# MEASURING TEMPORAL SELF-CONTINUITY OVER THE LIFE SPAN

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When people perceive their past, present, and future self as one, rather than as separate entities, they are said to have self-continuity. This concept has been linked to a reduced tendency to devalue future rewards relative to present ones (also known as temporal discounting). The three papers in this volume seek to better understand self-continuity, its relation to temporal discounting, and how it might change over the life span.

Because time perception has been defined in multiple ways by multiple researchers, Chapter 1 assessed distinctiveness among five widely-used time perception measures administered to a community life span sample. Four principal components emerged, suggesting distinction among all but two of the measures, with self-continuity forming a separate factor that was positively associated with age.

Previously, self-continuity had only been studied in binary present-future comparisons. It remained unknown whether people perceive the transition from their present self to future self as gradual. In an undergraduate student sample, Chapter 2 examined these questions using both explicit (self-report) and implicit measures of self-continuity (me/not me trait-rating task). For comparison, temporal discounting was assessed as well. Both the explicit and implicit self-continuity tasks yielded similar functions, resembling the gradual trajectory seen in temporal discounting. Additionally, links between individual response times from the implicit self-continuity task and individual discounting functions raise the possibility that self-continuity, like

temporal discounting, may be driven by a dual systems process.

Because self-continuity has received little attention in aging research, Chapter 3 examined age differences in self-continuity trajectories for both past and future. Older adults reported greater explicit and implicit self-continuity as compared to younger adults, especially for increasingly distant time points. These findings raise important questions as to whether age differences in self-continuity translate into age differences in decision scenarios such as temporal discounting, and whether adults may select (and benefit from) differing decision strategies depending on their position in the life span. Chapter 4 provides a synthesis and proposes directions for future research on self-continuity, its relation to temporal discounting, and possible mechanisms underlying age differences.

# BIOGRAPHICAL SKETCH

Joshua Rutt studies the extent to which people perceive "sameness" in themselves over time—past, present, and future—including how this changes with age and how it affects decisions that require trade-offs between present and future. He has an M.S. in Psychology from Villanova University, and a B.A. in psychology from the University of Michigan.

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# LIST OF ABBREVIATIONS

TSC = Temporal Self-Continuity

FTP = Future Time Perspective Scale (Lang & Carstensen, 1996)

ZTPI = Zimbardo Time Perspective Inventory (Zimbardo & Boyd, 1999)

RT = Reaction Time in me/not me task

LIST OF SYMBOLS

$k$ = Hyperbolic discounting parameter from Equation 2, Chapter 2

$k$ = Exponential discounting parameter from Equation 2, Chapter 2

$\delta$ = Delta parameter from Equations 3 and 4, Chapter 2

$\beta$ = Beta parameter from Equations 3 and 4, Chapter 2

$\omega$ = Omega parameter from Equation 3, Chapter 2

$\mu$ = Mu parameter from Equation 4, Chapter 2

$\sigma$ = Sigma parameter from Equation 4, Chapter 2

$\pi$ = pi from Equation 4, Chapter 2

## PREFACE

Because humans can imagine events that have not yet happened, have already happened, or are happening presently but in a distant place, we can represent things that are not "real" to our physical senses. Despite the ability to transcend these psychological distances (Trope & Liberman, 2010), humans still seem to have difficulty bridging the gap between now and later (e.g., procrastination; Ariely & Wertenbroch, 2002), or between self and other (e.g., projection biases; Loewenstein, O'Donoghue, & Rabin, 2003). Such gaps even apply to our very own selves over time. We can see our present selves in the mirror and imagine our future selves 10 years from now, but the extent to which we can construe these two entities as one, rather than two separate people, may have implications for how we make decisions involving trade-offs between present and future.

This dissertation focuses on temporal self-continuity (TSC). This concept has attracted increasing interest, but it is still poorly-understood—both in terms of what it is and in terms of its practical implications. First, it is not clear how TSC relates to other aspects of time perspective that have been considered in the literature; is it really a distinct concept?

Second, prior research has focused on dichotomous comparisons between the present and distant future selves and it is not clear whether the transition to present and future is gradual or stepwise—also, if perceptions of TSC do change gradually, do they slip into the future in a linear trajectory, or do they show distortions similar to the Weber-Fechner Law that holds true for auditory or visual perception (Fechner, 1860; Weber, 1850) as well as perceptions of temporal distances (Zauberman, Kim, Malkoc, & Bettman, 2009)?

Third, the existing literature on TSC has focused on the future, but it is important to understand whether characteristics and patterns of our future selves are mirrored in the way we conceive of ourselves in the past. According to one prominent account, anticipated future events may be simulated based on one's episodic memory about the past. Specifically, the constructive episodic simulation hypothesis (Schacter & Addis, 2007) assumes that episodic memory is constructive in that episodes are remembered by reconstructing their key elements, and thus episodic memory is well-equipped for a similar constructive process in episodic future-thought. Multiple studies have found strong association between remembered past events and anticipated future events (Addis, Wong, & Schacter, 2008), supporting this hypothesis. However, this mirroring of the future in the past has not been studied in the context of perceived TSC.

Fourth, there is some evidence that TSC may vary across individuals, but little is known about the sources of such variations. Chronological age was shown to be associated with several other aspects of time perception and there is theoretical reason to suspect that it may influence TSC as well (Hershfield, 2011). TSC is inherent in autobiographical thought and narratives (Hooker, 2002), but also subject to age-related shifts in cognitive processing and resources (Bluck & Alea, 2008). Consistent with this view, Gaesser, Sacchetti, Addis, and Schacter (2011) found age-related declines in episodic details in both an autobiographical interview task and in an imagination task about probable future events. However, it is not clear whether decrements in episodic detail would also weaken perceived TSC. Theoretical support for age differences in TSC also comes from socioemotional selectivity theory (SST, Carstensen, 2006; Carstensen, Isaacowitz, & Charles, 1999) which suggests that age-associated limitations in future time horizons lead younger adults to pursue future oriented goals such as information acquisition whereas older adults focus on emotional well-being in the present moment. Thus, one might expect older adults to live in an extended present. Based on such considerations, the role of chronological age in TSC will be a major focus in this dissertation. However, I will also consider a range of other potential covariates including personality traits, which have been linked to concepts such as foresight and impulsivity, and cognitive abilities, which have been associated with self-control and the ability to mentally simulate future events.

Finally, I begin to explore the practical implications of variations in TSC. Specifically, I examine potential links between TSC and temporal discounting, the tendency to discount the value of future outcomes with increasing distance from the present (Ainslie, 1975, Frederick, Loewenstein, & O'Donoghue, 2002, Samuelson, 1937). This phenomenon is most commonly studied with regard to monetary outcomes but was found to extend to discounting of consumables and health states as well (Frederick et al., 2002).

The three chapters in this volume successively address some of these key limitations in our understanding of TSC. Specifically, Chapter 1 establishes TSC as an independent construct relative to existing conceptualizations of time perception and thus provides the basis for further investigation. This study also provides initial evidence that TSC may differ by age.

Chapter 2 examines whether TSC shows a gradual function over time (as opposed to a sudden or stepwise transition from present to future) and explores a range of theoretically implicated approaches to modeling such trajectories. This study contrasts patterns of TSC for explicit versus implicit measures. It also examines convergence between trajectories of TSC and temporal discounting.

Chapter 3 extends these findings to examine age differences in TSC within a community-based life span sample, assesses TSC patterns across both the past and the future, and systematically considers a range of potential covariates.

Chapter 4, finally, compares and contrasts findings across studies, identifies limitations and open questions, and proposes an agenda for future research.

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CHAPTER 1

# AGE PATTERNS IN MENTAL REPRESENTATIONS OF TIME: UNDERLYING CONSTRUCTS AND RELEVANT COVARIATES

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Abstract

*Background/Study Context*: Research suggests that mental representations of time encompass multiple distinct aspects that vary with age, but prior studies rarely assessed more than one aspect of time perception and did not systematically consider relevant covariates. This lack of integration across studies hampers theory building and limits a deeper understanding of underlying constructs.

*Methods*: Five widely used and conceptually distinct measures of time perception (i.e., perceived life position, global future horizons, future orientation and planning, self-continuity, and the temporal extension of episodic future thought) were administered to a demographically stratified adult life-span sample. Theoretically implicated covariates including cognition, current affect, personality, and subjective health were also assessed.

*Results*: Principle component analyses suggested a four-component solution. Perceived life position and global future horizons formed a single component reflecting subjective life span; the remaining measures each constituted separate components. The life span component and episodic future thought were negatively associated with age, self-continuity was positively associated with age, and future orientation did not vary by age. Among the covariates, mental and physical health showed the most pronounced associations with time perceptions, but the direction of effects varied across components.

*Conclusion*: Findings suggest that mental representations of time encompass multiple components that show distinct age patterns and associations with covariates. Implications for theory building and practical applications are discussed.

*Keywords:* Aging, time perception, future time perspective, time horizons, self-continuity, subjective health, self-rated mental and physical health, emotion.

## Introduction

A growing body of research indicates that the way people perceive and structure their time and envision their future varies systematically across the adult life span (for reviews see Löckenhoff, 2011; McFadden & Atchley, 2001). These age-related shifts in mental representations of time have been linked to consequential outcomes including social partner preferences (Lang & Carstensen, 2002), financial decisions (Löckenhoff, O'Donoghue, & Dunning, 2011), and medical choices (Löckenhoff & Carstensen, 2007; Löckenhoff et al., 2013). However, our current understanding of such effects is limited in several respects. First, time perception has been defined and assessed in multiple ways. Because most studies selectively examine one of these aspects at a time, it is not clear to what extent age patterns in different measures of time perception are related to each other. This hampers integration across studies because age differences in the same underlying concept may be assessed with different measures and reported in disjoint streams of literature. As a result, researchers may be replicating each other's efforts without knowing it. Second, because explanatory frameworks have disproportionately focused on age-related limitations in actuarial life expectancy (e.g., Carstensen, 2006; Hancock & Rausch, 2010), the role of other theoretically implicated covariates is poorly understood. This limits theory building because it is not clear whether any observed age differences reflect age per se or age-associated changes in other variables.

In response to these open questions, the present study examined age differences in five widely used and conceptually distinct measures of time perception in an adult life-span sample. We also assessed a range of theoretically implicated covariates. To put our research into context, we now review prior evidence for age-related shifts in different aspects of time perception and consider relevant explanatory factors. We then present the rationale and hypotheses for the present study.

**Age Differences in Mental Representations of Time**

The existing literature on age differences in time perception can be classified broadly into four categories: global time horizons pertaining to the life span as a whole, general thoughts about the future and one's future self, construals of concrete future events, and the estimation of actual time intervals (Löckenhoff, 2011). Because the present study seeks to examine age differences in *mental representations* of time, we focus on the first three of these categories (for reviews of age differences in estimations of actual time, see Block, Zakay, & Hancock, 1998; McAuley, Jones, Holub, Johnston, & Miller, 2006).[1]

**Global time horizons** refer to a person's general perspective on their position within the entirety of their psychological past, present, and future—constituting their "life space" (Lewin, 1951, p. 246). At the most basic level, this includes the representation of one's perceived location in the life span, which is typically assessed using a straight line anchored by the terms 'birth' and 'death' on which participants are asked to mark their current standing (Cottle & Pleck, 1969; Hancock, 2010). Not surprisingly, aging is linked with a tendency to perceive oneself as farther advanced on this continuum; although, relative to their actuarial life expectancy, older adults tend to underestimate their life position to a greater extent (Hancock, 2010; Kleinspehn-Ammerlahn, Kotter-Grühn, & Smith, 2008).

A complementary approach to conceptualizing global time horizons has emphasized the extent to which individuals experience time as limited versus expansive (Carstensen, 2006; Carstensen, Isaacowitz, & Charles, 1999). This perspective not only considers perceptions of lifetime per se, but also captures the implications of expanded versus limited time horizons for future opportunities and goal pursuit (Carstensen & Lang, 1996). Consistent with age patterns in life position, older as compared to younger adults were found to perceive their global time horizons and future possibilities as more limited (Carstensen, 2006; Carstensen et al., 1999; Fung, Carstensen, & Lutz, 1999; Fung, Lai, & Ng, 2001).

Taken together, the literature suggests that chronological age is associated with both a more advanced life position and more limited future horizons, but the association between these concepts has yet to be systematically examined.

**General future-directed thought** differs from global time horizons in that it captures broad cognitive frames of thinking about the future (relative to the present or the past) without any references to specific endpoints or concrete future events. Specifically, Zimbardo and Boyd (1999) conceptualize future orientation as the degree to which individuals emphasize forward planning and the achievement of future goals. Although future orientation is considered as a learned tendency, once established, it is thought to remain relatively stable over time (Zimbardo & Boyd, 1999). To date, research on adult age differences in future orientation is equivocal: Data from a U.S. student sample and a French sample of older adults suggest that future orientation increases with age (Gana, Klein, Saada, & Trouillet, 2013; Zimbardo & Boyd, 1999), data from a U.S. community sample indicate a curvilinear age pattern with highest future orientation scores in midlife (Guthrie, Lessl, Ochi, & Ward, 2013), and data from a U.S. patient sample reveal no age effects (Laguette et al., 2013).

Beyond generalized measures of future orientation, one specific aspect of future thought that has garnered recent interest is self-continuity, defined as the degree to which individuals perceive themselves as similar to their future self. This concept has been explored *implicitly* by asking people to indicate whether or not a series of trait adjectives describes them at present and in the future (e.g., Wakslak, Nussbaum, Liberman, & Trope, 2008, Study 4; Ersner-Hershfield, Garton, Ballard, Samanez-Larkin, & Knutson, 2009; Ersner-Hershfield, Wimmer, & Knutson, 2009, Study 2; D'Argembeau et al., 2010) and *explicitly* by asking participants to indicate the degree of overlap between their current and future selves on a visual scale of overlapping circles (Ersner-Hershfield, Garton, et al., 2009). So far, research on age differences in future self-continuity is limited, with one study suggesting that older age is associated with greater perceived continuity with one's future self (Hershfield, 2011) and another suggesting that when asked to generate future selves, older adults create selves that are temporally closer than those of their younger counterparts (Chessell, Rathbone, Souchay, Charlesworth, & Moulin, 2014).

In summary, research on age differences in future directed thought is very limited, findings are inconsistent, and associations between future orientation (as defined by Zimbardo & Boyd, 1999) and continuity with one's future self remain to be explored.

**Episodic future thought,** finally, refers to people's construal of concrete future events. Typical scenarios ask participants to list a number of specific and personal events that they are likely to encounter in the future and to indicate at which point in time they expect each event to occur (Fellows & Farah, 2005; Schacter, Addis, & Buckner, 2007; Schacter, Gaesser, & Addis, 2013; Spreng & Levine, 2006; Wallace, 1956). The distribution of generated events usually follows a power function with the majority of events clustered in the near future (Spreng & Levine, 2006), but for older as compared to younger adults this function appears to have a steeper slope with an even smaller number of events reported in the distant future (Schacter et al., 2013; Spreng & Levine, 2006).

To recapitulate, the existing literature on age differences in mental representations of time suggests that compared to younger adults, older adults view their global horizons as more limited, perceive their future selves as more proximal and more continuous with their current selves, and engage in episodic future thought about less distant events. Although these age patterns are generally consistent with each other, there are some exceptions (future orientation, for instance, shows a mixed pattern of age effects), and correlation patterns among specific aspects of time perception have yet to be systematically examined. For instance, Cottle and Pleck's (1969) life position measure and Carstensen and Lang's (1996) Future Time Perspective Scale appear to tap into closely related concepts and show similar age patterns, but it remains unknown whether the two assessments are empirically related. Moreover, relatively little is known about the role of potential covariates.

## Covariates

Prior research has considered a range of correlates of individual differences in mental representations of time. However, the empirical record is somewhat disjointed, as some aspects of time horizons and some types of correlates have been more thoroughly researched than others.

**Demographic variables.** Given the inherent association between advanced chronological age and mortality, the majority of studies examining demographic predictors of time horizons have focused on the role of actuarial life expectancy (for a review see Löckenhoff, 2011). Apart from its association with mortality, age may affect mental representations of time by shifting the ratio of a specific future time interval relative to the years already lived (e.g., five years represent 1/4 of lived years for a twenty-year-old but 1/16 of lived years for an octogenarian; Lemlich, 1975). Other demographic variables may play a role in mental representations of time as well. Women are more accurate than men in estimating their position in the life span relative to their actuarial life expectancy (Hancock, 2010), but show lower levels of future orientation than their male counterparts (Padawer, Jacobs-Lawson, Hershey, & Thomas, 2007). Further, being societally disadvantaged or part of an underrepresented minority limits not only actuarial life expectancy (Murray et al., 2006), but also future thought and planning (Padawer et al., 2007; Sirin, Diemer, Jackson, Gonsalves, & Howell, 2004).

