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While a training model of cognitive intervention targets the improvement of particular skills through instruction and practice, an engagement model is based on the idea that being embedded in an intellectually and socially complex environment can impact cognition, perhaps even broadly, without explicit instruction. We contrasted these 2 models of cognitive enrichment by randomly assigning healthy older adults to a home-based inductive reasoning training program, a team-based competitive program in creative problem solving, or a wait-list control. As predicted, those in the training condition showed selective improvement in inductive reasoning. