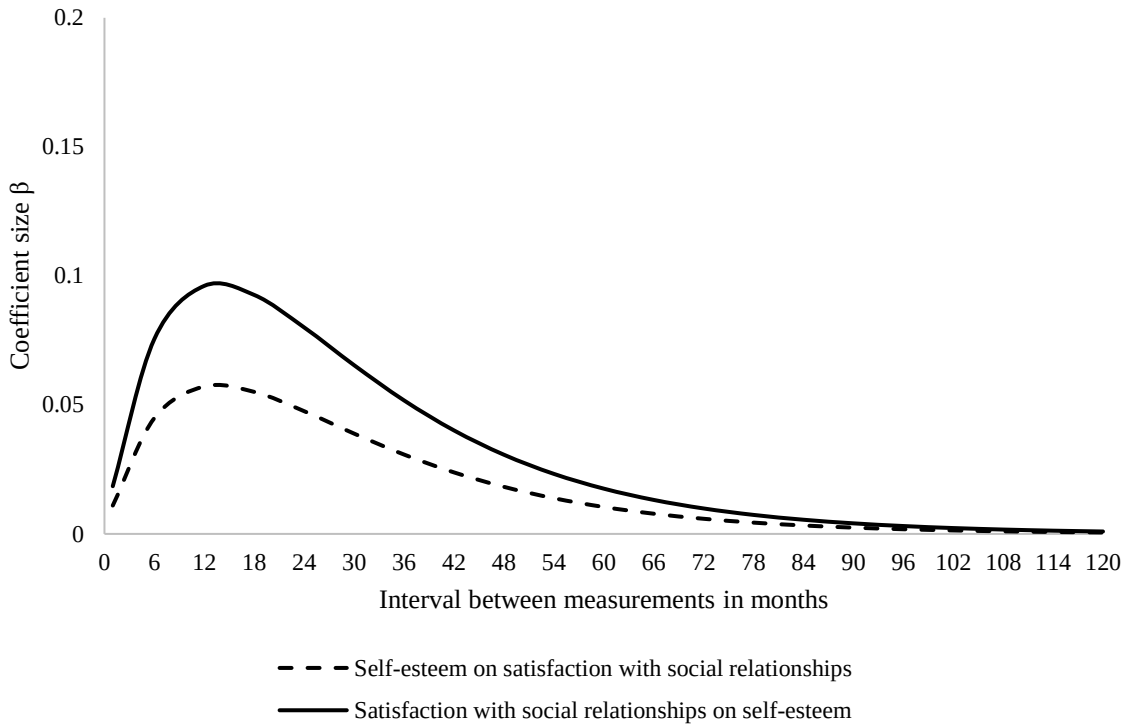


Note. The figure shows the discrete (time-specific) autoregressive estimates of self-esteem (dashed curve) and satisfaction with social relationships (solid curve) at intervals from 1 month to 10 years. The estimates are presented as standardized coefficient β.

Cross-lagged effects of self-esteem and satisfaction with social relationships. We next examined the within-person association between self-esteem and satisfaction with social relationships by probing the continuous cross-lagged effects for intervals between one month and ten years. The effect of satisfaction with social relationships on self-esteem was descriptively larger (b_{range} = [.001; .083], β_{range} = [.001; .096], $p_{range} < .05$) than the effect of self-esteem on satisfaction with social relationships (b_{range} = [.001; .066], β_{range} = [.001; .057], $p_{range} < .05$; see also Figure 4). Comparing the model to one in which the cross-lagged effects were constrained to be equal indicated a significant difference in model fit between the constrained model and the unconstrained model (Δ-2LL(1) = 1,455.4, $p < .001$, ΔAIC = 1,453.5), confirming that the effect of satisfaction with social relationships was larger than

that of self-esteem. Therefore, temporary fluctuations in satisfaction with social relationships predicted corresponding temporary fluctuations in self-esteem at a later time point, and temporary changes in self-esteem were positively related to temporary changes in satisfaction with social relationships at a later time point, but this latter effect was smaller in magnitude. In contrast to the cross-lagged estimates from the CT-SEM, the cross-lagged effects for the RI-CT-SEM were largest across a 1-year interval, as can be seen in Figure 4. Taken together, these findings converge with those produced by the CT-SEM such that we found significant cross-lagged effects in both directions. However, the effect of satisfaction with social relationships on self-esteem was significantly larger than the reciprocal effect only in the RI-CT-SEM model, but not in the CT-SEM model. Moreover, whereas mean-level differences between individuals had an increasing, though asymptotic effect at ever-longer intervals, the effect of temporary deviations (i.e., after accounting for between-person trait variability) appeared largest at intervals of around one year.

Figure 4. Cross-lagged regression coefficients of self-esteem on satisfaction with social relationships and of satisfaction with social relationships on self-esteem of the RI-CT-SEM.



Note. The figure shows the discrete (time-specific) autoregressive estimates of self-esteem (dashed curve) and satisfaction with social relationships (solid curve) at intervals from 1 month to 10 years. The estimates are presented as standardized coefficient β.

Robustness Analyses

To examine the robustness of our primary findings, we performed several additional CTM analyses. First, we examined whether our findings on a general measure of satisfaction with social relationships also held for satisfaction with a more specific relationship type, namely romantic satisfaction. As in the primary analyses, the CT-SEM showed a bidirectional, positive effect of self-esteem on romantic satisfaction and of romantic satisfaction on self-esteem. Moreover, the effects were stronger over increasingly long intervals. Similar to the primary analyses, the effects of self-esteem on romantic satisfaction and of romantic satisfaction on self-esteem did not significantly differ in strength. Interestingly, for the RI-CT-SEM, the model converged on estimates of low to high stability

(β = .238 and β = .746 for 1-month intervals for self-esteem and satisfaction with social relationships, respectively) and medium to strong cross-lagged effects (β = .538 and β = .330, respectively). The cross-lagged effects peaked across intervals of 1 month or shorter, and decreased in strength over ever-longer intervals. We reran the model several times to test whether the estimates were not an uncertain fit due to convergence on a local maximum, but we reached similar estimates across attempts. The direction of these effects was in the expected direction.

Second, we explored the possibility that the 1-year peak in strength that we found in the main RI-CT-SEM model is an artifact of the design of LISS where the minimum lag between measurements is approximately 1 year. We examined whether selecting LISS data from only 2-year intervals changed the interval at which our cross-lagged effects would peak in strength. In this case, we would expect that using only data with intervals of 2 years would shift the peak in strength from a 1-year towards a 2-year interval between measurements. Similar to the main CT-SEM, we found a bidirectional positive association between self-esteem and satisfaction, which became stronger across longer intervals. In contrast to the main CT-SEM model, where the cross-lagged effects did not significantly differ in size, in this analysis the effect of satisfaction with social relationships on self-esteem was significantly greater than the effect of self-esteem on satisfaction with social relationships. For the RI-CT-SEM and similar to the main analyses, we found a positive bidirectional association, which was strongest at intervals between 6 and 12 months. Unlike the main RI-CT-SEM, a model in which the cross-lagged effects were set equal did not fit significantly worse. This indicates that the effects of self-esteem on satisfaction with social relationships and of satisfaction with social relationships on self-esteem did not significantly differ in strength.

Third, by fitting our models to data from the PAIRFAM study, we examined whether the findings from our main analyses converged with those from another dataset. In

preliminary analyses, we found that the measurement model for the self-esteem measure used in the PAIRFAM study fitted the data poorly. As a result, the estimates of the CT-SEM and RI-CT-SEM model using this data should be interpreted with caution, as the estimation may have been affected by the poor measurement of self-esteem. The analyses indicated a bidirectional relation between self-esteem and satisfaction with social relationships. Unexpectedly, however, we found a negative effect of self-esteem on satisfaction with social relationships, together with an expected positive effect of satisfaction with social relationships on self-esteem. Moreover, these effects peaked in strength around intervals of 6 to 12 months (CT-SEM) or in intervals of shorter than 1 month (RI-CT-SEM)[7].

In summary, estimates from the robustness checks suggest that our primary findings may at least in part hold for more specific relationship types. Moreover, they were not dependent on the actual measurement interval in the data, though they may be partly sample-dependent, as indicated by the discrepant results in the PAIRFAM dataset. However, given the poor fit of the measurement model of self-esteem, caution should be taken in the interpretation of the PAIRFAM models. A full description of the findings of these models can be found on pages 20-38 of the SOM.

Discussion

Several theoretical accounts have posited a relation between self-esteem and social relationships (e.g., sociometer theory, interpersonal theory; Leary & Baumeister, 2000; Leary et al., 1995; Sullivan, 1953), and existing research has yielded mixed results regarding the direction and strength of the association between them. Previous research has measured self-esteem and satisfaction with social relationships across different time intervals, suggesting

[7] We also fitted a CT-SEM and RI-CT-SEM model with a manifest self-esteem (mean score) variable instead of a latent construct with three manifest indicators (see Table S16 and S17 and Figure S11 and S12 in the SOM). Findings from these models were highly similar to the ones reported here and in the SOM. This suggests that the issues in the way the three items measured self-esteem could not be alleviated by taking out the poorly fitting measurement model of self-esteem.

that this variability might contribute to the different findings identified in the literature. In the current study, we focused on the role of timing to gain greater insight into the inconsistent findings in past research regarding the direction of the association and to shed light on potential underlying mechanisms. Specifically, we examined the association between self-esteem and satisfaction with social relationships across different time intervals using a continuous time modeling approach on 10 years of data from a nationally representative Dutch panel study.

Cross-Lagged Effects Between Self-Esteem and Satisfaction with Social Relationships

To answer our primary research question, we investigated the directionality of the links between self-esteem and satisfaction with social relationships by specifying two models using continuous time modeling – a cross lagged panel model and a random-intercept cross-lagged panel model. Both models provided support for a bidirectional effect between self-esteem and satisfaction with social relationships. The presence of a reciprocal positive association between self-esteem and satisfaction with social relationships in both models suggests that there is a positive feedback loop. The cross-lagged panel model indicated that people who report higher self-esteem tend to report higher satisfaction with social relationships at a later time. A bidirectional effect is in line with the recent meta-analysis by Harris and Orth (2019), which reported that the effect of self-esteem on social relationships was similar in size to the effect of social relationships on self-esteem. Following a suggestion from one of the reviewers, we also examined whether the estimates from the cross-lagged panel model were consistent with the overall pattern of estimates in previous research (as reviewed in Table S1). We found a positive correlation, indicating that our estimates were similar to those found in previous work (see Table S15).

One limitation of the cross-lagged panel model is that the results are likely to be confounded with pre-existing variability in people’s initial standing in both self-esteem and

satisfaction with social relationships. After accounting for this, the random-intercept model showed that if people experience a temporary increase in self-esteem, they subsequently experience a temporary increase in their satisfaction with their social relationships. The directionality and sign of these effects were thus also in line with previous research. Similar to the cross-lagged panel model, following the suggestion from the reviewer we correlated our estimates from the random-intercept cross-lagged panel model with estimates from previous research (Table S1) to examine correspondence between this study and previous studies, and we found a negative correlation (see Table S15). This might be explained by the fact that while the estimates were often positive in both models, the pattern of strength of the relations over time differed between the random-intercept and the traditional cross-lagged panel model – and thus, as an extension likely also between the random-intercept model and previous studies. There were some additional and noteworthy differences between the models. Findings from the cross-lagged panel model provided support for an effect of self-esteem on satisfaction with social relationships that was similar in magnitude as the effect of satisfaction with social relationships on self-esteem. In the random-intercept cross-lagged panel model, the effect of satisfaction with social relationships was significantly greater than the effect of self-esteem, but the difference between them was small ($\Delta\beta = .04$).

Because analyzing large samples often yields significant effects, we also consider the effect size of the association between self-esteem and satisfaction with social relationships. The small size of the found effects suggests that although self-esteem may be a predictor of satisfaction with social relationships at a later time point ($\beta < .120$ for the random-intercept cross-lagged panel model) and that satisfaction with social relationships may also be a predictor of self-esteem ($\beta < .100$), these effects might not be very consequential in daily life. For instance, based on the random-intercept cross-lagged panel model, a one-unit increase in satisfaction with social relationships (on a 10-point scale) would be expected to be associated

with an increase of 0.10 in self-esteem (on a 7-point scale) one year later. In practice, this would mean that persons whose satisfaction with social relationships increased by an entire point would probably rate their self-esteem only marginally better a year later. This suggests that these effects, significant though they are, may have limited practical impact, especially in the short run (i.e., a *very small* effect size, even following new benchmarks for psychological effects and taking into account longitudinal stability in constructs; Adachi & Willoughby, 2015; Funder & Ozer, 2019).

Therefore, our findings provide some support for theories posing that social relationships influence self-esteem (e.g., interpersonal theory, sociometer theory, TMT) and those that view self-esteem as a predictor of satisfaction with social relationships (e.g., SBP). At the same time, however, our small effect sizes provide more nuance to the ideas put forward in these theories, which suggest that self-esteem plays a major role in social relationships and social relationships in self-esteem (e.g., that the function of self-esteem is to track fluctuations in social inclusion). One possibility is that more substantial dynamic influences between relationships and self-esteem might occur at younger ages than investigated in this study (i.e., LISS participants were 18 or older) or that self-esteem and relationships are influenced by stable third factors, like genetic influences and/or personality. For instance, Big Five personality traits have been found to be a strong predictor of self-esteem (Robins, Tracy, Trzesniewski, Potter, & Gosling, 2001) as well as satisfaction with social relationships (Malouff, Thorsteinsson, Schutte, Bhullar, & Rooke, 2010; Back et al., 2011), with more extraverted and more emotionally stable individuals generally reporting both higher self-esteem and more satisfying relationships with others.

Examining Different Time Intervals in The Relation Between Self-Esteem and Satisfaction with Social Relationships

In addition to directionality, using CTM allowed us to examine how the effects may

differ as a function of time interval. Estimates from the cross-lagged panel model indicated that both effects were larger for longer time intervals. This is consistent with the idea that although state effects regress towards the mean, trait effects may accumulate over time (Hamaker et al., 2015). That is, the relation between stable differences between people might be stronger when measured across a longer interval, because the effects of shorter intervals build up. In contrast, results from the random-intercept cross-lagged panel model showed that effects of more temporary deviations from trait levels appeared largest at intervals of one year.

It is difficult to compare the effects we found over different time intervals to extant research due to previous research examining the effects only at the interval at which they were measured, and generally using analyses that do not account for existing variability in people's initial standing in self-esteem and social relationships. Moreover, these studies often differed in design characteristics from the present research – and from each other – making them difficult to compare (see for instance Table S1). Finally, although the meaning of the autoregressive and cross-lagged effects is the same in the continuous models as in traditional models, the way they are estimated differs in an important way. Specifically, continuous time modeling estimates continuous effects using data from all datapoints and then transforms these estimates into discrete estimates for specific intervals, whereas traditional models estimate effects using data from only that specific interval. Therefore, even though the meaning of the estimates is the same, the estimates of continuous models and traditional models may be different, for instance because differences in the length of intervals in the study are not taken into account in the latter cases (e.g., Voelkle et al., 2012).

With this caveat in mind, however, it is interesting to note that the trend of findings in previous research is that most studies reporting bidirectional effects used shorter rather than longer intervals between studies (e.g., 1-year in Study 2 of Mund et al., 2015; Mund &

Nestler, 2019; 2-years in Schaffhuser et al., 2014). The plotted discrete estimates produced by the random-intercept cross-lagged panel model show that our estimates of temporary deviations in self-esteem and satisfaction with social relationships were similar to results from earlier work. That is, we found overall weak bidirectional effects for all tested intervals (i.e., from 1 month to 10 years) and found that the effects were largest for the random-intercept model around intervals of 1 year. This finding suggests that inconsistencies in the findings of previous studies regarding self-esteem and satisfaction with social relationships may at least in part be explained by the timescale that was used to assess the variables. This is in line with meta-research on time lags in panel studies, which found that generally shorter time lags (i.e., shorter than 1 year) are preferred to examine effects (Dormann & Griffin, 2015). Thus, our findings build on those from earlier work that suggest that panel studies with larger intervals (e.g., five years) may be most suited to investigate cumulative trait effects. To increase their ability to detect psychological effects of more fluctuating phenomena, they might consider increasing their measurement resolution.

Interestingly, the estimates produced by the cross-lagged panel model, which showed increasingly large effects over longer time intervals, did not converge with previous findings regarding the intervals at which the effects are largest. It is possible that this may be due to the way that continuous time modeling produces estimates of cross-lagged effects. Specifically, this approach uses information from all data to estimate the underlying continuous process between self-esteem and satisfaction with social relationships, before pulling estimates for specific, discrete intervals. In doing so, it may be that the cross-lagged panel model in continuous time modeling is more sensitive to detecting the accumulation of trait effects of these constructs than are studies that only examine the effect at one measurement interval and that have estimated a cross-lagged panel model only on data for that interval.

Our findings contribute to the growing body of literature that explicitly examines the role of timing for psychological effects (e.g., Mueller et al., 2018; Wagner et al., 2018), and we are among the first to examine timing for the relation between self-esteem and satisfaction with social relationships specifically. As such, our findings provide first clues for what processes might underlie the association between self-esteem and satisfaction with social relationships. Specifically, our finding that these effects peak at intervals of 1 year suggests that factors contributing to this relation play out across a 1-year timescale.

In the case of the effect of self-esteem on later satisfaction with social relationships, it might be that temporary increases in self-esteem in turn trigger increases in social activity (e.g., going out more, calling one's friends more often) and perhaps more relationship-enhancing social behaviors, such as increasing intimacy with close others (e.g., engaging in deep conversations). Such effects have been labeled as self-broadcasting (Murray et al., 2002; Swann et al., 2007; Zeigler-Hill et al., 2013). These changes in social behavior could result over a period of several months in improved relationships (both new ones and improved existing ones). It may in turn take some time for individuals to perceive the improvements in their relationships and thus for their satisfaction with these relationships to adjust accordingly.

In the case of the effect of satisfaction with social relationships on later self-esteem, increases in satisfaction with their social relationships may signal to individuals a positive shift in their desirability as a relationship partner (Sullivan, 1953, Leary & Baumeister, 2000; Leary et al., 1995) or make them feel that they fulfill a meaningful role in the social group, thus decreasing their awareness of their own mortality through a sense of social immortality (Greenberg et al., 1986; Solomon et al., 1991). Due to the relative stability of trait levels of self-esteem (e.g., Kuster & Orth, 2013; Orth et al., 2010), it may take several months for these changes in satisfaction with social relationships to result in longer-term changes in self-esteem.

Examining the Robustness of Our Primary Findings

We tested the robustness of our main findings by specifying additional continuous time models using a domain-specific relationship variable (i.e., romantic relationship satisfaction), using only data that were separated by 2-year intervals, and using data from a different panel study (i.e., German PAIRFAM study). In the following, we discuss the outcomes of these robustness checks.

First, we examined whether our results held for the association between self-esteem and romantic satisfaction. In line with recent studies on self-esteem and relationship quality, the findings from the cross-lagged panel model replicated those of the primary analyses, with a positive bidirectional effect that was larger in magnitude across longer intervals. The effects of self-esteem and romantic satisfaction did not significantly differ in strength. Interestingly, the random-intercept cross-lagged panel model produced estimates of low stability (e.g., β = .238 and β = .746 for self-esteem and satisfaction with social relationships for a 1-month interval) and high cross-lagged coefficients (i.e., β = .538 and β = .330, respectively). In contrast to the cross-lagged panel model and our main analyses, the cross-lagged effects peaked at intervals of 1 month or shorter, and decreased in magnitude across longer intervals. The estimates of this model were unexpected given our main analyses and our review of previous work. To get more insight into which model more accurately reflects the data, we examined the zero-order correlations produced by the observed self-esteem and romantic satisfaction data. We found that the estimates of this model did not correspond to the autocorrelations of self-esteem (i.e., the zero-order correlation was generally between .65 and .75 across the 10-year range of our data) and romantic satisfaction (i.e., *r* generally between .55 and .65), and correlations between self-esteem and romantic satisfaction (i.e., *r* around .20; see Table S7). It should, however, be noted that these correlations reflect rank-order stability, whereas estimates from the random-intercept model reflect stability of deviations

from individuals' mean level. It is therefore possible that the low stability and high cross-lagged within-person effects are simply not visible in the zero-order correlations. Our comparison of the estimates from the random-intercept model to the correlations may suggest that the random-intercept model on romantic satisfaction is not accurate for our data, but we cannot be certain. It is also possible that self-esteem and romantic satisfaction predict each other on a shorter timescale than self-esteem and satisfaction with social relationships more generally. This might be the case because romantic partners tend to be in closer, in most cases daily, contact (e.g., Mund et al., 2015). Future research using data with shorter time intervals should examine whether the difference in the degree of contact influences the timescale at which the association between self-esteem and relationship satisfaction plays out. In any case, this first robustness analysis indicates that the estimates produced by our random-intercept cross-lagged panel model may be especially sensitive to noise in the data, due to greater model complexity and its examination of only within-person prospective effects.

Second, our analyses examining data with only 2-year measurement intervals largely replicated our main findings. In both models, we found support for a positive bidirectional association. In contrast to our main analyses, the effect of satisfaction with social relationships on self-esteem was stronger than that of self-esteem on social relationship satisfaction in the cross-lagged panel model, whereas in the main analyses the effects did not significantly differ in strength. Moreover, the effects did not significantly differ in strength in the random-intercept cross-lagged panel model whereas there was a significantly stronger effect of satisfaction with social relationships in our main analyses. Similar to our main analyses, with regards to timing the robustness checks suggested increasingly strong effects across longer intervals in the cross-lagged panel model and a peak in strength in shorter intervals in the random-intercept cross-lagged panel model. Specifically, the latter model suggested that the effects may best be examined across intervals ranging from 6 to 12 months, which is similar

to the estimate of 1-year intervals in the main random-intercept model.

Third, analyses of data from the PAIRFAM study indicated some similarities to our primary analyses in the LISS dataset, but also some notable differences. Specifically, findings from both the cross-lagged panel model and the random-intercept cross-lagged panel model suggested a bidirectional association, with a positive effect of satisfaction with social relationships on self-esteem, but a negative effect of self-esteem on satisfaction with social relationships. With regard to timing, the effects were greatest across intervals of 6 to 12 months in the cross-lagged panel model, and across intervals of shorter than 1 month in the random-intercept model. However, it is important to note that there were differences in measures, design, and sample composition between the PAIRFAM and LISS datasets, which may explain some of the observed differences in results. Furthermore, we encountered some issues in the measurement of self-esteem, which may have affected the estimation of the continuous time models. The findings from the PAIRFAM model and differences between the PAIRFAM and LISS dataset are discussed in greater detail on pp. 32-40 of the SOM.

In sum, our robustness checks show that the findings from the cross-lagged panel model on self-esteem and romantic satisfaction, and the findings using only 2-year intervals largely replicated the findings from our primary analyses using the LISS panel data. However, analyses in the PAIRFAM data show that the findings from our main analyses may, in part, be specific to the LISS sample in terms of the sign of the associations and the intervals at which they appear greatest. That said, the measurement of self-esteem in this sample was not acceptable, lowering the trustworthiness of these findings. Further replication efforts with datasets that are more comparable in terms of sampling and measurement properties are thus needed.

Stability of Self-Esteem and Satisfaction with Social Relationships

We also examined the stability of self-esteem and satisfaction with social relationships. The estimates from our cross-lagged panel model suggested small-to-medium stability estimates after a 10-year interval for both the effect of self-esteem (β = .326) and the effect of satisfaction with social relationships (β = .473). For self-esteem, this is mostly comparable to the medium-to-large effect sizes reported in previous research across a similar time range (e.g., Trzesniewski et al., 2003). However, the stability estimate for satisfaction with social relationships is substantially higher than the small-to-medium effect size that has been found in previous work on stability of social relationship variables across longer intervals, such as relationship quality at an interval of six years (r = .22; Sturaro et al., 2008). When controlling for stable trait differences between persons (i.e., the random-intercept cross-lagged panel model), the predictive effect of self-esteem and satisfaction with social relationships at one time point on themselves at a later time point was only moderate for shorter intervals (e.g., β = .302 and β = .530 for a 1-year interval for self-esteem and satisfaction with social relationships, respectively) and nearly nonexistent for longer intervals (e.g., β < .001 and β = .002 for a 10-year interval).

The much lower autoregressive coefficients found in the RI-CT-SEM for both self-esteem and satisfaction with social relationships speak to the relatively limited “inertia” of temporary deviations; that is, the relative speed with which an individual’s self-esteem returns to the trait level over and over again. Although speculative, perhaps these deviations were mostly due to transient factors, such as life events (e.g., being hospitalized for a relatively minor health issue, moving to another town, or friends moving to another town) or more ordinary events in daily life (e.g., sudden but ultimately resolved conflicts).

Importantly, the stability of satisfaction with social relationships was higher than the stability of self-esteem in both models. Although some prior research suggested that relationship variables generally have a lower stability than personality variables (e.g., Neyer

& Asendorpf, 2001), this did not seem to be the case in the data examined in this research. Interestingly, the recent meta-analysis by Harris and Orth (2019) also reported slightly higher stability for social relationships than for self-esteem; based on longitudinal data from 30 samples assessed across an average of 2.3 years, they reported rank-order stability of .60 for measures of relationship quality. A possible explanation for this finding is that the perception of one's relationships itself has trait-like features (Branje et al., 2002; Sarason et al., 1990). For instance, some individuals may have a personality (e.g., high extraversion and/or low neuroticism) that allows them to evaluate their relationships with others more positively (Buecker et al, 2020). This may especially be reflected in measures of relationship satisfaction that assess global evaluations of one's relationships with a variety of people, which was the case in the present study. Another possible explanation is that previous research generally used younger populations (e.g., Sturaro et al., 2008), in which social relationships may not yet be as stable as in later adulthood.

Limitations

The findings of our study should be interpreted in light of several limitations. First, our constructs were not measured with the same precision. Specifically, self-esteem, which was assessed with the ten-item RSE Scale (Rosenberg, 1965) showed acceptable reliability across all waves of data, whereas the reliability of our single-item measure of satisfaction with social relationships was unknown. Past research has suggested that the reliability of single-item measures of highly schematized constructs such as life satisfaction is approximately .70 (Cheung & Lucas, 2014; Lucas & Donnellan, 2012; Pavot, 2018). Given their conceptual similarity, we may expect similar reliability for our measure of satisfaction with social relationships. Thus, in the present study, reliability of the measure for self-esteem was likely higher than that of satisfaction with social relationships, but there is reason to assume that the reliability of the single-item measure was acceptable for the present analyses. However,

differences in reliability attenuate effect size (Kanyongo, Brook, Kyei-Blankson, & Gocmen, 2007), and it may be that the observed effects can, in part, be confounded by differences in reliability of the measurement instruments. The present study found higher stability for relationship satisfaction, making it likely that the estimated cross-lagged effects were, if anything, an under-estimate. Therefore, it may be expected that the same conclusions would have been drawn if both constructs were measured equally reliable.

Second, although complex statistical models such as continuous time modeling can help us identify the role of measurement intervals in the strength of effects, there are issues that accompany such models that should be noted. With regard to the performance of our models, we attempted a robustness check by computing a model on self-esteem and a relationship-specific type of satisfaction, romantic satisfaction. The cross-lagged panel model replicated our main findings, but the random-intercept cross-lagged panel model produced estimates that were unexpected given our data and previous work on self-esteem and satisfaction with social relationships (i.e., low stability and very strong cross-lagged effects). We believe these issues to be related to a combination of different aspects of our data (e.g., high percentage of missingness, weak data structure due to widely varying measurement intervals both across individuals and within individuals). However, they may also highlight a relative sensitivity of continuous time modeling analyses. This may have especially been an issue for the random-intercept cross-lagged panel model, because its effects reflect only within-person variance; in contrast, the cross-lagged panel model estimates effects that reflect a combination of between- and within-person variance. As a result, despite its utility for our research question, the random-intercept model may be less stable and produce less consistent findings (e.g., Orth et al., 2020). Given that some of these issues also existed for the other reported analyses (e.g., high percentage of missingness), we believe it is important to take into account this uncertainty, and emphasize the need for replication of the present findings in

future research.

Third, although stationarity is a core assumption of the continuous time models we ran (Voelkle et al., 2012), we could not test this assumption. However, due to the heterogeneity of our sample, we assumed the estimated continuous processes of the present study to be stationary. Related to this is the assumption that time is the only factor influencing the autoregressive and cross-lagged effects in our models (Voelkle et al., 2012). Yet, for example, experiences of life events may play a role in the association between self-esteem and satisfaction with social relationships – and perhaps in particular with regard to the transient effects of the random-intercept cross-lagged panel model. While it is possible to include both time-invariant and time-varying predictors in *ctsem* (Driver & Voelkle, 2017; Driver et al., 2017), it would be computationally difficult to estimate a model that includes all factors that may affect the parameters due to its complexity.

Finally, there are limitations to the study design. As is the case with many panel studies, our data were based on self-reports, which are subject to shared method bias (Podsakoff, MacKenzie, & Podsakoff, 2012). This may have resulted in inflated associations between our variables of interest. Moreover, it is possible that individuals with higher self-esteem (or satisfaction with social relationships) have a general response style towards positive reporting. Additional research using different measurements (e.g., dyadic measures of relationship quality), possibly in addition to self-report, would be needed to rule out these alternative explanations. In addition, our measure of satisfaction with social relationships is but one of many social relationship variables that have been studied in previous research, such as social support and relationship quantity. At the same time, our measure of satisfaction was very broad in the sense that it reflects satisfaction across many different kinds of relationships (e.g., romantic relationships, close friends, family). Our robustness checks focusing on romantic relationship satisfaction indicated that our main findings also held for a specific type

of relationship satisfaction in the cross-lagged panel model, but not in the random-intercept cross-lagged panel model An explanation for the latter result might be that estimates of structural coefficients are less consistent in the random-intercept cross-lagged panel model than in the cross-lagged panel model (Orth et al., 2020; Usami, Todo, & Murayama, 2019). Therefore, research with even larger samples and a larger number of waves is needed to examine this association using random-intercept cross-lagged panel models compared to cross-lagged panel models. Related to this, although it was not possible to include measures of possible mediating processes such as social activities in the present research, we believe that including such measures of potential underlying mechanisms is an important next step for research on self-esteem and social relationships.