**Physical and emotional well-being.** To some extent, the links between demographic variables and time perception may reflect shared variance with physical health (Guthrie, Butler, & Ward, 2009; Lasser, Himmelstein, & Woolhandler, 2006). On the one hand, physical health may influence time perception: Poor physical health places limitations on global time horizons—even among younger adults (Kooij & Van De Voorde, 2011; Rasmussen & Elverdam, 2007). Moreover, false feedback indicating to older adults that they physically outperformed their age peers on a grip strength task subsequently lowered their perceived life position (Stephan, Chalabaev, Kotter-Grühn, & Jaconelli, 2013). On the other hand, time perception may influence physical health: Individuals with lower levels of future-oriented thought and shorter future time horizons are less likely to engage in preventive health behaviors and more likely to engage in risky activities which may ultimately result in poorer health outcomes (Daugherty & Brase, 2010; Gellert, Ziegelmann, Lippke, & Schwarzer, 2012; Sansbury, Dasgupta, Guthrie, & Ward, 2014; Whitaker et al., 2011). Thus rather than being unidirectional, the relationship between mental representations of time and physical health appears to be reciprocal.

Mental health and emotional well-being are associated with time horizons as well, and, again, the pattern of associations appears to be complex. On the one hand, socioemotional selectivity theory, a life-span theory of motivation (Carstensen, 2006), argues that age-related limitations in future time horizons lead to a prioritization of emotional well-being in the present moment. Consistent with the theory, age-related limitations in global horizons were found to be associated with the pursuit of emotion regulatory goals, an emphasis on positively valenced stimuli, and—ultimately—more positive emotional states (Charles & Carstensen, 2010;

Löckenhoff & Carstensen, 2008; Reed & Carstensen, 2012). However, whereas shorter global time horizons may benefit older adults' mental health, greater future orientation and planning have been linked to positive emotionality (Desmyter & De Raedt, 2012). Moreover, longitudinal decreases in future orientation portended subsequent declines in well-being in an older sample (Kotter-Grühn & Smith, 2011). Thus, associations between time perspective and well-being appear to show divergent patterns across different aspects of time perception.

**Cognition and personality**. Age-related changes in cognition (for a review see Craik & Salthouse, 2008), may affect perceptions and conceptualizations of time as well. Specifically, reductions in processing speed can partially account for age differences in the subjective speed of time (Baudouin, Vanneste, Pouthas, & Isingrini, 2006), age-related decrements in executive functioning may limit future planning (de Paula, Neves, Levy, Nassif, & Malloy-Diniz, 2012), and reductions in working memory capacity may limit the accurate mental simulation of future events (Cole, Morrison, & Conway, 2013).

However, not all aspects of cognition are negatively affected by age. Semantic world knowledge, for example, is fairly well-preserved with age (Craik & Salthouse, 2008) and may be used to derive accurate predictions about future events without having to rely on complex mental simulations. Moreover, healthy aging is associated with modest increases in conscientiousness (Roberts, Walton, & Viechtbauer, 2006), a dispositional tendency towards planful and organized behavior. This personality trait has been linked with increased future thought and planning (Prenda & Lachman, 2001; Zimbardo & Boyd, 1999) and may counteract some of the detrimental effects of age-related reductions in fluid intelligence on people's ability to anticipate their future.

## The Present Study

In summary, prior evidence suggests that mental representations of time encompass several distinct concepts that appear to vary with age and show differential associations with relevant covariates. Because studies rarely examine more than one of these concepts at a time, correlations among them and their relative associations with age and other relevant covariates remain unclear. Thus the existing literature lacks integration—it is unknown how the various conceptualizations of time perception map onto each other. Consequently, theory-building is limited because overarching associations among age differences in different aspects of time perception remain elusive.

As a step towards addressing these questions, the present study examined age differences and patterns of associations among five widely used and conceptually distinct measures of time perception including perceived position in the life span (Hancock, 2010), future time horizons (Carstensen & Lang, 1996), general future orientation and planning (Zimbardo & Boyd, 1999), self-continuity (Ersner-Hershfield, Garton, et al., 2009), and the temporal extension of episodic future thought (Fellows & Farah, 2005). The measures were administered to a demographically stratified adult life-span sample along with assessments of relevant covariates including cognitive functioning, current affect, personality, and subjective health.

Based on the prior literature, we expected that age would be negatively associated with life position, future time horizons, and the temporal extension of episodic future thought, positively associated with self-continuity, and unrelated to future-oriented thought and planning. A central goal of the present research was to uncover patterns of association among different assessments of time perception. Given the aforementioned similarities in theoretical conceptualizations and age patterns for life position (Hancock, 2010) and future time horizons (Carstensen & Lang, 1996), we suspected that the two measures might reflect the same underlying construct. We also examined potential associations among the remaining time perception measures although—based on the relatively distinct theoretical frameworks underlying each measure—we did not expect to find strong links among them.

Finally, we predicted that covariates would show differential associations with specific aspects of time perception but, because of the aforementioned gaps in in the research record, we focused on exploratory analyses without posing any specific hypotheses.

## Method

### Participants

Ninety community-dwelling participants (aged 21-89) from Tompkins County, NY were recruited through posted flyers, newspaper and internet advertisements, and through an existing database. Undergraduate students were explicitly excluded because they are in a unique life situation which could conceivably skew their time perceptions (especially in the case of graduating seniors who are about to undergo a major life transition; Fredrickson, 1995).

Participants were compensated $15 for their time. To obtain an adult life-span sample that was balanced with regard to gender and race, participants were recruited by age group (< 40 years, 40-59, 60 and over) and selectively enrolled to maintain the same proportion of demographic characteristics within each group. The final age distribution did not show any age clusters and subsequent analyses therefore treated age as a continuous variable.

The second column of Table 1 reports demographic characteristics and shows mean values in our sample for the time perception measures and potential covariates. Due to computer failure and/or experimenter error, four participants had missing data on the Digit-Symbol measure, three participants had missing data on the SF-12 measure and one participant had missing data on the life position measure. Cases with missing data were excluded pairwise for correlations and list-wise for all other analyses.

**Measures**

**Life position** was assessed with the Lines Test (Cottle & Pleck, 1969) following Hancock (2010). Participants were shown a horizontal line (160 mm in length), with birth marked on the left end and death on the right end. They were instructed to indicate their subjective position by drawing a vertical line at the appropriate point along the timeline. The distance (in mm) measured from the left end to the mark defined subjective position in the life span.

**Future time horizon** was measured with the Future Time Perspective Scale (FTP, (Carstensen & Lang, 1996; Lang & Carstensen, 2002). Participants rated the degree to which they agreed with ten statements using a 7-point Likert scale. Statements covered topics such as the extent to which participants felt they had many remaining future opportunities, expected to set new goals in the future, and perceived their future was open-ended versus time-limited (Lang & Carstensen, 2002). The scale was scored by reversing negatively worded items and summing the responses. Cronbach's alpha was .94.

**Future orientation** was measured by the Future subscale from the Zimbardo Time Perspective Inventory (ZTPI; Zimbardo & Boyd, 1999). Items include the tendency to plan ahead, follow a predictable schedule, and make steady progress on long-term projects (Zimbardo & Boyd, p. 1287). After reversing negatively scored items, responses were summed. Cronbach's alpha was .77.

**Future self-continuity** was assessed following Ersner-Hershfield, Garton, and colleagues' (2009) modification of the Inclusion of Other in the Self Scale (Aron, Aron, & Smollan, 1992). Participants were shown 7 pairs of circles labeled "current self" and "future self" ranging from complete separation to nearly complete overlap. Participants indicated perceived similarity with their future self (3 months from now) on a scale from 1 (least similar) to 7 (most similar).

**Episodic future thought** was assessed following the procedure by Wallace (1956) as described in Fellows and Farah (2005). An experimenter asked participants to generate five events that might happen to them at some point in the future. After noting down all five events, the experimenter asked participants how far into the future they expected each event to occur. Subsequent analyses focused on the delay (in years) to the most proximal (minimum distance) and most distal event (maximum distance).

**Cognitive ability** was assessed with a battery capturing processing speed (Digit-Symbol Coding; Wechsler, 1981), working memory (letter-based N-Back; n = 2; Ragland et al., 2002), and vocabulary (Nelson-Denny Reading Test, 25-item vocabulary scale; Brown, Fishco, & Hanna, 1993).

**Current affect** was assessed with two items adapted from Nielsen, Knutson, and Carstensen (2008) asking participants to rate their current emotional state on 7-point scales indicating valence (1 = very negative to 7 = very positive) and arousal (1 = not aroused at all to 7 very aroused).

**Subjective health** was assessed with the SF-12 (Ware, Kosinski, & Keller, 1998). This measure is widely used in psychological and clinical research and yields scores for both mental health and physical health. Scores were computed using the recommended scoring algorithms (Ware et al., 1998).

**Personality traits** were screened with a 10-item version of the Big Five Inventory (Rammstedt & John, 2007) assessing neuroticism, extraversion, openness, agreeableness, and conscientiousness with two items each. In spite of its short length, this measure was previously shown to have acceptable reliability and validity indices (Rammstedt & John, 2007). After reversing negatively scored items, we computed sums for each of the traits.

**Procedure**

The study was conducted individually in a laboratory room. Participants provided informed consent, responded to demographic questions and ratings of current affect, and completed assessments of personality, self-rated health, and multiple aspects of time horizons. After a series of unrelated tasks involving decision making and regret, participants completed the cognitive measures. They were then debriefed and paid for their participation.

Measures were administered using E-Prime software (Version 2.0; Psychology Software Tools, 2009) with the exception of the Digit-Symbol measure and the life position measure (administered with paper and pencil), and the episodic future thought measure (administered orally).

**Data Analyses**

In preliminary analyses, we obtained descriptive information for each of the demographic characteristics, covariates, and time perception measures and examined their associations with age. This provided a general characterization of the sample and allowed us to assess whether the intended stratification of demographic characteristics across age groups was successful. We also computed raw correlations among all variables to assess whether previously observed age differences in time perception measures and covariates were replicated in the present sample.

Next, we examined the degree to which the different time perception measures assessed distinct constructs. To this end we conducted a principal component analysis (Suhr, 2005) with Varimax rotation and Kaiser Normalization. Finally, we conducted regression analyses to examine the role of covariates for age differences in each of the different components.

## Results

### Preliminary Analyses

**Descriptive statistics** are shown in the second column of Table 1. Participants ranged in age from 21 to 89 years. Because we intentionally oversampled older adults, our sample was older, less diverse, and more female than the local population in Tomkins County, NY (http://quickfacts.census.gov/). Sex and racial composition did not differ significantly by age indicating that age-stratification with regard to those characteristics was successful.

**Correlations with age** are shown in the third column of Table 1 and allowed us to examine whether previously observed age differences in covariates and individual time perception measures were replicated in the present sample. Consistent with the literature on cognitive aging (Salthouse, 2010), higher chronological age was associated with higher crystallized abilities (vocabulary scores) but lower fluid abilities (working memory and processing speed scores). Age differences in subjective health also showed typical patterns (Happell & Koehn, 2011) in that higher age was associated with better mental but worse physical health. There were no significant associations between age and current affective valence and arousal, but for personality traits, we observed common age-related patterns suggesting decreases in neuroticism and increases in agreeableness (e.g., Roberts et al., 2006; Terracciano, Costa, & McCrae, 2006), although these effects remained at the trend level (ps = .1). Finally, we replicated prior research on age differences in time perception: Age was associated with a more advanced life position, more limited global horizons, greater self-continuity, and a shorter extension of episodic future thought, but unrelated to general future orientation. In combination, these findings indicated that the present sample showed typically observed age patterns in time perceptions and relevant covariates and was therefore well-suited to conduct the intended analyses.

## Associations Among Time Perception Measures

As seen in the bottom right portion of Table 1, there were significant correlations among the different aspects of time perception. As expected, there was a strong association between a more advanced position in the life span and a more limited future time horizon, but beyond that, each of the time perception measures under consideration was significantly associated to at least one of the other measures.

To further examine this pattern of associations, we conducted a principal component analysis. The Eigenvalue criterion suggested a 2-component solution, but this solution only accounted for 56% of the variance, and two of the variables (self-continuity and future orientation) did not load highly on either component. A four component solution supported by the Scree test offered a better fit explaining 85% of the variance (shown in Table 2). In this solution, life position and FTP scores constituted the first component reflecting global life span, the minimum and maximum extension of episodic future thought constituted the second component, and future self-continuity and future orientation each formed a separate component.

## Associations with Age and Other Covariates

Figure 1 shows linear associations between chronological age and each of the 4 component scores. Adding quadratic and cubic effects of age did not yield a significant increase in explained variance (all ps > .5). As seen in the figure, Component 1 (reflecting global life span) showed a substantial age-related decrease. Component 2 (extension of episodic future thought) also showed a decrease with age although the effect was more moderate in size. Component 3 (self-continuity), in turn, showed a moderate increase with age, whereas

Component 4 (future oriented thought and planning) did not vary by age.

Next, we examined the extent to which the different types of covariates could account for the observed age effects in Components 1, 2, and 3. Current affect and personality were not considered because correlational analyses indicated that they were not significantly associated with age in the present sample (see Table 1). For each of the three components, we computed a regression analysis with age entered in Block 1. To account for the potential influence of cognitive functioning on responses to time perception assessments, cognitive measures were entered in Block 2. To examine the role of subjective health, mental and physical health were added in Block 3. The results of these analyses are summarized in Table 3.

For Component 1 (global life span), cognitive variables did not explain any additional variance after chronological age had been accounted for, but subjective health added significantly to the explained variance, with better mental and physical health predicting a more extended view of the future.

Component 2 (minimum and maximum extension of episodic future thought) showed a different pattern: None of the covariates added to the explained variance, and the age effect was significant only for Block 1. After adding cognitive variables to the model in Blocks 2 and 3, age was no longer significant.

For Component 3 (future self-continuity), adding cognitive covariates in Block 2 yielded a significant effect of vocabulary whereas age was no longer significant. However, $\Delta R^2$ for Block 2 did not reach statistical significance. Block 3 adding subjective health did reach statistical significance indicating that better mental health predicted greater self-continuity.

## Discussion

This study extended our understanding of age differences in temporal construal by examining age effects in five conceptually distinct aspects of time perception as well as their associations with each other and with relevant covariates in a demographically stratified life-span sample. We found that the five time perception measures represented four distinct components which differed in age patterns and specific covariates.

**Associations Among Time Perception Measures**

The most prominent finding was a marked association between advanced life position and global future time horizons (as measured by the FTP scale). The two measures emerged as a single component in a principle component analysis. This does not necessarily imply that these concepts are interchangeable, but it suggests that the corresponding streams of literature might cross-fertilize each other. For instance, researchers interested in subjective life position may draw inspiration from the literature on global future time horizons (Carstensen, 2006) and begin to explore the implications of life position for goal priorities. Conversely, researchers studying global time horizons may consider recent findings examining discrepancies between actuarial and perceived life position (Hancock, 2010) and explore similar dissociations between chronological age and FTP scores.

The finding that episodic future thought, self-continuity, and future planning constitute separate components of time perception has important theoretical implications as well. Research on age differences in future self-continuity, for example, is relatively scarce, and it is relevant for researchers in this emerging area that self-continuity appears to be relatively independent from other aspects of time perception. Further, our findings support the notion that future orientation (as captured by the ZTPI; Zimbardo & Boyd, 1999) constitutes a generalized tendency to engage with the future that is only weakly associated with episodic future thought and unrelated to self-continuity and global position in the life span.

**Associations with Age and Other Covariates**

Our study also adds to the extant literature by reporting age differences for four different aspects of time perception within the same adult life span sample. Because the sample was stratified by age and ethnic composition, these factors could be ruled out as possible causes for the observed age discrepancies. Further, although the four components differed in specific age slopes, all of the observed age effects were linear as opposed to quadratic or cubic in nature. This suggests that the underlying factors shift gradually across the life span without any stepwise or curvilinear effects. This speaks against a role of distinct age-graded life events and time markers (e.g., retirement) and also indicates that age effects are not due to reversible changes in contextual factors (e.g., decreased spare time in midlife; Ginn & Fast, 2006).

Among the various covariates under consideration, only cognitive functioning and subjective health showed significant correlations with age and aspects of time perception and were therefore included in subsequent regression analyses. Adding cognitive variables did not yield a significant increase in explained variance for any of the components. This indicates that age differences in fluid or crystallized abilities cannot account for the observed age differences in time perception. However, we found that including subjective health significantly added to the explained variance in both global life span and future self-continuity. Specifically, better mental health was associated with both an extended life span and greater self-continuity. Better physical health, in contrast, was selectively associated with a more extended life span. These findings align with prior research indicating that variations in mental and physical well-being are linked to global time horizons (e.g., Stephan et al., 2013) and provide initial evidence that the influence of mental health extends to future self-continuity as well. The marginally significant effect of vocabulary on future self-continuity, in contrast, is more puzzling. However, if one considers vocabulary as a proxy for crystallized world knowledge and experience (Verhaeghen, 2003), one could argue that such knowledge may also entail the understanding that individual characteristics remain fairly stable over time.

**Limitations and Future Research**

Of course, our study has some important limitations that need to be considered when interpreting the results. First, the findings are cross-sectional and correlational in nature. Thus, cohort differences in life experiences may have skewed our findings, and further research is needed to establish longitudinal trajectories and examine causal associations between age, time perception, and covariates. Second, with the exception of cognitive assessments, we relied on self-report measures raising concerns about common method bias. Findings could be strengthened by adding measures of objective health, observer ratings of personality or mood, and implicit measures of time perception (e.g., D'Argembeau et al., 2010). Further, although we aimed to include a range of well-established and conceptually distinct assessments of time perception, there are, of course, other measures to consider. In particular, future work should include concepts that are more closely linked to behavioral implications (e.g, the tendency to discount future financial outcomes, Frederick, Loewenstein, & O'Donoghue, 2002) and measures that explore the symmetry between remembering the past and anticipating the future (Spreng & Levine, 2006). Finally, the present study does not control for the recent experience of significant life events or milestones. As noted previously, undergraduate students were purposely excluded to avoid the potential influence of life events associated with college life, but participants may have recently experienced other major life events (e.g., starting a new job, becoming a grandparent, or facing serious illness). Because life events may shift individuals’ time horizons (Peetz & Wilson, 2014) and differ by age, controlling for such effects would be a valuable target for future studies.

