# 14 Episodic Memory and Cognitive Control: Contributions to Creative Idea Production

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Creative ideas have long been considered to result from the flexible combination of concepts stored in long-term memory (Mednick, 1962). Seminal creativity theories emphasized the contribution of semantic memory and the spreading activation of concepts within semantic networks as central to creative idea production. Recently, however, it has become clear that in addition to semantic memory, other cognitive systems make important contributions to the production of creative ideas. In this chapter, we highlight two such systems – episodic memory and cognitive control – with a focus on the brain networks thought to support these processes. We describe recent behavioral work on the contributions of episodic memory and cognitive control to creative thought. We also address neuroimaging evidence on brain mechanisms supporting episodic memory and cognitive control during creative idea production, with an emphasis on functional brain networks and their interactions. The chapter concludes by describing a framework that incorporates the multiple neurocognitive systems underlying creative ideation.

## Cognitive Control and the Frontoparietal Control Network

An increasing body of behavioral evidence indicates that creative thought can benefit from cognitive control and executive functions. These core cognitive abilities allow people to monitor and direct mental activity in a goal-directed manner. Although executive functions have historically been studied in the context of cognitive tasks that require sustained external attention (e.g., complex working memory span tasks; Kane et al., 2004), recent work has begun to explore the role of executive cognition in tasks involving sustained internal attention, such as creative divergent thinking (Benedek et al., 2016). Several recent studies have examined individual differences in executive processes and creative cognitive ability using an individual differences approach. An emerging consensus from this work is that creative thought recruits higher-order processes associated with executive functions, including fluid intelligence, broad retrieval ability, and inhibitory control.

The Cattell–Horn–Carroll (CHC) model of human intelligence defines several lower-order cognitive abilities that underlie a higher-order general intelligence factor (McGrew, 2009). Individual variation in these abilities has been shown to predict aspects of creative cognition. For example, fluid intelligence – the ability to solve novel problems via visual–spatial and verbal reasoning – is associated with performance on a range of creative tasks, such as generating alternate uses for common objects (Beaty & Silvia, 2012; Benedek et al., 2014a; Forthmann et al., 2016; Vartanian, Martindale, & Kwiatkowski, 2003), solving insight problems (DeYoung, Flanders, & Peterson, 2008; Lee & Therriault, 2013), and producing novel metaphors (Beaty & Silvia, 2013; Silvia & Beaty, 2012). Because fluid intelligence is strongly correlated with working memory capacity (Kane et al., 2004), it may impact creative thought by providing attention control and the capacity to maintain and manipulate multiple items in active storage.

Another cognitive ability associated with divergent thinking performance is broad retrieval ability (McGrew, 2009) – the ability to strategically search memory, shift between conceptual categories, and select among competing exemplars (Badre & Wagner, 2007; McGrew, 2009; Troyer, Moscovitch, & Winocur, 1997). Broad retrieval ability is often measured with verbal fluency tasks that require retrieving items from a given category (e.g., animals), a process that involves the generation and maintenance of higher-order retrieval strategies that constrain semantic search processes (Unsworth, Spillers, & Brewer, 2010). The ability to strategically search memory may account for the association of broad retrieval ability with performance on the alternate uses divergent thinking task (Benedek, Könen, & Neubauer, 2012; Silvia, Baety, & Nusbaum, 2013) as well as tasks involving the production of novel metaphoric expressions (Beaty & Silvia, 2013; Silvia & Beaty, 2012).

The involvement of cognitive control in creativity is further supported by research on executive functions. In a recent study, Benedek et al. (2014b) examined the associations among divergent thinking ability, fluid intelligence, and three executive functions: *updating* (monitoring and replacing items in working memory), *shifting* (switching between task sets and demands), and *inhibition* (suppressing pre-potent response tendencies). Replicating past work, the authors found that fluid intelligence predicted increased originality of divergent thinking responses. They also found that originality was associated with updating and inhibition, and that updating statistically accounted for the relationship between fluid intelligence and originality. These findings suggest that divergent thinking involves the capacity to focus attention, manage the contents of working memory, and suppress pre-potent response tendencies.