Conclusion

The present study examined the links between self-esteem and satisfaction with social relationships across different time intervals, ranging from one month to ten years. We found evidence for bidirectional positive effects. Additionally, when accounting for stable differences between individuals in their average levels of self-esteem and satisfaction with social relationships, the effect of satisfaction with social relationships on later self-esteem was greater than the effect of self-esteem on later social relationships. The weak effect size of these relations adds nuance to theories that suggest that self-esteem and satisfaction with social relationships are strongly associated with each other, and instead points to the idea that both self-esteem and satisfaction with social relationships are each influenced by many third factors, such as personality.

With regard to timing, we found that the strength of the effects were largest at one year after accounting for stable differences in people's average levels of self-esteem and satisfaction with social relationships. This is in line with previous studies that found bidirectional effects in shorter (i.e., 1-2 year) but not longer (i.e., 6-9 year) intervals, and also

suggests that relatively long-term processes may underlie these links (e.g., changes in social activities). The small effect sizes may explain why previous research has resulted in inconsistent findings, as large samples, high power, and – as the present study suggests – a relatively short interval (i.e., one year) might be needed to detect such effects.

The current study is a first step in examining the role of timing in the association between self-esteem and satisfaction with social relationships, but more research using different samples is needed to see whether the current findings can be generalized to other populations and to further our understanding of these relations. Furthermore, our study underlines the usefulness of continuous time modeling for answering new research questions, but also highlights the relative sensitivity of these models, especially with regard to the more complex random-intercept cross-lagged panel model. More research is needed to gain a better understanding of the relative strengths and limitations of these models when examining the relation between self-esteem and satisfaction with social relationships across time.

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Self-Esteem and Satisfaction with Social Relationships across Time

Supplementary Material

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The present study was registered on the Open Science Framework at https://osf.io/ngv3y/.

Scripts and other materials are provided on the Open Science Framework page at https://osf.io/yz2c4/.

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Table S1. Overview of study characteristics and findings from longitudinal studies on self-esteem social relationships (relationship quality and relationship satisfaction).

Study	Study duration	Interval between measurements	Sample characteristics	SE measure	SR measure	Statistical model	SE → SR	SR → SE
Denissen, Penke, Schmitt, & Van Aken, 2008 [a] (Study Ia: daily measures)	25 days	1 day	*N* = 241 German adults, M_{age} = 29.86 years (SD = 9.79), 93% female	Rosenberg Self-Esteem Scale (4 items)	Quality of interaction with closest family member, other family members, closest friend, other friends, and partner (i.e., ratings of "enjoyment", "feeling important", and "respected")	Multilevel model with quality of interaction as predictor of relationship satisfaction. Additional variables: gender, quality of interaction × gender interaction term.		**Closest family member** *b* = -0.01, *p* > .10 **Other family member** *b* = -0.02, *p* > .10 **Closest friend** *b* = 0.07, *p* < .01 **Other friends** *b* = 0.12, *p* < .01 **Partner** *b* = 0.04, *p* < .10
Mund, Finn, Hagemeyer, Zimmermann, & Neyer, 2015 (Study II)	3 years	1 year	*N* = 2,124 heterosexual German adult couples who remained together during study duration, M_{age} females = 31.35 years (SD = 5.55) and M_{age} males = 34.16 years (SD = 6.10)	Rosenberg Self-Esteem Scale (3 items)	Relationship satisfaction ("In general, how satisfied are you with your relationship?")	Bivariate latent change model. Additional variables: age and relationship duration.	**T1 on ΔT1-T2** Actor: *β* = .10, *p* < .01 Partner: *β* = .05, *p* = .01 **T2 on ΔT2-T3** Actor: *β* = .06, *p* < .01 Partner: *β* = .02, *p* = .43 **ΔT1-T2 on ΔT2-T3**	**T1 on ΔT1-T2** Actor: *β* = .06, *p* < .01 Partner: *β* = .03, *p* = .14 **T2 on ΔT2-T3** Actor: *β* = .03, *p* = .18 Partner: *β* < .01, *p* = .91 **Change ΔT1-T2 on change ΔT2-T3** Actor: *β* = .05, *p* = .02 Partner: *β* = .01, *p* = .77

							Actor: β = -.01, p = .79 Partner: β = -.01, p = .78	
Mund & Nestler, 2019 [ab]	3 years	1 year	N = 2,665 German adults.	Rosenberg Self-Esteem Scale (3 items)	Relationship satisfaction (“In general, how satisfied are you with your relationship?”)	Cross-lagged panel model (CLPM), random-intercept cross-lagged panel model (RI-CLPM), autoregressive latent trajectory model with structured residuals (ALT-SR), and the dual change score model (DCSM).	**CLPM** b = .02, p > .01 **RI-CLPM** b = .23, p < .01 **ALT-SR** b = .17, p < .01 **DCSM** b = -3.65, p < .01	b = - .01, p > .01 b = .02, p < .01 b = .02, p < .01 b = .23, p < .01
Marshall, Parker, Ciarrochi, & Heaven, 2014 [a]	5 years	1 year	N = 961 Australian adolescents, M_{age} = 13.41 years (SD = 0.53), 49% female	Rosenberg Self-Esteem Scale (10 items)	Satisfaction with perceived social support (Social Support Questionnaire; Ciarrochi, Chan, & Bajgar, 2001; Sarason, Sarason, & Shearin, 1986; 4 items)	Cross-lagged panel model with equality constraints on stability and cross-lagged coefficients. Additional variables: network size, gender, non-English-speaking background,	β = .13, p < .001	β = .01, p = *ns*

						parental country of birth, SES, and IQ.		
Schaffhuser, Wagner, Lüdtke, & Allemand, 2014 [a]	2 years	2 years	*N* = 141 heterosexual dating, cohabiting, or married Swiss couples, M_{age} = 50.00 years (SD = 19.10)	Rosenberg Self-Esteem Scale (10 items)	Relationship satisfaction (with the Relationship Assessment Scale; Sander & Böcker, 1993; 7 items)	Actor-Partner Interdependence Model. Covariate: neuroticism.	**Intrapersonal (Within-person association)** *b* = .06, *p* > .05 **Interpersonal (Within-couple association)** *b* = .05, *p* > .05	**Intrapersonal** *b* = -.03, *p* > .05 **Interpersonal** *b* = .11, *p* < .05
Orth, Robins, & Widaman, 2012 [a]	12 years	3 years	*N* = 1,824 American adolescents and adults, M_{age} = 49.3 years (SD = 18.3), 57% female	Rosenberg Self-Esteem Scale (10 items)	Relationship satisfaction (Relationship scale; Gilford & Bengtson, 1979; 10 items)	Cross-lagged panel model with equality constraints on stability and cross-lagged coefficients.	*β* = .05, *p* < .05	*β* = .01, *p* > .05
Erol & Orth, 2014 [a] (Study I)	12 years	3 years	*N* = 885 cohabiting or married American adult couples, M_{age} female = 51.8 years (SD = 16.7) and M_{age} male = 54.3 years (SD = 17.1)	Rosenberg Self-Esteem Scale (10 items)	Relationship satisfaction (Relationship scale; Gilford & Bengtson, 1979; 10 items)	Bivariate growth curve model. Additional variables: Age and relationship duration.		**Intercepts on intercept** Females and males: *β* = .24, p < .05 **Intercepts on slope** Females and males: *β* = -.02, p > .05 **Slopes on slope** Females: *β* = .23, p < .05 Males: *β* = .24, p < .05 **Slopes on intercept** Females and males: *β* = -.04, p > .05

Boden, Fergusson, & Horwood, 2008 [b]	10 years	6 and 4 years	*N* = 1,265 New Zealander adolescents	Coopersmith Self Esteem Inventory (1981)	Romantic relationship quality (Intimate Relations Scale; Braiker & Kelley; 25 items)	Random effects model. Additional variables: family background, family functioning, individual characteristics, child abuse, and prior mental health.	*b* = .07, *p* > .20	
Mund, Finn, Hagemeyer, Zimmermann, & Neyer, 2015 [ac] (Study I)	8 years	4 and 4 years	*N* = 186 German adults, M_{age} = 26.82 years (SD = 3.01), 66% female	Self-Description Questionnaire III (Marsh & O'Neill, 1984; 6 items)	Relationship satisfaction (Satisfaction with the Relationship Assessment Scale; Sander & Böcker, 1993; 7 items)	Bivariate latent change model. Additional variables: age and relationship duration.	**T1 on change T1-T2** *β* = .06, *p* > .30 **T2 on change T2-T3** *β* = .08, *p* > .30 **Change T1-T2 on change T2-T3** *β* = -.07, *p* > .50	**T1 on change T1-T2** *β* = .08, *p* > .30 **T2 on change T2-T3** *β* = .02, *p* > .30 **Change T1-T2 on change T2-T3** *β* = -.01, *p* > .50
Erol & Orth, 2014 [a] (Study II)	15 years	6 and 9 years	*N* = 6,116 cohabiting or married American adult couples, M_{age} women = 40.3 years (SD = 15.2) and M_{age} men = 43.0	Rosenberg Self-Esteem Scale (3 items)	Relationship satisfaction (“Taking things all together, how would you describe your relationship?”; answered on a scale from	Bivariate growth curve model. Additional variables: age and relationship duration.		**Intercept on intercept** Females: *β* = .34, p < .05 Males: *β* = .33, p < .05 **Intercepts on slope** Females and males: *β* = -.17, p < .05 **Slope on slope** Females: *β* = .22, p < .05

			years (SD = 15.7)		*very unhappy* to *very happy*)			Males: β = .26, p < .05 **Slopes on intercept** Females and males: β = -.03, p > .05
Sturaro, Denissen, Van Aken, & Asendorpf, 2008 [a]	6 years	6 years	*N* = 154 German adolescents, assessed at age 17, 47% female	General Self-Esteem scale of the Self Description Questionnaire III (SDQ III; Marsh & O'Neill, 1984; 6 items)	Relationship quality (Network of Relationships Inventory; Furman & Buhrmeister, 1985)	Path analyses.	**Mother** Support: β = -.15, p > .05 Conflict: β = -.08, p > .05 **Father** Support: β = -.04, p > .05 Conflict: β = -.09, p > .05 **Best friend** Support: β = .04, p > .05 Conflict: β = -.04, p > .05	**Mother** Support: β = .14, p > .05 Conflict: β = -.19, p < .05 **Father** Support: β = .10, p > .05 Conflict: β = -.23, p < .01 **Best friend** Support: β = .08, p > .05 Conflict: β = -.18, p < .05

Note. SE = self-esteem; SR = social relationships.

Studies were chosen based on the following criteria: Studies had to a) examine (unidirectional or bidirectional) links between self-esteem and the subjective experience of social relationships (i.e., relationship quality and relationship satisfaction), b) use a non-clinical sample of c) adolescents or adults. Studies are sorted by interval between measurements.

[a] Exact p-values were not reported in the manuscript.

[b] Descriptive information concerning age and sex were not reported in the manuscript.

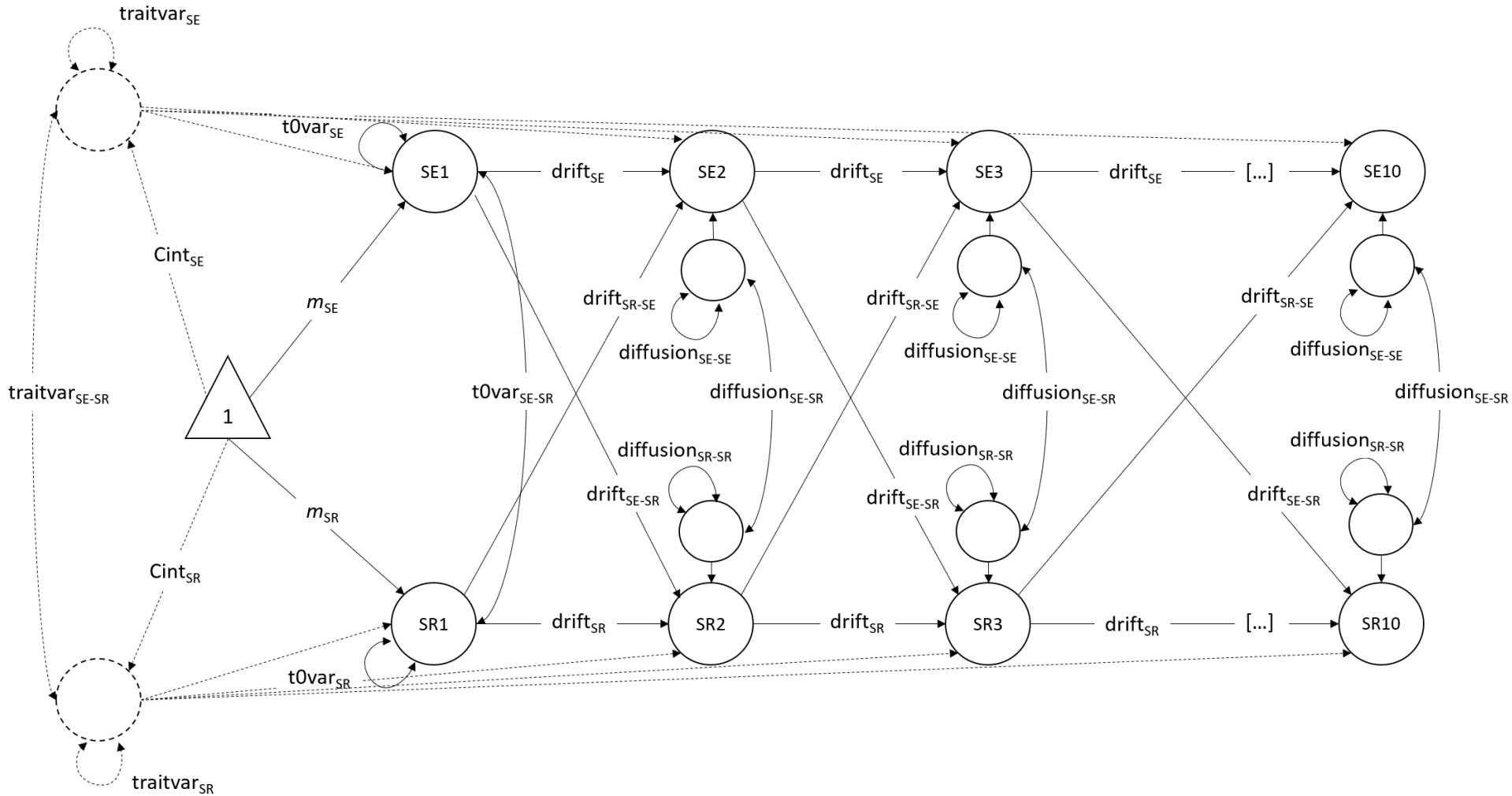
[c] Initial correlation (r = .34, p < .001) and correlated changes at T2 (r = .26, p = .019) and at T3 (r = .33, p = .002) were significant.

Table S2. Measurement schedule of self-esteem and satisfaction with social relationships across the ten waves of data included in the paper.