In conclusion, our findings set the stage for integrating divergent streams of the literature on age differences in time perception. Beyond their theoretical contributions, our results also have practical implications. Time perspective has been linked to various aspects of financial and decision making and health behavior (Gellert et al., 2012; Löckenhoff & Rutt, 2015). Given that our findings implicate subjective health as a key covariate of time perceptions, it may be feasible to shift time perceptions by counteracting perceptions of age-related decline (e.g., via targeted social comparisons, Cheng, Fung, & Chan, 2007, or implicit priming, Levy, Pilver, Chung, & Slade, 2014). As discussed in the introduction, associations between time perception and subjective health appear to be reciprocal and it may be possible to initiate 'virtuous circles' by which better subjective health results in shifting time horizons which in turn stimulate health-promoting behavior.

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Footnote

[1] Of course, perceptions of time encompass both the past and the future (Lewin, 1951). However, past perceptions draw heavily on age differences in memory processes which have been the focus of decades of intensive research (for reviews see Craik & Salthouse, 2008; Salthouse, 2010). The present study therefore prioritizes age differences in perceptions and conceptualizations of future time that remain comparatively underexplored.

Table 1

Participant Characteristics and Correlations with Age and Time Perspective Measures for All Potential Covariates

| | *M(SD)* / % | $r_{Age}$ | $r_{LifePosition}$ | $r_{FTP}$ | $r_{ZPTI}$ | $r_{Self\text{-}Continuity}$ | $r_{Episodic(Min.)}$ | $r_{Episodic(Max.)}$ |
|---|---|---|---|---|---|---|---|---|
| Demographics | | | | | | | | |
| Age | 49.81 (18.71) | | .86** | -.51** | -.06 | .26* | -.12 | -.43** |
| Sex (% female) | 64% | -.04 | -.02 | .08 | .10 | -.15 | -.12 | -.04 |
| Race (% White) | 86% | .07 | .07 | -.21* | -.07 | .09 | -.08 | .01 |
| Cognition | | | | | | | | |
| Vocabulary | 17.98 (4.90) | .36** | .31** | -.34** | -.02 | .35** | -.09 | -.13 |
| Working memory | .78 (.23) | -.37** | -.31** | .18 | -.02 | .02 | .09 | .19 |
| Processing speed | 56.81 (14.17) | -.68** | -.60** | .32** | .03 | -.16 | .04 | .40** |
| Affect | | | | | | | | |
| Valence | 5.02 (1.23) | .19 | .10 | .26* | .22* | -.03 | -.08 | -.15 |
| Arousal | 3.33 (1.57) | .10 | .06 | .05 | -.02 | -.09 | -.06 | .03 |
| Subjective health | | | | | | | | |
| Mental | 47.25 (12.13) | .30** | .13 | .12 | .15 | .30** | .11 | -.08 |
| Physical | 50.26 (9.25) | -.33** | -.39** | .39** | .10 | -.07 | .11 | .09 |
| Personality | | | | | | | | |
| Neuroticism | 5.83 (2.03) | -.18 | -.06 | -.05 | .04 | -.28** | -.20 | .06 |
| Extraversion | 6.60 (1.95) | .13 | .13 | .02 | -.03 | .04 | -.07 | -.09 |
| Openness | 7.79 (1.78) | -.09 | -.07 | .12 | .09 | -.05 | .13 | .07 |
| Agreeableness | 7.08 (2.04) | .18 | .04 | .17 | .02 | .06 | .01 | -.18 |
| Conscientiousness | 8.03 (1.54) | .09 | .02 | .26* | .20 | .01 | .10 | -.15 |
| Time perspectives | | | | | | | | |
| Life position | .59 (.22) | .86** | | | | | | |
| FTP | 46.80 (15.45) | -.51** | -.60** | | | | | |
| ZPTI | 3.79 (0.56) | -.06 | -.03 | .08 | | | | |
| Self-continuity | 5.62 (1.76) | .26* | .23* | -.12 | .08 | | | |
| Episodic (Min.) | 1.30 (2.10) | -.13 | -.07 | .03 | .21* | .11 | | |
| Episodic (Max.) | 15.00 (15.27) | -.43** | -.32** | .13 | .16 | .06 | .41** | |

*Notes*. Correlations for sex and race are point-biserial, all others are Pearson correlations. FTP = Lang and Carstensen's (1996) Future Time Perspective Scale, ZTPI = Zimbardo Time Perspective Inventory, Future Orientation Scale. ***p* < .01, **p* < .05.

Table 2

Rotated Component Matrix for Principal Component Analysis

Examining Patterns of Association Among Time Perception Measures

| | Component | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| FTP | **.90** | -.03 | .02 | .09 |
| Life position | **-.86** | -.20 | .19 | .05 |
| Episodic (Min.) | -.08 | **.83** | .02 | .18 |
| Episodic (Max.) | .24 | **.83** | .06 | -.02 |
| Self-continuity | -.11 | .07 | **.99** | .04 |
| ZTPI | .04 | .13 | .04 | **.98** |

*Notes*. Rotation converged in five iterations. Loadings over .3 are shown in bold font. FTP = Lang and Carstensen's (1996) Future Time Perspective Scale, ZTPI = Zimbardo Time Perspective Inventory, Future Orientation Scale.

Table 3

Regression Analyses Examining the Role of Covariates for Age Differences in Components of Time Perception

| | $\beta_{\text{Component 1}}$ | $\beta_{\text{Component 2}}$ | $\beta_{\text{Component 3}}$ |
|---|---|---|---|
| Block 1 | | | |
| Age | -.71** | -.30** | .26* |
| $R^2$ | .51** | .09** | .07* |
| Block 2 | | | |
| Age | -.66** | -.25 | .20 |
| Vocabulary | -.06 | -.03 | .24* |
| Working memory | .01 | .04 | .02 |
| Processing speed | .04 | .04 | .02 |
| $\Delta R^2$ | .00 | .00 | .06 |
| Block 3 | | | |
| Age | -.61** | -.30 | .10 |
| Vocabulary | -.05 | -.02 | .27* |
| Working memory | .05 | .03 | .01 |
| Processing speed | .06 | .03 | .00 |
| Mental health | .20* | .09 | .31** |
| Physical health | .23** | -.03 | .05 |
| $\Delta R^2$ | .08** | .01 | .09* |

*Note*. Component 1 = global time horizons; Component 2 = extension of episodic future thought; Component 3 = future self-continuity.
** $p < .01$, * $p < .05$.

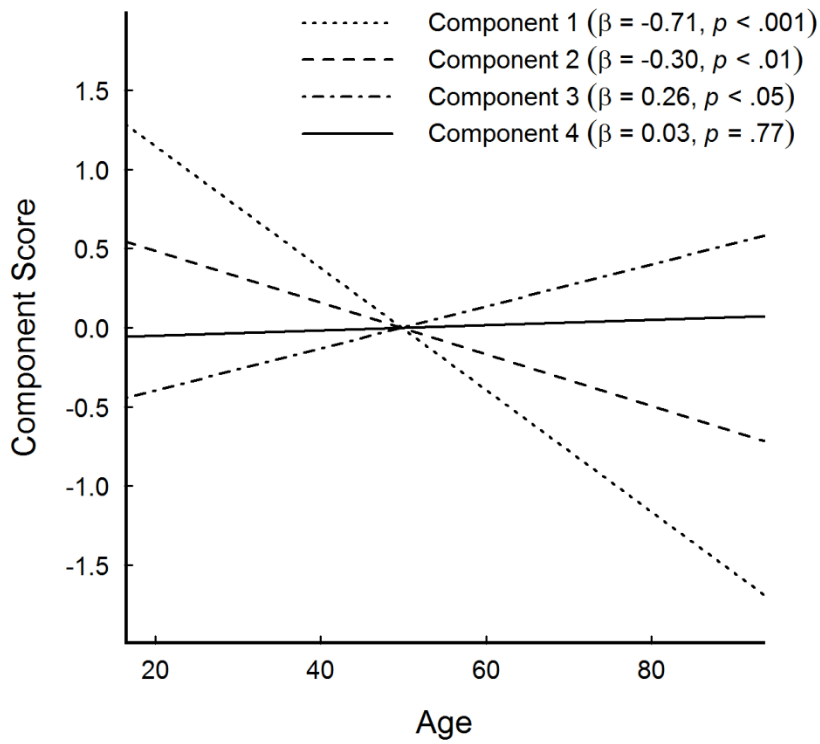


*Figure 1*. PCA regression scores, for each of four components, by age. Component 1 = global life span; Component 2 = extension of episodic future thought; Component 3 = future self-continuity; Component 4 = future planning and orientation.

CHAPTER 2

# CONVERGING EVIDENCE FOR DUAL SYSTEM PROCESSES IN TEMPORAL SELF-CONTINUITY AND TIME DISCOUNTING

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Abstract

Dual system models are ubiquitous in the decision making literature, including economics and neuroscience, and have been successfully used to model temporal discounting, the tendency to devalue future outcomes. More recently, researchers have begun to examine variations in perceived continuity between one's present and future self, and it has been suggested that temporal self-continuity can be modeled by a dual system approach as well. The present study examined this possibility by comparing temporal self-continuity, measured both explicitly and implicitly and over multiple temporal distances, to monetary discounting patterns assessed over the same temporal distances. Self-continuity decreased as a gradual function of temporal distance, following a double exponential function. We found the same gradual pattern with regard to temporal discounting. Additionally, individual response times from the implicit self-continuity task were linked to transitions from steep drops to flatter trajectories in individual discounting functions. This suggests that self-continuity, like temporal discounting, may be driven by a dual system process, which raises the possibility that both are manifestations of the same mechanisms.

## Introduction

Prior theory and research have proposed various dual systems models of decisions involving temporal trade-offs (Heatherton & Wagner, 2011). These theoretical models typically propose one system that biases the person toward “impatience” and immediate rewards; and a second system that exerts self-control or biases the person toward delayed rewards which may carry higher long-term benefits (Kool, McGuire, Wang, & Botvinick, 2013). It is not fully understood how such dual systems interact to determine decision outcomes. They may compete with each other, or as recent evidence suggests, they may be more collaborative, with a self-control system modulating an “impatient” reward-based system (Hare, Camerer, & Rangel, 2009). Individuals may vary in the relative strength of the two systems, as well as the extent to which each system contributes to decisions (van den Bos & McClure, 2013).

Existing dual systems theories and evidence draw on both neuroscience (i.e., specific neural networks comprising each system) and economics (i.e., patterns of monetary choices resulting from the interplay of both systems; Frederick, Loewenstein, & O’Donoghue, 2002; Fudenberg & Levine, 2006; Kool et al., 2013; van den Bos & McClure, 2013). A potentially related concept is future self-continuity—the extent to which people perceive similarity between their present and future self (Ersner-Hershfield, Garton, Ballard, Samanez-Larkin, & Knutson, 2009), but it remains unclear to what extent this concept can be mapped onto existing dual systems models.

The present study examined whether variations in self-continuity over time show a similar, gradual pattern as previously reported discontinuities in decisions requiring temporal trade-offs. This would suggest that similar dual process mechanisms are at the root of these phenomena. Although possible associations between these constructs have received little attention, there is extensive literature on each respective topic. To put our approach into perspective, we review some of the most recent and prominent work, beginning with an introduction to the decision making phenomenon of temporal discounting that has inspired much of the extant theory and research on dual systems models.

**Temporal Discounting**

The widely-documented tendency to assign less value to rewards the further they are delayed into the future is known as *temporal discounting* (Ainslie, 1975; Frederick et al., 2002; Samuelson, 1937). Informally, it can be conceptualized as an "impatient" preference for immediate rewards and a resulting tendency to devalue delayed rewards. This phenomenon is most commonly studied with regard to monetary outcomes but was found to extend to discounting of consumables and health states as well (Frederick et al., 2002). While researchers agree that the devaluing of future outcomes occurs gradually with increasing temporal distance, various functional shapes have been proposed to model the exact trajectories.

**Economic perspectives.** The earliest attempts to model temporal discounting were rooted in classical economic theory with the assumption that people increasingly discount rewards with progressively further delays into the future, but that this discount rate remains constant. That is, reward value would be discounted at the same rate per year if the delay were 3 years as if it were 10 years. This assumption of a consistent discount rate over time resulted in a model based on an exponential function:

$$A * \exp^{-k d} \qquad (1)$$

Here, $d$ is the delay (e.g., seconds, days, months, years); A is the starting value when $d = 0$, and k is the exponential discounting parameter to be estimated.

However, empirical data on human discounting behavior were found to violate the assumption of an exponential function. Consequently, behavioral economists proposed a new discounting model as a hyperbolic decrease in subjective value over time (Ainslie, 1975; Mazur, 1984), and this widely-used single-parameter hyperbolic function has generally provided a better fit to empirical data than the exponential function:

$$A / (1 + kd) \qquad (2)$$

Here, $d$ is the delay (e.g., seconds, days, months, years); A is the starting value when $d = 0$, and k is the hyperbolic discounting parameter to be estimated.

However, the simplicity of the hyperbolic model still fails to capture certain subtle aspects of discounting behavior. Moreover, behavioral economic theories of temporal discounting increasingly proposed an interplay among dual systems, often referred to dual-selves (Fudenberg & Levine, 2006) or multiple selves (Ainslie, 1992; Laibson, 1997; Monterosso & Luo, 2010), with a “nearsighted” self who is focused on immediate gratification competing with a “farsighted” self who is focused on long-term benefits (e.g., Frederick et al., 2002). Similarly, Metcalfe and Mischel (1999) differentiated between an affective or “hot” system representing the desire for immediate rewards and a deliberative or “cool” system prioritizing self-control and strategic action. Given such accounts, it has been argued that researchers should not use a single parameter to model behavior that is likely driven by multiple underlying motivations which may conflict at times (Frederick et al., 2002; van den Bos & McClure, 2013). Drawing on such ideas, neuroscientists began to consider the neural substrates of temporal discounting which has led to further development in dual systems perspectives.

**Neuroscience perspectives.** One influential neural model of temporal discounting was proposed by McClure, Laibson, Loewenstein, and Cohen (2004) positing that a distinct limbic network assesses the value of immediate rewards, and a separate and predominately prefrontal network assesses the value of delayed rewards. In contrary, Kable and Glimcher (2007) argued that only a single network (limbic regions) codes for value, regardless of delay. However, although findings by Hare and colleagues (2009) supported the single-valuation-system model proposed by Kable and Glimcher (2007), they also supported a model similar to that proposed originally by McClure et al. (2004). Specifically, they suggested that although a single limbic region may process reward valuation (both immediate and delayed), a separate control network may exert top-down modulation of the valuation network to suppress overly-nearsighted decisions. These two proposed networks overlapped substantially with those originally put forward by McClure et al. (2004) as the immediate-versus-delayed reward networks. Thus, there remains strong support for at least two distinct systems contributing to intertemporal decisions, although the evidence suggests a minor revision to McClure et al. (2004) in that, rather than capturing immediate valuation versus delayed valuation, the two networks are thought to map onto valuation versus self-control (Peters & Büchel, 2011).

In reviewing neuroscience-based dual system models, it is worth noting that the two systems potentially conflict with each other. Neuroscientists have studied decision conflict by comparing non-effortful decisions to those for which the person has mixed views or otherwise has difficulty deciding (e.g., Carter et al., 1998). For example, greater choice difficulty in a temporal discounting task when both options seem fairly equal has been associated with slower reaction times and increased activity in the anterior cingulate cortex (McClure, Botvinick, Yeung, Green, & Cohen, 2007).

Based on such considerations, a new neuroscience-based model for temporal discounting was proposed. McClure and colleagues (2007) introduced a variation on a two-parameter model (Laibson, 1997) with the same two parameters β and δ, representing the valuation and control networks, respectively, but this variation adds a third parameter (ω) to quantify the relative contribution of the two networks. That is, ω estimates what proportion of the discount function is influenced by the β system, independent of β and δ values. This has been called the double exponential model (van den Bos & McClure, 2013) and is shown as Equation 3:

$$(1 - \omega) * (A * \delta^{d}) + \omega * (A * \beta^{d}) \qquad (3)$$

It combines two exponential discount functions (hence "double exponential"), but because their discount rates differ, it is not exponential in shape. Instead, it is nearly hyperbolic. However, while the one-parameter hyperbolic (Equation 2) has no relevance to dual systems, as it simply models a graceful curve, the trajectory for Equation 3 is consistent with a dual system model in the clear dichotomy between a steeper slope at first (β parameter), and a flatter slope thereafter (δ parameter).

The double-exponential model has shown compatibility with temporal discounting data from binary as well as continuous response options, and has demonstrated better fit to discounting data than simpler hyperbolic functions (Takahashi, 2008). Moreover, van den Bos and McClure (2013) demonstrated its statistical fit with data from prior brain imaging studies that support the valuation/control network model. For these reasons, we expected that this model would present the best fit for temporal discounting data in the present study.

