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Self-Esteem and Satisfaction With Social Relationships Across Time

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Research on the longitudinal association between self-esteem and satisfaction with social relationships has 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 (i.e., CT-SEM) to examine cross-lagged relations between the constructs, 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 (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 1 year, with smaller effect sizes at both shorter and longer intervals. In addition, 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

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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 et al., 2012; Cohen, 2004). The link between self-esteem and relationship outcomes has been of particular interest to social scientists (Marshall et al., 2014; Sturaro et al., 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 pro-

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The present study is 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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vide 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 et al., 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 et al., 1995), and terror management theory (TMT; Greenberg et al., 1986; Solomon et al., 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 proposes that individuals express their self-esteem through their social behaviors, which others in turn then observe and react to (Swann et al., 2007; Zeigler-Hill et al., 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 et al., 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 et al., 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 nine 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 nonclinical adolescent and adult samples (see Supplemental Table S1 in the online supplemental materials 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 et al., 2008; Erol & Orth, 2014; Schaffhuser et al., 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 vs. satisfaction more specifically) was operationalized, or which specific relationships were examined (i.e., relationship with romantic partner vs. 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 three 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 et al., 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 et al., 2003), but also considerable fluctuations within individuals across time (e.g., Donnellan et al., 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 et al., 2002; Sarason et al., 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 vs. state fluctuations within persons) and the time intervals between measurements.

The emphasis on selecting appropriate intervals between measurement occasions 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 et al., 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 et al., 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 et al., 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 codevelopment of self-esteem between heterosexual romantic partners, the researchers found that changes in self-esteem of husbands predicted changes in wives' self-esteem (Wagner et al., 2018). As in the study by Mueller et al. (2018), these effects appeared strongest across intervals of 2 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 Models (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 et al., 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 et al., 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 et al., 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.

The 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 Supplemental Table S1 in the online supplemental materials) 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 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 nonreligious 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 peri-

odically added to the sample, resulting in a total of 14,741 respondents, 7,962 (54%) of whom were female (see Supplemental Table S5 of the online supplemental materials for a full overview of the descriptive statistics such as the age and gender distribution for each year). Because of 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 Supplemental Table S2 of the online supplemental materials for a detailed description of the longitudinal design). Ethical approval is required by the *Wet Medisch-Wetenschappelijk Onderzoek* (Medical Research Involving Human Subjects Act; for more information on the WMO law, see https://wetten.overheid.nl/, entry BWBR0009408), although research institutions may require ethical approval for other types of research as well. The LISS panel is not subject to any such requirements, but instead follows the terms stated in the general law for the regulation of data protection (AVG; see https://avgb.nl/), and two principles in particular. First, participants provide informed consent for participation and can withdraw this consent at any time during the study. Second, scientific research is exempt from the prohibition on processing of personal data. Therefore, no ethical approval was obtained for the LISS panel data used in the present study.[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 et al., 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. S9 of the online supplemental materials), 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 et al., 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 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

[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 et al., 2019; Gnambs et al., 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.

[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/.

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 (Supplemental Table S5 in the online supplemental materials, 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. Supplemental Figure S1 in the online supplemental materials 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., 1 month, 6 months, 1 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 et al., 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 10 RSE items to three parcels (Little et al., 2013; for item assignment see p. S9 of the online supplemental materials). 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 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 online supplemental materials, pp. S9–S10 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).

[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 & 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, 2015). The sign of the drift parameters for the cross-lagged effects depends on the direction of the effect.

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. Because of several statistical and practical reasons, our final analysis plan deviated from the one outlined in our registration (https://osf.io/ngv3y/).[4] Table 1 shows a complete overview of the deviations from our preregistration and the reasons for these deviations.

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, 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. 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 attrition. In the PAIRFAM study, self-esteem was measured with three items that were based on the RSE (an example item is "I like myself just the way I am," other items are provided on p. S12 of the online supplemental materials) 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 CTM using the construct, we report the measurement invariance tests and further PAIRFAM CTM analyses in the online supplemental materials (see p. S17 for the measurement invariance tests and pp. S32–S40 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 to 7.34 (on a scale from 1 to 10), and the standard deviations from 1.53 to 1.69 (see Supplemental Table S5 of the online supplemental materials for a full overview of the descriptive statistics for each year). This suggests that, on average, participants reported relatively high (i.e., above the midpoint 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 Supplemental Table S6 in the online supplemental materials), indicating a small to medium positive relation between the two constructs.

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 2 shows the estimated drift matrix. Because of 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

[4] Table 1 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 preregistration 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.

[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/.

[6] This is in contrast to the measurement checks reported in a PAIRFAM Technical Paper by Sonntag et al. (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 Supplemental Table S3 in the online supplemental materials 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.

Table 1
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 was 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 to 2015	Use of data from the LISS panel from 2008 to 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 latent variable for self-esteem in our CTM	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 across 10 waves (i.e., for ten items instead of three parcels). This approach was extended to the CFA test for consistency.

Note. LISS = Longitudinal Internet Studies of the Social Sciences; CFA = confirmatory factor analysis; CTM = continuous time models.

these effects, they have to be transformed into discrete coefficients.

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 10 years. Figure 1 shows a graphical representation of the probed, discrete autoregressive effects. Table 2 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 1 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, $\Delta -2LL(1) = 173.9$, $p < .001$, $\Delta AIC = 171.9$. This difference was particularly visible across longer intervals (e.g., 10 years).

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 10 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],

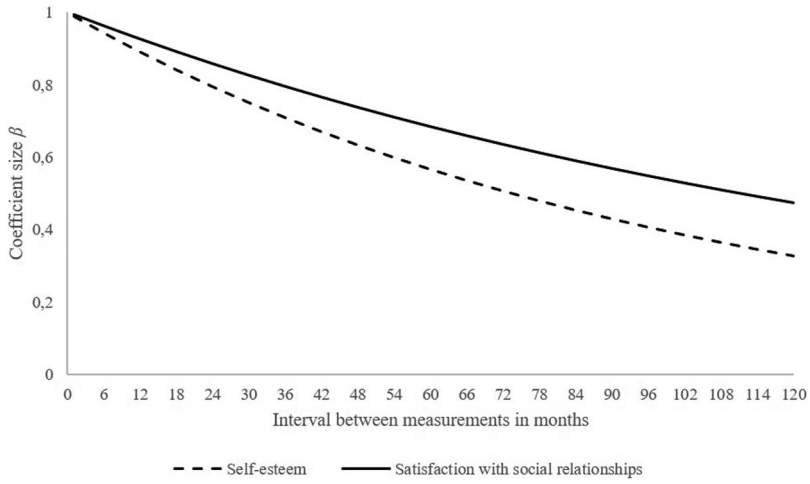
Table 2
Continuous and Discrete Parameter Estimates of Self-Esteem and Satisfaction With Social Relationships of the Continuous Time Structural Equation Models

	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. CI = confidence interval; 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 1

Autoregressive Regression Coefficients for Self-Esteem and Satisfaction With Social Relationships of the Continuous Time Structural Equation Models (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.

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.

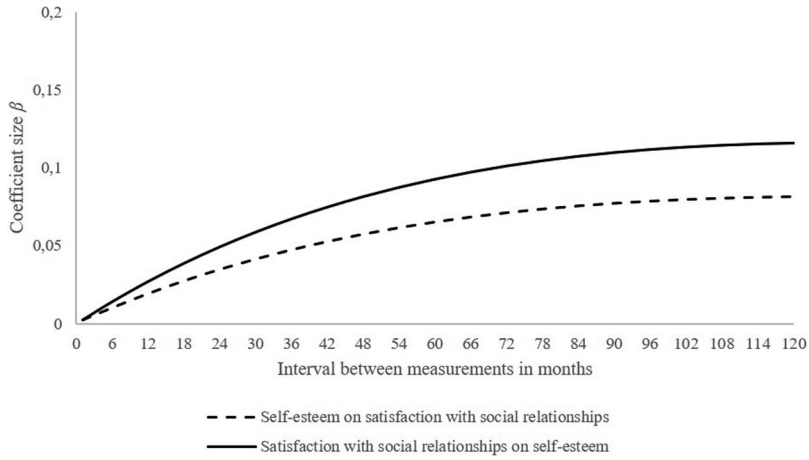
RI-CT-SEM

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

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 Continuous Time Structural Equation Models (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.

Table 3
Continuous and Discrete Parameter Estimates of Self-Esteem and Satisfaction With Social Relationships of the Random-Intercept Continuous Time Structural Equation Models

Path	Drift parameters			Discrete estimates			
	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. CI = confidence interval; 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.

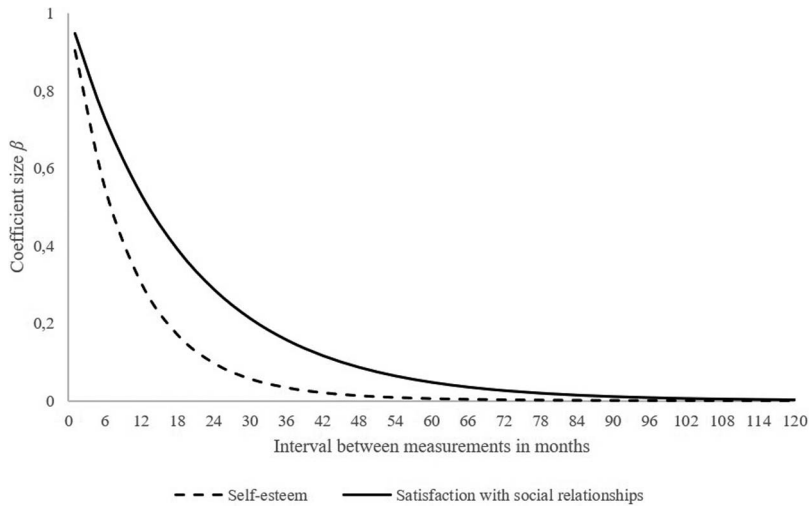
for stable interindividual differences at the first time point, and thus represents changes in people's temporary deviations from their person-specific trait levels. Table 3 shows the estimated drift parameters of the RI-CT-SEM. As in the CT-SEM, the drift matrix describes the continuous relations between 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.