	Wave/ Year	1 2008	2 2009	3 2010	4 2011	5 2012	6 2013	7 2014	8 2015	9 2016	10 2017
Self-esteem	Data collection period	05-05 to 05-29	05-04 to 05-27	05-03 to 05-26	05-02 to 05-29	05-07 to 05-29	05-06 to 05-28	11-03 to 11-25	11-02 to 11-24	No data collection	05-07 to 05-29
	Second opportunity	08-04 to 08-27	06-01 to 06-30	06-07 to 06-30	06-06 to 06-29	06-04 to 06-26	06-03 to 06-25	12-01 to 12-31	12-07 to 12-29		06-04 to 06-26
Satisfaction with social relationships	Data collection period	02-04 to 02-26	02-02 to 02-25	02-01 to 02-24	02-07 to 02-27	02-06 to 02-28	02-04 to 02-26	02-03 to 02-25	10-05 to 10-27	10-03 to 10-25	10-02 to 10-31
	Second opportunity	05-05 to 05-29	03-02 to 03-25	03-01 to 03-28	03-07 to 03-28	03-05 to 03-27	03-04 to 03-26	03-03 to 03-25	11-02 to 11-24	11-07 to 11-29	11-06 to 11-28

Note. Dates are reported in the month-day (mm-dd) format. Data collection period represents the period in which the questionnaires about self-esteem (personality questionnaire) and satisfaction with social relationships (social relationships questionnaire) were available to the participants. If participants did not complete the questionnaire during this period, they were requested to do so again at a later timepoint in the year, during the second opportunity.

Figure S1. Path diagram of the continuous time model within a structural equation framework for self-esteem and satisfaction with social relationships.



Note. The figure shows a path diagram for the CT-SEM and RI-CT-SEM (parameters and paths in dashes denote this model), including all autoregressive and cross-lagged paths estimated for self-esteem and satisfaction with social relationships. SE = self-esteem; SR = satisfaction

with social relationships. Latent variables are presented in circles, manifest indicators are omitted from the figure for simplicity; SR was measured as a single item but was specified as a latent variable in the model. The mean structure is indicated by a unit triangle. The model further includes means (*m*), variances ($t0var_{SE}$, $t0var_{SSR}$), and the covariance between self-esteem and satisfaction ($t0var_{SE\text{-}SR}$) at the first measurement occasion. Diffusion arrows represent variances ($diffusion_{SE\text{-}SE}$ and $diffusion_{SR\text{-}SR}$) and covariance ($diffusion_{SE\text{-}SR}$) at later time points. Drift parameters capture the continuous (i.e., time-independent) autoregressive ($drift_{SE}$ and $drift_{SR}$) and cross-lagged ($drift_{SE\text{-}SR}$ and $drift_{SR\text{-}SE}$) effects; the discrete effects depend on the function of the paths and the time interval. The dataset included 10 annual assessments across 10 years, which varied across individuals. Note that despite the simplified depiction of our variables of interest, self-esteem and satisfaction with social relationships were not measured at the same time in the LISS panel (see Table S2 of the SOM). To simplify the data structure, we realigned each participant's data so that their first measurement was at time point 0 and their next measurements were measured in relation to this time point (i.e., number of months since first measurement).

1. Measurement invariance tests of self-esteem.

We examined measurement invariance for self-esteem in the data used for our main analyses (LISS panel) and in the data used for one of our robustness checks (PAIRFAM). Given their relative independence of sample size, change in the Root Mean Squared Error of Approximation (RMSEA; Steiger, 1989) and the Comparative Fit Index (CFI; Bentler, 1990) were used as indicators of relative model fit instead of change in the χ^2 fit statistic. Differences of less than .015 for RMSEA (Chen, 2007) and less than .01 for CFI (Cheung & Rensvold, 2002) were seen as indicating invariance.

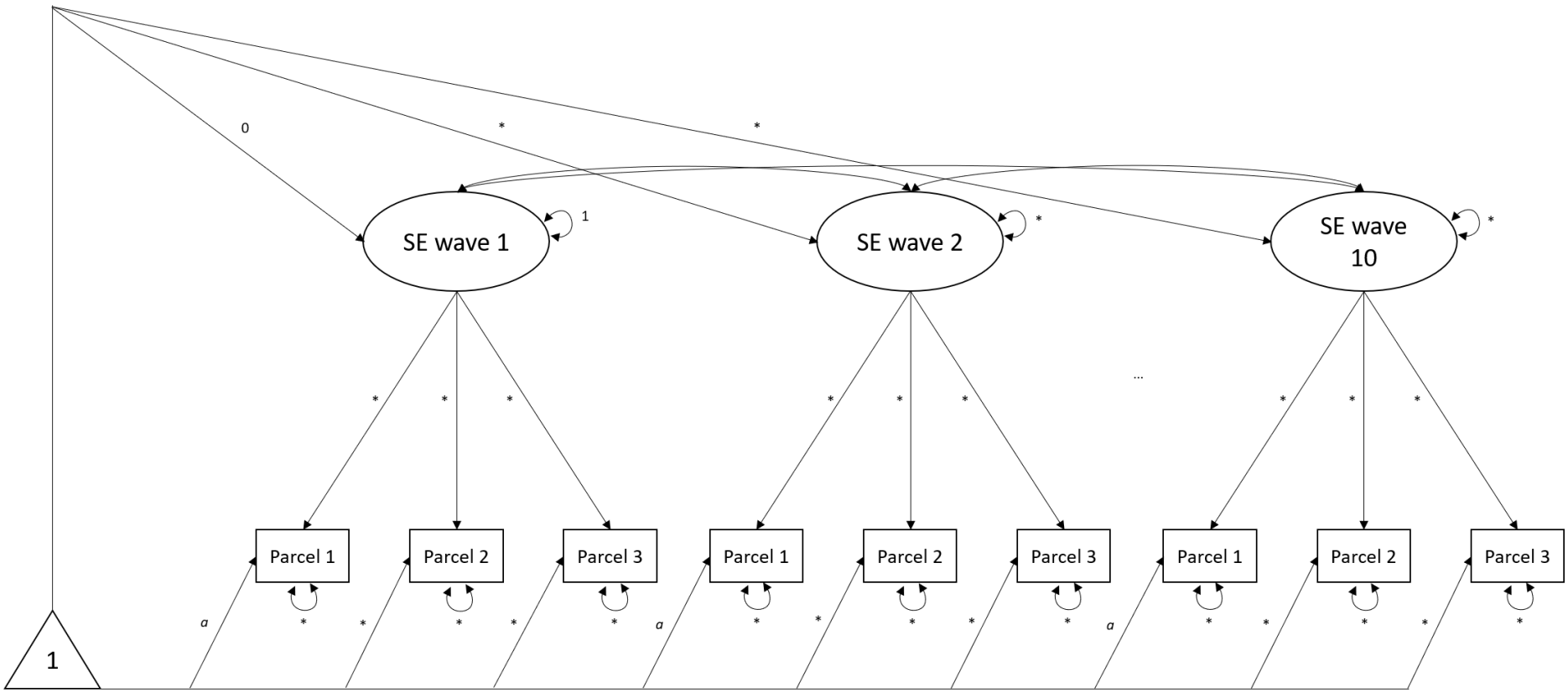
LISS panel

As described in the main text, we tested measurement invariance for the LISS panel on three item parcels. We assigned items into parcels by dividing the items into two lists based on whether they were positively or negatively worded. We then randomly assigned the items to three parcels so that the positively and negatively worded items were divided equally across the parcels. The first parcel included four items: “On the whole, I am satisfied with myself”, “I feel that I’m a person of worth, at least on an equal plane with others”, “At times, I think I am no good at all” (reverse-coded), and “I feel I do not have much to be proud of” (reverse-coded). The second parcel consisted of three items: “I am able to do things as well as most other people”, “I take a positive attitude towards myself”, and “I wish I could have more respect for myself (reverse-coded). The final parcel also included three items: “I feel that I have a number of good qualities”, “I certainly feel useless at times” (reverse-coded), and “All in all, I am inclined to feel that I am a failure” (reverse-coded).

We first tested whether the measurement model was the same across waves (i.e., configural invariance; see Figure S2). This model yielded adequate fit (χ^2 = 5398.15, p < .001, RMSEA = .045, CFI = .950). Next, we tested whether factor loadings were equal across waves (i.e., weak invariance). This model also showed adequate fit (χ^2 = 5425.20, p < .001,

RMSEA = .044, CFI = .950), and did not fit the data significantly worse than the previous model (ΔRMSEA = .001, ΔCFI < .001). We then constrained all indicator intercepts to be equal across waves (i.e., strong invariance), which yielded adequate fit to the data (χ^2 = 5463.70, p < .001, RMSEA = .042, CFI = .950), and did not show significantly worse fit than the previous model (ΔRMSEA = .002, ΔCFI < .001). Lastly, we set indicator variances to be equal across time (i.e., strict invariance). This model also showed adequate fit to the data (χ^2 = 5538.96, *p* < .001, RMSEA = .041, CFI = .949), and did not fit the data significantly worse than the strong invariance model (ΔRMSEA = .001, ΔCFI = .001). We concluded that for these waves, the self-esteem measurement met the requirements for strict invariance.

Figure S2. Path diagram of the model estimated for the measurement invariance tests in the LISS dataset.

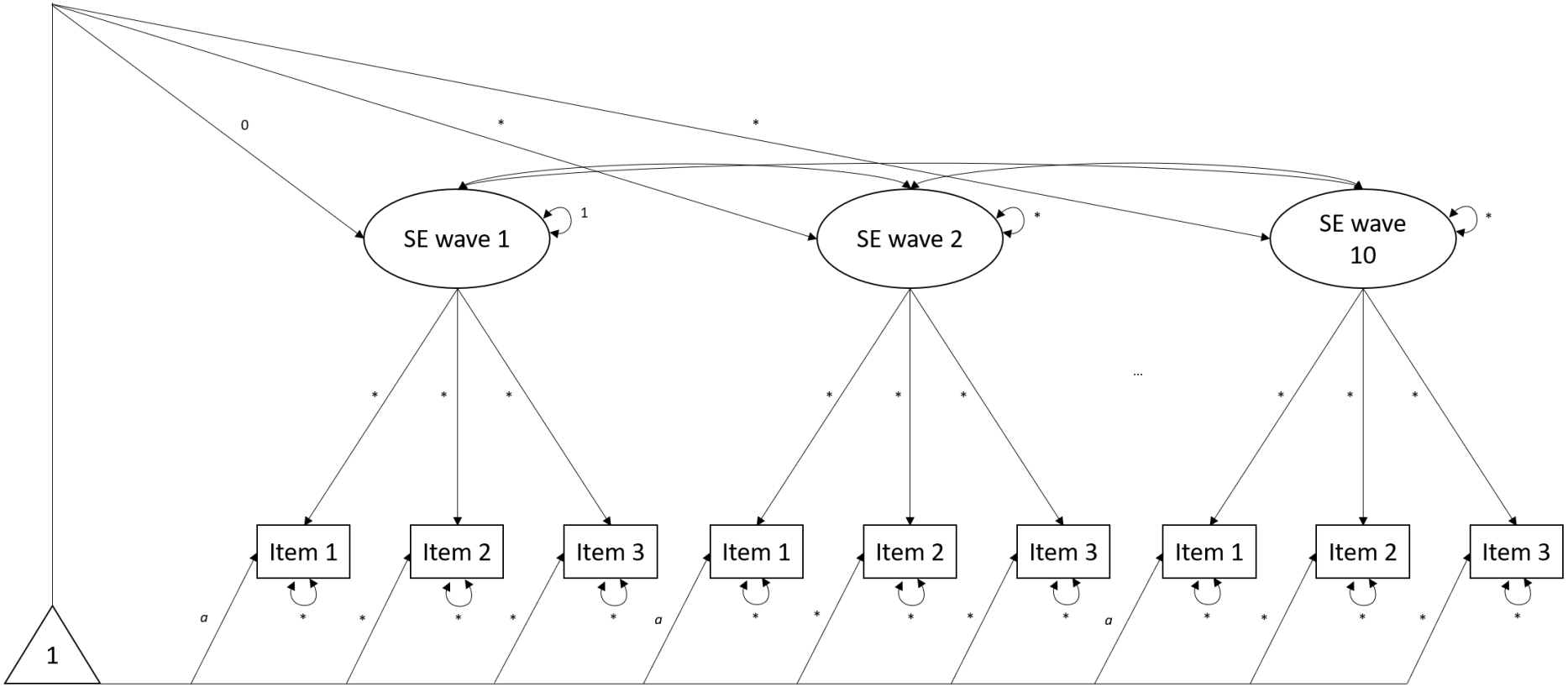


Note. To test whether our measure of self-esteem was interpreted the same way across assessments, we tested for longitudinal measurement invariance across the 10-year span of the LISS data. We could not test invariance for 2016 (i.e., Wave 9) as self-esteem was not measured that year and for 2010 (i.e., Wave 3) as there was no data overlap with self-esteem in 2008 and 2009. The figure shows the model specification for Wave 1, which was different from the other waves because we had to fix the mean of the latent self-esteem factor and the intercept of the first parcel for the purpose of identification. The figure additionally shows the specification for Wave 2 and Wave 10; model specification for the data from Waves 4-8 was equal to these waves.
a = indicator intercept fixed to equality across waves.

PAIRFAM

For the PAIRFAM dataset, we tested the fit of the measurement model of self-esteem, using the three items as indicators of a latent self-esteem variable (see Figure S3). These items were “Sometimes I believe that I’m worthless”, “I like myself just the way I am”, and “All in all, I am pleased with myself”. The fit of this model across all data was unacceptable (χ^2 = 9587.62, p < .001, RMSEA = .381, CFI = .844), indicating that the three items that were used to measure self-esteem were not good indicators of the construct in the PAIRFAM dataset. It is important to note that this is in contrast to the measurement checks reported in a PAIRFAM Technical Paper by Sonntag, Neyer, and Schubach (2015; see Figure S4), which demonstrated good fit for the measurement model of self-esteem with slightly different model specifications (i.e., RMSEA = .001, CFI= 1.000 for the configural model, RMSEA = .995, CFI = .054 for the weak invariance model, RMSEA = .988, CFI = .058 for the strong invariance model, RMSEA = .987, CFI = .055 for the strict invariance model; see Table S3 for the model specification differences).