While both economic and neuroscience perspectives routinely refer to dual systems or selves, such entities are typically inferred from intertemporal choice preferences (economics) or patterns of neural activation (neuroscience) with little reference to the associated subjective experiences. In recent years, however, evidence for the phenomenology of thinking about oneself over time has emerged from a variety of fields and begun to coalesce into a nuanced understanding of temporal self-continuity.

**Temporal Self-Continuity**

Social psychologists have long noted that there is a difference between how we perceive ourselves at present and who we expect to be in the future. Early work in this area emphasized differences in the *content* of present and future descriptions with particular emphasis on the motivational consequences of aspired or feared future selves (Markus & Nurius, 1986). More recently, researchers have noted that conceptualizations of present and future selves also differ in *levels of representation*. According to construal level theory (Trope & Liberman, 2010), events and objects are represented differentially depending on their psychological distance. Like spatial distance (physically close vs. distant events) and social distance (self vs. other), temporal distance has been found to be associated with less concrete and more abstract construals (for a review see Trope & Liberman, 2010). Heller, Stephan, Kifer, and Sedikides (2011), for instance, found that participants' five-factor trait assessments for themselves in the distant future (3 years) relative to the near future (1 month) were not only more positive but also less variable. Further, Wakslak, Nussbaum, Liberman, and Trope (2008) found faster reaction times when participants were asked to describe their traits 10 years from now compared to the present, and D'Argembeau, Stawarczyk, Majerus, Collette, and Van der Linden (2010) reported faster reaction times when participants responded to trait ratings 5 years into the future as compared to the present. Both reduced variability and faster reaction times point towards a representation of the self based on overarching traits as opposed to situational emotions or states (D'Argembeau et al., 2010; Wakslack et al., 2008). In fact, when people are asked to make decisions about various concrete activities, the choices made for one's future self are more similar to the choices made for others than they are to the choices made for one's present self. This indicates that, consistent with construal level theory, people think about their distant self largely the same way they think about a different person (Pronin, Olivola, & Kennedy, 2008).

The evidence reported so far compared present and future construals at the group level, but a series of recent studies indicates that there is considerable individual variability in the extent to which people perceive that they are "continuous" over time, or will remain the "same person" in the future as they are today (Bartels & Urminsky, 2011; Ersner-Hershfield, Garton, et al., 2009; Hershfield et al., 2011). In the context of this paper, this individual difference construct will be referred to as *temporal self-continuity* (TSC).

TSC can be assessed explicitly or implicitly. Bartels and Urminsky (2011, Study 5), for example, used graphs of overlapping circles to explicitly assess participants connectedness to their future self (in 1 year) and found significant interindividual variation. Similarly, Ersner-Hershfield, Garton, and colleagues (2009) asked participants to rate the degree of perceived similarity with their future self (10 years from now) using a series of overlapping circles adapted from Aron, Aron, and Smollan's (1992) Inclusion of Other in the Self Scale. In addition, Ersner-Hershfield, Garton, and colleagues (2009) administered an implicit measure asking participants to rate whether a series of traits was descriptive of their present and future selves and computed the discrepancy between the two ratings. They found that the explicit and implicit measures of

TSC showed considerable convergence and that individuals differed significantly from each other in their degree of future connectedness.

Conceivably, the mechanisms involved in construing present versus future selves may be associated with the dual systems proposed in economic and neuroscience perspectives on intertemporal choice. A number of authors have argued this point (van den Bos & McClure, 2013; Kool et al., 2013), and there is some initial empirical evidence supporting this perspective. Both Ersner-Hershfield, Garton, and colleagues (2009) and Bartels and Urminsky (2011) reported that greater TSC was associated with reduced temporal discounting, and Ersner-Hershfield, Garton, and colleagues (2009) reported associations between TSC and savings rates. Furthermore, thinking about present selves was found to engage different areas of the brain than thinking about future selves (D'Argembeau et al., 2010, Ersner-Hershfield, Wimmer, & Knutson, 2009).

Understanding links between TSC, discounting, and dual systems approaches could provide valuable insight into cognitive models of the self—the mental constructs—that guide the decisions that people make when considering temporal trade-offs. However, the previous literature has characterized TSC, multiple selves, construal levels, and other related constructs in a binary fashion, tacitly implying a stepwise function such as the one presented in Equation 4:

$$(A * (0.05 + \arctan((x - \mu) / \sigma) / \pi)) + b \qquad (4)$$

Here A is the starting value, $\mu$ is a free parameter and $\sigma$ is held constant at -0.01 to restrict the fitted trajectories to stepwise shapes. An intercept parameter (b) is also included to allow for variance in TSC change, independent of functional shape. Like Equation 3, Equation 4 implies a transition between two functions, but whereas Equation 3 transitions from one curvilinear function to another, Equation 4 transitions from a vertical linear function to a horizontal linear function.

While discounting tasks routinely assess discounting rates for multiple future time points, TSC studies have focused on single points of temporal comparisons. Thus, researchers have not been able to examine whether TSC is better described by a stepwise function (Equation 4) or a more gradual function (Equations 1, 2, and 3).

**The Present Study**

Taken together, there is growing evidence that the processes involved in TSC and related constructs may be associated with the dual systems proposed in economic and neuroscience perspectives on intertemporal choice. A better understanding of such associations would provide important insights into the role of cognitive models of the self with regard to temporal discounting and other future-oriented choices, but the lack of consistent measurement approaches has hampered an integration of these respective fields.

To address this gap in the research record, we assess TSC over several temporal distances (as opposed to the predominantly dichotomous literature on multiple selves) and thus account for the months and years between the present and the distant future. Further, we employ both implicit and explicit measures of TSC, and we assess reaction times as a proxy for processing demands. A key goal is to examine whether explicit and implicit TSC as well as temporal discounting show evidence of similar dual systems mechanisms, and, if yes, which of the aforementioned equations is most appropriate to describe such effects.

If temporal discounting is driven by dual systems, and if temporal discounting is related to thinking about one's self over time, we would expect that TSC also involves dual systems. We would further expect to see associations between dual systems in TSC and dual systems in temporal discounting. Thus, we expect that:

**Hypothesis 1:** Patterns of discontinuity between people's present and future selves are associated with their temporal discounting functions.

As mentioned above, much of the prior literature on TSC has focused on binary comparisons between present and distant future selves. At first glance, this would imply a stepwise transition. However, if the dual systems processes implied in the neuroscience and discounting literature are also found in TSC, one would expect that the transition follows a double exponential model composed of two gradual functions that vary in slope. We therefore propose that:

**Hypothesis 2:** Explicit and implicit TSC share the gradual shape that prior studies have found in temporal discounting which is best fit by a double exponential model.

Additionally, if TSC involves dual mechanisms that must transition from one to the other as people switch from thinking about their present selves to progressively distant future "selves," one would expect to see a transition point at which the two systems compete. Empirically, this is likely to manifest itself in longer reaction times. Based on these considerations, we expect that:

**Hypothesis 3:** Individual reaction times in TSC tasks do not monotonically increase or decrease with increasing distance, but peak at a certain point into the future. The exact timing of the peaks varies across individuals and corresponds to participants' individual switch points in their double exponential discounting functions—that is, the transition from steeper to flatter discounting.

We tested these hypotheses in an undergraduate student sample. Across six temporal distances ranging from 1 month to 10 years we assessed explicit TSC using a modified Inclusion of Other in the Self Scale (Aron et al., 1992) and implicit TSC using a me/not me task (D'Argembeau et al., 2010; Wakslak et al., 2008). Participants also completed a monetary temporal discounting task involving the same six temporal distances. For each measure, we compared relative fit with a double-exponential as opposed to a stepwise model. For comparison purposes, we also fitted linear, exponential, and hyperbolic functions. We controlled for variations in demographic characteristics and also assessed a range of theoretically implicated covariates that may be associated with individual differences in TSC. Specifically, we examined the global extension of participants' future horizons, which may place an upper limit on self-continuity (Carstensen, 2006), cognitive functioning, which may be associated with response times and the ability to understand instructions, five-factor personality traits, which have been associated with a propensity for impulsivity and future planning (Roberts, Jackson, Fayard, Edmonds, & Meints, 2009), and subjective health which may change over time and thus may influence TSC.

## Method

### Participants

Undergraduate students (*N* = 90) were recruited through posted flyers and Cornell University's online study recruitment system (Sona Systems, Ltd.). Although students are of course not representative of the general population, there is no reason to expect qualitative differences in their TSC relative to the general public. Thus, a student sample is well suited for this initial study. Participants received 2 participation credits for a 60-minute session. Table 1 shows descriptive sample characteristics.

### Temporal Self-Continuity and Discounting Measures

***Temporal distances.*** All assessments used multiple temporal distances presented at the same intervals: at present, in 1 month, in 3 months, in 6 months, in 1 year, in 5 years, in 10 years. As much as possible, we selected distances that would map onto those used in prior research. The higher sampling rate within the first year was based on pilot findings suggesting maximal interindividual variance within that frame.

***Guided imagination task.*** Following D'Argembeau et al. (2010), before administering the TSC measures, participants first completed a guided imagination task in which they imagined themselves at each future temporal distance. For each distance, they were given 15 seconds to imagine a typical day and the people in their social networks at that time. The goal of this task was to ensure, as much as possible, that participants were equally-primed with thoughts related to various future distances.

***Explicit TSC.*** Participants rated perceived similarity with their future selves on a visual scale adapted from Ersner-Hershfield, Garton, et al. (2009) based on a modified Inclusion of Other in the Self Scale (Aron et al., 1992). For each temporal distance, seven progressively-overlapping circle pairs were shown, with a rating of 1 indicating least similarity (i.e., no overlap in circles) and 7 indicating most similarity (i.e., nearly complete overlap in circles).

***Implicit TSC.*** In a task adapted from D'Argembeau et al. (2010), participants were asked to indicate whether or not a stimulus word (i.e., a trait adjective) described them at the specified temporal distance (e.g., at present, in 3 months, in 1 year). To explore the role of valence, ten positive trait words (e.g., wise, patient, relaxed, cheerful) and ten negative trait words (e.g., dull, rude, withdrawn, careless) were selected from a standardized list (Anderson, 1968). Pairs of positive and negative words were matched on word length, number of syllables, and word use frequency based on the SUBTLEXus database (Brysbaert & New, 2009). Stimulus words were presented on a computer screen, one at a time, and participants responded either "Yes" or "No" via button-press.

Four trials comprised a block, and each block specified a temporal distance on which participants based their responses. For each temporal distance, we examined reaction times (RTs) and calculated percent agreement with present trait ratings. For RT data, outliers (+/- 3SD) were identified and replaced with the participants' mean.

In addition to the 7 temporal distances (including the present), a control condition was included which simply asked, "Is this a POSITIVE word?" This condition was included to test for systematic differences in RT between the control condition and each of the temporal distances, as this condition requires no future-oriented thought. As expected, preliminary analyses indicated that mean RT was significantly shorter for the control condition than for any of the temporal distance conditions (all *p*s < .001). We therefore excluded the control condition in subsequent analyses. Preliminary analyses also found no systematic differences between responses for positive and negative traits words. Further analyses therefore did not control for valence.

***Temporal discounting***. A computerized discounting task asked participants to choose between greater monetary rewards received further into the future, or smaller rewards available immediately (based on Zauberman, Kim, Malkoc, & Bettman, 2009). The initial (smaller) reward was $75, and future intervals used the same temporal distances used for the TSC measures. Subjects were instructed, "Imagine you had a give certificate worth $75. You can either use it today for $75, or you can wait and use it at a later date but for an increased value." Participants were then asked, for each temporal distance, "How much would the gift certificate have to be worth for you to wait [temporal distance] to receive the certificate?"

## Covariates

***Demographics*** included age, gender, race, and socioeconomic status.

***Future time horizon*** was measured with the Future Time Perspective Scale (FTP; Carstensen & Lang, 1996). Participants rated the degree to which they agreed with ten statements using a 7-point Likert scale. Statements covered topics such as the extent to which participants felt they had many remaining future opportunities, expected to set new goals in the future, and whether their future was open-ended versus time-limited (Lang & Carstensen, 2002). After inverting reverse-scored items, scores were summed with higher scores indicating more expansive time horizons.

***Subjective health*** was assessed with the SF-12 (Ware, Kosinski, & Keller, 1996) which yields separate ratings for mental and physical health with higher scores indicating better health.

***Cognition*** was assessed in the following domains: Vocabulary (Nelson-Denny Reading Test, vocabulary section; Brown, Fishco, & Hanna, 1993), processing speed (Digit-Symbol Coding; Wechsler, 1997), working memory (letter-based *n*-back; $n = 2$; Ragland et al., 2002), and numeracy (Schwartz, Woloshin, Black, & Welch, 1997).

***Personality*** was assessed with a 60-item measure of the Five-Factor Model of personality (FFI; Costa & McCrae, 1989). Separate scores were generated for each of the five trait domains: Neuroticism, extraversion, openness, agreeableness, and conscientiousness.

## Procedure

Participation consisted of a single session lasting approximately 60 minutes which took place in a private room at the Healthy Aging Laboratory at Cornell University. With the exception of the Digit Symbol task, participants responded to all tasks via computer (E-Prime, Version 2.0; Psychology Software Tools, 2009).

Before the session, participants provided informed consent. They then completed a demographic questionnaire and the guided imagination task. Next, explicit TSC, implicit TSC, and discounting were assessed in counterbalanced order using a Latin square design. Within each task, temporal distances were presented in randomized order. Afterwards, participants completed the questionnaire-based assessments including future time horizon, subjective health, the cognitive tasks, and the personality assessment. They were then thanked and debriefed.

**Analyses**

For TSC and discounting measures, each participant's mean response was calculated for each of the temporal distances. Targeted analyses tested the predictions that TSC and temporal discounting are associated (Hypothesis 1), that they share similar functional forms that are gradual rather than stepwise (Hypothesis 2), and that individual RT patterns from the implicit TSC task are linked to individual discounting trajectories (Hypothesis 3). We now describe the specific analyses in more detail.

To test Hypothesis 1, we used multilevel models to examine associations between TSC and temporal discounting.

To compare functional forms for explicit TSC, implicit TSC, and discounting (Hypothesis 2), we examined goodness of fit of the aggregate data with a linear association and with exponential (Equation 1), hyperbolic (Equation 2), double exponential (Equation 3), and stepwise models (Equation 4). Once the most appropriate function for each measure was determined, individual parameters for each participant were estimated and used in further analyses. Correlational analyses examined the relative strength of associations between TSC measures and the remaining covariates.

To test Hypothesis 3, we first examined whether RTs for the implicit TSC task peaked at a particular temporal distance occurring after the present but before 10 years. For individuals who showed such a peak, we recorded the temporal distance at which it occurred. Next, we compared the individual RT patterns from the implicit TSC task to the parameters of the double-exponential model fitted to the temporal discounting task. Specifically, we assessed whether the temporal distance at which an individual's discount function transitioned from a steep drop to a more gradual slope could be predicted by the temporal distance at which the individual's RTs from the implicit TSC task were longest. Supplemental analyses examined variations in RT across temporal distances.

## Results

### Sample Characteristics

Descriptive statistics are shown in Table 1 for demographics and other covariates. Participants ranged in age from 18 to 25 years. Socioeconomic status was distributed across all 5 categories (i.e., lower income to upper income). Mean future time horizon score was 55.42, and scores ranged from 18 to 68. Mean scores were within typical ranges for subjective health, cognitive functioning, and personality.

### Multilevel Models

The associations between temporal discounting and explicit/implicit TSC (Hypothesis 1) were examined using two-level models estimating the effects of TSC, as a function of temporal distance, on subjective value in the temporal discounting task. Separate models were run for explicit and implicit TSC measures. Intercept was specified as a random effect and temporal distance was specified as a fixed effect. This method accounts for possible non-independence among error terms due to the participants' repeated responses.

Consistent with Hypothesis 1, subjective value in the discounting task was associated not only with greater explicit continuity with one's future self over time ($b = 6.09$, $SE = .57$, $p < .001$), but also with greater implicit TSC, as measured by higher agreement between present and future trait ratings ($b = 1.09$, $SE = .09$, $p < .001$).

**Fitting Functional Curves**

Next, we tested Hypothesis 2 that similar functional trajectories fit both the TSC and the temporal discounting data. Linear, exponential (Equation 1), hyperbolic (Equation 2), double exponential (Equation 3), and stepwise (Equation 4) functions were fitted to the aggregate data. This was done separately for explicit TSC, implicit TSC, and temporal discounting. The analyses were conducted using SAS PROC NLMIXED (Littell, Miliken, Stroup, Wolfinger, & Schabenberger, 2006) to account for the non-independence across repeated measures (i.e., participants provided responses for each temporal distance). This allowed us to statistically compare the five functions for each construct. Differences in BIC > 10 between two models suggest a better fit for the model with the smaller value (Kass & Raftery, 1999). Table 2 reports the fit statistics for explicit TSC, implicit TSC (percent agreement with present trait ratings), and temporal discounting.

For *explicit TSC*, the double exponential function provided a better fit than the linear, exponential, hyperbolic, and stepwise function (see Table 2). This was consistent with our hypotheses. Figure 1 (top) illustrates this with a double exponential curve fitted to the data points for explicit TSC.