The notion that divergent thinking taps cognitive control and executive functions is consistent with seminal theories on the cognitive basis of creative thought. Finke, Ward, and Smith (1992) conceptualized creativity as a two-stage, recursive process of idea generation and idea evaluation, with generation associated with spontaneous combinatory mechanisms and evaluation associated with controlled convergent mechanisms. Although this framework remains popular in contemporary research, it remains unclear whether idea generation and evaluation occur in isolation and whether both processes benefit from cognitive control. Because performance on creative idea generation tasks is associated with cognitive abilities (e.g., broad retrieval ability and pre-potent response inhibition), the notion that it solely arises from spontaneous processes seems problematic.

Further evidence for a role of executive cognition in creative thought processes comes from considerable neueroimaging evidence reporting activation of the brain's frontoparietal control network. Also referred to as the executive control network (ECN) or cognitive control network (CCN), the frontoparietal control network is comprised of lateral prefrontal and anterior inferior parietal cortices (Spreng, Sepulcre, Turner, Stevens, & Schacter, 2013; Vincent, Kahn, Snyder, Raichle, & Buckner, 2008). This brain system has shown reliable activation during experimental tasks requiring focused attention to and active manipulation of both external stimuli (e.g., working memory) and internal representations (e.g., autobiographical planning). Like other large-scale brain networks, the control network is spatially and temporally distinct during the resting-state (Vincent et al., 2008). However, as described below, the control network also interacts with other brain networks to support goal-directed task performance (Spreng et al., 2010).

The dorsolateral prefrontal cortex (DLPFC) is a core hub of the frontoparietal control network (Vincent et al., 2008). Meta-analyses have identified the DLFPC and other regions of lateral prefrontal cortex as among the most consistent cortical regions associated with creative task performance (Gonen-Yaacovi et al., 2013; Wu et al., 2015). The DLPFC has shown activation in studies of domain-general creative thinking, such as the classic alternate uses task (Abraham et al., 2012; Kleibeuker, Koolschijn, Jolles, De Dreu, & Crone, 2013). Studies of domain-specific artistic performance have also implicated the DLPFC, including musical improvisation (Beaty, 2015; Pinho, de Manzano, Fransson, Eriksson, & Ullén, 2014), poetry composition (Liu et al., 2015), and artistic drawing (Ellamil, Dobson, Beeman, & Chrsitoff, 2012; Kowatari et al., 2009). Notably, the DLPFC has shown preferential engagement during experimental paradigms that involve idea evaluation compared to idea generation (e.g., Ellamil et al., 2012; Liu et al., 2015). Together, these findings suggest that the DLPFC – a region involved in cognitive control and executive functions – plays an important role in certain aspects of creative cognition. In the context of the behavioral research described above, the DFLPC may support creative thought by inhibiting goal-incongruent conceptual knowledge, maintaining focused attention and higher-order task goals, and manipulating information in working memory.

Another prefrontal region consistently implicated in creativity studies is the left inferior frontal gyrus (IFG; Boccia, Piccardi, Palermo, Nori, & Palmiero, 2015; Gonen-Yaacovi et al., 2013). The left IFG is located in the ventrolateral prefrontal cortex, a region primarily involved in controlled memory retrieval processes often assessed with verbal fluency tasks (Badre & Wagner, 2004; Thompson-Schill, 2003). In the creativity literature, the left IFG has shown robust activity during performance on verbal divergent thinking tasks (Benedek et al., 2014a; Fink et al., 2009; Kleibeuker et al., 2013; Vartanian et al., 2013). For example, Benedek et al. (2014a) reported an association between the creative quality of divergent thinking responses and BOLD signal change in the left IFG during divergent thinking. The involvement of the left IFG during creative cognition is consistent with behavioral research on broad retrieval ability and divergent thinking (Beaty & Silvia, 2013; Benedek et al., 2012; Silvia et al., 2013), and may reflect neural activity related to the strategic search of memory and selection of concepts among competing alternatives.

## Episodic Memory and the Default Network

Studies of cognitive control and divergent thinking have been complemented recently by an emerging area of research that has examined the possible contributions of episodic memory to creative cognition. Episodic memory was classically defined by Tulving (1983, 2002) as a neurocognitive system that supports the ability to recollect specific past personal experiences. That perspective has broadened during recent years, as it has become increasingly clear that episodic memory also contributes importantly to a range of cognitive functions, including imagining future experiences (Klein, 2013; Schacter et al., 2012; Szpunar, 2010), counterfactual thinking (De Brigard, Addis, Ford, Schacter, & Giovanello, 2013; Schacter, Benoit, De Brigard, & Szpunar, 2015), and means-end problem-solving (Jing, Madore, & Schacter, 2016; Madore & Schacter, 2014; Sheldon, McAndrews, & Moscovitch, 2011). There is now increasing evidence that episodic memory also contributes to divergent creative thinking. We will first review behavioral evidence on this point, and then consider relevant observations from neuroimaging studies concerning the neural underpinnings of such effects that have linked episodic memory and creative thinking with the interconnected set of brain regions known as the default network.

### Behavioral Evidence Linking Episodic Memory and Divergent Creative Thinking

Perhaps the first evidence suggesting a link between episodic memory and divergent creative thinking comes from a study of young adults by Gilhooly, Fioratou, Anthony, and Wynn (2007). In their experiment, participants performed the well-studied Alternate Uses Task (AUT), where they are asked to generate novel and appropriate uses for a common object. Gilhooly et al. observed that people occasionally draw on episodic memories when performing the AUT, primarily during the early phases of task performance. In a study of healthy young and older adults, Addis, Pan, Musicaro, and Schacter (2016) administered the AUT to participants who were also required to remember past experiences, and to imagine experiences that might occur in their personal futures or might have (but did not) occur in their personal pasts. They reported that performance on the AUT is positively correlated with the number of episodic details that participants report when they imagine possible future experiences. However, this correlation with AUT performance was specific to imagined future events, and was not observed for imagined or recalled past events. In a neuropsychological study, Duff, Kurczek, Rubin, Cohen, and Tranel (2013) found that amnesic patients with severe impairments of episodic memory as a consequence of bilateral hippocampal damage are also impaired on the Torrance Tests of Creative Thinking, which provide a broad assessment of divergent thinking. However, because such patients also typically have problems in acquiring new semantic memories, it is unclear whether the observed divergent thinking deficit specifically implicates episodic memory in divergent thinking processes. Moreover, the creativity deficit in amnesic patients does not seem to be selective for divergent thinking. A recent study by Warren, Kurczek, and Duff (2016) provides evidence that amnesic patients also exhibit deficits in convergent thinking, i.e., the ability to generate the single best solution to a problem. They found that hippocampal amnesic patients performed poorly on the Remote Associates Test (RAT; Bowden & Jung-Beeman, 1998; Mednick, 1962), a widely used test of convergent thinking that requires participants to generate a solution word that forms a common word/phrase with each of the three main parts of a target word triad (e.g., for “Eight/Skate/Stick” the solution word is “Figure”).

Madore, Addis, and Schacter (2015) recently provided evidence for a stronger link between episodic memory and AUT performance. In their experiments, participants received an *episodic specificity induction* – brief training in recollecting specific details of a recent experience – prior to performing the AUT. The specificity induction used in this study is based on the well-established Cognitive Interview (CI; Fisher & Geiselman, 1992), a protocol used primarily in forensic contexts to increase episodic retrieval from eyewitnesses. When receiving the CI-based specificity induction, participants are encouraged to focus on episodic details pertaining to people, objects, and actions in a recently viewed video of an everyday scene (i.e., people performing actions in a kitchen setting). Several previous studies have shown that this specificity induction, compared with a control induction where participants provide their general impressions of a recently viewed video, selectively increases the number of episodic details that participants provide on subsequent tasks that require remembering past experiences and imagining future experiences, while having no effect on the number of semantic details that participants provide on such tasks (Jing et al., 2016; Madore, Gaesser, & Schacter, 2014; Madore & Schacter, 2016; for review, see Schacter & Madore, 2016).

In the first experiment by Madore et al. (2015), specificity and control inductions were given prior to performance on two main tasks: the AUT, and an object association task that required participants to generate common associates of objects but did not require divergent thinking. Critically, the specificity induction resulted in a significant increase on several standard measure of AUT performance: the total number of uses generated, appropriate uses (i.e., total number of uses that are feasible), categories of uses (i.e., total number of unique categories that uses can be binned under for each cue) and categories of appropriate uses (i.e., appropriate uses that are clustered into categories, often referred to as flexibility). By contrast, the specificity induction had no effect on performance of the object association task. Note also that the effects of the specificity induction on AUT performance were limited to the generative outputs noted above: they did not impact ratings of elaboration (i.e., a rating of how detailed each generated use is) or creativity (i.e., a rating of how original/unusual each generated use is). A second experiment compared effects of the specificity induction on AUT performance with performance of a convergent thinking task, the RAT. Results revealed that, once again, the specificity induction significantly boosted performance on all measures of generative output on the AUT compared with a control induction, but failed to produce a significant effect on the RAT (note, however, that the Type of Induction × Type of Test interaction was only marginally significant, $p = .051$).