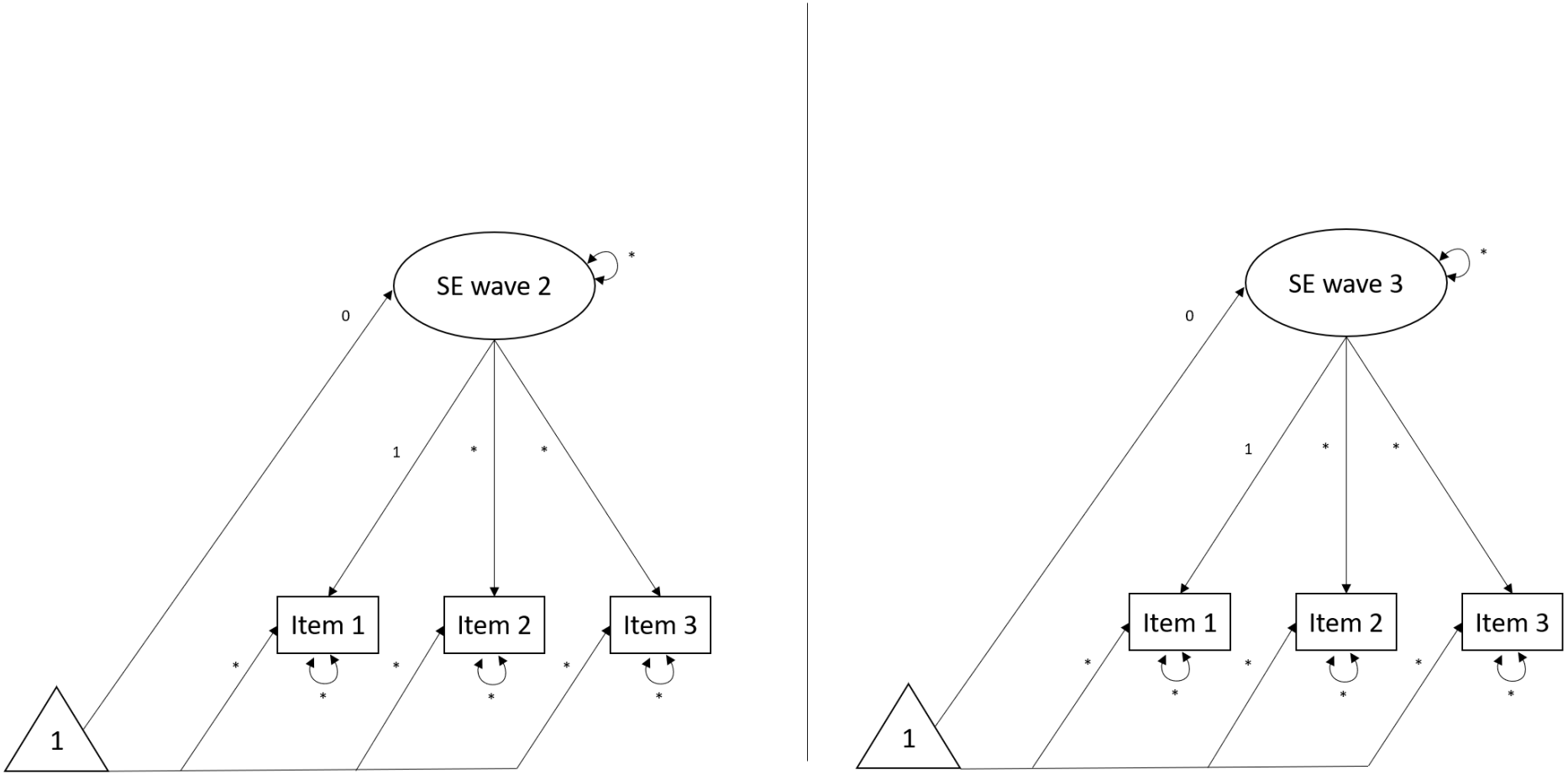
Figure S3. Path diagram of the model estimated for the measurement invariance tests in the PAIRFAM dataset.



Note. To test whether our measure of self-esteem was interpreted the same way across assessments, we tested for longitudinal measurement invariance across the 10-year span of the PAIRFAM data. The figure shows the model specification for Wave 1, which was different from the other waves because we had to fix the mean of the latent self-esteem factor and the intercept of the first item for the purpose of identification. The figure additionally shows the specification for Wave 2 and Wave 10; model specification for the data from Waves 3-9 was equal to these waves.

a = indicator intercept fixed to equality across waves.

Figure S4. Path diagram of the model estimated for the measurement invariance tests in the technical paper by Sonntag et al., (2015).



Note. The figure shows the estimated model for multigroup measurement invariance, as tested in the PAIRFAM technical paper by Sonntag et al. (2015). They tested invariance across Wave 2-10 of the dataset, as the self-esteem questionnaire was filled out across the phone with a test leader in Wave 1, whereas online questionnaires were used from Wave 2 onwards. The figure shows the model specification for Wave 2 and 3 as an example, but model specification was the same for every consecutive wave (i.e., every different “group”, under the testing of multiple groups).

In this model, identification had to be done for each wave separately. As such, the mean of the latent self-esteem factor and the factor loading of the first indicator was fixed in each model.

Table S3. Differences in the fitted measurement model for self-esteem PAIRFAM Technical Paper and the present study.

Our measurement invariance tests	PAIRFAM Technical Paper (Sonntag et al., 2015)
Tested for longitudinal measurement invariance. Because of this specification, the model that we tested includes variables from all waves (e.g., a latent self-esteem variable for Wave 1, Wave 2, etc.).	Tested for multigroup measurement invariance. In this specification, separate models are fitted for every measurement wave (e.g., a model with a latent variable and indicators for Wave 1, a model for Wave 2, etc.)
Allowed for covariances between latent factors across time. That is, within the model including all measurement waves, we allowed the latent constructs of self-esteem at different measurement waves to be related (e.g., self-esteem at Wave 1 with self-esteem at Wave 2), because the underlying construct is measured in the same individuals over time and can thus be considered to have some trait-like qualities (i.e., we expect someone's self-esteem at one point to be somewhat related to their self-esteem at a different point).	Did not allow between-wave covariances between latent factors. That is, because the model was estimated separately for each wave, each model is considered a separate case that is not related to the (estimates in) the other models. Thus, because self-esteem at one measurement wave is considered to be independent of self-esteem at another wave (e.g., Wave 1 from Wave 2), the latent constructs are not allowed to covary.
Estimated the factor loadings for all indicators per latent factor. We did this so we would get more information regarding the factor loadings (i.e., instead of for 2 of the items, we now get it information about loadings for all three items). To make sure the latent factors could be scaled (i.e., because a latent construct doesn't have a measurement scale, this needs to be assigned), we fixed the variance of the latent self-esteem factor at Wave 1 to 1.	The factor loading of every first item per latent factor (i.e., item 1 for each wave) was set to 1. This was done so that the latent construct of self-esteem could be scaled.
The intercept of the first latent factor was set to 0 for scaling purposes. Because all other measurement waves and thus latent factors were estimated in the same model, intercepts for all other latent factors could be freely estimated.	The intercept of all latent self-esteem factors had to be set to 0 for scaling purposes. This had to be done for every latent factor because the model was estimated separately for each wave.

Note. The PAIRFAM Technical Paper on measurement invariance made use of the "measurementInvariance()" command which was formerly part of the *lavaan* R package (Rosseel, 2012) but is now part of the *semTools* package (Jorgensen, Pornprasertmanit, Schoemann, & Rosseel, 2020; though it will cease to be included in future versions of the package). This command can be used to test a series of more stringent invariance models.

Because of the poor fit found in our model, we decided to focus in the measurement invariance tests on the model comparison statistics and not on the overall fit of the model. Fitting increasingly strict models, we found that model fit did not significantly worsen across steps of increasing invariance (see Table S4). Thus, we concluded for the self-esteem measurement in the PAIRFAM data, 1) that the measurement model was inadequate, but that 2) relative to less restrictive models, it technically met the requirements for strict invariance.

Table S4. Measurement invariance tests for self-esteem in the PAIRFAM dataset.

	χ^2	*p*	RMSEA	CFI	ΔRMSEA	ΔCFI
Configural invariance	16,084.04	< .001	.059	.849		
Weak invariance	15,697.58	< .001	.059	.849	< .001	< .001
Strong invariance	16,553.48	< .001	.057	.841	.002	.008
Strict invariance	18,611.59	< .001	.059	.821	.002	.020

Table S5. Descriptive statistics per study year.

		Year/Sample Size									
		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Variable	Parameter	7,514	6,176	6,391	5,882	6,118	5,973	7,430	5,885	5,312	6,900
Sex	%	54%	54%	54%	54%	53%	54%	54%	54%	53%	54%
Age	*M*	45.88	46.48	47.95	49.44	43.88	50.81	49.47	35.63	51.53	49.91
	SD	15.94	16.58	20.02	17.46	17.23	17.71	17.96	15.77	18.00	18.39
Self-esteem	*M*	5.66	5.62	5.56	5.54	5.55	5.57	5.55	5.31	–	5.54
	SD	0.97	0.96	0.98	0.98	0.97	1.00	1.01	1.11	–	1.01
	α	.90	.90	.88	.90	.89	.91	.90	.92	–	.90
Relationship	*M*	7.32	7.32	7.33	7.28	7.31	7.34	7.26	7.29	7.29	7.28
satisfaction	*SD*	1.69	1.61	1.58	1.58	1.61	1.61	1.54	1.55	1.53	1.54
	α	–	–	–	–	–	–	–	–	–	–

Table S6. Zero-order correlations between self-esteem and satisfaction with social relationships in the LISS dataset for all study years.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
1. SE 2008																			
2. SE 2009	.723																		
3. SE 2010	–	–																	
4. SE 2011	.670	.705	.708																
5. SE 2012	.600	.627	.701	.289															
6. SE 2013	.626	.679	.675	.743	.740														
7. SE 2014	.605	.655	.661	.711	.712	.759													
8. SE 2015	.632	.579	.636	.686	.519	.737	.829												
9. SE 2016	–	–	–	–	–	–	–	–	–										
10. SE 2017	.582	.619	.657	.689	.653	.730	.742	.686	–										
11. SR 2008	.299	.307	.633	.283	.216	.270	.260	.350	–	.245									
12. SR 2009	.317	.347	.555	.305	.281	.284	.280	.319	–	.262	.607								
13. SR 2010	.287	.324	.272	.304	.215	.289	.264	.290	–	.274	.576	.647							
14. SR 2011	.293	.328	.291	.321	.317	.312	.299	.232	–	.285	.540	.620	.660						
15. SR 2012	.265	.324	.300	.306	.230	.307	.287	.261	–	.288	.536	.608	.629	.680					
16. SR 2013	.279	.325	.260	.309	.332	.332	.327	.297	–	.304	.538	.580	.602	.645	.670				
17. SR 2014	.241	.278	.323	.298	.358	.317	.322	.263	–	.293	.482	.539	.565	.606	.629	.665			
18. SR 2015	.245	.264	.294	.295	.310	.313	.336	.233	–	.305	.450	.492	.503	.562	.562	.601	.612		
19. SR 2016	.244	.277	.273	.304	.343	.309	.318	.232	–	.344	.460	.499	.529	.557	.566	.629	.607	.626	
20. SR 2017	.246	.268	.303	.316	.321	.325	.344	.189	–	.334	.434	.490	.516	.539	.554	.590	.608	.618	.643

Note. SE = self-esteem; SR = satisfaction with social relationships.
No correlations were calculated for 2016 as self-esteem was not measured that year and for 2010 as there was no data overlap with self-esteem in 2008 and 2009.

2. Robustness checks of our main analyses.

Romantic Satisfaction

First, we examined whether our primary findings also hold for satisfaction with a more specific type of relationships, romantic satisfaction. Zero-order correlations for self-esteem and romantic satisfaction are provided in Table S7. In the CT-SEM, we found support for a positive bidirectional association between self-esteem and romantic satisfaction (see Table S8). Plotting the discrete effects showed that the effects became stronger across longer time intervals (Figure S5). Comparing a model in which the cross-lagged effects were freely estimated to one in which they were constrained to be equal showed that the second model did not fit the data significantly worse (Δ-2LL(1) = 0.2, p = .643, ΔAIC = 1.8), indicating that the effects of self-esteem (b_{range} = [.001; .059], β_{range} = [.001; .052]) and romantic satisfaction (b_{range} = [.001; .067], β_{range} = [.002; .076]) were not significantly different in magnitude.

For the RI-CT-SEM, we repeatedly found unexpected estimates for both the stability (i.e., β = .238 and β = .746 for 1-month stability for self-esteem and satisfaction with social relationships, respectively; see Table S9) and cross-lagged coefficients (β = .538 and β = .330, respectively). Plotting the effects, we found that the cross-lagged effects were strongest at intervals of 1 month or shorter, and decreased in magnitude across longer intervals (see Figure S6; b_{range} = [.147; .997], β_{range} = [.079; .538] and b_{range} = [.026; .178], β_{range} = [.049; .330] for self-esteem and satisfaction with social relationships, respectively).

Table S7. Zero-order correlations between self-esteem and romantic satisfaction in the LISS dataset for all study years.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
1. SE 2008																			
2. SE 2009	.723																		
3. SE 2010	–	–																	
4. SE 2011	.670	.705	.708																
5. SE 2012	.600	.627	.701	.289															
6. SE 2013	.626	.679	.675	.743	.740														
7. SE 2014	.605	.655	.661	.711	.712	.759													
8. SE 2015	.632	.579	.636	.686	.519	.737	.829												
9. SE 2016	–	–	–	–	–	–	–	–											
10. SE 2017	.582	.619	.657	.689	.653	.73	.742	.686	–										
11. RS 2008	.206	.189	.405	.157	.000	.144	.138	.087	–	.085									
12. RS 2009	.211	.247	.762	.193	.150	.174	.165	.128	–	.147	.650								
13. RS 2010	.196	.218	.178	.215	.008	.185	.179	.230	–	.166	.571	.673							
14. RS 2011	.221	.254	.217	.247	.173	.224	.215	.201	–	.199	.582	.644	.668						
15. RS 2012	.198	.234	.249	.221	.250	.232	.226	.069	–	.187	.539	.600	.620	.686					
16. RS 2013	.199	.226	.227	.219	.231	.239	.238	.137	–	.210	.504	.545	.586	.648	.694				
17. RS 2014	.198	.217	.237	.201	.231	.234	.224	.197	–	.203	.493	.532	.580	.627	.657	.699			
18. RS 2015	.183	.225	.218	.220	.198	.241	.240	.162	–	.217	.458	.504	.512	.581	.596	.638	.630		
19. RS 2016	.192	.213	.164	.203	.229	.227	.224	.120	–	.206	.422	.489	.518	.592	.592	.624	.599	.685	
20. RS 2017	.188	.202	.176	.211	.217	.215	.221	.064	–	.212	.424	.485	.506	.564	.575	.610	.611	.663	.718

Note. SE = self-esteem; RS = romantic satisfaction.

No correlations were calculated for 2016 as self-esteem was not measured that year and for 2010 as there was no data overlap with self-esteem in 2008 and 2009.

Table S8. Continuous and discrete parameter estimates of self-esteem and romantic satisfaction of the CT-SEM.