For *implicit TSC*, the double exponential function provided a better fit than the linear, exponential, and hyperbolic function (see Table 2). The fit statistic was also better for the double exponential than for the stepwise function, but the difference in BIC was below 10 and thus not considered sufficient to conclude a better fit. Figure 1 (bottom) illustrates this with a double exponential curve fitted to the data points for implicit TSC.

For *temporal discounting*, finally, the double exponential function provided a better fit to the temporal discounting data than linear, exponential, hyperbolic, or stepwise functions. This replicated prior findings in the literature and was consistent with our hypotheses (see Figure 2, bottom).

**Reaction Time Analyses**

To test the assertion that RTs in implicit TSC are linked to transitions in discounting functions (Hypothesis 3), we first examined differences in aggregate RT by temporal distance and then derived individual-level indicators to be used in further analyses.

**Variations in RT by temporal distance.** In the aggregate data, RTs for implicit TSC peaked at 3 months and declined gradually thereafter (see Figure 2, top). To test for variations in RT by temporal distance, we fit a 3-level model, with RT at Level 1, trait word at level 2, and temporal distance at level 3. Intercept and trait word were specified as random effects and temporal distance was specified as a fixed effect. Residuals from this model did not fit criteria for normality; therefore a natural log-transformation was applied for further analyses. RTs varied significantly by temporal distance ($b$ = -.005, $SE$ = 0.001, $p$ < .001). Post-hoc comparisons between 3 months and each of the other distances including at present, using Bonferroni correction for 6 comparisons, indicated that mean RT was significantly longer for 3 months than for 5 years and 10 years ($p$s < .001; minimum for statistical significance would be .008).

To further explore RTs as potential indicators of decision conflict, we examined whether intraindividual variability in RTs varied by temporal distance as well. For each respondent, we computed the SD in RTs across trait words for each temporal distance. Next, to compare RT standard deviations by temporal distance we fit a 2-level model with RT standard deviation at level 1 and temporal distance at level 2. Intercept was specified as a random effect and temporal distance as a fixed effect. RT standard deviations were largest at 3 months. They were significantly larger for 3 months than for at present, 1 month, 5 years, and 10 years (*p*s < .05 after Bonferroni correction for 6 comparisons). To investigate further, we created a binary variable indicating whether or not each individual's RT peaked at 3 months. A subsequent analysis revealed an interaction between this variable and temporal distance ($p < .001$), such that those whose mean RT was longest at 3 months also showed significantly greater standard deviations in RT at 3 months than any other temporal distance (*p*s < .01 after Bonferroni correction for 6 comparisons). For individuals whose peak RT was not at 3 months, RT standard deviations were not significantly different from any other temporal distance. In combination, this indicates that, consistent with the notion of conflicting systems, the 3-month peak in mean RT is accompanied by a peak in RT variability at 3 months although some respondents appear to show this pattern more than others.

**Associations between RT and temporal discounting.** In a next step, we explored the predicted associations between RTs in implicit TSC and the transition between slopes of the temporal discounting function. As seen in Figure 2, the RT peak at 3 months for the implicit TSC task (top) visually maps onto the transition between slopes in the discounting task (bottom), which would be consistent with Hypothesis 3. Similar patterns were observed when individually graphing each respondent's RTs for the implicit TSC task against their double exponential discounting function. To statistically test for the proposed association between these constructs, we manually coded the timing of individual RT peaks by recording the temporal distance, in months, at which the longest RT occurred. We then examined correlations between the timing of the RT peaks and individual-level parameters from the double exponential discounting function.

Specifically, we focused on ω which represents the relative contribution to discounting by the β and δ systems. In other words, varying the ω parameter in the model while holding the other 2 parameters constant affects the time (in this case, in months) at which the discounting function transition from steeper to flatter. As expected, the resulting values correlated significantly with individual ω estimates ($r = -.24$, $p < .05$). This suggests that greater contribution to discounting from the β system (i.e., valuation network) relative to the δ system (i.e., control network), is associated with RT peaks occurring sooner rather than later in the implicit TSC task.

**Covariates**

To explore associations between discounting, TSC, and the different covariates, we used maximum likelihood estimation in SAS PROC NLMIXED (Littell et al., 2006) to fit double exponential trajectories (Equation 3) to each individual's data for explicit TSC, implicit TSC, and temporal discounting. For each participant, this resulted in three parameter estimates for each of the three measures. We then computed correlations between each of these parameters and the different covariates. Results are shown in Table 3. Among the three constructs, implicit TSC showed the largest number of significant associations with covariates, but no clear pattern was discernible, and—after applying Bonferroni corrections for multiple comparisons—none of the associations remained significant.

## Discussion

The present study was the first to administer explicit and implicit measures of TSC along with a temporal discounting measure with regard to multiple temporal distances ranging from a single month up to a decade. We found the expected links between explicit and implicit TSC and temporal discounting which supported Hypothesis 1 and replicated existing literature (e.g., Bartels & Urminsky, 2011; Ersner-Hershfield, Garton, et al., 2009). More importantly, however, this was the first study to document a gradual shape in TSC and explore its relative fit with various theoretically implicated functions. In support of Hypothesis 2 and consistent with dual systems perspectives, the best-fitting function for both explicit TSC and temporal discounting was the double exponential model. For implicit TSC, a similar pattern was found although the difference between the relative fit of a double exponential model and a stepwise function did not reach statistical significance. This could be due to limited sensitivity of the measure, a point to which we return below, but it is also possible that functions for implicit and explicit TSC do in fact differ from each other with implicit TSC following a more step-like function as implicated by construal level theory. Future research should explore this possibility.

With regard to reaction times in the implicit TSC task, our findings mapped onto previous studies that reported a decrease in RT from present to future (D'Argembeau et al., 2010; Wakslak et al., 2008). However, because the present study measured RTs at multiple temporal distances rather than a binary present-future comparison, it also revealed a peak in mean RT at an intermediate distance (i.e., 3 months). To our knowledge, this is the first study to report such an effect. Moreover, we found support for Hypothesis 3 in that the temporal distance of participants' peak RTs in the implicit TSC task was associated with the transition point of their temporal discounting functions from steep to flat.

Contrary to expectations, the various covariates under consideration showed no systematic associations with the individually-fitted double exponential parameters for TSC or the discounting function. Thus, interindividual variations in the temporal dynamics of subjective value and self-similarity do not appear to be associated with cognitive functioning, global future horizons, subjective health, or five factor traits. Thus, future research needs to explore a wider range of possible covariates to explore associations with other aspects of individual differences.

Beyond providing partial support for our hypotheses, our findings have broader theoretical implications. The RT findings in particular offer novel evidence suggesting that thinking about multiple "selves" over time may involve a transition that occurs when a sufficiently-distant future self is no longer perceived as consistent with the present self. This is reflected by a peak in the length and variability of RTs occurring - on average - about 3 months into the future. It is also reflected in temporal discounting patterns that transition from a steep drop to a relatively flat function around this same temporal distance. These findings may point towards a situation of decision conflict where two cognitive mechanisms compete for processing the same material. The initial increase in RT from the present to three months may also reflect a process of anchoring and adjusting (Tversky & Kahneman, 1974) where participants anchor their ratings for future selves in the present moment and then adjust for expected differences due to the passing of time. However, as temporal distance increases, adjustment likely takes longer and longer. At some point, adjustment may be no longer feasible, and respondents shift to an alternative, less demanding approach. Similar patterns were recently reported by Tamir and Mitchell (2013) who examined reaction times for answering descriptive questions about others. They observed that RTs were longer for others who were seen as similar to the self and thus accessible to anchoring and adjustment as opposed to dissimilar others who were likely processed with less demanding strategies.

Although the convergence in TSC and discounting patterns would suggest that the two phenomena are driven by the same neural mechanisms, it is of course possible that entirely different dual systems are at work, albeit with a common "cutoff point" between subjective present and future within a given individual. Also, while a two-systems model appears to fit well, there may be more than two systems contributing to some types of decisions (e.g., Peters &

Büchel, 2011, suggest a prospection system in addition to valuation and control). Supplementing behavioral data with corresponding neural markers would be an important step in differentiating among these possibilities. To obtain a clearer understanding of neural mechanisms, one might prescreen participants based on behavioral data to focus on those who show prominent increases in RT at intermediate distances. Within this group, one could then obtain fMRI data to examine relative overlap with the neural systems implicated in prior work (e.g., Hare et al., 2009.

Further research is also needed to explore the causal dynamics among subjective ratings of TSC, behavioral preferences in discounting tasks, and the relative strength of the underlying brain networks. Both TSC and discounting could be considered as manifestations of the ability to vividly imagine one's self in the future and consider future consequences which is rooted in the relative strength of various neural systems. Thus, TSC could be viewed as an epiphenomenon that reflects patterns of brain activity and choice preferences but cannot exert a causal influence on brain or behavior. However, recent evidence suggests that changing TSC may at least change behavioral patterns. Hershfield and colleagues (2011) found that presenting young participants with a computer-rendered avatar of their older self increased TSC and promoted retirement savings. A next step for future research would be to examine brain activation patterns resulting from successful TSC manipulations such as those by Hershfield and colleagues (2011). This may begin to establish whether certain brain activation patterns can be influenced by experimentally induced shifts in TSC.

Another open question concerns the degree of distinctiveness between TSC, especially implicit TSC assessed by future trait ratings, and other forms of future thought including episodic simulation. Conceivably, perceiving oneself as similar to one's future self may be aided by the ability to imagine one's future in rich detail and although research on brain lesions indicates that episodic prospection and temporal discounting are governed by distinct brain regions, (Fellows & Farah, 2005) similar evidence for TSC is not yet available. Further, Szpunar, Spreng, and Schacter (2014) suggest that prospection may take many forms including semantic, or hybrid episodic-semantic prospection and certain forms of future thought may include non-simulation processes such as prediction (Szpunar et al., 2014). Accordingly, an appropriate classification for anticipating one's future traits may be a hybrid episodic-semantic prediction. To differentiate among such concepts, one would have to assess their associations within the same sample—ideally with regard to the same range of time horizons.

Of course, future research is also needed to address some important methodological limitations of the present research. One key concern is the use of an undergraduate student sample. It is not known whether the findings would transfer to representative samples including adults of all ages. In addition to age, the use of a student sample may have also limited the variability in other measures such as socioeconomic status, cognitive ability, and subjective health.

Another limitation is that, although the present study administered two TSC measures that produced three dependent variables, other aspects of TSC such as emotional connectedness to the future self were not assessed. Moreover, the measures we did use could benefit from further refinement. It is possible that our implementation of the implicit TSC task was limited in sensitivity because it focused on trait ratings which, according to laypeople's views, are seen as relatively stable over time (note that % agreement with the present leveled off at above 80%). Including more malleable concepts such as states, values, or social roles, could increase the sensitivity of this assessment. Similarly, the explicit TSC measure only provided seven degrees of overlap between the circles. Future implementations might allow participants to freely vary the overlap in the circles along a sliding scale.

If the basic pattern of our results is corroborated by future research it would not only promote new theoretical insights but also offer practical guidance on tackling problem behaviors that result from a tendency to overvalue the present relative to the future. Such issues are prevalent in a variety of outcome domains including finances, diet and exercise, or substance use disorders which have all been notoriously resistant to attempts at behavior change. If TSC, temporal discounting, and patterns of neural activation are different manifestation of the same phenomenon, it may be beneficial to address all three components in a combined intervention which aims to increase TSC at the level of mental representations (e.g., Hershfield et al., 2011), promote beneficial decisions patterns at the behavioral level, and address imbalances in neurotransmitters through pharmacological interventions. More importantly, TSC-based approaches may have a role in prevention. Limitations in TSC may represent a risk factor that could be screened for unobtrusively before manifest problems develop. This may prove especially valuable for adolescents who are in the process of establishing health and spending habits that are likely to last a lifetime.

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Table 1

Descriptive Sample Characteristics

| | *M(SD) / %* |
|---|---|
| Demographics | |
| Age | 20.02 (1.34) |
| Gender (% female) | 62% |
| Race (% White) | 50% |
| SES | 2.79 (1.23) |
| Subjective health | |
| Subjective physical health | 52.83 (7.42) |
| Subjective mental health | 42.70 (10.65) |
| Cognition | |
| Vocabulary | 16.38 (3.72) |
| Working memory | 0.89 (0.11) |
| Processing speed | 70.99 (12.32) |
| Numeracy | 0.74 (0.23) |
| Personality | |
| Neuroticism | 2.95 (0.34) |
| Extraversion | 2.79 (0.26) |
| Openness | 2.87 (0.32) |
| Agreeableness | 2.99 (0.34) |
| Conscientiousness | 2.65 (0.28) |
| Future time horizon | 55.42 (8.10) |

*Note*. SES = Socioeconomic status; 1 = lower income; 5 = upper income.

Table 2

Comparisons of Alternative Models for TSC and Discounting Data (Fit Statistics and Parameter Estimates for Aggregate Data)

| | BIC | Parameter | Estimate |
|---|---|---|---|
| Explicit TSC | | | |
| Linear function | 2488.7 | B | -0.0319 |
| Exponential function | 2447.2 | k | 0.0068 |
| Hyperbolic function | 2411.2 | k | 0.0107 |
| Double exponential (generalized quasi-hyperbolic) function | 2261.2 | β | 0.2140 |
| | | δ | 0.9963 |
| | | ω | 0.1902 |
| Stepwise arctangent function | 2377.1 | A | 2.0520 |
| | | μ | 0.9989 |
| | | B | 5.8800 |
| Implicit TSC: Percent Agreement between Present | | | |
| Linear function | 5133.7 | B | -0.1706 |
| Exponential function | 5120.3 | K | 0.0019 |
| Hyperbolic function | 5113.0 | K | 0.0022 |
| Double exponential (generalized quasi-hyperbolic) function | 4735.5 | B | 0.0124 |
| | | δ | 0.9997 |
| | | Ω | 0.1321 |
| Stepwise arctangent function | 4740.0 | A | 14.2458 |
| | | μ | 0.9630 |
| | | B | 92.2140 |
| Temporal Discounting | | | |
| Linear function | 6072.7 | B | -0.6444 |
| Exponential function | 5558.1 | k | 0.1087 |
| Hyperbolic function | 5436.1 | k | 0.1620 |
| Double exponential (generalized quasi-hyperbolic) function | 5345.2 | β | 0.5091 |
| | | δ | 0.9894 |
| | | ω | 0.4929 |
| Stepwise arctangent function | 5587.3 | A | 35.5960 |
| | | μ | 2.3328 |
| | | B | 44.8808 |

*Notes*. Smaller BIC values indicate better fit to the data; BIC > 10 between two models suggest a better fit for the model with the smaller value (Kass & Raftery, 1999).
Exponential function = Equation 1; Hyperbolic function = Equation 2; Double exponential function = Equation 3; Stepwise function = Equation 4.

Table 3

Correlations of Parameters from the Double-Exponential Models for Explicit TSC, Implicit TSC, and Temporal Discounting with Theoretically Implicated Covariates

| | Explicit TSC | | | Implicit TSC | | | Discounting | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\beta_{ExpTSC}$ | $\delta_{ExpTSC}$ | $\omega_{ExpTSC}$ | $\beta_{ImpTSC}$ | $\delta_{ImpTSC}$ | $\omega_{ImpTSC}$ | $\beta_{Disc}$ | $\delta_{Disc}$ | $\omega_{Disc}$ |
| Demographics | | | | | | | | | |
| Age | .02 | -.07 | .08 | -.14 | -.13 | -.14 | .05 | .00 | .04 |
| Gender (female) | -.17 | -.03 | .08 | -.12 | **.24*** | .06 | -.17 | -.01 | -.03 |
| Race (white) | .14 | .09 | .10 | .11 | -.11 | .08 | .01 | .01 | -.06 |
| SES | -.07 | **.27*** | .13 | -.10 | .04 | -.10 | .03 | -.00 | .01 |
| Background | | | | | | | | | |
| Future time horizon | -.06 | -.12 | -.11 | .02 | .16 | -.20 | .16 | -.03 | -.06 |
| Subjective physical health | .12 | .17 | -.06 | -.17 | .05 | **-.28*** | .10 | .04 | -.16 |
| Subjective mental health | .07 | -.04 | -.03 | .08 | .15 | -.08 | .12 | .04 | .08 |
| Personality | | | | | | | | | |
| Neuroticism | .00 | -.16 | .06 | -.05 | .09 | .17 | .00 | .09 | -.04 |
| Extraversion | -.04 | .06 | .14 | .06 | .03 | .05 | -.01 | -.05 | .02 |
| Openness | .20 | -.06 | .10 | .09 | **-.36**** | .18 | -.15 | -.12 | -.01 |
| Agreeableness | .10 | .00 | -.17 | .03 | .08 | **-.31**** | -.05 | -.07 | .02 |
| Conscientiousness | .08 | .05 | .12 | -.01 | .03 | .09 | -.09 | -.04 | -.15 |
| Cognition | | | | | | | | | |
| Vocabulary | .16 | .09 | .18 | .10 | -.16 | -.06 | .01 | .01 | .01 |
| Numeracy | .09 | -.03 | .11 | -.04 | **-.39**** | -.05 | **-.21*** | -.09 | .13 |
| Working memory | .10 | .09 | -.08 | -.08 | -.09 | -.09 | -.04 | .04 | -.05 |
| Processing speed | -.07 | .13 | -.03 | .09 | .12 | **-.24*** | .11 | .04 | .04 |

*Notes*. Correlations are Spearman's rho correlations to address the deviation from normality in the parameter distributions.
Correlations for gender and race are point-biserial,
Significant correlations are shown in bold.
SES = Socioeconomic status; 1 = lower income; 5 = upper income.
**$p$ < .01, *$p$ < .05.

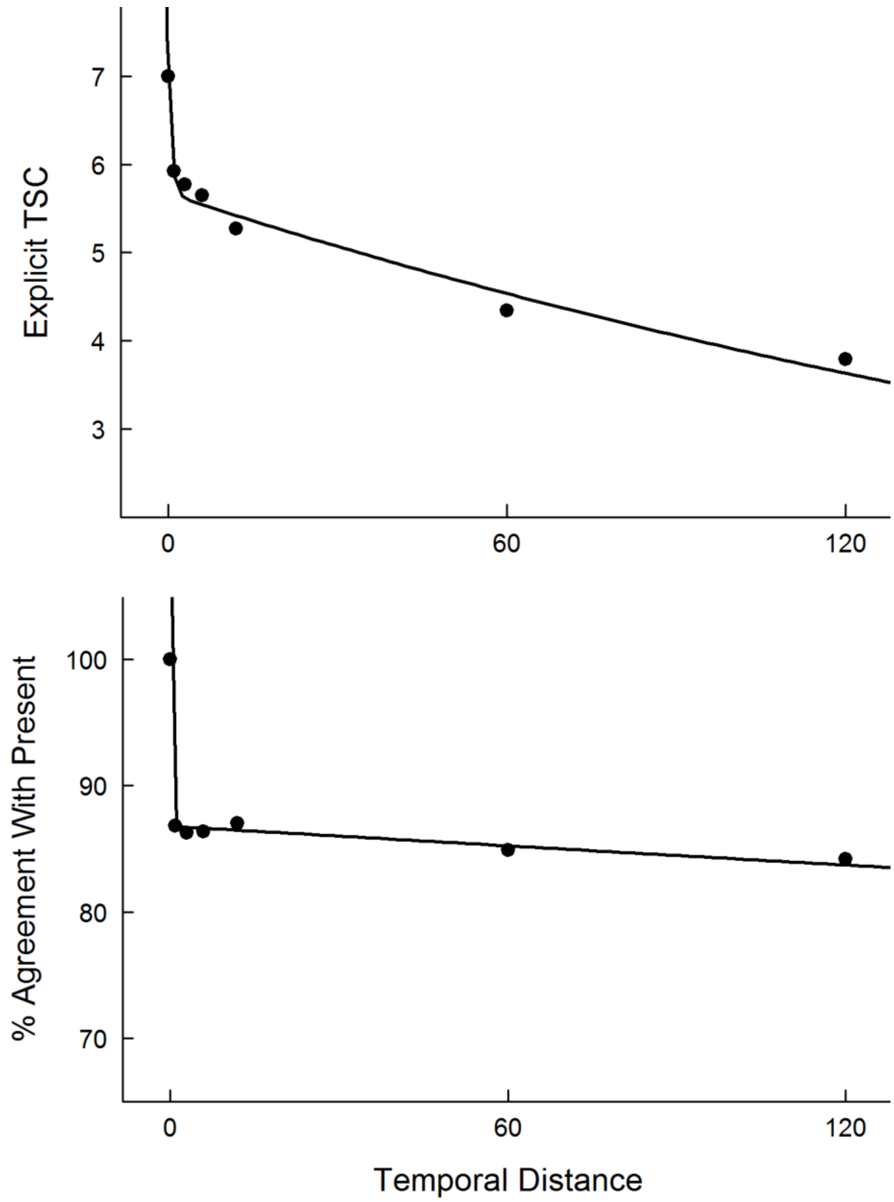


*Figure 1.* Aggregate scores for explicit TSC (top) and implicit TSC (bottom, measured by percent agreement with present trait ratings). Solid points indicate mean TSC values for each temporal distance. Curves indicate double exponential trajectories (Equation 3) fitted to the aggregate data points for each measure.

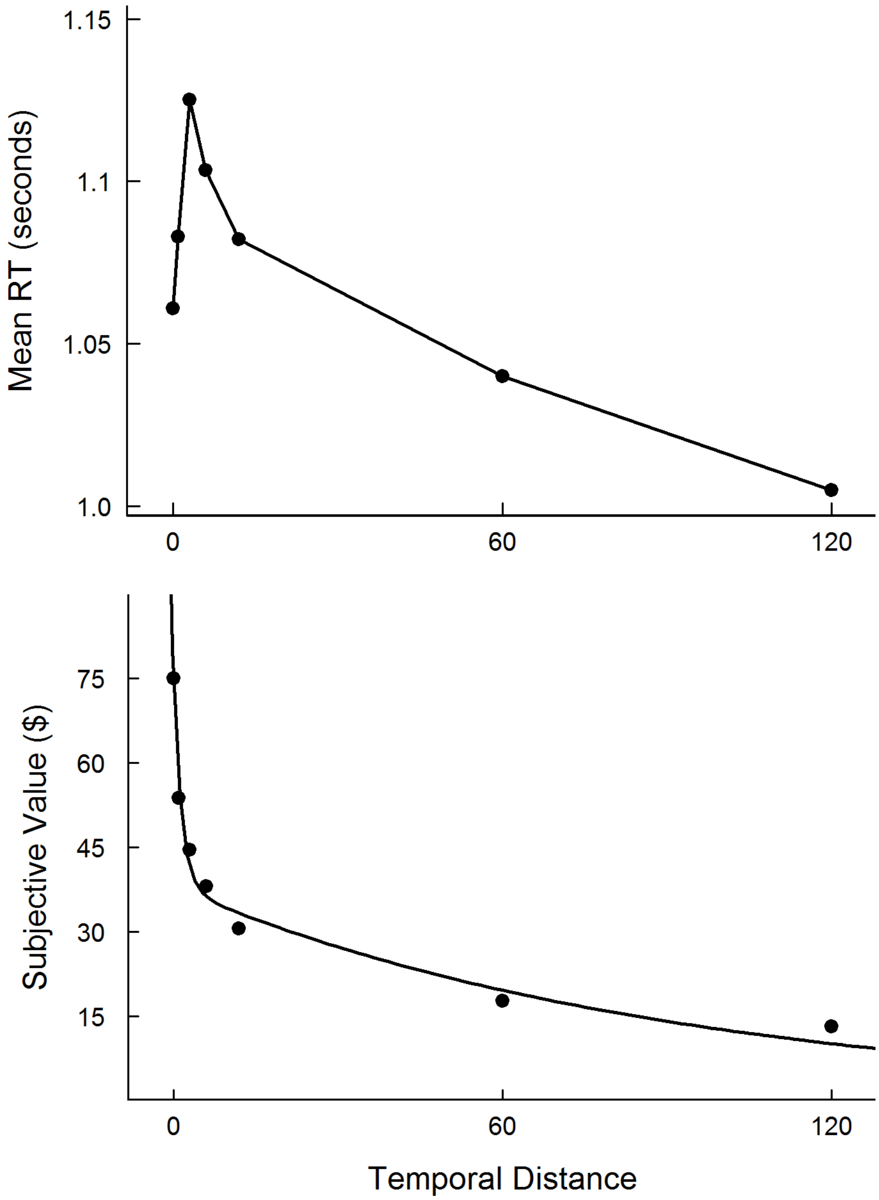


*Figure 2.* (top) Aggregate reaction times in the implicit TSC task plotted for each temporal distance. (bottom) Aggregate temporal discounting values plotted for each temporal distance; curve shows double exponential trajectory (Equation 3) fitted to aggregate data.

# CHAPTER 3

# FROM PAST TO FUTURE: TEMPORAL SELF-CONTINUITY ACROSS THE LIFE SPAN

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Abstract

Although perceived continuity with one's future self has attracted increasing research interest, age differences in this phenomenon remain poorly understood. The present study is the first to simultaneously examine past and future self-continuity across multiple temporal distances using both explicit and implicit measures and controlling for a range of theoretically implicated covariates in an adult life span sample ($N$ = 91, aged 18-92, $M$ = 5.15, $SD$ = 19.20, 56% female). Perceived similarity to one's self across 6 past and 6 future time points (1 month to 10 years) was assessed with an explicit self-report measure and an implicit me/not me trait rating task. In multilevel analyses, age was significantly associated with greater implicit and explicit self-continuity, especially for more distant intervals. Further, reaction times in the implicit task increased with temporal distance for older adults but decreased with temporal distance for younger adult, especially for future ratings. This points toward age differences in the underlying mechanisms of self-continuity. Multilevel models examined the role of various covariates including personality, cognition, future horizons, and subjective health and found that none of them could fully account for the observed age effects. Taken together, our findings suggest that chronological age is associated with greater self-continuity although specific mechanisms and correlates may vary by age.

## Introduction

Most of us would agree that who we are depends not only on our present thoughts, feelings, and activities but also on our experiences and recollections of the past and the way we envision ourselves into the future; in other words, where we have been and where we are going. Initial inquiries in temporal construal relating the present self to the past self (temporal comparison theory; Albert, 1977) and to the future self (Parfit, 1971), have led to broader questions about the degree of temporal self-continuity that individuals experience over time as well as possible implications for well-being and decision making.

With respect to aging, some have argued that self-continuity is a key element in preserving well-being and a sense of identity in the face of age-related changes (Baltes, Lindenberger, & Staudinger, 2006), but to date, relevant research is distributed across multiple fields, and individual studies focus on select aspects of past or future construal. The present study paves the way for an integration across theoretical frameworks by providing a comprehensive assessment of multiple aspects of temporal self-continuity (TSC) in an adult life span sample.

## Theoretical Background

To put our findings into context, we now review select lines of theory and research that each have relevance to TSC but have approached it from different angles. Within Hooker's (2002) three-tiered life-span model of personality, core aspects of TSC are captured at the second level including possible selves (Markus & Nurius, 1986), personal goals (Carstensen, 2006; Ebner, Freund, & Baltes, 2006), as well as aging-related expectations (Heckhausen & Krueger, 1993). TSC is also inherent in autobiographical thought and narratives which can be understood as an overarching aspect of personality (Hooker, 2002), but are also subject to age-related shifts in cognitive processing and resources (Bluck & Alea, 2008). In addition, emerging research in behavioral economics has linked perceived similarity with one's future self to financial decisions (Ersner-Hershfield, Garton, Ballard, Samanez-Larkin, & Knutson, 2009). Drawing on these diverse theoretical frameworks, we integrate ideas and concepts to develop the rationale for the present study.

**Possible Selves and Personal Goals**

Markus and Nurius (1986) first introduced the notion of "possible selves" defined as who a person imagines being in the future, including aspects they hope will become part of themselves in the future and those they hope will not. The authors propose that possible selves are generated based on one's past but exert an influence on the person's present behavior. This behavior helps the person pursue goals that move them toward the person they hope to become. To date, age-differences in possible selves have not been explicitly explored but one would expect them to be linked with age-related shifts in goal priorities. Theoretical perspectives on age associated motivational changes have focused on two potential mechanisms - age-related decrements in cognitive and physical functioning and age-associated limitations in future time horizons.

Although laypersons' views of aging tend to highlight age-related losses, life-span developmental theorists have long recognized that both gains and losses can occur at any point in the life span, although the relative ratio of gains relative to losses decreases with age (e.g., Baltes, 1997). Action-theoretical perspectives propose that people are proactive agents in negotiating such changes and reorient from striving for gains towards maintenance or prevention of losses (Ebner et al., 2006). In terms of TSC, this implies that older adults may be increasingly motivated to strive for continuity, whereas younger adults may expect and prefer a (positively) changed future self.

Socioemotional selectivity theory (SST, Carstensen, 2006; Carstensen, Isaacowitz, & Charles, 1999), in turn, provides an alternative view of age differences in motivational priorities. It suggests that age-associated limitations in future time horizons lead to changes in goal priorities with younger adults pursuing future oriented goals such as information acquisition whereas older adults focus on emotional well-being in the present moment. The association between changes in future horizons and TSC has not been examined, but conceivably, a focus on the present might blur differences between the past, present, and future self with older adults living (subjectively) in an extended present.

**Expectations About Aging**

Expectations about aging may influence TSC as well. Heckhausen and Baltes (1991) examined age differences in perceived controllability of age-related changes and found that changes in later life were perceived as less controllable and less favorable. Similarly, Heckhausen and Krueger (1993) studied expected change in various traits over the adult lifespan. For undesirable traits, older adults expected very little change whereas younger adults expected a substantial increase from younger to older adulthood. No substantial differences emerged for expected change in positive traits (Heckhausen & Krueger, 1993). This is consistent with action theoretical perspectives (Ebner et al., 2006) which propose limited opportunities for growth with advancing age resulting in a tendency to anticipate continuity and to prioritize maintaining the current functional state and avoid gaining undesirable traits.

One question raised by these studies is whether a person’s past influences expectations for the future. If substantial change has occurred in the past, will the person anticipate similar levels of change in the future? While research on age-related goal shifts and aging expectations has primarily focused on the future and rarely addressed the past, inquiries into autobiographical thought show the opposite pattern.

**Autobiographical Thought**

It has been noted that past and future autobiographical thought show similarities in phenomenal characteristics and respond similarly to increasing temporal distance and variations in valence (D'Argembeau & Van der Linden, 2004). The episodic simulation hypothesis (Schacter & Addis, 2008; Schacter, Gaesser, & Addis, 2013) explains such similarities by arguing that recall of past events and anticipation of future events rely on similar resources. Research on age differences in autobiographical thought has primarily focused on recall of past events and revealed significant age-related decrements with older adults recalling fewer perceptions and thoughts relevant to the specific event and more unrelated thoughts and general semantic knowledge (for a review see Old & Naveh-Benjamin, 2008). The limited evidence for age differences in future thought shows convergent effects, with older adults offering fewer episodic details but greater semantic content (Addis, Musicaro, Pan, & Schacter, 2010; Cole, Morrison, & Conway, 2013). This work suggests that age-related changes in past and future TSC are symmetrical. However, it is not clear whether age-associated reductions in episodic detail translate into lower or higher levels of perceived similarity with past and future states.

**Behavioral Economics**

A final line of research relevant to TSC comes from the field from behavioral economics where researchers have long sought to explain the phenomenon of temporal discounting, that is, the tendency to devalue future outcomes relative to more immediate ones (Ainslie, 1975, Frederick, Loewenstein, & O'Donoghue, 2002, Samuelson, 1937). Recent evidence suggests that individuals who feel more similar to their future selves (e.g., 10 years later) are less likely to discount future outcomes and more likely to select larger, delayed over smaller immediate rewards (Bartels & Urminsky, 2011; Ersner-Hershfield et al., 2009). Research on age differences in temporal discounting has found that older adults are less likely to discount the future (for a review see Löckenhoff, 2011) and at least one study suggests that the age-related tendency to perceive one's future emotions as more continuous with present feelings can partially account for this effect (Löckenhoff, O'Donoghue, & Dunning, 2011). These findings point towards age-related increases in future TSC, although convergent effects for the past remain to be explored.

**The Present Study**

Taken together, the prior literature offers some initial hints that TSC may vary by age. Convergent findings ranging from life-span theories of motivation to behavioral economic approaches hint that with age, concepts related to TSC may show greater continuity between the present and the past and/or future. However, a comprehensive understanding of age effects is hindered by discrepancies in research practices across fields. TSC has an explicit component (self-reports) and an implicit component (typically assessed through a "me/not me" task which contrasts trait endorsements for the present with those for the past and future, D'Argembeau, Stawarczyk, Majerus, Collette, & Van der Linden, 2010), but the two are rarely examined in the same study. Also, most prior studies have focused on extreme comparisons between the present and the distant past/future, and it is not clear whether TSC follows a stepwise or gradual function as temporal distance increases. Finally, studies typically focus on either the past or the future, which makes it impossible to assess whether age effects differentially affect one or the other.

The present study aims to address these limitations by measuring TSC in an adult life-span sample using implicit and explicit measures across multiple temporal distances in both the past and the future. This allows us to assess the slope by which the subjective present 'slips' into the future and past and examine how this differs by individual and by age. We also examine the degree of symmetry between future and past self-continuity (plotted as a function of distance from the present) and consider potential covariates including subjective health (implicated by action-theoretical frameworks), future time horizons (implicated by SST), cognitive functioning (implicated by research on age differences in autobiographical thought), and personality (implicated by age differences in personality traits; Roberts, Walton, & Viechtbauer, 2006).

## Method

### Participants

Ninety-one community-dwelling participants aged 18 - 92 (*M* = 5.15, *SD* = 19.20, 56% female, 84% white) were recruited via advertisements and an existing database. We aimed for a sample representative of the local community and with comparable demographic characteristics across different ages. Table 1 shows descriptive sample characteristics and their associations with age. Participants were compensated $25 for their participation.

### Temporal Self-Continuity Assessments

**Temporal distances.** Temporal distances (at present, 1 month, 3 months, 6 months, 1 year, 5 years, 10 years) were the same across all tasks described below. The higher sampling rate within the first year was based on pilot findings suggesting maximal interindividual variance within that frame. Past and future ratings were presented in separate blocks and the order was counterbalanced across participants. For consistency, both the past and the future block included an "at present" condition. For further analyses, all target intervals were converted to months.

**Guided imagination task**. The past and future blocks began with a guided imagination task adapted from D'Argembeau et al. (2010) in which participants imagined themselves at each future interval or recalled themselves at each past temporal distance. For each interval they were given 15 seconds to imagine a typical day, including their activities and the people in their social networks at that time.

**Explicit TSC task.** Participants rated perceived similarity with their future / past selves on a visual scale adapted from Ersner-Hershfield and colleagues (2009) based on the Inclusion of Other in the Self Scale (Aron, Aron, & Smollan, 1992). Participants chose among 7 pairs of circles labeled “current self”/”future self” and “current self”/”past self” that ranged from complete separation (1 = least similar) to almost complete overlap (7 = most similar).

**Implicit TSC task.** In a me/not me task adapted from D’Argembeau et al. (2010), participants indicated whether or not a trait adjective (e.g., wise) described them at a specified temporal distance. Six positive trait words (wise, patient, relaxed, tidy, forgiving, cheerful) and six negative trait words (dull, rude, withdrawn, careless, lazy, worrying) were selected from a standardized list (Anderson, 1968). Pairs of positive and negative words were matched, as closely as possible, on word length, number of syllables, and word use frequency based on the SUBTLEXus database (Brysbaert & New, 2009). Each trait word was presented once for each temporal distance. Four trials comprised a block, each block focused on the same temporal distance, and the order of blocks was randomized across participants. The target temporal distance (e.g., 6 months from now) remained at the top of the screen during each block as the trait words were presented, one at a time, and participants responded either “Yes” or “No” via button-press.

In addition to the 7 temporal distances (including “at present”), a control condition was included which simply asked, “Is this a POSITIVE word?” This condition was included to test for systematic differences in reaction times (RTs) between the control condition and each of the temporal distances, as the control condition requires no future-oriented thought. For further analyses we computed the percentage of agreement with present trait ratings for each temporal distance. We also recorded RTs for each trial (outliers > 3SD above a participants' mean were replaced with the participants' mean).

## Measures

**Demographics.** Age, gender, ethnicity, race, income, and years of education were assessed.

**Future time horizons.** On the Future Time Perspective Scale (FTP; Carstensen & Lang, 1996), participants rated the degree to which they agreed with ten statements using a 7-point Likert scale. Statements covered topics such as the extent to which participants felt they had remaining future opportunities, expected to set new goals in the future, and whether their future was open-ended versus time-limited (Lang & Carstensen, 2002). For further analyses, we inverted revers-coded items and computed a summary score with higher scores indicating more expansive time horizons.

**Personality.** A 10-item measure of the Five-Factor Model of personality was administered (BFI-10; Rammstedt & John, 2007) generating 5 subscale scores corresponding to extraversion, openness to experience, agreeableness, neuroticism, and conscientiousness.

**Subjective health** was assessed with the SF-12 (Ware, Kosinski, & Keller, 1996) where scoring algorithms yields separate ratings for mental and physical health.

**Cognition.** Cognitive performance was assessed in the following domains: Vocabulary (Nelson-Denny Reading Test, vocabulary section; Brown, Fishco, & Hanna, 1993), processing speed (Digit-Symbol Coding; Wechsler, 1997), and working memory (letter-based *n*-back; $n = 2$; Ragland et al., 2002).

### Procedure

Participation consisted of a single, 60-minute session. With the exception of the Digit

Symbol task, participants responded to all tasks via computer (E-Prime, Version 2.0; Psychology Software Tools, 2009).

After providing informed consent, participants completed a demographic questionnaire followed by the TSC measures. All measures were administered twice: In one block participants responded regarding the future, and in another block they responded regarding the past. The order of the past/future blocks was counterbalanced across participants. Each block began with the guided imagination task followed by the TSC tasks. The order of the TSC tasks was counterbalanced across participants, but for each participant the task order was the same for the past and the future block. Within each task, the various temporal distances and the control condition were presented in randomized order. Participants also completed a temporal discounting task which is not discussed further since it goes beyond the scope of the present study.

Participants then completed the time horizon and personality measures, the subjective health assessment, and the cognitive tasks. Finally, they were paid, thanked, and debriefed.

**Data Analyses**

The experimental design was nested such that temporal distance (in months) was nested within trait word which was in turn nested within participants. We therefore employed multilevel modeling to examine age differences in different aspects of TSC. For all models, a random effect was specified for intercept. Fixed effects were specified for temporal distance, temporal direction (coded as past = -1, future = 1), and age. The model examining RTs in the implicit task also included “trait word” as an additional random effect to account for the influence of word length and other aspects of readability on response times. A natural log transformation was applied to the temporal distance variable to ensure that residuals fit criteria for normality. Age was centered at the sample's mean (5.15) to allow for meaningful interpretation of the regression coefficients. Estimates were obtained using restricted maximum likelihood estimation (REML).

First, an intercept-only model was fit to the data for each dependent variable to estimate the ratio of interindividual-to-intra-individual variability. For explicit TSC, the intra-class correlation (ICC) was .26, suggesting that 26% of the total variance in explicit TSC was attributable to variability between individuals. For implicit TSC, the intraclass correlations were .29 for percent agreement with present trait ratings, and .30 for RT. This suggests a need to model both within- and between-subjects effects, justifying multilevel analyses as an appropriate approach to our data.

For each of the three dependent variables (explicit TSC, implicit TSC, and implicit RT) we then fitted exploratory models including main effects of age, temporal direction, and temporal distance, as well as all higher order interactions. The final models retained the main effects and all significant interactions. Supplemental analyses examined the role of covariates. Any covariates showing significant associations with age (see Table 1) were added to the models to examine whether age effects remained significant. Because of concerns about collinearity, covariates were added one at a time.

## Results

### Explicit Temporal Self-continuity

A 3-level model estimated effects of age and temporal direction (future vs. past), as a function of temporal distance, on self-reported similarity to future and past selves (Table 2). The effect for temporal direction failed to reach significance, indicating that participants' perceived similarity to their past selves did not differ substantially from perceived similarity to their future selves. There were significant main effects of age (indicating higher explicit TSC with advanced age) and temporal distance (indicating progressively lower explicit TSC with increasing distance from the present). This effect was qualified by a significant interaction between age and temporal distance indicating that the decrease in explicit TSC with distance was less steep in older as compared to younger adults. This pattern is illustrated in Figure 1.

**Implicit Temporal Self-continuity: Percent Agreement with the Present**

A 3-level model estimated effects of age and temporal direction (future vs. past), as a function of temporal distance, on percent agreement with present trait ratings on the me/not me task (Table 3). As for explicit ratings, the main effect of temporal direction was not significant. Main effects were significant for both age (indicating that implicit TSC increased with age) and temporal distance (indicating that implicit TSC decreased with increasing distance from the present). These main effects were qualified by a significant interaction between temporal direction and temporal distance indicating that the drop in implicit TSC with increasing distance was less pronounced for the future than for the past. As for explicit TSC, there was an age by temporal distance interaction: Compared to younger adults, older adults' implicit TSC decreased less steeply as a function of temporal distance (see Figure 2).

**Implicit Temporal Self-continuity: Reaction Time**

To test for differences in RT between the control condition and the temporal (i.e., self-continuity) conditions, we first fit a four-level model that included temporal direction, word, and subject as random effects and condition (i.e., the control condition and the seven levels of temporal distance) as a fixed effect. Residuals from this model did not fit criteria for normality; therefore, a natural log-transformation was applied to RTs for analysis. Using Bonferroni correction for 7 comparisons, mean RT was significantly shorter for the control condition than for any of the temporal distance conditions (all *p*s $< .001$) suggesting that, as expected, responses involving TSC judgments elicited more extensive processing. We therefore excluded the control condition in subsequent analyses. We fit a similar model to test the effect of stimulus valence, and found that positive and negative words did not differ significantly in their effects on RT. We therefore dropped valence from subsequent analyses as well.

We then fit a three-level model including word and subject as random effects and age, temporal direction, and temporal distance (excluding the control condition) as fixed effects. Main effects were significant for temporal distance, temporal direction, and age, all with positive coefficients indicating that RTs were higher for longer temporal distances, for the past (relative to the future), and for older as compared to younger adults. These main effects were qualified by a significant age by temporal distance by temporal direction interaction (see Table 4). To examine the interaction, we fit separate 3-level models for the future and past conditions including word and subject as random effects (see Table 5). For the past condition, main effects were significant for temporal distance ($b$ = 1.843, $SE$ = .174, $p$ < .001) and age ($b$ = .544, $SE$ = .188, $p$ < .01). However, the age by temporal distance interaction was not significant ($b$ = -.013, $SE$ = .009, $p$ = .15). For the future condition, there was a significant main effect of age as well as a significant interaction between age and temporal distance ($b$ = .021, $SE$ = .008, $p$ < .014; see Table 4) indicating that the effect of temporal distance on RT varied by age. As seen in Figure 3, RTs for older adults were similar across temporal distances. RTs for younger adults, in contrast, became faster with greater distance into the future.

**Covariate Analyses for Explicit Temporal Self-continuity**

In a final step we examined whether the interactions between age and temporal distance remained significant after controlling for each of the covariates that showed significant associations with age (i.e., race, mental health, physical health, FTP, neuroticism, vocabulary, working memory, and processing speed; see Table 1). In addition to the main effects and interactions shown in Tables 2-4, each model included the main effect of the covariate and the interaction between the covariate and temporal distance. We fit separate models for each of the covariates and for each of the three TSC variables (i.e., explicit TSC, implicit trait agreements, and implicit RTs). For analyses examining implicit RTs, we selectively focused on the future condition which had shown a significant age by temporal distance interaction.

After including the covariates, the main effects of age and the age by temporal distance interactions remained statistically significant (*p*s < .05) for all models with one exception: For RTs in the future condition of the implicit task, including FTP as a covariate reduced the age by temporal distance interaction to a trend (*p* = .07).

**Discussion**

To our knowledge, this is the first study to examine age differences in TSC measured both explicitly and implicitly and across multiple temporal distances into the past and future. Consistent with hypotheses, advancing age was associated with greater explicit and implicit TSC, especially for increasingly greater temporal distances.

In general, these findings are consistent with expectations of age-related goal changes away from growth and toward maintenance (Ebner et al., 2006) as well as the possibility (raised by SST, Carstensen, 2006) that older adults may be living in an “extended present” and thus perceive little if any difference between their present, past, and future selves.

Analyses of RT data also point towards potential age differences in the underlying mechanisms of TSC: When rating their future traits, younger adults responded more quickly to increasingly future time intervals whereas older adults’ response times did not vary by distance. One way to interpret these results is that whereas older adults focus on maintenance goals, younger adults focus on growth-oriented goals and therefore find it easier to describe their anticipated future selves than their present selves. Another interpretation is that, older adults use the same episodic simulation processes to estimate trait ratings for their present and future selves because their future is merely seen an extension of the present whereas younger adults may shift to a different, less resource intensive mechanism once their future selves become so dissimilar from their present selves that episodic simulation is no longer possible. Further research is needed to tease apart these possibilities.

We also considered a range of covariates that might account for age differences in TSC, but found that none of the variables under consideration could account for the observed age effects. Thus, further research on potential mechanisms behind age differences is needed. As noted, this may involve a further exploration of the role of growth versus maintenance goals or neuroimaging work assessing potential age differences in the brain regions recruited during TSC ratings.

One limitation of the present research is our focus on two select measures of implicit and explicit TSC. As mentioned above, multiple operational definitions and measures of TSC have been used across various prior studies, and they appear to differ greatly and may be assessing different constructs. It would be valuable for future research to investigate the extent to which the various TSC measures that have been used in aging research correlate with those used in the present study. Factor analyses could suggest whether multiple underlying future self dimensions exist, which could then guide future research regarding the specific role each component may play in health and well-being across the life span.

Another limitation is that the present study did not control for significant life events, such as those that may be associated with younger adulthood and identity formation (e.g., starting a career). Also, episodic future and past thought may have influenced TSC ratings in the current experimental paradigm. As noted previously, older adults were found to produce fewer episodic details but greater semantic content during episodic recall or prospection (Addis et al., 2010; Cole et al., 2013). Our results suggest that if episodic detail is indeed related to TSC, its association is negative—fewer episodic details predicting greater TSC. When younger adults simulate their past and future, mentally, they may do so in a manner that is rich in details and this would include past details they remember as different from their present selves as well as future details they anticipate as different from their present selves. These details would highlight differences, rather than similarities, between one's present self and temporally-distant selves. Older adults, on the other hand, would not have this level of detail, thus no such differences would be highlighted.

Further, the present study's design was cross-sectional and thus cannot control for potential cohort effects in conceptualizations of the self over time. Conceivably, generation-specific world events may have occurred to certain cohorts but not others, and these events may have constituted significant life events and may have affected identity formation. An excellent target for further investigation would be to study longitudinal changes in TSC using the measures from the present study in a life span sample, over multiple temporal distances. This would also make it possible to assess age differences in the accuracy of anticipated future similarity, in the same ways that prior studies have examined age differences in accuracy of anticipated future life satisfaction (e.g., Lachman et al., 2008; Lang, Weiss, Gerstorf, & Wagner, 2013; Ryff, 1991).

Future research should also examine whether age differences in TSC translate into age differences in decision scenarios involving temporal discounting and other forms of intertemporal choice. With a growing population of older adults and scarcity in access to health care and financial resources, it will be critical to understand how future self-construal may influence decisions regarding health and finances. Many such choices will require trade-offs between the present and future, and it will be essential to understand how adults may select (and benefit from) differing strategies depending on their position in the life span.

Beyond a better understanding of age effects, our findings contribute to the broader literature on TSC by comparing explicit and implicit measures and by highlighting the interindividual variability. Questions remain for future research to further clarify the function of TSC in well-being, decision making, and other measures of positive adjustment, and how it may play differing roles for people at different positions in the life span.

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Table 1

Descriptive Information for Demographics and Covariates and their Correlations with Age

| | *M(SD)* | $r_{\text{Age}}$ |
|---|---|---|
| Demographics | | |
| Age | 5.15 (19.20) | -- |
| Sex (% female) | 56% | -.03 |
| Race (% White) | 84% | .31** |
| Education level | 5.51 (1.73) | .20 |
| SES | 2.40 (1.12) | .20 |
| Background | | |
| Mental health | 45.57 (11.68) | .34** |
| Physical health | 5.38 (9.97) | -.35** |
| FTP | 44.55 (14.74) | -.51** |
| Personality | | |
| Neuroticism | 5.68 (2.09) | -.34** |
| Extraversion | 6.62 (2.30) | .03 |
| Openness | 7.67 (1.87) | .04 |
| Agreeableness | 7.51 (1.84) | .09 |
| Conscientiousness | 8.03 (1.67) | -.10 |
| Cognition | | |
| Vocabulary | 18.49 (4.15) | .49** |
| Working Memory | .86 (.13) | -.31** |
| Processing Speed | 57.74 (14.44) | -.71** |

*Notes*. Correlations for sex and race are point-biserial, all others are Pearson correlations.
FTP = Lang and Carstensen's (1996) Future Time Perspective Scale.
SES = Socioeconomic status; 1 = lower income; 5 = upper income.
***p* < .01, **p* < .05.

Table 2

Estimates for Explicit Temporal Self-Continuity: Self-reported Inclusion of Other in the Self Scale

| | Estimate | *SE* | *p* |
|---|---|---|---|
| Fixed effects | | | |
| Intercept* | 5.857 | .106 | .001 |
| Temporal distance | -.310 | .012 | .001 |
| Temporal direction | -.090 | .054 | .097 |
| Age | .012 | .006 | .039 |
| Temporal distance x Age | .004 | .001 | .001 |
| Random effects | | | |
| Variance Intercept | .743 | .156 | .001 |
| Variance Temporal direction | .312 | .079 | .001 |
| Residual Variance | 1.500 | .064 | .001 |

*Note*. The temporal distance variable was natural log-transformed to ensure that residuals fit criteria for normality.
*The intercept is centered at 1 month.

Table 3

Estimates for Implicit Temporal Self-Continuity: Percent Agreement with Present Trait Ratings in the Me/Not Me Task

| | Estimate | *SE* | *p* |
|---|---|---|---|
| Fixed effects | | | |
| Intercept | 91.558 | .838 | .001 |
| Temporal distance | -1.971 | .093 | .001 |
| Temporal direction | -.396 | .493 | .423 |
| Age | .113 | .044 | .012 |
| Temporal direction x Temporal distance | -.206 | .093 | .028 |
| Temporal distance x Age | .036 | .005 | .001 |
| Random effects | | | |
| Variance Intercept | 41.811 | 9.852 | .001 |
| Variance Temporal direction | 28.068 | 6.175 | .001 |
| Residual Variance | 92.276 | 3.954 | .001 |

*Note*. The dependent variable is scaled in numerical percent (i.e., each unit is a percentage point).

Table 4

Estimates for Implicit Temporal Self-Continuity: Reaction Time in the Me/Not Me Task

| | Estimate | *SE* | *p* |
|---|---|---|---|
| Fixed effects | | | |
| Intercept | 719.486 | 3.921 | .001 |
| Temporal distance | .903 | .125 | .001 |
| Temporal direction | 5.703 | .340 | .001 |
| Age | .557 | .165 | .001 |
| Temporal direction x Temporal distance | .940 | .125 | .001 |
| Temporal distance x Age | .004 | .007 | .567 |
| Temporal direction x Age | -.013 | .021 | .525 |
| Temporal distance x Temporal direction x Age | -.017 | .007 | .01 |
| Random effects | | | |
| Variance Intercept | 870.465 | 135.003 | .001 |
| Word Intercept | 65.397 | 29.577 | .027 |
| Covariance Intercept, Word | 218.922 | 16.306 | .001 |
| Residual Variance | 1987.005 | 23.590 | .001 |

*Note*. Estimates are for effects on raw reaction time (in milliseconds).

