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The Conceptual Building Blocks of Everyday Thought: Tracking the Emergence and Dynamics of Ruminative and Nonruminative Thinking

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How do thoughts arise, unfold, and change over time? Are the contents and dynamics of everyday thought rooted in conceptual associations within one's semantic networks? To address these questions, we developed the Free Association Semantic task (FAST), whereby participants generate dynamic chains of conceptual associations in response to seed words that vary in valence. Ninety-four adults from a community sample completed the FAST task and additionally described and rated six of their most frequently occurring everyday thoughts. Text analysis and valence ratings revealed similarities in thematic and affective content between FAST concept chains and recurrent autobiographical thoughts. Dynamic analyses revealed that individuals higher in rumination were more strongly attracted to negative conceptual spaces and more likely to remain there longer. Overall, these findings provide quantitative evidence that conceptual associations may act as a semantic scaffold for more complex everyday thoughts, and that more negative and less dynamic conceptual associations in ruminative individuals mirror maladaptive repetitive thoughts in daily life.

Keywords: concepts, dynamics, language, mind-wandering, rumination

Supplemental materials: https://doi.org/10.1037/xge0001096.supp

In everyday life, thoughts come and go, changing in content, affective tone, and conceptual scope—much like a "stream," as noted by William James (1890). In the early days of psychology, spontaneous thoughts revealed through free association were a mainstay of

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Data and task materials for this study can be found at https://osf.io/j5vn2/?view_only=449d1ed6f90e4651badc0b47a9302ae5.

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diagnosis (Jung, 1919). Today, the vast majority of research ignores these dynamic properties and instead relies on retrospective methods and trait questionnaires to characterize the content of thought, or uses experience sampling techniques to capture static snapshots of momentary experience. Consequently, how thoughts arise and unfold over time—in different ways for different people—remains poorly understood.

A deeper understanding of the dynamics of thought would shed important light on psychopathology, where numerous mental health disorders are associated with persistent intrusive thoughts—a mental "stickiness" that makes it difficult for individuals to let go of negative (often self-focused) content (Ottaviani et al., 2013). Indeed, *repetitive negative thinking* and the broader construct *maladaptive repetitive thought* have gained appreciation as transdiagnostic phenomena, increasing risk for mental illness and relapse, contributing to the maintenance of primary symptoms, and negatively impacting health and well-being (Ehring & Watkins, 2008; Kaplan et al., 2018; Mcevoy et al., 2014; Spinhoven et al., 2018). Rumination and other forms of repetitive negative thinking are thought to reflect excessive automatic constraints on cognition, whereby thoughts are guided outside of one's control toward affectively charged, personally salient content (Andrews-Hanna et al., 2020; Christoff et al., 2016; Nolen-Hoeksema et al., 2008). Fueled by autonomic inflexibility (Ottaviani et al., 2013, 2015), as well as heightened activity, connectivity, and restricted dynamics of brain networks linked to emotional and personal salience (Kaiser et al., 2016; Makovac et al., 2020), these automatic and habitual biases in thinking have been proposed to constrain the scope of thoughts and restrict their dynamic properties (Christoff et al., 2016).

The dynamics of thought are also relevant for a range of cognitive processes characterized by their unguided, or explorative (as opposed to exploitative), properties (Irving, 2016; Sripada, 2018). Unlike repetitive negative thoughts, *spontaneous thoughts* are considered free from strong constraints to guide them; consequently, such thoughts flow with ease (Andrews-Hanna et al., 2018; Christoff et al., 2016). Spontaneous thoughts have also been proposed to play an important role in the efficiency and consolidation of semantic and episodic memory by facilitating associative links among items and contexts, and by helping individuals to organize and make sense of their past experiences and extract meaningful patterns from the world (Fox et al., 2016; Mildner & Tamir, 2019; Mills et al., 2018). Dreaming, mind-wandering, and flexible stages of creative thinking have been featured as different types of spontaneous thought, characterized by heightened variability and spontaneous neural activity of the hippocampus and functionally connected brain regions (Christoff et al., 2016; Mildner & Tamir, 2019; Raffaelli et al., 2020).

To illuminate the dynamics of thought and provide insight into a range of cognitive and clinical processes, we employed a behavioral paradigm—which we call the Free Association Semantic task (FAST)—whereby participants rapidly generated aloud free association chains following "seed" words that varied systematically in valence. In this dynamic free association paradigm, participants were instructed that each concept generated need only to be related to the previous concept generated. For example, following the seed word "win," a participant might respond "lose," followed by "fail," followed by "grades," "school," "bus," and so on). Participants' concept chains were then analyzed for their dynamic properties, allowing us to track the way thoughts arise, unfold and transition over time, in different ways for different people.

At the heart of the FAST task are concepts and conceptual associations, widely considered to represent the basic building blocks of thought (Bar et al., 2007). Conceptual associations have been shown to be influenced by a variety of state and trait factors, including mood and creativity (Bar et al., 2007; Baror & Bar, 2016; Bower, 1981; Gray et al., 2019; Kenett et al., 2014; Mednick, 1962). The neural underpinnings of conceptual processing appear to overlap with brain regions involved in self-generated thought (Andrews-Hanna et al., 2014; Binder et al., 2009; Binder & Desai, 2011; Renoult et al., 2019), raising the hypothesis that the way we access semantic information may illuminate our more complex everyday thinking patterns. Conceptual associations may therefore offer a more objective window into the roots of complex patterns of everyday thinking than introspective approaches, which come with concerns that participants may use self-report scales differently, exhibit biases or failures in memory, or that some people may be more or less aware of their thoughts (Schwarz & Sudman, 1994; Trnka & Smelik, 2020). Here we used the FAST task to quantify similarities between conceptual associations and everyday thinking patterns and tested our secondary prediction that individuals with high levels of repetitive negative thinking exhibit more negative and less dynamic conceptual associations.

Method

Participants

Participants consisted of 97 healthy adults recruited from Craigslist across the greater Denver area and from existing subject databases assembled by the University of Colorado Boulder Institute for Behavioral Genetics. Data from three participants were omitted for failing to understand task instructions. Ninety-four remaining participants were included in subsequent analyses. Mean age was 28.03 yrs (SD = 4.93, range = 18–39 yrs). The sample included 34 non-Hispanic White Americans (19 female), 31 Hispanic White Americans (16 female), and 29 African American participants (16 female). Most participants also underwent MRI scanning as part of a separate, unrelated study (Losin et al., 2020). Sample size was constrained by the goals of this broader study. However, we conducted a power analysis (with G* Power 3) using an effect size from our previous autobiographical thought-sampling study, which showed that the content of self-generated autobiographical thoughts predicted trait rumination (f^2 = .17; Andrews-Hanna et al., 2013). A sample size of n = 79 is sufficient to detect an effect of this size at 95% power in the current study, indicating sufficient power with the present sample.

Participants were free from self-reported MRI-related contraindications, current use of psychoactive or pain medications, and current or recent (past 6 months) neurological or psychiatric diagnosis or pain-related medical condition. Written informed consent was obtained in accordance with the University of Colorado Boulder Internal Review Board. Participants were compensated in cash for participation.

Materials and Procedures

Self-Report Questionnaires

Trait rumination was assessed with Brooding and Reflection subscales of the 22-item Ruminative Responses Scale (RRS; Treynor et al., 2003). Scores on the two subscales were strongly correlated ($r = .63$, $p < .001$) and summed to create a rumination score. Trait affect was assessed with the 20-item Trait Positive and Negative Affect Schedule (PANAS), including separate subscales for positive affect and negative affect (Watson et al., 1988). Participants completed the RRS and Trait Positive and Negative Affect Schedule measures at home prior to the experimental session. State affect was assessed at the beginning of the experimental session using the 20-item state version of the Positive and Negative Affect Schedule, including separate subscales for positive state affect and negative state affect (Watson et al., 1988). State negative affect, trait negative affect, and RRS scores were positively skewed (state negative affect = 2.51, SE = .25; trait negative affect = 2.21, SE = .25; RRS = 1.37, SE = .25). Thus, we transformed these scores across participants using a Box-Cox transformation (*boxcox* in R software; https://www.r-project.org/).