	Drift parameters			Discrete estimates			
Path	Estimate	Standard error	95% CI	1 month	1 year	5 years	10 years
				Autoregressive effects			
SE → SE	-.011	< .001	[-.010671 , -.010661]	.989/.989	.880/.880	.529/.529	.283/.283
RS → RS	-.006	< .001	[-.005800 , -.005790]	.994/.994	.933/.933	.709/.709	.505/.505
				Cross-lagged effects			
SE → RS	.001	< .001	[.001284, .001296]	.001/.001	.014/.012	.047/.042	.059/.052
RS → SE	.001	< .001	[.001466 , .001475]	.001/.002	.016/.018	.054/.062	.067/.076

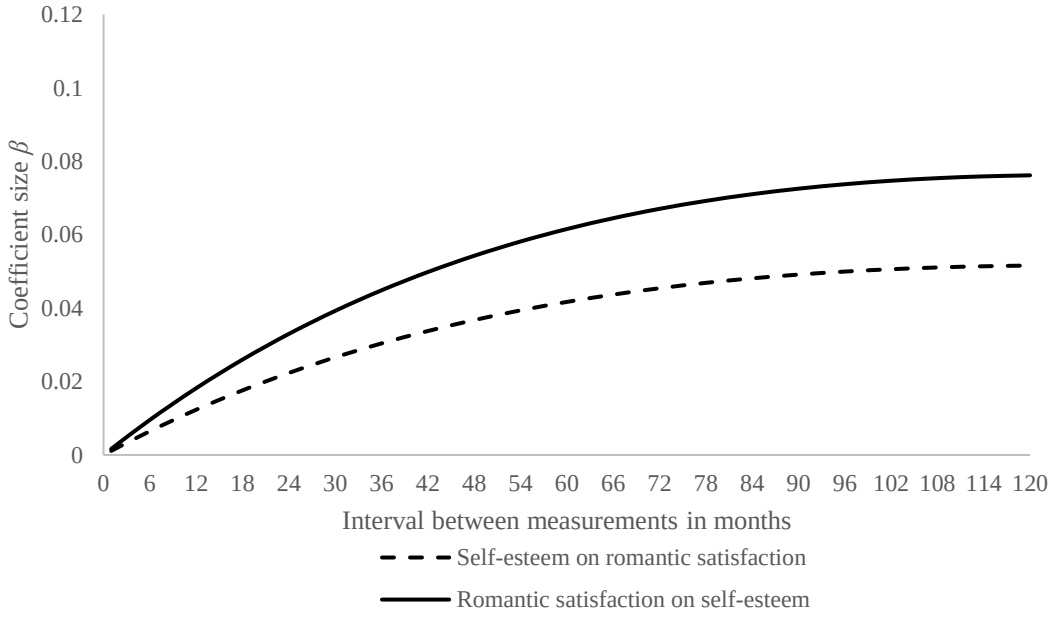
Note. *-2LL*(161,388) = 376,146.8. Missing data were handled using Full Information Maximum Likelihood estimation.
SE = self-esteem; SR = romantic satisfaction. All reported effects were significant at the .05 level. The left part of the table shows the continuous (i.e., time-independent) autoregressive and cross-lagged estimates in the drift matrix. The right part of the table reports the discrete (i.e., time-dependent) unstandardized (first estimate) and standardized (second estimate) effects at intervals of 1 month, and 1, 5, and 10 years.

Table S9. Continuous and discrete parameter estimates of self-esteem and romantic satisfaction of the RI-CT-SEM.

	Drift parameters			Discrete estimates			
Path	Estimate	Standard error	95% CI	1 month	1 year	5 years	10 years
				Autoregressive effects			
SE → SE	-6.610	.737	[-6.622622, -6.597878]	.238/.238	.200/.200	.092/.092	.035/.035
RS → RS	-2.122	.231	[-2.125448, -2.117699]	.746/.746	.625/.625	.289/.289	.110/.110
				Cross-lagged effects			
SE → RS	8.820	.969	[8.803742, 8.836273]	.997/.538	.836/.451	.386/.208	.147/.079
RS → SE	1.574	.170	[1.571290, 1.576997]	.178/.330	.149/.276	.069/.128	.026/.049

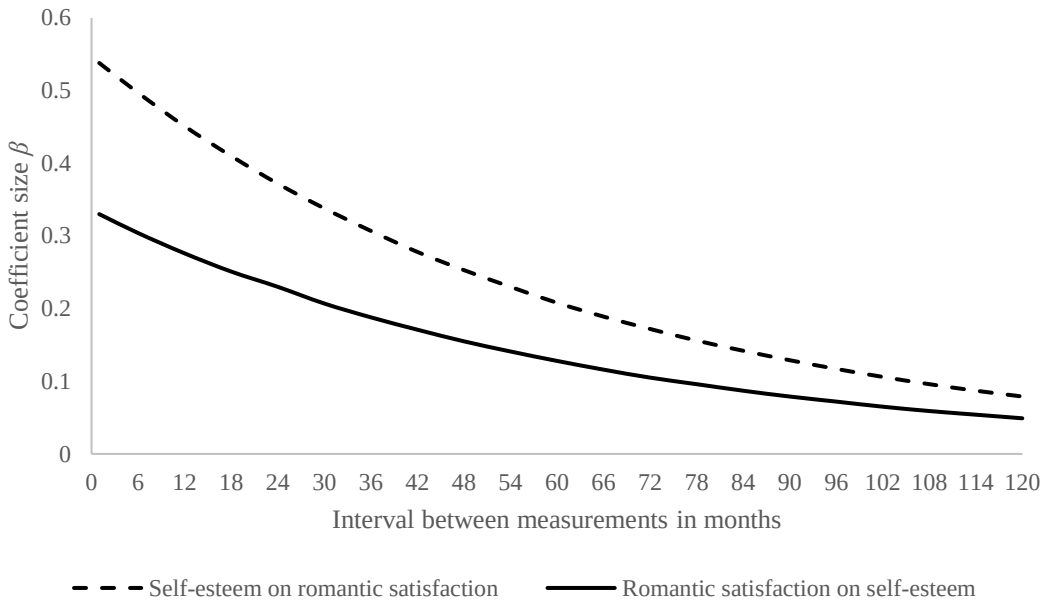
Note. *-2LL*(161,378) = 369,046.1. Missing data were handled using Full Information Maximum Likelihood estimation.
SE = self-esteem; RS = romantic satisfaction. All reported effects were significant at the .05 level. The left part of the table shows the continuous (i.e., time-independent) autoregressive and cross-lagged estimates in the drift matrix. The right part of the table reports the discrete (i.e., time-dependent) unstandardized (first estimate) and standardized (second estimate) effects at intervals of 1 month, and 1, 5, and 10 years.

Figure S5. Cross-lagged regression coefficients of self-esteem on romantic satisfaction and of romantic satisfaction on self-esteem of the CT-SEM.



Note. The figure shows the discrete (time-specific) autoregressive estimates of self-esteem (dashed curve) and romantic satisfaction (solid curve) at intervals from 1 month to 10 years. The estimates are presented as standardized coefficient β.

Figure S6. Cross-lagged regression coefficients of self-esteem on romantic satisfaction and of romantic satisfaction on self-esteem of the RI-CT-SEM.



Note. The figure shows the discrete (time-specific) autoregressive estimates of self-esteem (dashed curve) and romantic satisfaction (solid curve) at intervals from 1 month to 10 years. The estimates are presented as standardized coefficient β.

2-Year Measurement Intervals

Next, we selected only datapoints that were 2-years apart, to test whether shifting the actual measurement interval in the data would affect the peak in the strength of the effects. The model that was fit to the data remained the same. For the CT-SEM, we found a positive bidirectional association between self-esteem and satisfaction with social relationships (see Table S10). A graphical representation of the plotted cross-lagged effects across time shows that these effects became stronger across increasingly long intervals (Figure S7). Moreover, imposing equality constraints on the cross-lagged effects resulted in significantly poorer fit (Δ-2LL(1) = 79.5, $p < .001$, ΔAIC = 77.5), indicating that across intervals the effect of satisfaction with social relationships (b_{range} = [.002; .089], β_{range} = [.003; .110]) was stronger than the effect of self-esteem (b_{range} = [.002; .105], β_{range} = [.002; .085]).

For the RI-CT-SEM, running the running the model repeatedly resulted in unrealistically strong cross-lagged effects (e.g., βs of > .30 at a 1-month interval) – and improbably low autoregressive effects (e.g., βs of < .50 at a 1-month interval). Therefore, we switched to the newer *ctsem* fitting routine for the running of this model, which is based on probabilistic programming language (Driver & Voelkle, 2017). Apart from using different language, we estimated this model in the same way as the original models that used the older fitting routine, thus making comparison between the models possible. As for the CT-SEM, we found a positive effect of self-esteem on satisfaction with social relationships and of satisfaction with social relationships on self-esteem (see Table S11). Plotting the discrete estimates, we see that effects increased in strength up until intervals of 6 to 12 months, after which they become less strong (Figure S8). Imposing equality constraints on the cross-lagged effects did not significantly worsen model fit (Δ-2LL(1) = 0.3, $p < .590$, ΔAI = 1.5), suggesting that the effects of self-esteem (b_{range} = [.002; .089], β_{range} = [.003; .110]) and

satisfaction with social relationships (b_{range} = [.002; .089], β_{range} = [.003; .110]) did not differ in strength.

Table S10. Continuous and discrete parameter estimates of self-esteem and satisfaction with social relationships of the CT-SEM using only data with 2-year lags.

	Drift parameters			Discrete estimates			
Path	Estimate	Standard error	95% CI	1 month	1 year	5 years	10 years
				Autoregressive effects			
SE → SE	-.011	.001	[-.010671 , -.010643]	.989/.989	.880/.880	.533/.533	.290/.290
SR → SR	-.007	.001	[-.007059 , -.007002]	.993/.993	.919/.919	.662/.662	.444/.444
				Cross-lagged effects			
SE → SR	.002	.001	[.002212, .002763]	.002/.002	.027/.022	.088/.071	.105/.085
SR → SE	.002	< .001	[.002000 , .002210]	.002/.003	.023/.028	.075/.092	.089/.110

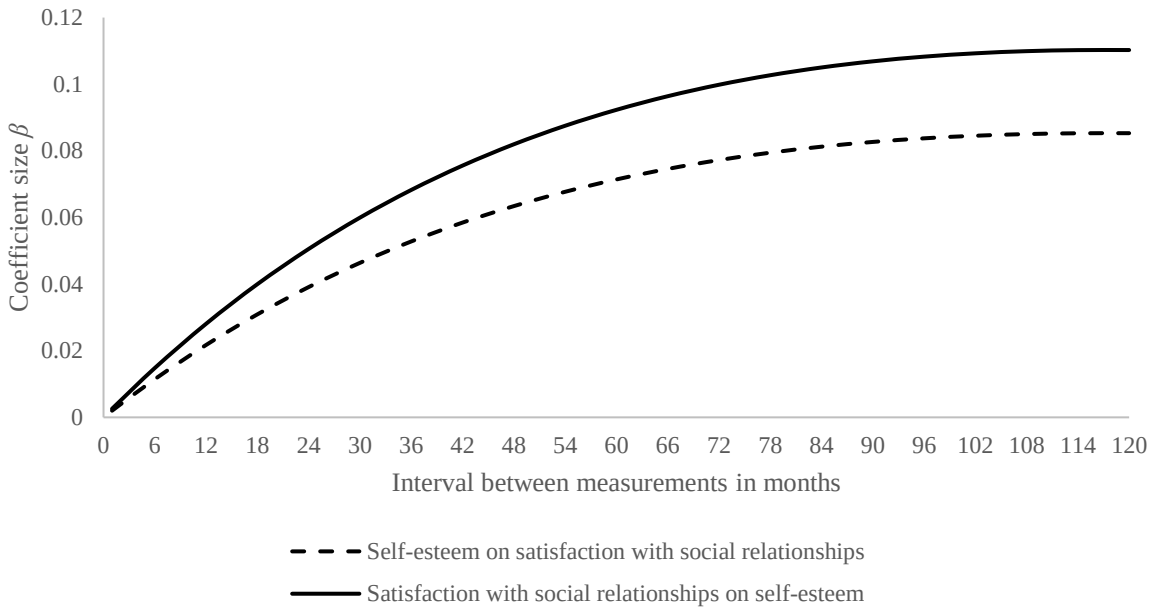
Note. *-2LL*(53,313) = 126,436.8. Missing data were handled using Full Information Maximum Likelihood estimation.
SE = self-esteem; SR = satisfaction with social relationships. All reported effects were significant at the .05 level. The left part of the table shows the continuous (i.e., time-independent) autoregressive and cross-lagged estimates in the drift matrix. The right part of the table reports the discrete (i.e., time-dependent) unstandardized (first estimate) and standardized (second estimate) effects at intervals of 1 month, and 1, 5, and 10 years.

Table S11. Continuous and discrete parameter estimates of self-esteem and satisfaction with social relationships of the RI-CT-SEM using only data with 2-year lags.

	Drift parameters			Discrete estimates			
Path	Estimate	Standard error	95% CI	1 month	1 year	5 years	10 years
			Autoregressive effects				
SE → SE	-.165	.063	[-.166770 , -.163230]	.850	.192	.007	.003
SR → SR	-.073	.029	[-.074207 , -.072593]	.931	.471	.049	.007
			Cross-lagged effects				
SE → SR	.035	.035	[.034023 , .035977]	.030	.093	.006	-.001
SR → SE	.053	.057	[.051022 , .054178]	.046	.146	.018	-.002

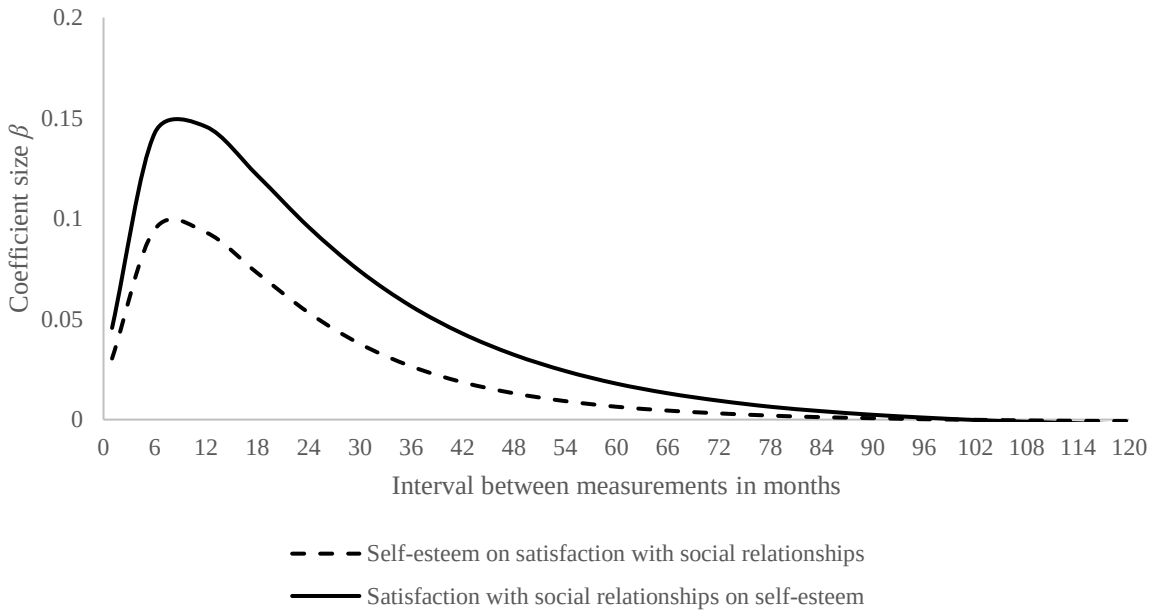
Note. *LL* = -62,380.9. Missing data were handled using Bayesian inference.
SE = self-esteem; SR = satisfaction with social relationships. All reported effects were significant at the .05 level. The left part of the table shows the continuous (i.e., time-independent) autoregressive and cross-lagged estimates in the drift matrix. The right part of the table reports the discrete (i.e., time-dependent) standardized effects at intervals of 1 month, and 1, 5, and 10 years.