Table 5

Separate Past and Future Estimates for Implicit Temporal Self-Continuity: Reaction Time in the Me/Not Me Task

| | Estimate | *SE* | *p* |
|---|---|---|---|
| **Future** | | | |
| Fixed effects | | | |
| Intercept (future) | 713.783 | 3.896 | .001 |
| Temporal distance (future) | -.038 | .161 | .815 |
| Age (future) | .571 | .170 | .001 |
| Temporal distance x Age (future) | .021 | .008 | .014 |
| Random effects | | | |
| Variance Intercept (future) | 911.287 | 142.922 | .001 |
| Word Intercept (future) | 55.877 | 26.191 | .033 |
| Covariance Intercept, Word (future) | 268.699 | 23.047 | .001 |
| Residual Variance (future) | 165.636 | 28.843 | .001 |
| **Past** | | | |
| Fixed effects | | | |
| Intercept (past) | 725.188 | 4.379 | .001 |
| Temporal distance (past) | 1.843 | .174 | .001 |
| Age (past) | .544 | .188 | .010 |
| Temporal distance x Age (past) | -.013 | .009 | .148 |
| Random effects | | | |
| Variance Intercept (past) | 1123.224 | 175.292 | .001 |
| Word Intercept (past) | 75.252 | 34.677 | .030 |
| Covariance Intercept, Word (past) | 277.058 | 25.295 | .001 |
| Residual Variance (past) | 1928.016 | 33.690 | .001 |

*Note*. Estimates are for effects on raw reaction time (in milliseconds). Separate models are reported here for the future and past conditions, thus the temporal direction variable is not included.

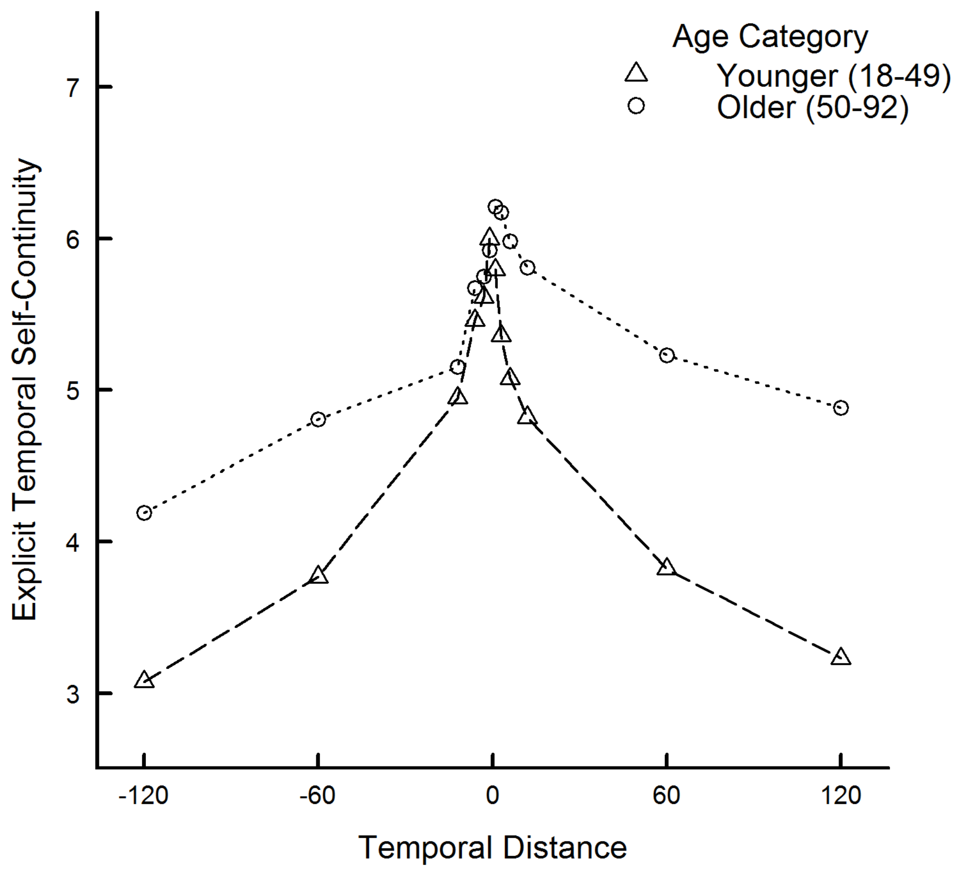


*Figure 1.* Explicit temporal self-continuity plotted separately for younger (18-49) and older (50-92) adults.

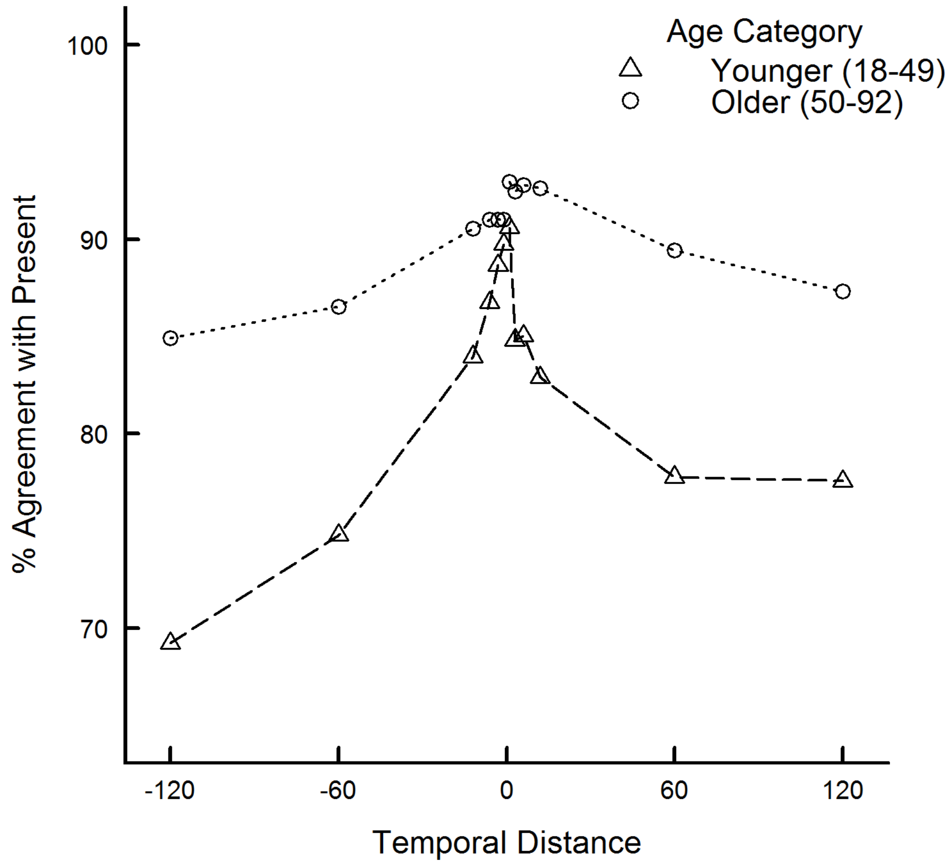


*Figure 2.* Percent agreement, in me/not me trait ratings, with present ratings. Separate plots are for younger and older adults.

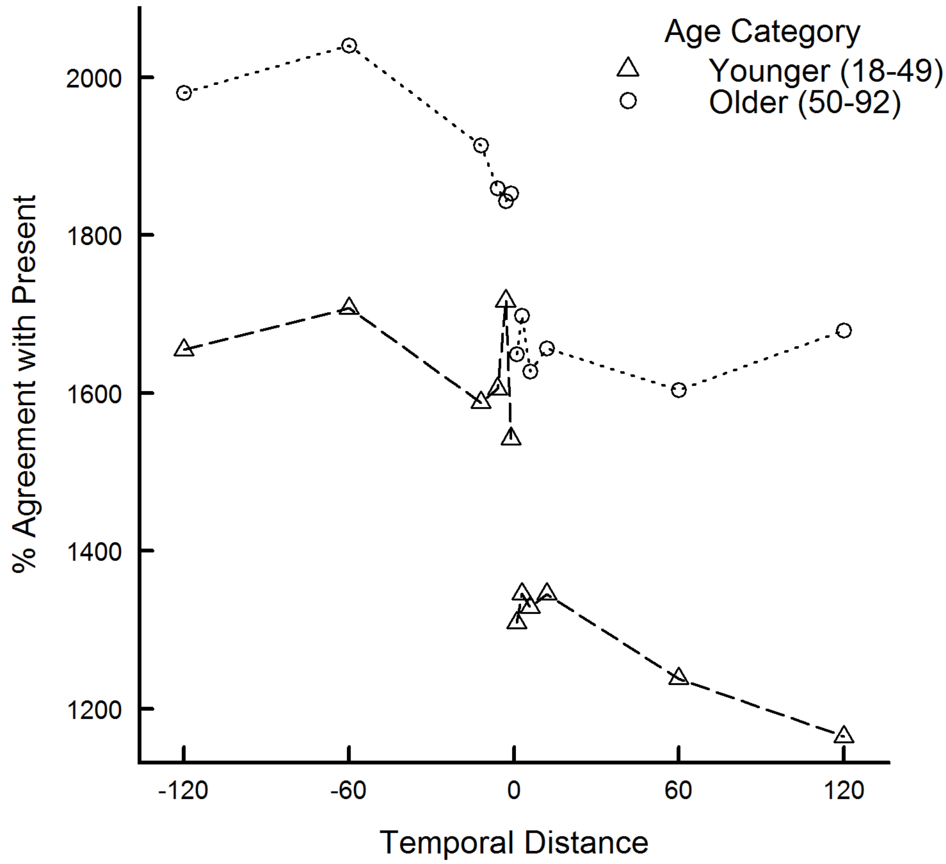


*Figure 3.* Reaction time in me/not me trait rating task, as a function of temporal distance. Separate plots are for younger and older adults.

# CHAPTER 4

## IMPLICATIONS FOR FUTURE RESEARCH

The broadest objective in presenting the three studies in this volume was to address key gaps in the research record on self-continuity (TSC) in order to achieve a more comprehensive understanding of this newly emerging construct. While prior research has established that individuals differ in the degree to which they feel continuous with their future self and that greater continuity is associated with long-term financial decisions, age, and other individual difference variables, multiple open questions remained. Chapters 1-3 successively addressed some of the most pressing of these questions.

Chapter 1 established future self-continuity as an independent time perception construct that is relatively distinct from existing concepts such as broader future time horizons or trait-type measures of future orientation. Additionally, findings confirmed previously reported age effects such that older adults showed higher self-continuity than younger respondents. However, findings were limited because the study only included a single, explicit self-continuity measure and a single future reference point.

Chapter 2 addressed these concerns by examining multiple future temporal distances using both an explicit and an implicit assessment of TSC. This approach helped to address key questions concerning the temporal trajectory of self-continuity. Is it a continuous process whereby a person perceives that they will be the same person tomorrow as they are today and that they will be a different person in 10 years, but in-between there is a gradual shift from being the “same person” to being “not the same person?” Chapter 2 presented evidence that this may indeed be the case. Specifically, TSC appears to follow a similar gradual but discontinuous trajectory over time as temporal discounting, both following a double exponential function.

Chapter 3 further built upon this work by addressing not only future but also past self-continuity and found that future self-construal is mirrored (at least to some extent) by past self-construal. Chapter 3 also followed up on preliminary evidence for age differences in TSC from Chapter 1. Results suggest that while the shape of TSC trajectories shows the same hyperbolic pattern across age groups, advanced age is associated with higher implicit and explicit TSC for both the past and the future—especially for greater temporal distances.

In the following sections, I propose a program of future research based on the open questions raised by our findings. There are some obvious next steps to expand upon the findings presented in Chapters 1 to 3. First, while Chapter 1 suggested that TSC is relatively independent of from other conceptualizations of time horizons, Chapter 2 found that TSC follows a similar gradual trajectory as the temporal discounting of future outcomes. There are of, course other psychological variables that were found to show a similar functional pattern with distance from the present self. Social discounting (Jones & Rachlin, 2006), the tendency to devalue financial gains made by increasingly distant others, may involve similar processes and show similar behavioral results, assuming the paradigm involves social distances roughly equivalent to the temporal distances in our study. Beyond social distance, the findings may also apply more broadly to other forms of psychological distances considered by construal level theory (Trope & Liberman, 2010) that have so far been studied using binary contrasts between close and distant contexts and stimuli. Upon closer examination such forms of psychological distance may reveal double exponential trajectories as well.

Another direction for future studies concerns the optimal assessment of TSC. First, interindividual variations in trajectories of TSC warrant further examination. Although Chapters

2 and 3 suggest that the aggregate data across individuals follow a double exponential pattern, this approach fails to account for the possibility that patterns may vary across individuals. Some individuals, though perhaps a minority, may show TSC patterns that yield a better fit to exponential than to hyperbolic functions (an effect reported for temporal discounting measures by Green et al., 1999) and yet others may show a stepwise or even a flat function. The theoretical and practical implications of such variations in trajectories remain to be explored.

Further research should also consider the level of universality or specificity at which TSC is assessed. Chapters 2 and 3 included both an explicit and an implicit measure, but while the explicit visual scale broadly encompassed the whole future self, the implicit scale was specifically focused on trait adjectives. It might be instructive to expand the measure to include adjectives describing other aspects of individual differences such as physical abilities and functioning, cognitive skills, or interpersonal relations. This would be of particular interest with regard to the observed age differences: While personality was found to be increasingly stable in later life, physical and cognitive functioning tend to follow downward trajectories in advanced age (Craik & Salthouse, 2008; Roberts, Walton, & Viechtbauer, 2006; Ware et al., 1995), which may result in reduced TSC on these dimensions. Thus, different subdomains of implicit TSC may vary in their age trajectories.

Beyond age, there are, of course, other individual difference variables that might affect TSC. Although the present studies did not find evidence for variations by gender or ethnicity, it is conceivable that socioeconomic status may play a role. Lower-income individuals may focus to a greater extent on their present selves, owed at least in part to their need to survive day-to-day (Hershfield, 2011). Thus, instead of temporal discounting leading to worse financial outcomes (a narrative often found in the literature), the path of causality may be reversed in that dire financial straits elicit a focus on the present. In studying this and other individual-level covariates, it would be important to consider how to quantify individual differences in TSC. For example, correlations and factor analyses would be difficult if multiple functional parameters were used as dependent variables in TSC. This would be the case if a 3-parameter double exponential model were used to estimate individual-level parameters. Despite double exponential model's superior fit to TSC data, a single-parameter model (e.g., the simple hyperbolic model; Equation 2 in Chapter 2) may be most appropriate for analyses such as these. Also, as mentioned in Chapter 2, considering the vast literature on links between substance use disorders and steeper temporal discounting (Bickel, Landes, Kurth-Nelson, & Redish, 2014; Dougherty et al., 2014; Koffarnus, Jarmolowicz, Mueller, & Bickel, 2013; McClure & Bickel, 2014), it is quite conceivable that substance abuse and other clinical conditions may affect TSC. Differences in TSC between clinical and healthy populations would thus be an important area for further exploration.

Finally, as mentioned in Chapter 3, there are multiple avenues that could be pursued regarding the role of prospection and past thought in TSC. In particular, it would be important to inquire whether age-associated reductions in episodic detail translate into higher levels of perceived similarity with past and future states. As noted earlier, it is possible that younger adults' highly-detailed representations of their past and future selves may highlight differences, rather than similarities, with their present selves. This stands in contrast to older adults, with less-detailed episodic representations, who might not perceive as many differences. This possibility implicates episodic detail as a theoretically-relevant covariate that future research should be investigating.

More generally, it would be interesting to assess the extent to which continuity with past and future selves relies on semantic, as opposed to episodic, prospection and recall.

Autobiographical tasks asking participants to generate future events (e.g., Wallace, 1956) differ from TSC tasks asking participants to imagine their future selves in that the former refer to concrete episodes that could be simulated as a mental “video” with a temporal component. The latter, in contrast, generally refer to a static state of affairs (i.e., one’s traits) in the future and thus could be considered as more semantic. However, participants could conveivably incorporate specific episodes into their thoughts about their future and past selves. Thus, TSC may involve a hybrid form of temporal thought involving both semantic and episodic processes (Szpunar, Spreng, & Schacter, 2014). Similarly, it may be that TSC involves a specific mode of future thought, prediction, in that it requires educated guesses on whether certain traits will or will not be present in one’s future self (Szpunar et al., 2014). Future research should tease apart the relative contribution of such processes in more detail.

Taken together, the findings presented in this volume offer a multitude of questions to pursue for future research. In further exploring the concept of TSC, we may come to understand it as a more powerful force driving decision behavior than was previously thought. Now is the optimal time to gain a deeper understanding regarding TSC and the role it plays in decision processes. It is clear there is individual variation, as suggested by Chapters 2 and 3, and thus it is unlikely that TSC is immutable. Hence, if adverse outcomes of unusually high or low levels of TSC are observed, it may lend itself to change through effective interventions. This dissertation sets the stage for exploring such possibilities and encourages a stronger prioritization of temporal self-continuity in social, business, developmental, economic, neural, and other decision sciences.

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