Stability of Self-Esteem and Satisfaction With Social Relationships

We transformed the drift parameters into discrete coefficients for time intervals from 1 month to 10 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 3 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 3, 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 10 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, $\Delta\text{-}2LL(1) = 881.9$, $p < .001$,

Figure 3
Autoregressive Regression Coefficients of Self-Esteem and Satisfaction With Social Relationships of the random-intercept Continuous Time Structural Equation Models (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.

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.

Cross-Lagged Effects of Self-Esteem and Satisfaction With Social Relationships

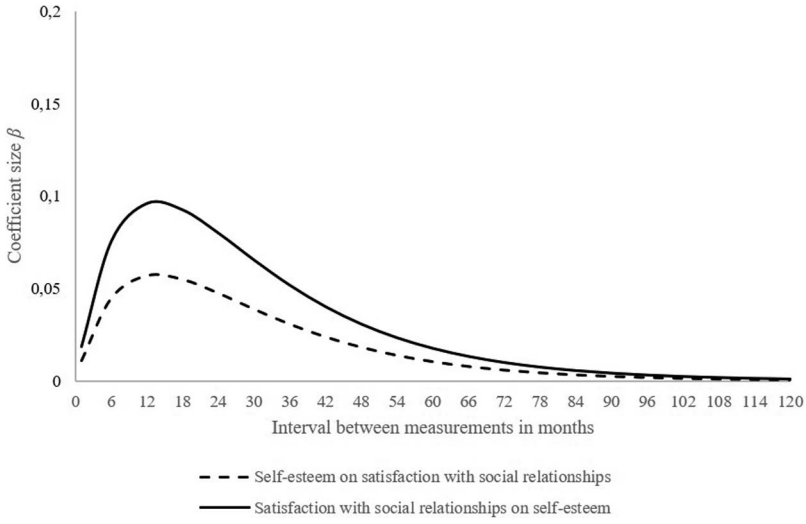
We next examined the within-person association between self-esteem and satisfaction with social relationships by probing the continuous cross-lagged effects for intervals between one month and 10 years. The effect of satisfaction with social relationships on self-esteem was descriptively larger (b_{range} = [.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 1 year.

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-

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 random-intercept Continuous Time Structural Equation Models (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.

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 toward 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 pp. S20–S38 of the online supplemental materials.

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 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 Supplemental Table S1 in the online supplemental materials). We found a positive correlation, indicating that our estimates were similar to those found in previous work (see Supplemental Table S15 in the online supplemental materials).

One limitation of the cross-lagged panel model is that the results are likely to be confounded with preexisting 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 (Supplemental Table S1 in the online supplemental materials) to examine correspondence between this study

[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 Supplemental Tables S16 and S17 and Supplemental Figures S11 and S12 in the online supplemental materials). Findings from these models were highly similar to the ones reported here and in the online supplemental materials. 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.

and previous studies, and we found a negative correlation (see Supplemental Table S15 in the online supplemental materials). 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) 1 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., self-broadcasting perspective). 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 et al., 2001), as well as satisfaction with social relationships (Malouff et al., 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 toward 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 1 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, e.g., Supplemental Table S1 in the online supplemental materials). Finally, although the meaning of the autoregressive and cross-lagged effects is the same in the continuous time 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 metaresearch 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., 5 years) may be most suited to investigate cumulative trait effects. To increase their ability to detect psychological effects of more fluc-

tuating 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). Because of 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 CTMs 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., $\beta = .238$ and $\beta = .746$ for self-esteem and satisfaction with social relationships for a 1-month interval) and high cross-lagged coefficients (i.e., $\beta = .538$ and $\beta = .330$, 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 Supplemental Table S7 in the online supplemental materials). 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 data sets, 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 CTM. The findings from the PAIRFAM model and differences between the PAIRFAM and LISS dataset are discussed in greater detail on pp. S32–S40 of the online supplemental materials.

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 data sets 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 ($\beta = .326$) and the effect of satisfaction with social relationships ($\beta = .473$). 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 6 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., $\beta = .302$ and $\beta = .530$ for a 1-year interval for self-esteem and satisfaction with social relationships, respectively) and nearly nonexistent for longer intervals (e.g., $\beta < .001$ and $\beta = .002$ 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 and satisfaction with social relationships return 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 10-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 et al., 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 underestimate. 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 CTM we ran (Voelkle et al., 2012), we could not test this assumption. However, because of 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. Although 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 et al., 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 toward 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 et al., 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 10 years. We found evidence for bidirectional positive effects. In addition, 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 effects were largest at 1 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., 1 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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