Free Association Semantic Task

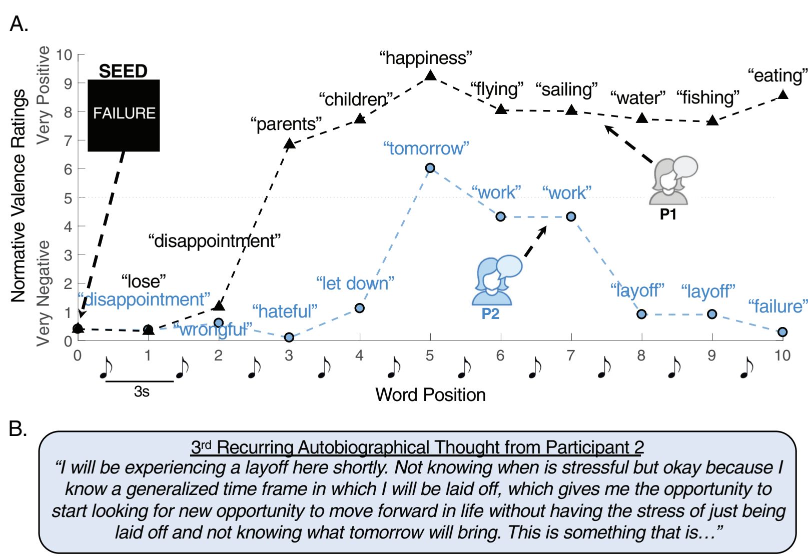
To illuminate the dynamic conceptual roots of thought, we developed the FAST (Figure 1A). Across separate trials, participants generated dynamic concept chains of ten words or phrases per trial (one generated every 3 s), seeded by experimenter-provided "seed concepts." In standard free association paradigms, participants are instructed to freely associate once per trial, or to generate multiple concepts all related to single seed concept. In contrast, the FAST task requires that each concept generated need only to be related to the previous concept in the chain, rather than the seed concept. Thus, the FAST task provides insight into the manner by which rapid conceptual associations dynamically unfold over time and vary as a function of seed characteristics.

Following a computerized practice task involving two trials, participants began an experimental task consisting of 21 total trials (21 dynamic concept chains), yielding 211 concepts/phrases per person. Each trial began with a seed concept in white font in the center of a black screen. Two seconds following its onset, the seed disappeared and was followed by a tone every 3 seconds until a total of 10 tones occurred. Following each tone, participants spoke aloud the first concept or phrase that came to mind in relation to the previous concept generated. If participants were unable to generate a new concept upon hearing the tone, they were instructed to repeat the previous concept they voiced aloud. Vocal omissions were replaced by the most recent concept generated, and trials were separated by a 10s break, signaled by the phrase "10s break" in white font. Breaks were followed by a 2-s preparatory period, during which "Get Ready for New Word" was displayed in green font. To encourage participants to speak freely without censorship, participants performed the task alone in a testing room and were informed that a different member of the research team would transcribe their audio at a later date. Indeed, audio files of the participants' self-generated concepts were later transcribed by different members of the study team for subsequent analysis.

Seed concepts were selected from the Affective Norms for English Words (ANEW) database (Bradley & Lang, 2010). Seeds spanned the full range of valence in the database, from 1.7 (*failure*)

Figure 1

The Free Association Semantic Task (FAST)



Note. (A) Spoken responses on the FAST paradigm are illustrated for two participants shown the seed word "failure." The valence of each concept, calculated from independent MTurk raters, is plotted on the y axis. (B) An excerpt from the second participant's third recurring thought illustrates qualitative similarities between FAST responses and everyday autobiographical thoughts. See the online article for the color version of this figure.

to 8.38 (*win*). Normative valence ratings for seed words were also extracted from the ANEW database, where they were previously scored using a Self-Assessment Manikin rating scale of 1 (*unhappy*) to 9 (*happy*). Negative trial types consisted of seven negatively valenced seeds (*failure*, *shame*, *pain*, *worry*, *alone*, *jealousy*, *crisis*), with normed ratings of valence and arousal of M = 2.28 (SD = .33) and M = 5.77 (SD = .70), respectively. Positive trials consisted of seven positive seeds (*win*, *beautiful*, *spouse*, *heart*, *father*, *trip*, *future*), with mean normed ratings of valence and arousal of M = 7.38 (SD = .55) and M = 6.31 (SD = .75). Neutral trials included concepts closer to the midpoint of the scale (*noise*, *want*, *teach*, *breath*, *advice*, *beginning*, *memory*), with normed ratings of valence and arousal of M = 5.88 (SD = .59) and M = 5.24 (SD = .45), respectively. Notably, positive and negative trial types significantly differed on valence (t test: t = 21.1, 95% CI [4.5,8 5.64], $p < .001$, d = 11.24), but not on arousal (t test: t = 1.38, 95% CI [−.31, 1.38], p = .19, d = .74). Positive trials were significantly higher than neutral trials in both valence (t test: t = 4.97, 95% CI [.85, 2.17], $p < .001$, d = 2.63) and arousal (t test: t = 3.21, 95% CI [.34, 1.79], p = .008, d = 1.73. Negative trials were significantly lower than neutral trials in valence (t test: t = −14.11, 95% CI [−4.16, −3.04], $p < .001$, d = −7.53), but not arousal (t test: t = 1.70, 95% CI [−.1,5 1.13], p = .12, d = .90). Near the end of the experimental session, participants supplied their own perceived ratings of affect, arousal, and perceived significance for each of the 21 seed words; these data are not analyzed for the purposes of the present study.

Notably, the FAST task complements and extends an associative chain task introduced by Benedek et al. (2012) and recently used by Gray and colleagues (2019) to show that creative individuals generate conceptual associations with greater forward "flow" (that is, larger semantic associative distances). The FAST task diverges from these paradigms by introducing auditory (as opposed to written/typed responses) by imposing time constraints to encourage more automatic links to one's semantic networks and by using affectively laden seeds.

Autobiographical Thought Sampling Task

A key objective of our study was to examine relationships between the nature of participants' conceptual associations as assessed during the FAST task, and participants' everyday autobiographical thinking patterns. To quantify the autobiographical thoughts that have been on participants' minds in daily life, we adapted the Autobiographical Thought Sampling task developed in a previous study (Andrews-Hanna et al., 2013). Following the FAST task and an instruction period (see the online supplemental materials), participants began by reflecting on thoughts that "have been on [their] mind within the past 30 days." When participants recalled one of their frequently occurring everyday thoughts, they pressed the spacebar and were subsequently audio- and video-recorded while describing the thought aloud for 30s (video data not analyzed). Participants then used a sliding scale to rate the thought on a variety of phenomenological characteristics, including positive and negative emotion, controllability, social orientation, centrality to one's self-identity, and mental imagery. Temporal orientation (past/present/future) and temporal specificity (whether the thought pertained to a specific event versus a more extended topic) were also characterized. Here, we focused on the two self-reported valence statements: "My emotions pertaining to this thought are POSITIVE" and "My emotions pertaining to this thought are NEGATIVE." Participants repeated the thought description and rating process until they recalled and characterized six thoughts in total. As with the FAST task, to minimize self-censoring, participants completed the task alone, and were informed that a different member of the research team would transcribe their audio at a later date (see Figure 1B for an excerpt from one participant).

Analyses

Word Overlap Analyses Between FAST and Autobiographical Thought Sampling Tasks

If there are fundamental links between one's rapid conceptual associations and everyday thinking patterns, FAST responses and the words appearing in everyday autobiographical thoughts should overlap, and there should be more across-task overlap *within individuals* than *between individuals*. To test this hypothesis, we performed an overlap analysis by calculating, for each FAST response, the number of times in which the response appeared in each participant's concatenated everyday autobiographical thoughts transcript. As part of preprocessing on the words, we used part-of-speech (POS) tagging and lemmatization. With POS tagging, we retained nouns, verbs, and adjectives. With lemmatization, we converted the words to their base dictionary form, ensuring that words such as "run" and "running" would be considered overlapping. From the POS tagged and lemmatized words, we obtained overlap counts between FAST responses and thought reports, resulting in a #participants × #participants count matrix. With this count matrix, we further normalized the matrix to correct for the base rate of the word frequency in three ways. First, we divided the counts by the total number of words in each participant's thought reports. Second, we divided the overlap counts by the total sum of row and column to correct for differences in base frequencies of each word. Third, to enhance the interpretability of the numbers, we conducted the min-max normalization, transforming the maximum value to 1 and the minimum value to 0.