Figure S7. Cross-lagged regression coefficients of self-esteem on satisfaction with social relationships and of satisfaction with social relationships on self-esteem of the CT-SEM using only data with 2-year intervals.



Note. The figure shows the discrete (time-specific) autoregressive estimates of self-esteem (dashed curve) and satisfaction with social relationships (solid curve) at intervals from 1 month to 10 years. The estimates are presented as standardized coefficient β.

Figure S8. Cross-lagged regression coefficients of self-esteem on satisfaction with social relationships and of satisfaction with social relationships on self-esteem of the RI-CT-SEM using only data with 2-year intervals.



Note. The figure shows the discrete (time-specific) autoregressive estimates of self-esteem (dashed curve) and satisfaction with social relationships (solid curve) at intervals from 1 month to 10 years. The estimates are presented as standardized coefficient β.

PAIRFAM Dataset

Finally, we fitted our CT-SEM and RI-CT-SEM models to self-esteem and satisfaction with social relationships data from the German Family Panel (PAIRFAM, release 10.0). Zero-order correlations of self-esteem and satisfaction with social relationships in the PAIRFAM dataset are provided in Table S12. To make the estimates of these analyses as directly comparable to the main analyses, we used the three self-esteem items as manifest indicators of a latent self-esteem variable, despite poor fit of the measurement model (χ^2 = 9587.62, p < .001, RMSEA = .381, CFI = .844). Each model was fitted twice: once with unconstrained cross-lagged parameters, and once with the cross-lagged parameters set to the coefficients of the main analyses. For both models, the fit of the constrained versus the unconstrained model differed significantly (Δ-2LL(1) = 166.1, p < .001 and AICΔ = 162.1, and Δ-2LL(1) = 165.0, p < .001 and AICΔ = 161.0 for the CT-SEM and the RI-CT-SEM respectively), indicating that the cross-lagged effect estimates were not equal to those of the main analyses. Therefore, we examined the estimates of the unconstrained CT-SEM (Table S13) and RI-CT-SEM model (Table S14).

For the CT-SEM, we found that there was a positive effect of satisfaction with social relationships on self-esteem and a negative effect of self-esteem on satisfaction with social relationships (Figure S9). That is, higher self-esteem predicted lower satisfaction with social relationships, but higher satisfaction with social relationships predicted higher self-esteem. With regards to the timing of the effect, the estimates show that the effects of self-esteem and satisfaction with social relationships peaked around intervals of 6 to 12 months.

Similar to the CT-SEM, we also found a positive effect of satisfaction with social relationships and a negative effect of self-esteem in the RI-CT-SEM. However, in this model the effects were decreasingly strong for all intervals measured, suggesting that the peak in strength was situated at intervals even shorter than were examined in the current study (i.e.,

shorter than 1 month; see Figure S10).

In conclusion, the CT-SEM model on self-esteem and romantic satisfaction and on data with 2-year intervals both showed a bidirectional positive effect. Moreover, this effect increased in magnitude across longer intervals. The RI-CT-SEM model for self-esteem and romantic satisfaction produced unexpected results, with strong bidirectional cross-lagged effects that peaked at intervals of 1 month or shorter. The RI-CT-SEM on data with 2-year intervals similarly showed this bidirectional effect, but found that it peaked across intervals of between 6 and 12 months. Furthermore, in the PAIRFAM dataset we found a bidirectional relation, with self-esteem predicting lower satisfaction with social relationships and higher satisfaction with social relationships predicting higher self-esteem at a later timepoint. The findings also differed in terms of the timescale, with effects reaching a peak in strength around intervals of 6 to 12 months in the CT-SEM, and in intervals of shorter than 1 month in the RI-CT-SEM. However, caution should be taken with interpreting the findings from the PAIRFAM data, as the fit of the measurement model of self-esteem was very poor.

Table S12. Zero-order correlations between self-esteem and satisfaction with social relationship in the PAIRFAM dataset for all study years.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
1. SE 2008																			
2. SE 2009	0.482																		
3. SE 2010	0.451	0.545																	
4. SE 2011	0.428	0.493	0.578																
5. SE 2012	0.457	0.488	0.551	0.613															
6. SE 2013	0.402	0.453	0.507	0.540	0.608														
7. SE 2014	0.406	0.446	0.484	0.551	0.603	0.612													
8. SE 2015	0.405	0.442	0.478	0.520	0.558	0.580	0.638												
9. SE 2016	0.404	0.434	0.480	0.522	0.571	0.562	0.615	0.635											
10. SE 2017	0.397	0.429	0.459	0.515	0.549	0.541	0.594	0.622	0.669										
11. SR 2008	0.225	0.186	0.155	0.150	0.162	0.144	0.179	0.139	0.135	0.124									
12. SR 2009	0.202	0.255	0.191	0.186	0.199	0.168	0.192	0.165	0.151	0.141	0.481								
13. SR 2010	0.184	0.200	0.239	0.203	0.198	0.180	0.203	0.156	0.165	0.146	0.442	0.531							
14. SR 2011	0.178	0.196	0.199	0.266	0.225	0.213	0.216	0.163	0.178	0.162	0.402	0.454	0.536						
15. SR 2012	0.168	0.188	0.192	0.215	0.259	0.221	0.217	0.191	0.179	0.178	0.369	0.409	0.478	0.539					
16. SR 2013	0.151	0.175	0.172	0.189	0.204	0.266	0.229	0.202	0.196	0.174	0.356	0.394	0.452	0.483	0.566				
17. SR 2014	0.182	0.195	0.171	0.213	0.224	0.221	0.279	0.234	0.224	0.207	0.347	0.384	0.431	0.461	0.503	0.546			
18. SR 2015	0.171	0.175	0.147	0.192	0.200	0.196	0.230	0.252	0.228	0.219	0.321	0.360	0.420	0.428	0.489	0.505	0.562		
19. SR 2016	0.145	0.167	0.174	0.184	0.195	0.206	0.221	0.222	0.259	0.217	0.334	0.344	0.399	0.410	0.451	0.465	0.513	0.568	
20. SR 2017	0.149	0.166	0.152	0.177	0.198	0.197	0.218	0.211	0.218	0.239	0.292	0.352	0.382	0.399	0.439	0.449	0.503	0.535	0.583

Note. SE = self-esteem; SR = satisfaction with social relationships.

Table S13. Continuous and discrete parameter estimates of self-esteem and satisfaction with social relationships of the CT-SEM in the PAIRFAM dataset.

	Drift parameters			Discrete estimates			
Path	Estimate	Standard error	95% CI	1 month	1 year	5 years	10 years
				Autoregressive effects			
SE → SE	-.372	.007	[-.371634 , -.371379]	.689/.689	.005/.005	< -.001/< -.001	< -.001/< -.001
SR → SR	-.077	.004	[-.077404 , -.077253]	.925/.925	.375/.375	.007/.007	< .001/< .001
				Cross-lagged effects			
SE → SR	-.070	.012	[-.069719 , -.069295]	-.056 /-.022	-.087/-.034	-.002/-.001	< -.001/< -.001
SR → SE	.026	.002	[.026023 , .026103]	.021/.053	.033/.083	.001/.002	< .001/< .001

Note. *-2LL*(265,541) = 738,617.4. Missing data were handled using Full Information Maximum Likelihood estimation.
SE = self-esteem; SR = satisfaction with social relationships. All reported effects were significant at the .05 level. The left part of the table shows the continuous (i.e., time-independent) autoregressive and cross-lagged estimates in the drift matrix. The right part of the table reports the discrete (i.e., time-dependent) unstandardized (first estimate) and standardized (second estimate) effects at intervals of 1 month, and 1, 5, and 10 years.

Table S14. Continuous and discrete parameter estimates of self-esteem and satisfaction with social relationships of the RI-CT-SEM in the PAIRFAM dataset.

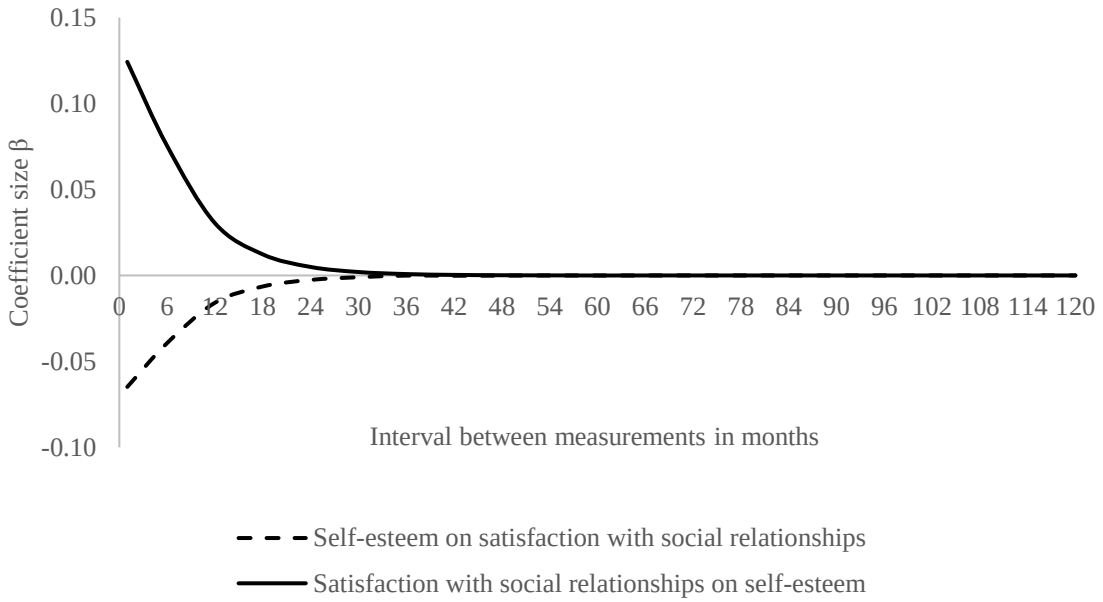
	Drift parameters			Discrete estimates			
Path	Estimate	Standard error	95% CI	1 month	1 year	5 years	10 years
				Autoregressive effects			
SE → SE	-1.667	.042	[-1.667576 , -1.666057]	.182/.182	-.003/-.003	< -.001/< -.001	< -.001/< -.001
SR → SR	-.125	.017	[-.124907 , -.124297]	.872/.872	.166/.166	< .001/< .001	< .001/< .001
				Cross-lagged effects			
SE → SR	-.721	.088	[-.722282 , -.719135]	-.322/-.065	-.079/-.016	< -.001/< .001	< -.001/< .001
SR → SE	.056	.007	[.055779 , .056026]	.025/.124	.006/.030	< .001/< .001	< .001/< .001

Note. *-2LL*(265,531) = 721,333.1. Missing data were handled using Full Information Maximum Likelihood estimation.
SE = self-esteem; SR = satisfaction with social relationships. All reported effects were significant at the .05 level. The left part of the table shows the continuous (i.e., time-independent) autoregressive and cross-lagged estimates in the drift matrix. The right part of the table reports the discrete (i.e., time-dependent) unstandardized (first estimate) and standardized (second estimate) effects at intervals of 1 month, and 1, 5, and 10 years.

Figure S9. Cross-lagged regression coefficients of self-esteem on satisfaction with social relationships and of satisfaction with social relationships on self-esteem of the CT-SEM in the PAIRFAM dataset.

Note. The figure shows the discrete (time-specific) autoregressive estimates of self-esteem (dashed curve) and satisfaction with social relationships (solid curve) at intervals from 1 month to 10 years. The estimates are presented as standardized coefficient β.

Figure S10. Cross-lagged regression coefficients of self-esteem on satisfaction with social relationships and of satisfaction with social relationships on self-esteem of the RI-CT-SEM in the PAIRFAM dataset.



Note. The figure shows the discrete (time-specific) autoregressive estimates of self-esteem (dashed curve) and satisfaction with social relationships (solid curve) at intervals from 1 month to 10 years. The estimates are presented as standardized coefficient β.

Discussion of the PAIRFAM Dataset Robustness Check

Because the poor measurement model fit of self-esteem in the PAIRFAM dataset may have impacted the estimation of the continuous time models, the findings from these models should be interpreted with caution. Therefore, we discuss the findings from these models here instead of in the main manuscript.

Before discussing the results of these models and their similarities with and differences from the primary analyses, it is worth nothing some difficulties we faced in our attempts to make as direct a comparison as possible between the PAIRFAM data and the LISS data. First, the PAIRFAM sample had a different age distribution than the LISS panel. On average, the participants in PAIRFAM were younger (26.3 years-old at Wave 1 compared to 45.9 in LISS) and the age range was smaller (16–39 years-old whereas the LISS panel represents the distribution in the general adult population). As a result, the PAIRFAM dataset primarily consists of young adults, often with young families, whereas the LISS panel contains individuals at more varied stages of life. As discussed earlier, it may be that more dynamic changes happen in earlier life, which may explain why our main findings differ from those using the PAIRFAM data. Second, to match the analytic strategy for our main analyses, the continuous time models fit to the PAIRFAM data also made use of manifest indicators of the latent self-esteem and satisfaction with social relationships variables. However, our initial test of the measurement model of self-esteem showed poor fit in the PAIRFAM data, suggesting that the three self-esteem items may not be good indicators of a latent self-esteem construct[8]. The lowered trustworthiness of the measurement of self-esteem in the PAIRFAM data is also reflected in the zero-order correlations, where autocorrelations of self-esteem

[8] We also fitted the CT-SEM and RI-CT-SEM models in the LISS dataset using only the three items that were included in the PAIRFAM data, as a check to see whether the unexpected results in the PAIRFAM dataset could be explained by the choice of these three items (See Table S18 and S19 and Figure S13 and S14 in the SOM). Findings from these analyses were similar to those of the main analyses, indicating that the discrepancy between the datasets could not be explained by the choice of the self-esteem items.

were lower than in the LISS dataset (generally between .55 and .60, as compared to between .65 and .75). The poor fit and the lower correlations suggest that, at least in combination, the self-esteem items may not adequately represent the self-esteem construct, which likely impacted the estimates produced by the models.

Keeping the poor measurement model for self-esteem in mind, the results of the PAIRFAM models suggest that there is a bidirectional association between self-esteem and satisfaction with social relationships in both the cross-lagged panel model and the random-intercept cross-lagged panel model. Similar to our primary analyses, we found that the effect of satisfaction with social relationships on self-esteem was positive, but the effect of self-esteem on satisfaction with social relationships was negative for both models using PAIRFAM data. Moreover, findings from these analyses also differed on the interval at which the effects appeared largest. Specifically, effects were greatest across intervals of 6 to 12 months in the cross-lagged panel model, and across intervals of shorter than 1 month in the random-intercept cross-lagged panel model. This is in contrast to our main analyses, where effects were greatest across ever-longer intervals or across intervals of 1 year, respectively.

3. Comparison to previous research.

Following a helpful suggestion from one of the reviewers, we decided to make a direct comparison between our findings and findings from previous research on self-esteem and relationship quality, including relationship satisfaction (see Table S1). We did this by comparing the *b* or β effect estimates of those prior studies to the discrete, *b* or β estimates from the current study for the same measurement interval. Comparisons were made by means of a bivariate correlation, and were made separately for: 1) the estimates for the effect of self-esteem on social relationships and 2) the estimates for the effect of social relationships on self-esteem. We examined the correlation of the estimates from previous studies with those from the cross-lagged panel continuous time model (i.e., CT-SEM) and with those from the random-intercept cross-lagged panel continuous time model (i.e., RI-CT-SEM).