Madore, Jing, and Schacter (2016) have recently extended the foregoing results in two ways. In an initial experiment, they replicated the boosting effects of the episodic specificity induction in young adults on the AUT (but not on the object association test), and showed that the same pattern of results is observed in healthy older adults. In a second experiment, Madore et al. (2016) asked whether the effect of the episodic specificity induction could be observed on another divergent thinking test known as the Consequences Task (Guilford, 1967; Torrance, 1974), an index of divergent thinking that requires participants to generate the consequences of various improbable, novel scenarios (e.g., flying without mechanical aids). Results revealed that, just as observed previously on the AUT, after receiving an episodic specificity induction, participants generated significantly more consequences of improbable scenarios than after receiving a control induction.

Given the evidence that episodic memory contributes to performance on the AUT and the Consequences Task, a further question concerns the types of ideas that are impacted by the induction. Several researchers have distinguished between "old" ideas (i.e., ideas that participants experienced or knew about prior to the study) and "new" ideas (i.e., ideas that emerged for the first time during the study; see Benedek et al., 2014a; Gilhooly et al., 2007). In the experiments by Madore et al. (2015, 2016), after having completed all tasks, participants judged each idea they produced on the AUT and the Consequences Task as either "old" or "new." Across tasks, there was some evidence that the episodic specificity induction increases the frequency of both "old" and "new" ideas, with the evidence for a boost in "old" ideas most robust for the AUT, and the evidence for a boost in "new" ideas most robust for the Consequences Task. However, these results must be interpreted with some caution, because labeling ideas as "old" and "new" is done retrospectively and could be subject to inaccuracies and biases (for discussion, see Madore et al., 2016).

Taken together, the findings from the foregoing studies suggest that episodic memory does make a contribution to creative cognition, but the contribution may be limited to divergent thinking. Schacter and Madore (2016) have argued that the specificity induction biases the way in which participants approach cognitive tasks by encouraging them to focus on episodic details related to places, people, objects, or actions. This focus on episodic details in turn impacts subsequent performance on those tasks that involve, at least to some extent, creating mental events or scenes that contain details like those emphasized during the specificity induction. By this view, a divergent thinking task such as the AUT or the Consequences Task involves the creation of mental events or scenes as participants attempt to imagine novel ways in which a familiar object could be used, and the specificity induction may help participants to create or retrieve more detailed mental events that support the generation of novel uses.

## Neuroimaging Evidence Linking Episodic Memory and Divergent Thinking with the Default Network

The default network refers to an interconnected set of brain regions that includes medial parietal cortex, including posterior cingulate cortex (PCC) and retrosplenial cortex (RSC), the posterior inferior parietal lobule (IPL), medial prefrontal cortex (PFC), medial temporal lobes (MTLs), and lateral temporal cortex (for reviews, see Andrews-Hanna, Smallwood, & Spreng, 2014; Buckner, Andrews-Hanna, & Schacter, 2008; Raichle, 2015). Early neuroimaging studies often relied on a passive "resting-state" as a baseline condition, where participants simply rested in the scanner without a task to perform. Although this resting period was initially of little empirical interest, researchers began to notice a consistent pattern of brain activity that emerged across several experiments, raising questions about whether this pattern reflected some "default mode" of the brain. Since the initial discovery of the default network, it has become increasingly clear that this network contributes to core functions of the mind (Andrews-Hanna et al., 2014; Buckner et al., 2008; Raichle, 2015). Most critical for the present purposes, a growing number of studies have linked the default network with remembering past experiences and imagining future experiences, which as noted earlier are both thought to depend on episodic memory (Schacter et al., 2012). More specifically, a set of brain regions referred as the *core network* (Schacter, Addis, & Buckner, 2007), which largely overlaps with the default network, shows similarly increased activity when people remember past experiences or imagine future experiences (for a recent meta-analysis, see Benoit & Schacter, 2015). According to the constructive episodic simulation hypothesis (Schacter & Addis, 2007), these neural similarities, and corresponding cognitive similarities between remembering the past and imagining the future (Schacter et al., 2012; Szpunar, 2010), reflect to a large extent the influence of episodic memory on imagining future and other hypothetical experiences.