The relative overlap frequency data were analyzed with Binomial tests as well as bootstrap tests using 10,000 iterations, followed by Bonferroni correction on the bootstrap statistics. Two main metrics were extracted: (a) the proportion of participants whose FAST responses showed greater overlap with those participants' *own* daily thoughts as compared with the daily thoughts of *other individuals*, and (b) the proportion of participants whose daily thought descriptions showed greater overlap with those participants' *own* FAST responses compared with the FAST responses of *other individuals*.

Text Analysis of Semantic Content

To explore how word frequency overlap extends to specific semantic categories, we used Linguistic Inquiry Word Count (LIWC) v2015, a text analysis program in which text is referenced to an online database of words organized into semantic categories (Pennebaker et al., 2015). We focused on categories spanning six key life domains likely to form the basis of personal current concerns (Klinger, 1971): *family*, *core drives/needs*, *work*, *money*, *home*, and *leisure*. *Work*, *money*, *home*, and *leisure* were selected from LIWC's own "Personal Concern" category, but we omitted two other Personal Concern subcategories, *religion* and *death*, given they exhibited the lowest base rates, and we were concerned that frequencies may be too low for meaningful analysis. *Family* is a subcategory within the LIWC *social* category that formed the basis of many autobiographical thoughts in this study (see Table S1 in the online supplemental materials), which had a higher LIWC base rate than the subcategory *friends*. We felt the broader "social" category was too large and nonspecific, given it also included broad references to gendered words (e.g., "girl," "boy," "her," "his"). Finally, many participants discussed topics surrounding their *core drives and needs*, a broader category including goal-oriented topics with relevance to current concerns (Andrews-Hanna et al., 2013; Klinger, 2009; Stawarczyk et al., 2013). For each participant, we computed the percentage of total words generated in each selected category across the 21 FAST trials. A similar analysis was performed for the six everyday thought descriptions, and the percentage of words belonging to each category was averaged across the six thoughts for analysis. These values were also summed across the concern-related categories to yield a total percentage of concern-related concepts.

To quantify conceptual similarities across the two tasks, we conducted robust linear regressions using *robustfit* in Matlab (Mathworks, Natick, MA). The percentage of FAST words belonging to any of the concern-related categories was used as a predictor in an initial model attempting to predict the total percentage of personally concerning concepts in participants' everyday thoughts. This analysis was followed by separate robust regression models exploring each concern/life domain category separately.

MTurk Valence Ratings of FAST Conceptual Associations

Conceptual associations generated by each participant were rated on valence by an independent group of 667 adults from Amazon's online crowdsourcing experiment platform, *MTurk* (www.mturk.com). Raters were between the ages of 18 and 55 years old and fluent in English. Each rater viewed 18 pseudorandomly drawn trials (each consisting of a seed followed by a chain of 10 concepts) generated from participants who completed the FAST task and were not allowed to enroll again in the study once completed. Raters viewed one trial at a time and were asked to "put yourself in the shoes of the participants in our prior study and use a sliding scale to make your best guess about the emotion you think each word conveyed to those participants." Raters evaluated the valence of each word or phrase in the chain using a sliding scale of 0 = *very negative* to 10 = *very positive*, with a middle anchor of 5 = *neutral*. When raters could not comprehend a word or phrase, they selected the option "I do not know what this means." Participants were given these additional instructions for rating valence:

> Select the negative extreme if you think the word meant something very negative, unhappy, unsatisfying, melancholy, or despairing to the participant. Select the positive extreme if you think the word meant something very positive, happy, pleasing, satisfying, or hopeful to the participant. If you think the word meant something completely neutral to the participant (i.e., neither negative nor positive), place the slider in the middle of the scale at a value of 5. The slider will also allow you to select intermediate feelings of emotion.

Raters were instructed to consider the context of the previous word(s) generated when making valence ratings, such that a word like "party" would be rated more positively if proceeded by "elegant" than "disastrous." In total, each concept chain was rated by at least 6 MTurk workers, with a range of 6–18 ratings per word/phrase. Participants were paid $.75 for completing 18 trials. Valence ratings for each conceptual association were averaged across raters and included as a predictor in a robust linear regression model predicting mean self-reported positivity of participants' frequent autobiographical thoughts, as well as in a second model predicting self-reported thought negativity.

Dynamic Analyses

For descriptive purposes, we first explored how the valence of the self-generated concepts varied over time within word chains as a function of seed valence. We extracted the MTurk-rated valence for each word generated from the first to the tenth position within each word chain and averaged valence values across trials for positive-, negative- and neutral-seed trials separately. These subject-level means were then averaged across participants to yield an overall descriptive time course of word valence following positive, negative, and neutral seeds, for descriptive purposes. Each participant's propensity to gravitate over time toward positive or negative affective conceptual states was estimated by fitting linear functions to valence ratings for each word chain separately and aggregating the slopes across trials. Significant positive slopes indicated a rise in valence over time, and significant negative slopes indicated a decline in valence over time.

We further explored dynamic shifts in affective conceptual space by exploring transitions between affective conceptual states using a two-state, discrete-time Markov-Chain Model. For each concept generated, we modeled two discrete states, positive (valence ≥ 5.0) and negative (valence < 5.0), and calculated the probability of transitioning to each state or remaining in the same state from the previous word generated. In separate regression models, we examined whether the model-estimated probabilities of remaining in positive and negative conceptual states (vs. switching to the opposite conceptual state) was predicted by individual differences in trait rumination. Following an analysis across all trials, we then examined relationships separately for positive, negative, and neutral trials to examine whether particular trial types were driving any observed effects. For completeness and at the request of a reviewer, we also modeled three states in separate Markov-Chain models: positive (valence = 6.0–10.0), neutral (valence = 4.0 – 5.9), and negative (valence = .0–3.9).

The duration with which participants remained in positive and negative conceptual states was calculated as our final measure of affective conceptual dynamics. For each participant, we computed the mean number of adjacent positive concepts (valence ≥ 5.00) generated across the 21 trials, as well as the mean number of adjacent negative concepts (valence < 5.00). In separate regression models, we then examined whether trait rumination predicted positive and negative state duration. Follow-up exploratory analyses were conducted to determine whether any observed effects were driven by positive, negative, or neutral trials.

Across all statistical tests, significance testing used a two-tailed threshold of $\alpha < .05$. Data can be downloaded at https://osf.io/j5vn2/?view_only=449d1ed6f90e4651badc0b47a9302ae5.

Results

Validating the Everyday Autobiographical Thought Sampling Task

As noted above, the Autobiographical Thought Sampling instructions emphasized thoughts that have been on participants' minds frequently "over the last month." This extended timeframe allowed us to quantify more stable patterns of everyday thinking rather than momentary thoughts that may have emerged solely during the behavioral session. We took several steps to verify that participants' thoughts were in line with the instructions and likely to be characteristic of everyday thinking patterns. First, participants' thoughts included language indicative of more stable, as opposed to momentary, session-specific thinking patterns (e.g., "I've thought a lot about. . .," "I've been thinking about. . .," "Lately I've been. . .," etc.). Topics also tended to be of high personal significance and generally were not the kinds of mundane topics more specific to the behavioral session, such as wondering what's for lunch or wondering about the purpose of the study. For illustrative purposes, ten thoughts from our participant pool were randomly selected and are summarized in Table S1 in the online supplemental materials. Finally, upon assessing associations between autobiographical thought valence and trait versus state affect, we found stronger relationships with trait affect (see below), suggesting a link to more stable patterns of affect.