The correlation estimates resulting from these comparisons suggest that the CT-SEM estimates are generally in line with estimates from previous studies, both for the effect of self-esteem on social relationships and for the effect of social relationships on self-esteem (Table S15). However, the correlation is quite modest for the effect of self-esteem on social relationships. Furthermore, the estimates from the RI-CT-SEM correlated negatively with findings from previous studies, indicating that the RI-CT-SEM findings did not correspond with previous research.

However, caution should be taken with the interpretation of these correlations, as noise exists due to, for instance, differences in study design, measurement instruments, and statistical models. For example, a random-intercept cross-lagged panel model was used in only one of the reported studies (Mund & Nestler, 2019). Second, and as is also already mentioned in the manuscript, while the meaning of the estimates from traditional models and continuous time models is the same, the way in which they are estimated is different. That is, traditional models base their estimates on only the information that is available for that

specific measurement interval, whereas continuous time models estimate a continuous association before transforming this coefficient in time interval-specific estimates.

Table S15. Correlations between the estimates from the reviewed studies and coefficients derived from the CT-SEM and RI-CT-SEM.

	CT-SEM estimate	RI-CT-SEM estimate
SE → SR estimate from previous studies	.179	-.217
SR → SE estimate from previous studies	.432	-.234

Note. SE = self-esteem; SR = social relationships.
For the purpose of comparison, we only included comparable effects; that is, we only included effects from previous studies that represented the effect of one timepoint on another.

4. Additional analyses

Table S16. Continuous and discrete parameter estimates of self-esteem and satisfaction with social relationships of the CT-SEM in the PAIRFAM dataset using a manifest self-esteem variable.

	Drift parameters			Discrete estimates			
Path	Estimate	Standard error	95% CI	1 month	1 year	5 years	10 years
				Autoregressive effects			
SE → SE	-.039	.003	[-.038698, -.038572]	.962/.962	.626/.626	.091/.091	.008/.008
SR → SR	-.092	.004	[-.092203, -.092049]	.912/.912	.328/.328	.001/.001	< -.001/< -.001
				Cross-lagged effects			
SE → SR	.008	.008	[.007562, .007843]	.007/.004	.043/.022	.013/.007	.001/.001
SR → SE	-.012	.001	[-.011952, -.011903]	-.011/-.022	-.066/-.128	-.020/-.039	-.002/-.004

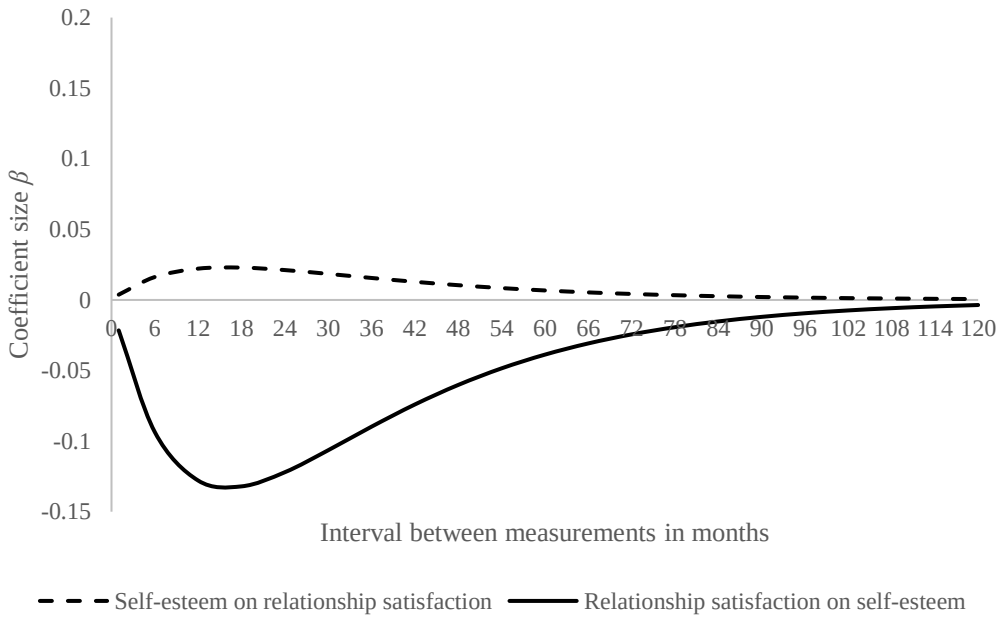
Note. *-2LL*(175,125) = 517,132.8. Missing data were handled using Full Information Maximum Likelihood estimation.
SE = self-esteem; SR = satisfaction with social relationships. All reported effects were significant at the .05 level. The left part of the table shows the continuous (i.e., time-independent) autoregressive and cross-lagged estimates in the drift matrix. The right part of the table reports the discrete (i.e., time-dependent) unstandardized (first estimate) and standardized (second estimate) effects at intervals of 1 month, and 1, 5, and 10 years.

Table S17. Continuous and discrete parameter estimates of self-esteem and satisfaction with social relationships of the RI-CT-SEM in the PAIRFAM dataset using a manifest self-esteem variable.

	Drift parameters			Discrete estimates			
Path	Estimate	Standard error	95% CI	1 month	1 year	5 years	10 years
				Autoregressive effects			
SE → SE	-.277	.030	[-.277777, -.276693]	.764/.764	.115/.115	.002/.002	< .001/< .001
SR → SR	-.160	.015	[-.160272, -.159715]	.858/.858	.269/.269	.005/.005	< .001/< .001
				Cross-lagged effects			
SE → SR	-.337	.036	[-.337799, -.336501]	-.272/-.097	-.441/-.158	-.009/-.003	< -.001/< -.001
SR → SE	-.044	.005	[-.044443, -.044255]	-.036/-.100	-.058/-.162	-.001/-.003	< -.001/< -.001

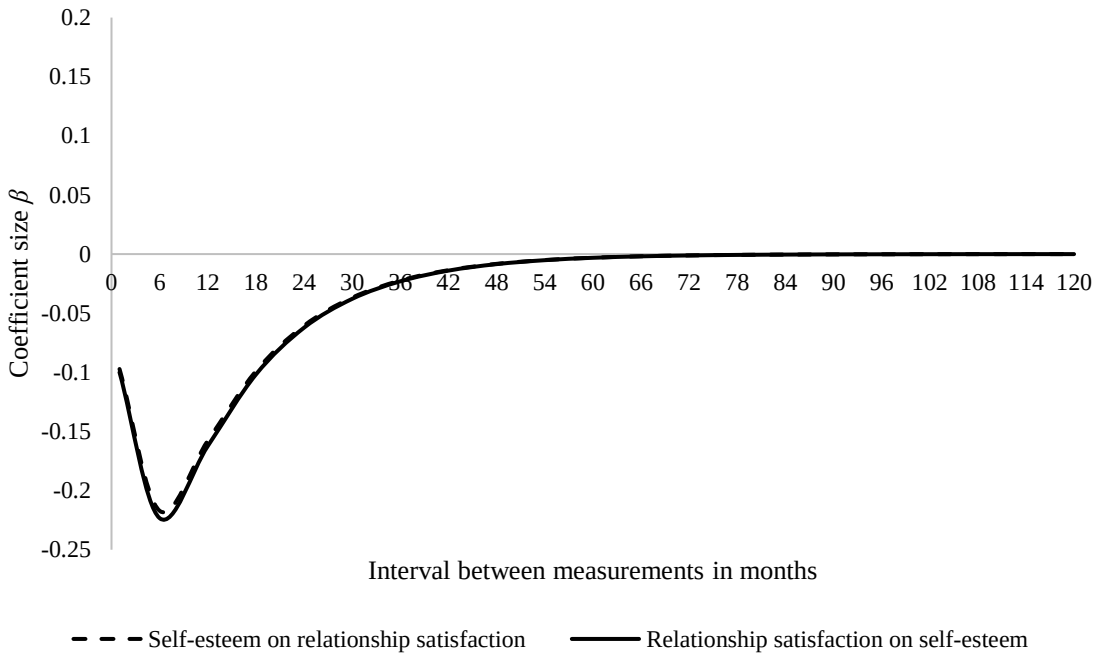
Note. *-2LL*(132,662) =385,789.5. Missing data were handled using Full Information Maximum Likelihood estimation.
SE = self-esteem; SR = satisfaction with social relationships. All reported effects were significant at the .05 level. The left part of the table shows the continuous (i.e., time-independent) autoregressive and cross-lagged estimates in the drift matrix. The right part of the table reports the discrete (i.e., time-dependent) unstandardized (first estimate) and standardized (second estimate) effects at intervals of 1 month, and 1, 5, and 10 years.

Figure S11. Cross-lagged regression coefficients of self-esteem on satisfaction with social relationships and of satisfaction with social relationships on self-esteem of the CT-SEM in the PAIRFAM dataset using a manifest self-esteem variable.



Note. The figure shows the discrete (time-specific) autoregressive estimates of self-esteem (dashed curve) and satisfaction with social relationships (solid curve) at intervals from 1 month to 10 years. The estimates are presented as standardized coefficient β.

Figure S12. Cross-lagged regression coefficients of self-esteem on satisfaction with social relationships and of satisfaction with social relationships on self-esteem of the RI-CT-SEM in the PAIRFAM dataset using a manifest self-esteem variable.



Note. The figure shows the discrete (time-specific) autoregressive estimates of self-esteem (dashed curve) and satisfaction with social relationships (solid curve) at intervals from 1 month to 10 years. The estimates are presented as standardized coefficient β.

Table S18. Continuous and discrete parameter estimates of self-esteem and satisfaction with social relationships of the CT-SEM using a 3-item self-esteem measure.

	Drift parameters			Discrete estimates			
Path	Estimate	Standard error	95% CI	1 month	1 year	5 years	10 years
				Autoregressive effects			
SE → SE	-.014	< .001	[-.014049, -.014035]	.986/.986	.845/.845	.436/.436	.196/.196
SR → SR	-.006	< .001	[-.006073, -.006064]	.994/.994	.930/.930	.701/.701	.497/.497
				Cross-lagged effects			
SE → SR	.002	< .001	[.001345, .001357]	.001/.001	.014/.014	.045/.044	.051/.049
SR → SE	.004	< .001	[.004105, .004115]	.004/.004	.044/.045	.137/.141	.155/.160

Note. *-2LL*(175,125) = 517,132.8. Missing data were handled using Full Information Maximum Likelihood estimation.
SE = self-esteem; SR = satisfaction with social relationships. All reported effects were significant at the .05 level. The left part of the table shows the continuous (i.e., time-independent) autoregressive and cross-lagged estimates in the drift matrix. The right part of the table reports the discrete (i.e., time-dependent) unstandardized (first estimate) and standardized (second estimate) effects at intervals of 1 month, and 1, 5, and 10 years.

Table S19. Continuous and discrete parameter estimates of self-esteem and satisfaction with social relationships of the RI-CT-SEM using a 3-item self-esteem measure.

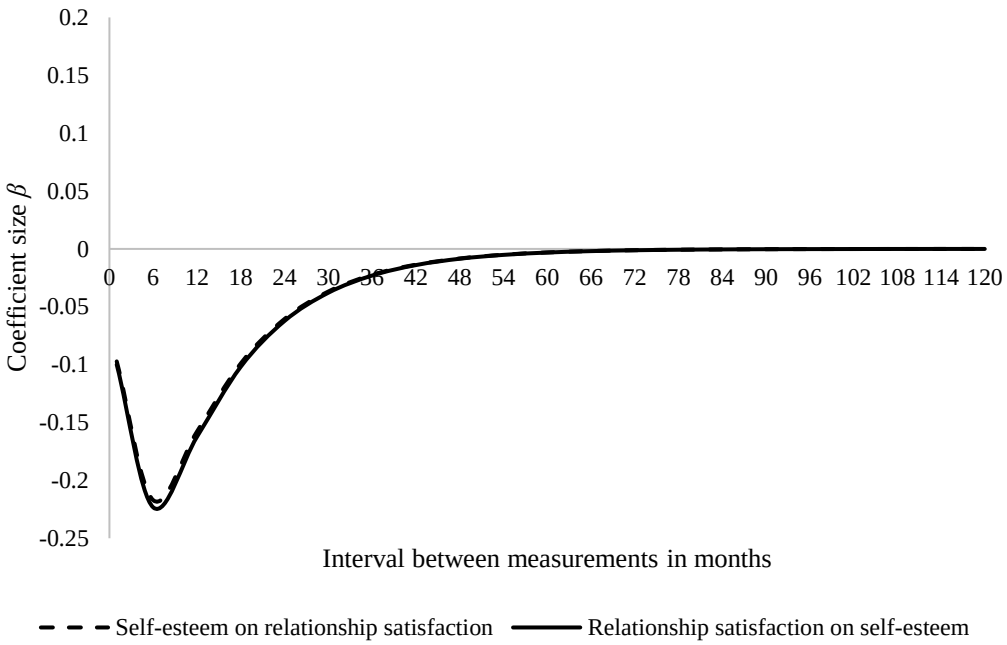
	Drift parameters			Discrete estimates			
Path	Estimate	Standard error	95% CI	1 month	1 year	5 years	10 years
				Autoregressive effects			
SE → SE	-.111	.005	[-.110952, -.110792]	.895/.895	.271/.271	.004/.004	< .001/< .001
SR → SR	-.054	.004	[-.053957, -.053836]	.948/.948	.532/.532	.048/.048	.002/.002
				Cross-lagged effects			
SE → SR	.012	.004	[.011920, .012044]	.011/.011	.055/.055	.009/.009	< .001/< .001
SR → SE	.022	.003	[.021823, .021931]	.020/.020	.100/.100	.017/.017	.001/.001

Note. *-2LL*(175,115) = 509,185.9. Missing data were handled using Full Information Maximum Likelihood estimation.
SE = self-esteem; SR = satisfaction with social relationships. All reported effects were significant at the .05 level. The left part of the table shows the continuous (i.e., time-independent) autoregressive and cross-lagged estimates in the drift matrix. The right part of the table reports the discrete (i.e., time-dependent) unstandardized (first estimate) and standardized (second estimate) effects at intervals of 1 month, and 1, 5, and 10 years.

Figure S13. Cross-lagged regression coefficients of self-esteem on satisfaction with social relationships and of satisfaction with social relationships on self-esteem of the CT-SEM using a 3-item self-esteem measure.

Note. The figure shows the discrete (time-specific) autoregressive estimates of self-esteem (dashed curve) and satisfaction with social relationships (solid curve) at intervals from 1 month to 10 years. The estimates are presented as standardized coefficient β.

Figure S14. Cross-lagged regression coefficients of self-esteem on satisfaction with social relationships and of satisfaction with social relationships on self-esteem of the RI-CT-SEM using a 3-item self-esteem measure.



Note. The figure shows the discrete (time-specific) autoregressive estimates of self-esteem (dashed curve) and satisfaction with social relationships (solid curve) at intervals from 1 month to 10 years. The estimates are presented as standardized coefficient β.

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