Several studies have also linked the default network with aspects of divergent creative thinking.

Ellamil, Dobson, Beeman, and Christoff (2012) examined brain activity during idea generation and evaluation in visual arts students. They found that idea generation was associated with default activity, whereas idea evaluation was associated with control network activity. Moreover, functional connectivity analysis revealed increased coupling of the default network with the control network, but only during the idea evaluation condition. Benedek et al. (2014a) reported that the hippocampus and MTL, which are strongly linked to episodic memory and are considered part of the default network, were among the regions that showed increased activation when participants performed the AUT during scanning. In a recent attempt to examine brain activity related to episodic memory, episodic simulation, and divergent thinking within the same individuals, Beaty et al. (2016) scanned participants while they remembered past experiences, imagined future experiences, or generated creative uses of objects. Results revealed that compared to a control condition, all three of these processes recruited core default network regions (i.e., posterior cingulate, bilateral angular gyrus) compared with the control condition, although episodic memory and episodic future simulation were associated with greater default network activity than was divergent creative thinking. An additional functional connectivity analysis that used the foregoing default network regions as seeds revealed that episodic memory and simulation were linked with increased coupling of the posterior cingulate with other default network regions. Divergent thinking, by contrast, was linked with increased coupling of the same posterior cingulate seed with default regions and also with regions involved in cognitive control, consistent with our earlier discussion. Taken together, an emerging body of neuroimaging evidence suggests that creative cognition recruits regions of the brain's default network, a pattern that may reflect the involvement of constructive episodic processes during the production of novel ideas.

## Episodic Memory, Cognitive Control, and Brain Network Dynamics

We have thus far described research on the neurocognitive mechanisms underlying creative cognition, with a focus on episodic memory and cognitive control. The contribution of episodic memory and cognitive control to creative thought is supported by neuroimaging studies reporting consistent activation of brain regions underlying these cognitive processes. Here, we consider how these neurocognitive systems may interact to support creative cognitive processes. Several recent fMRI studies have sought to address this question by examining functional interactions between brain regions during creative thinking tasks. This work has shown remarkable consistency in terms of the patterns of functional connectivity reported across various creative tasks, largely implicating interactions of the default and frontoparietal control networks. We suspect that such interactions reflect the interplay of memory systems and cognitive control during creative idea production. In a previous review (Beaty, Benedek, Silvia, & Schacter, 2016), we characterized default activity as reflecting the bottom-up generation of candidate ideas from long-term memory, and control network activity as reflecting top-down oversight via executive functions and cognitive control (cf. Jung, Flores, & Hunter, 2016; Jung, Mead, Carrasco, & Flores, 2013). We further proposed that default and control network interactions may depend on the extent to which a creative task requires goal-directed processing. In the following section, we extend this framework by describing specific cognitive functions that may underlie default and control network dynamics during creative cognition.

As noted above, the default network shows robust activation during tasks that involve constructive cognitive processes, such as recalling episodic memories and imagining future experiences (Schacter et al., 2012). The constructive-episodic simulation hypothesis (Schacter & Addis, 2007) suggests that such processes involve the extraction and combination of mnemonic information to construct a mental representation. We propose that default activity similarly reflects the operation of constructive processes related to the extraction and combination of mnemonic information during various creative thinking tasks. This hypothesis is consistent with classic theories of creative thought that emphasize the flexible combination of acquired knowledge via bottom-up associative processes (e.g., Mednick, 1962). Notably, however, such theories have focused almost exclusively on semantic memory, with relatively little consideration of episodic memory. We suspect that both memory systems – each of which draws on the default network (Burianova, McIntosh, & Grady, 2010) – affect creative thought by activating and integrating declarative and episodic knowledge in a bottom-up fashion.

These constructive processes can be directed and constrained to meet task-specific demands by engaging cognitive control. The behavioral research described above highlights several control processes linked to creative cognition, including inhibition, updating, and controlled retrieval. Thus, the interaction of memory and cognitive control – reflected in functional coupling of the default and control networks – may correspond to *goal-directed idea production*. Although many creative tasks are often open-ended, they also typically require responses that conform to the creative goal at hand. In this context, cognitive control can support creative performance by implementing the task goal. As noted earlier, in the AUT participants are asked to generate novel and appropriate uses for a common object. Here, the task goals are to generate an object use that is both novel (i.e., it deviates from its common purpose) and appropriate (i.e., it could actually be implemented). Cognitive control can facilitate these goals by directing memory search processes, inhibiting goal-incongruent information, and evaluating candidate ideas.

The interaction of cognitive control and memory systems may account for patterns of functional connectivity reported in recent fMRI studies (for a review, see Beaty et al., 2016). Beaty, Benedek, Kaufman, & Silvia (2015) examined whole-brain functional connectivity associated with performance on the alternate uses task, and extracted regions of interest from the whole-brain network to identify patterns of connectivity among regions. Divergent thinking was related to functional connectivity among regions of the default (e.g., PCC) and frontoparietal control (e.g., DLPFC) networks. In a similar study using the alternate uses task, Mayseless, Eran, & Shamay-Tssory (2015) found that the creative quality of divergent thinking responses was positively correlated with the strength of functional connectivity between regions of the default network (i.e., left angular gyrus) and the anterior cingulate, a region associated with cognitive control. Moreover, a study using a noun–verb creative association task found that the creative quality of participants' responses – defined as the semantic distance between noun cues and verb responses – predicted increased functional connectivity between the mPFC and the ACC (Green, Cohen, Raab, Yedibalian, & Gray, 2015). Taken together, these findings provide support for the notion that verbal creative thinking involves cooperation among cognitive control and default network regions, a pattern that may reflect the interaction of executive cognition and memory systems.

Default and control network coupling has also been reported in studies of artistic performance (Ellamil et al., 2012; Liu et al., 2015; Pinho et al., 2016). In a study of professional pianists, Pinho and colleagues found that improvising melodies based on specific emotions elicited functional coupling of the right DLPFC with core regions of the default network. Other studies have sought to dissociate network interactions associated with idea generation and evaluation. As noted earlier, Ellamil et al. (2012) conducted a study with visual artists and reported greater functional connectivity between default and control network regions during idea evaluation compared to generation. In a similar vein, Liu et al. (2015) found that professional poets exhibited greater functional coupling of default and control regions during the evaluation and revision of self-generated poetry, compared to an initial idea generation period. The generation and evaluation of creative ideas within various artistic domains may therefore involve differential interactions of the default and frontoparietal control networks, providing further evidence for the interaction of memory systems and cognitive control.

## Summary and Future Directions

In this chapter, we present evidence from recent behavioral and neuroimaging investigations that support the involvement of episodic memory and cognitive control during creative idea production. We suggest that episodic memory and cognitive control interact during creative cognitive processes, reflected in the activation of and functional connectivity among regions of the default and frontoparietal control networks. This interaction may reflect goal-directed idea production, with mnemonic functions of the default network related to generative processes that can be directed and constrained by the control network depending on creative task demands. The evidence suggests that default and control network coupling is central to both general creative thinking (e.g., divergent thinking) and aspects of artistic performance (e.g., musical improvisation). We believe this emerging literature provides important insights into how and when memory and cognitive control interact to support the production of new ideas.

An important direction for future research is to further clarify the default network's role in creative thought. We suggest that default activity reflects constructive processes linked to episodic memory (for further discussion, see Schacter, et al., 2007, 2012). Nevertheless, because the default network is associated with several cognitive processes with potential relevance to creative thought (e.g., semantic retrieval), a key direction for future research is to isolate default activity related to episodic processes during creative task performance, perhaps through the use of an episodic specificity induction along the lines discussed earlier in the chapter. In a similar vein, future research should clarify whether the default network contributes to creative thought via the operation of general constructive processes, activation of task-specific memory content, or both. We encourage neuroscience research to employ experimental manipulations that can further tease apart the specific cognitive processes underlying default and control network activity during creative idea production.

## Acknowledgments

R.E.B. was supported by grant RFP-15-12 from the Imagination Institute, funded by the John Templeton Foundation. D.L.S. was supported by National Institute of Mental Health RO1 MH060941 and National Institute on Aging RO1 AG08441.

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