Linguistic Similarities Across FAST Conceptual Associations and Everyday Autobiographical Thoughts

Overlap of Nouns, Verbs, and Adjectives

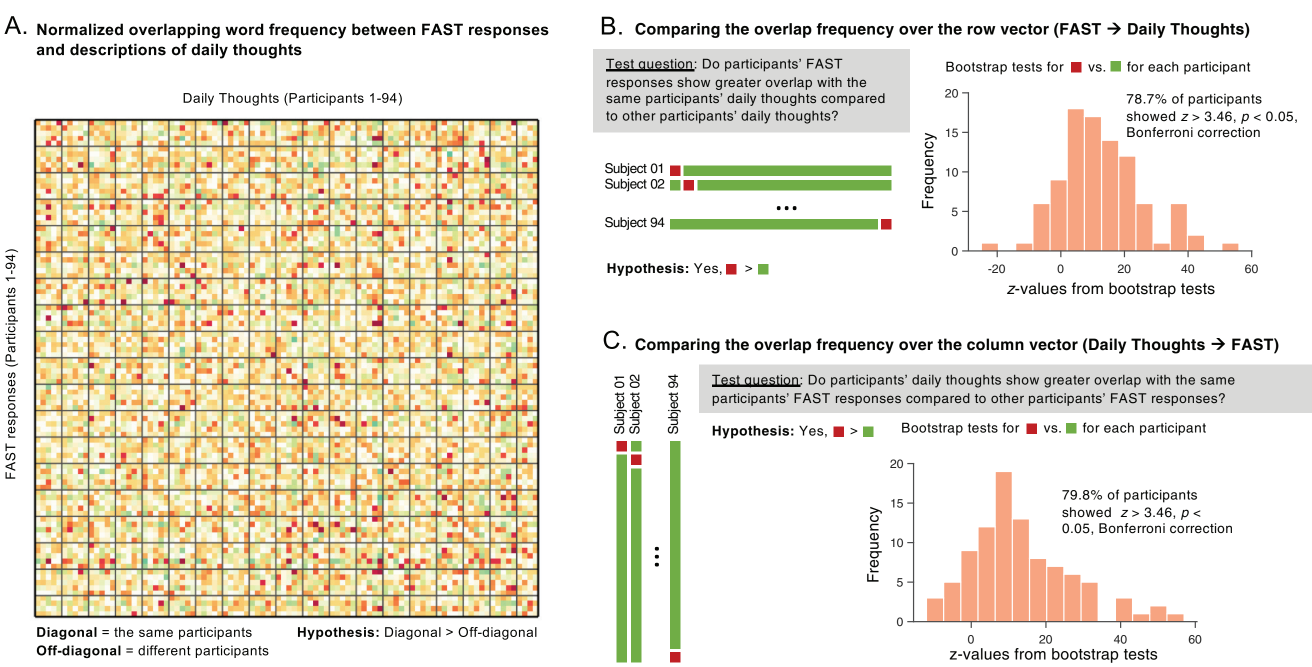
The participant word overlap matrix between FAST responses and Autobiographical Thought Sampling Tasks is displayed in Figure 2a. The diagonal of the matrix reflects degree of word overlap within the same participant. Word overlap between the two tasks tends to be higher *within* the same individuals (mean normalized overlap score $\pm$ *SD* = .39 $\pm$ .128) than *across* individuals (mean off-diagonal $\pm$ *SD* = .27 $\pm$ .095), resulting in higher on-diagonal than off-diagonal values. Binomial tests reveal this difference is highly significant (*ps* $<$ .0001). Results from bootstrap tests displayed in Figure 2b and 2c indicate that 78.7% (74/94) and 79.8% (75/94) of participants demonstrated significantly greater word overlap within individuals as compared with between individuals, *zs* = 5.57 and 5.78, all *ps* $<$ .0001.

Major Domains of Life/Personal Concerns

We assessed whether individual differences in the semantic content of participants' FAST responses predicted the content of autobiographical thoughts participants experienced frequently in daily life. On average across participants, 40.71% (*SD* = 11.88%) of the FAST concepts belonged to at least one of the six concern-related categories (*family*, *drives/needs*, *work*, *money*, *home*, and *leisure*), whereas 14.35% (*SD* = 4.62%) of the words use to describe participants' everyday thoughts belonged to at least one of the categories. Confirming our hypotheses, robust linear regression revealed that the overall expression of concern-related content in the FAST task predicted overall concern-related content in participants' everyday autobiographical thoughts (R^2 = .12, β = .35, *t* = 3.77, *p* $<$ .001). These positive relationships held for all individual

Figure 2

Free Association Semantic Task (FAST) Responses and Everyday Autobiographical Thought Descriptions Overlap in Word Usage



Note. (A) Normalized word frequency overlap matrix across participants' daily thought descriptions and FAST responses. A noticeable diagonal indicates greater overlap between tasks within participants (mean normalized overlap score $\pm$ *SD* = 0.39 $\pm$ 0.128) compared with across participants (mean off-diagonal $\pm$ *SD* = 0.27 $\pm$ 0.095), as predicted. This difference is highly significant (*ps* $<$ 0.0001, binomial tests). (B and C) Results of bootstrap tests show that 78.7% and 79.8% of participants demonstrated significantly greater word within the same individuals as compared with other individuals. See the online article for the color version of this figure.

categories (*family:* R^2 = .063, β = .25, *t* = 3.01, *p* = .0034; *drives/needs:* R^2 = .045, β = .21, *t* = 2.20, *p* = .03; *work*, R^2 = .13, β = .37, *t* = 3.67, *p* = .004; *home*, R^2 = .032, β = .18, *t* = 2.04, *p* = .045; *money*, R^2 = .027, β = .17, *t* = 1.95, *p* = .055) except *leisure* (R^2 = .013, β = .11, *t* = 1.39, *p* = .17; Figure 3A).

Valence Ratings

As a second index of similarity between individuals' associative semantic networks and their everyday thoughts, we quantified the valence ratings of the words generated across the two tasks. Robust regressions revealed that increased positive valence of FAST responses predicted self-reported positivity of everyday thoughts (Figure 3B; R^2 = .054, β = .24, *t* = 2.24, *p* = .028) but not self-reported negativity (R^2 = .023, β = −.15, *t* = −1.38, *p* = .17). Post hoc analyses revealed that these relationships were robust for conceptual associations following positive FAST seeds (word valence x self-reported positivity, R^2 = .10, β = .32, *t* = 3.21, *p* = .002; Word Valence × Self-Reported Negativity, R^2 = .080, β = −.28, *t* = −2.63, *p* = .01) but not following neutral or negative seeds (all *p*s > .14). Thus, participants who reported that their most pressing daily thoughts were more positive generated FAST conceptual associations that were objectively rated as more positive, particularly in response to positive seed concepts. Overall, these analyses support the notion that the structure of participants' semantic networks—as revealed from a dynamic free association task—is expressed in the content of participants' complex everyday autobiographical thoughts.

FAST Dynamics Reveal Attraction to Positive Affective Conceptual States

Change in Valence of Conceptual Associations Within Word Chains

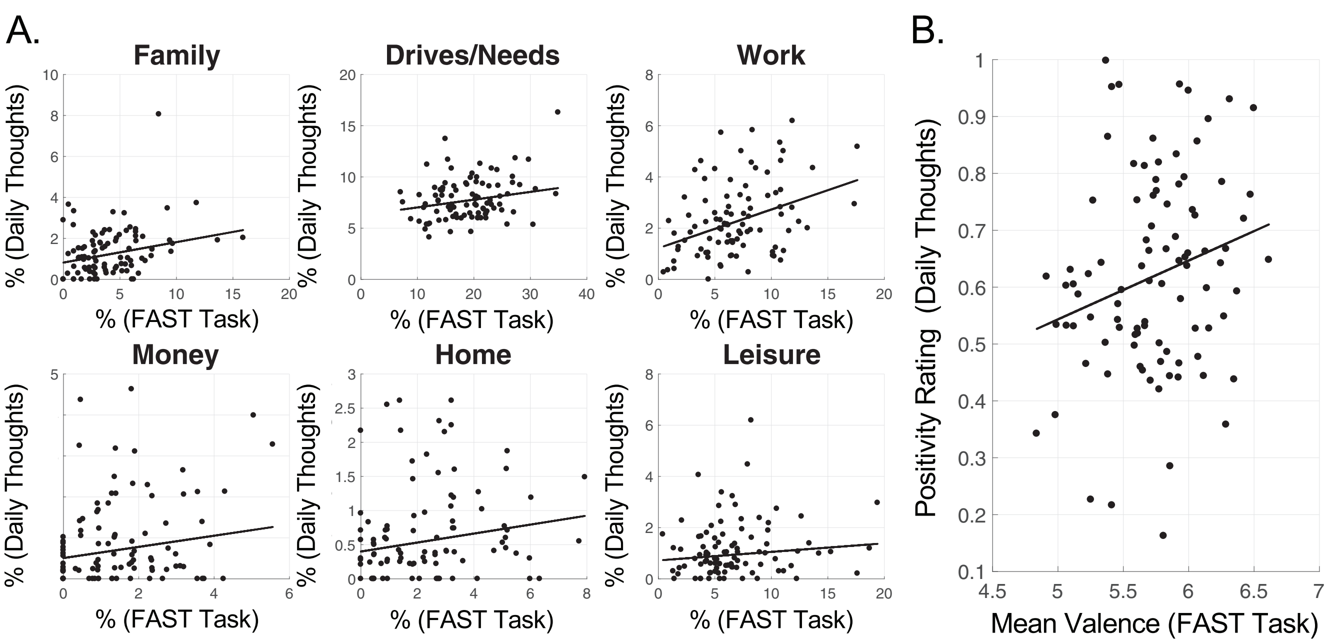
We next explored dynamic properties of participants' conceptual associations within word chains. We observed a slight negative linear slope for association chains following positive seeds ($b = -.080$, $t[93] = -7.34$, $p < .001$, M $\text{Valence}_{\text{1st Concept Generated}}$ = 6.87 on a scale of 0 to 10, where 0 = *very negative*, 5 = *neutral*, and 10 = *very positive*, M $\text{Valence}_{\text{10th Concept Generated}}$ = 6.58), indicating that the valence of subsequent conceptual associations became slightly less positive over time. Association chains following neutral seeds did not significantly change over time (*Neutral:* $b = .004$, $t[93] = .40$, $p = .69$, M $\text{Valence}_{\text{1st Concept Generated}}$ = 6.33; M $\text{Valence}_{\text{10th Concept Generated}}$ = 6.36), whereas association chains following negative seeds gradually became more neutral in valence, yielding a group-level positive slope (*Negative:* $b = .30$, $t[93] = 18.35$, $p < .001$, M $\text{Valence}_{\text{1st Concept Generated}}$ = 2.87; M $\text{Valence}_{\text{10th Concept Generated}}$ = 4.97). Thus, on average, participants' rapid conceptual associations tended to gravitate toward concepts that were neutral to mildly positive in valence.

Markov Chain Models

Markov chain analyses estimated the probability of transitioning between positive and negative conceptual valence states as a function of the valence of the previous word generated. The affective transition matrix is graphically represented in Figure 4A. If the

Figure 3

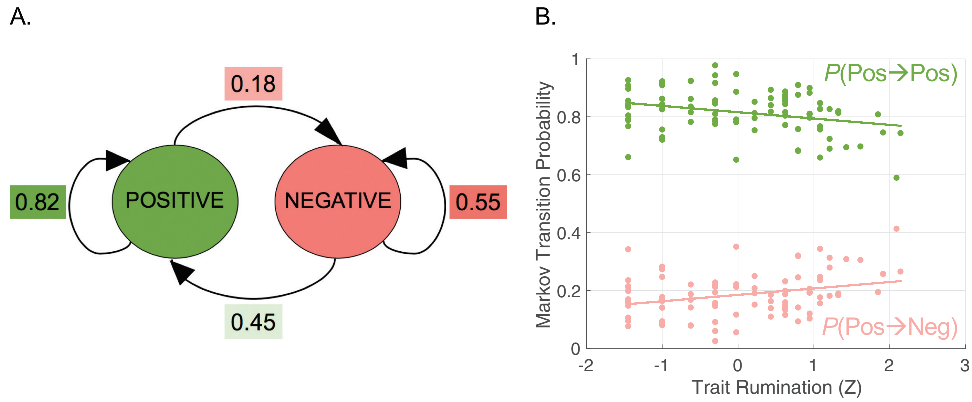
Everyday Autobiographical Thoughts Share Semantic and Affective Similarities With Rapid Conceptual Associations



Note. (A) Positive relationships between Free Association Semantic Task (FAST) semantic content and the content of everyday autobiographical thoughts are plotted on the left. (B) A positive relationships between valence of FAST concepts and everyday thoughts is plotted on the right.

Figure 4

Free Association Semantic Task (FAST) Associative Dynamics, and Relationships With Trait Rumination



Note. (A) The mean Markov transition probability matrix between positive and negative affective conceptual states is shown across participants. (B) Individuals who ruminate to a greater degree are less likely to remain in positive conceptual states (upper graph, green) and more likely to transition from positive to negative concepts (bottom graph, pink). See the online article for the color version of this figure.

previous concept generated was positive, participants were, on average, more likely to remain in a positive conceptual state than to switch to a negative conceptual state (*M P*[Pos→Pos] = .82, *SD* = .074; *M P*[Pos→Neg] = .18, *SD* = .074). Both probabilities significantly differed from .5 (*M P*[Pos→Pos]: one sample *t* test, *t*[93] = 41.18, 95% CI [.30, .33], $p < .001$, *d* = 4.32; *M P*[Pos→Neg]: one sample *t* test, *t*[93] = −41.24, 95% CI [−.33, −.30], $p < .001$, *d* = −4.32). If the previous concept generated was negative, participants were, on average, more likely to remain in a negative conceptual state than to switch to a positive state (*M P*[Neg→Neg] = .55, *SD* = .13; *M P*[Neg→Pos] = .45, *SD* = .13), with both probabilities significantly differing from .5 (*M P*[Neg→Neg]: one sample *t* test, *t*[93] = 3.58, 95% CI [.022, .075], *p* = .001, *d* = .38; *M P* [Neg→Pos]: one sample *t* test, *t*[93] = −3.55, 95% CI [−.075, −.021], *p* = .001, *d* = −.38).

The propensity to remain in a subsequent positive conceptual affective state was *stronger* than the propensity to remain in a subsequent negative conceptual affective state (paired *t* test: *t*[93] = 18.3, 95% CI [.24, .30], $p < .001$, *d* = 1.88). Likewise, the probability of switching from a negative to positive concept was stronger than the probability of switching from a positive to negative concept (paired *t* test: *t*[93] = 18.24, 95% CI [.24, .30], $p < .001$, *d* = 1.88). Thus, despite participants' overall tendency to remain in the same affective conceptual state as the previous concept, participants demonstrated a positive bias overall. Similar findings were observed using the three state Markov Model (Table S2 in the online supplemental materials).

Mean Duration of Positive and Negative FAST Responses

Across participants, the mean duration with which concepts remained in subsequently positive states was negatively correlated with the mean duration with which participants remained in subsequently negative conceptual states (*r*[92] = −.28, *p* = .007). Consistent with findings from the Markov chain analyses, participants' self-generated concepts tended to stay consistently positive for a longer duration than they stayed consistently negative (mean duration of positive concepts = 5.66 words, *SD* = 1.00, mean duration of negative concepts = 2.53, *SD* = .75, paired *t* test: *t*[93] = 21.59, 95% CI [2.84, 3.42], $p < .001$, *d* = 2.24). This pattern was true for both positive seed trials (*M* duration_{pos} = 7.31, *SD* = 1.72, *M* duration_{neg} = 1.22, *SD* = .74, paired *t* test: *t*[93] = 25.95, 95% CI [5.62, 6.56], $p < .001$, *d* = 2.67) and neutral seed trials (*M* duration_{pos} = 6.48, *SD* = 1.63, *M* duration_{neg} = 1.60, *SD* = .70, paired *t* test: *t*[93] = 22.55, 95% CI [4.44, 5.30], $p < .001$, *SD* = 2.33), but was reversed for negative seed trials, such that participants remained in negative conceptual states significantly longer than positive conceptual states (*M* duration_{pos} = 3.20 words, *SD* = 1.38, *M* duration_{neg} = 4.77, *SD* = 1.77, paired *t* test: *t*[93] = −5.34, CI [−2.16, −.99], $p < .001$, *d* = −.55).

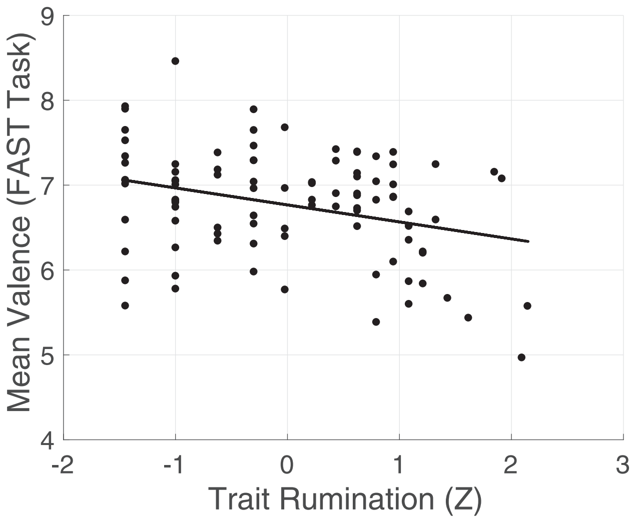
Taken together, these findings converge to suggest that the conceptual space of individual's semantic networks are generally attracted toward positive concepts and away from negative concepts.

Increased Negative Conceptual Biases and Altered Associative Dynamics Relate to Trait Rumination

Consistent with our predictions, higher trait rumination predicted more negatively valenced conceptual associations (R^2 = .050, β = −.22, *t* = −2.20, *p* = .030; see Figure 5). Post hoc analyses revealed that the relationship between word valence and trait rumination depended on the seed valence, such that rumination was most strongly predicted by more negative FAST concepts following positive seed words (R^2 = .098, β = −.31, *t* = −3.16, *p* = .002), but not following negative (R^2 = .00, β = −.004, *t* = −.035, *p* = .97) or neutral seed words (R^2 = .006, β = −.079, *t* = −.76, *p* = .45).

Importantly, the bias toward negative conceptual states in ruminative individuals was also reflected in the dynamic properties of the FAST task. Higher trait rumination predicted increased probability of shifting from positive to negative concepts (R^2 = .089, β = .30, *t* = 3.00, *p* = .003) and decreased probability of remaining in a positive conceptual state (R^2 = .089, β = −.30, *t* = −3.00, *p* = .003; Figure 4B). Following negative FAST responses, however, ruminative individuals were no more or less likely to remain in a subsequently negative affective state (R^2 = .013, β = −.11, *t* = −1.08, *p* = .28). As

Figure 5
Relationships Between Free Association Semantic Task (FAST) Valence and Trait Rumination



Note. Higher trait rumination is associated with FAST concepts objectively rated as less positive/more negative.

with earlier analyses, these patterns appeared to be most robust when restricting analyses to positive seed trials (P[Pos→Neg]: $R^2 = .16$, $\beta = .39$, $t = 4.10$, $p < .001$; P[Neg→Neg]: $R^2 = .00$; $\beta = .034$, $t = .33$, $p = .74$), but not neutral or negative seeds (all $ps > .10$).

Similar findings were also observed when including a "neutral" state as a third conceptual state in three-state Markov Models (Table S1 in the online supplemental materials). Higher trait rumination predicted increased probability of shifting from positive to negative concepts ($R^2 = .051$, $\beta = .23$, $t = 2.23$, $p = .028$) and a marginally decreased probability of remaining in a positive conceptual state ($R^2 = .039$, $\beta = -.20$, $t = -1.94$, $p = .055$). When analyzing Markov transition probabilities following positive seed words alone, trait rumination also predicted an increased probability of shifting from neutral FAST responses to negative FAST responses ($R^2 = .11$, $\beta = .32$, $t = 3.21$, $p = .002$).

The mean duration (number) of FAST concepts in which participants remained in positive or negative conceptual states within word chains largely paralleled Markov transition probabilities. Across all seed words, trait rumination predicted lower average state duration in positive conceptual states ($R^2 = .057$, $\beta = -.24$, $t = -2.34$, $p = .021$), but not average duration of negative states ($R^2 = .00$, $\beta = .006$, $t = .06$, $p = .95$). However, both effects became stronger and significant when restricting the analysis to positive seed words (Rumination × Positive Duration: $R^2 = .12$, $\beta = -.34$, $t = -3.49$, $p = .001$, negative duration: $R^2 = .072$, $\beta = .27$, $t = 2.67$, $p = .009$). Collectively, these findings suggest that trait rumination is associated with an increased bias away from positive and toward negative conceptual states, accompanied by restricted dynamics.

Contributions of State and Trait Affect

State Affect

To examine the contribution of participants' state affect to the valence of FAST responses and everyday autobiographical thoughts, positive and negative subscale scores of the PANAS-State questionnaire were included as predictors in several multiple regression models (see Table 1). Neither PANAS subscales predicted mean FAST valence; however, participants who reported more negative state affect at the beginning of the session rated their everyday autobiographical thoughts as less positive and more negative in valence. Upon controlling for PANAS scores, the significance levels of models examining relationships between the FAST and thought-sampling tasks remained the same, except for a now marginally significant effect of FAST word valence on self-reported everyday thought positivity ($R^2 = .11$, $F[3, 90] = 3.51$, $p = .018$, $\beta_{\text{FAST Valence}} = .20$, $t_{\text{FAST Valence}} = 1.96$, $p_{\text{FAST Valence}} = .054$).

Trait Affect

Trait negative affect was a significant predictor of both FAST word valence and valence of thoughts recalled during the Autobiographical Thought Sampling Task (see Table 1). Individuals reporting higher levels of trait negative affect generated more negative FAST words and rated their everyday autobiographical thoughts as less positive and more negative in valence. Additionally, participants who reported more positive trait affect rated their everyday autobiographical thoughts as more positive in valence (the relationship with self-reported negativity was not significant). When controlling for trait affect, the previously significant relationship between FAST valence and thought positivity became

Table 1
Relationships With State and Trait Affect

Outcome variables (separate models)	R	Adj R^2	F	p	β_{PANAS} State-Pos	t_{PANAS} State-Pos	p_{PANAS} State-Pos	β_{PANAS} State-Neg	t_{PANAS} State-Neg	p_{PANAS} State-Neg
State affect (PANAS-State)										
Daily thoughts—Pos	.26	.046	3.26	.043	.056	.55	.58	−.25	−2.85	**.015**
Daily thoughts—Neg	.29	.061	4.04	.021	−.075	−.75	.46	.28	2.73	**.008**
FAST valence	.14	−.002	.89	.41	.11	1.07	.29	−.081	−.78	.44
Trait affect (PANAS-Trait)										
Daily thoughts—Pos	.39	.13	7.98	.001	.25	2.50	**.014**	−.26	−2.65	**.009**
Daily thoughts—Neg	.39	.13	7.93	.001	−.17	−1.71	.091	.32	3.26	**.002**
FAST valence	.21	.022	2.03	.14	−.017	−.17	.87	−.21	−2.00	**0.048**

Note. FAST = Free Association Semantic Task; PANAS = Positive and Negative Affect Scale; PANAS State-Pos = Positive Subscale Score on the State Version of the PANAS; PANAS State-Neg = Negative Subscale Score on the State Version of the PANAS; PANAS Trait-Pos = Positive Subscale Score on the Trait Version of the PANAS; PANAS Trait-Neg = Negative Subscale Score on the Trait Version of the PANAS. Significant effects at $p < 0.05$ are highlighted in bold font.

nonsignificant (R^2 = .18, F[3, 90] = 6.44, p = .001; $\beta_{\text{FAST Valence}}$ = .17, $t_{\text{FAST Valence}}$ = 1.74, $p_{\text{FAST Valence}}$ = .086). For FAST valence following positive seed words, previously significant relationships between FAST valence and thought positivity remained significant (R^2 = .20, F[3, 90] = 7.31, $p < .001$; $\beta_{\text{FAST Valence Pos Seeds}}$ = .22, $t_{\text{FAST Valence Pos Seeds}}$ = 2.29, $p_{\text{FAST Valence Pos Seeds}}$ = .024), whereas relationships between FAST valence and thought negativity became marginal (R^2 = .18, F[3, 90] = 6.71, $p < .001$ $\beta_{\text{FAST Valence Pos Seeds}}$ = −.19, $t_{\text{FAST Valence Pos Seeds}}$ = −1.95, $p_{\text{FAST Valence Pos Seeds}}$ = .055).

In sum, relationships between the behavioral tasks and affect at the *trait* level seem to be more robust than affect at the *state* level, suggesting that the tasks and the relationship between them may be more influenced by one's stable affective personality.

Contributions of Gender and Age

Males and females did not differ significantly on trait rumination or any of the behavioral measures, with the exception of Markov transition probabilities following positive seed words. In this case, males were more likely to remain in subsequently positive FAST states than females (P[Pos→Pos]: t[92] = 2.27, p = .026), and were less likely to switch from positive to negative conceptual states (P[Pos→Neg]: t[92] = −2.19, p = .031). When controlling for gender, trait rumination still predicted a significantly reduced probability of remaining in positive states (R^2 = .093, $\beta_{\text{rumination}}$ = −.29, $t_{\text{rumination}}$ = −2.86, $p_{\text{rumination}}$ = .005).

Males and females did not differ significantly with respect to age (males: M = 27.2 yr, SD = 4.89; females: M = 28.7 yr, SD = 4.91; t[92] = −1.43, p = .16), and age did not predict trait rumination (R^2 = .00, β = −.016, t = −.15, p = .88). However, increased age predicted more negatively valenced FAST responses on negative seed trials (R^2 = .11, β = −.34, t = −3.44, p = .001). Controlling for age, trait rumination continued to show a nonsignificant relationship with FAST negative seed valence (R^2 = .11, $\beta_{\text{rumination}}$ = −.009, $t_{\text{rumination}}$ = −.09, $p_{\text{rumination}}$ = .93). Increased age also predicted a greater Markov transition probability of remaining in negative conceptual states (P[Neg→Neg]: R^2 = .091, β = .30, t = 3.04, p = .003), and a lower probability of transitioning from negative to positive words (P[Neg→Pos]: R^2 = .093, β = .30, t = 3.07, p = .003). When controlling for age, trait rumination continued to show a nonsignificant relationship with these variables (ps = .28). Finally, age also predicted an increased mean duration of subsequent negative FAST responses following negative seed words (R^2 = .053, β = .23, t = 2.26, p = .026), and a decreased mean duration of subsequent positive FAST responses following negative seed words (R^2 = .084, β = −.29, t = −2.91, p = .005). When controlling for age, the previously nonsignificant relationships between trait rumination and duration of negative and positive states remained nonsignificant (ps > .18).

In summary, although age and gender associated with some behavioral measures in our study, neither age nor gender altered the significance of any of the previously reported findings.

Discussion

Here we introduce the FAST to provide insight into the emergence, dynamics, and conceptual roots of human thought. Using this paradigm in a community sample of 94 adults, we link the thematic content, affective characteristics, and dynamics of rapid conceptual associations to frequent real-world autobiographical thoughts and individual differences in trait measures of rumination. Individuals scoring higher on trait rumination were more strongly attracted to negative conceptual spaces and, at least for responses following positive seed words, were more likely to remain there longer.

Spontaneous Thought as a Dynamic Process

Our findings underscore the importance of dynamics—and affective dynamics in particular—as an underexplored aspect of human thought. By sampling how conceptual associations change in real time, the FAST task provides insight into the constituent elements and dynamic trajectories of human thought. Although our Markov state transition and duration analyses provide insight into the dynamics of thought over relatively short intervals, approaches that model cognition as a dynamic system could also be applied in future studies to longer time periods and across different representational systems (Becker & Neuberg, 2019; Thelen & Smith, 2006).

The current results offer a possible behavioral manifestation of a neurocognitive taxonomy of thinking that we and our colleagues recently put forth, whereby restricted dynamics emerges an important manifestation of thoughts guided by constraints on cognition (Christoff et al., 2016). This dynamic framework features two kinds of constraints that guide and stabilize cognition over time. *Deliberate constraints* are evoked when one guides one's thoughts in an intentional manner, as in goal-directed thought. Conversely, *automatic constraints* are at play when thoughts emerge unintentionally, yet are nevertheless drawn toward particularly salient topics, memories, emotions, and external stimuli. The heightened salience of affective and personally-relevant material is thought to stabilize attention toward such material and consequently limit the flexibility and variability of thought (Andrews-Hanna et al., 2020), consistent with the findings from the FAST task.

According to this framework, thoughts are only free to flow, or wander, with ease when deliberate and automatic constraints are sufficiently relaxed. Such is the state space of *spontaneous thought*, encompassing dreaming, mind-wandering, and flexible stages of creative thinking. Although spontaneous and automatically-constrained thoughts are both perceived as emerging outside our deliberate control, only spontaneous thoughts are *unguided*, free from constraints on cognition (Irving, 2016). We believe this framework draws important attention to the role of mental exploration (versus exploitation)—mainly studied in the context of decision making and behavior (Hills et al., 2015)—as an important yet underexplored factor characterizing mental states and cognitive traits (Sripada, 2018).

Toward More Objective Behavioral Signatures of Repetitive Negative Thinking

Rumination is a type of repetitive negative thinking involving "repetitively and passively focusing on symptoms of distress and on the possible causes and consequences of these symptoms" (Nolen-Hoeksema et al., 2008). Repetitive negative thinking is considered a transdiagnostic risk factor for a range of mental health disorders, with additional adverse effects on physical health and neurocognitive function across the life span (Ehring & Watkins, 2008; Kaplan et al., 2018; Kashdan & Rottenberg, 2010). In the current study, individuals with greater levels of trait rumination generated conceptual associations rated by an independent group of raters as more negative and demonstrated dynamic responses indicative of a stronger attraction to more negative conceptual states, especially when starting from positive seed concepts. This type of mental "stickiness" in rumination has been observed in everyday mood fluctuations (Koval et al., 2012; Moberly & Watkins, 2008) and working memory and attention tasks (Gotlib & Joormann, 2010), and its extension to biases in conceptual associations may partly underlie alterations in long-term memory and autobiographical thought displayed by ruminative individuals (Andrews-Hanna et al., 2013, 2020; Kircanski et al., 2015; Watkins, 2008).

Although it remains unclear what factors led to stronger effects of rumination on FAST responses following positive seed words, particularly, it is notable that our sample was a predominantly nonclinical sample, with 12% of participants meeting Beck Depression Inventory II criteria for mild, moderate, or severe depression. Furthermore, we acknowledge that individual differences in rumination were positively skewed, indicating that more participants exhibited low as compared with high levels of trait rumination. Future work extending the FAST paradigm to clinical samples might reveal stronger and more widespread effects of rumination across valence.

Concepts and Conceptual Associations: The Building Blocks of Autobiographical Thought

Our findings demonstrate that FAST conceptual associations shared similarities in semantic content and valence with the autobiographical thoughts participants frequently experience in daily life. More specifically, participants who were more likely to generate FAST conceptual associations related to particular personal concerns (that is, "work") were also more likely to exhibit everyday thoughts related to those same specific concerns. Additioinally, participants who generated FAST words rated objectively as more positive in valence rated their own common everyday thoughts as more positive as well. Irrespective of the specific semantic and emotional content of the words generated, word overlap analyses revealed that the autobiographical thought sampling task and FAST shared similarity in word usage within individuals, suggesting that the two tasks tap into an overlapping set of concepts that relate to a person's unique concerns and life circumstances, rather than general concepts shared across the population. Taken together, these results provide quantitative evidence that the content and "stickiness" of our conceptual associations relates to how and why we think the way we do, a finding foreshadowed by Psychology's early researchers (for example, Jung, 1919).

The current results lend support to neurocognitive theories suggesting that semantic memory (that is, conceptual knowledge) may act as a scaffold for more complex self-generated thoughts, including episodic recollection, episodic future thinking, and "imagination" broadly construed (Abraham & Bubic, 2015; Binder et al., 2009; Irish, 2020; Irish et al., 2012; Renoult et al., 2019). Complex everyday thoughts are composed of individual elements (a.k.a. "concepts"), thought to be linked together by their associations with specific episodic events, statistical regularities in the way such concepts are learned and expressed in language (that is, "virus" and "corona"), or by other mental associations unique to one's life and one's habits of thought (that is, "parents" and "disappointment," or "work" and "layoff" as examples from the participants in Figure 1; Bar et al., 2007; Bower, 1981). Conceptual prompts as part of the FAST task may trigger access to these more established associative links through spreading activation of concepts (Collins & Loftus, 1975). Pinpointing individual differences in semantic associations between concepts may provide insight into individual differences in the units or building blocks of both momentary (that is, state-like) and more stable (that is, trait-like) thoughts. More broadly, the FAST task provides critical insight into these basic building blocks of thought, and sheds important light on individual difference factors related to how different people think.

Supporting these ideas, converging evidence suggests substantial overlap between brain regions supporting a range of more basic conceptual processes such as lexical or semantic judgments and narrative comprehension and those supporting more complex self-generated thoughts including spontaneous cognition, autobiographical episodic memory, prospective thinking, emotional appraisals, mentalizing, and so on (Addis, 2020; Andrews-Hanna et al., 2014; Binder et al., 2009; Renoult et al., 2019). Collectively, regions of overlap are purported to belong to the so-called "default network," a brain system thought to support the emergence of thoughts/attention decoupled from immediate sensory input, which humans tend to "default to" during passive rest periods (Binder et al., 1999; Buckner et al., 2008; Raffaelli et al., 2020; Raichle et al., 2001; Smallwood et al., 2012). Critically, the default network may also support our ability to schematize, understand, and make meaning out of a wide range of perceptual stimuli, memories, and socioemotional experiences (Andrews-Hanna & Grilli, 2021; Koban et al., 2021; Roy et al., 2012; Satpute & Lindquist, 2019; Woo et al., 2014).

How disparate brain regions or neural patterns within the default network contribute to different aspects of conceptual processing remains a matter of debate—with relevance to clinical and lesion populations (Irish, 2020; Irish & Piolino, 2016)—that would be benefited by future research (Binder & Desai, 2011; Renoult et al., 2019; Sheldon et al., 2019). The FAST task marks an important step in this direction by offering insight into the origins of different types of thought, with a paradigm that could be adapted for use in physiological and brain imaging contexts.

State Versus Trait Contributions

Another outstanding question poised for future research surrounds the contributions of state versus trait-level factors to the FAST and Autobiographical Thought Sampling tasks, and the individual difference relationships between them. Both tasks were administered in the same behavioral session, and relationships between the tasks could have arisen as a result of common influences of state affect and unprompted thoughts. Alternatively (or additionally), relationships between the tasks could reflect the contribution of more stable everyday thinking and mood patterns that may be grounded in learned associations between concepts.

Trait affect was a somewhat stronger predictor of responses on the two tasks than state affect and explained a considerable amount of variance in the relationships between the tasks. These findings are in line with studies employing standard free word association tasks, which have revealed links to more stable individual difference factors spanning creativity (for example, Benedek et al., 2012), mental health (Merten, 1993), and neurodegenerative disease (Gewirth et al., 1984). The role of trait affect is also consistent with the Autobiographical Thought Sampling instructions, where participants were asked to retrieve thoughts that had been frequently on their minds *over the past month* and demonstrated content and word usage reflective of more stable current concerns.

To provide more insight into the role of state versus trait factors, future studies could (a) employ mood induction techniques to directly manipulate state affect and cognition, (b) compare FAST responses to participants' thinking assessed outside of the lab using Ecological Momentary Assessment (Arch et al., 2021; Kircanski et al., 2015), or (c) administer the Autobiographical Thought Sampling task and the FAST task on different days. The latter option would also help address the possible limitation that thoughts recalled during the Autobiographical Thought Sampling task may have been "primed" by the FAST task, which always occurred first. Despite the strong links with trait-level factors observed in this study, we acknowledge that trait and state factors are undoubtedly tightly linked, each influencing the other.

How the FAST Task Can Add to Standard Task Paradigms

The FAST task complements and extends standard paradigms used to assess internal thought and emotion. The task minimizes demands on metacognitive awareness, episodic memory, and introspection, and does not assume that participants use phenomenological rating scales identically (Schwarz & Sudman, 1994). Thus, the paradigm may be an ideal way to assess thought and emotion across the life span, and in a variety of clinical populations such as those with memory dysfunction and low metacognitive and/or emotional awareness (e.g., Lane & Schwartz, 1987). The FAST task can also be adapted to neuroimaging contexts and is ideally suited for dynamic analyses, including analyses on both short timescales (e.g., trial-to-trial fluctuations) and longer timescales (Becker & Neuberg, 2019; Kuppens et al., 2010; Thelen & Smith, 2006). Such metrics could have important translational predictive potential, similar to how a "slowing down" of everyday mood dynamics can predict key transitions in depressive symptomology (van de Leemput et al., 2014). Although the current study focused analyses primarily on the valence of participants' conceptual associations, the FAST task also offers additional auxiliary measures such as semantic similarity between concepts and metrics from network science (Kenett & Faust, 2019).

Conclusions

Recent years have brought a growing appreciation into the dynamic nature of the brain, whereby brain regions have been shown to fluctuate in their levels of activity and connectivity in temporally and contextually dependent ways (Ciric et al., 2017; Dixon et al., 2017; Tagliazucchi & Laufs, 2015). Once viewed as intrinsically stable over time, patterns of network connectivity at "rest" seem to shape-shift across relatively short intervals, consistent with the idea of a *chronnectome* (Calhoun et al., 2014; Preti et al., 2017). There is some suggestion that these dynamically-shifting metastates reflect the emergence and dynamic unfolding of ongoing thought when individuals are left alone undisturbed (Karapanagiotidis et al., 2020; Kucyi, 2017; Smallwood et al., 2021; Van Calster et al., 2017; Zabelina & Andrews-Hanna, 2016). Paradigms such as the FAST task are ideally suited for these directions for future research, because they could be used as behavioral correlates of individual differences in the dynamics of the brain at rest and provide objective real-time cognitive signatures of dynamically fluctuating brain activity.

Our findings regarding individual differences in affective dynamics complement and extend promising recent work applying dynamic free association paradigms to creativity, whereby creative individuals have been shown to generate conceptual associations with greater forward "flow" (larger semantic distances between concepts generated; Gray et al., 2019; Kenett & Faust, 2019). Taken together, this work opens up an exciting new array of possibilities for future research, including the application of semantic similarity analyses to mental health constructs such as rumination and the use of computational methods to characterize the semantic architecture of thought and shed light on wandering and sticky minds.

Context

This project was conceived of at the University of Colorado when all authors except Byeol Kim and Jihoon Han were conducting research in the Institute of Cognitive Science and the Department of Psychology and Neuroscience. The study was a component of a larger cognitive neuroscience project in Tor Wager's laboratory centered around physical and emotional pain in an adult community sample. At the time the authors were designing the study, Jessica R. Andrews-Hanna's research program had been focused on understanding adaptive and maladaptive spontaneous cognition and autobiographical thought, which intersected with Choong-Wan Woo and Tor Wager's expertise on pain, affect, and ways of making *meaning* (or conceptual understanding/significance) out of such processes. Thus, this project represented a collaboration among the team, which the authors have continued their more recent collaborative work with each other at other institutions.

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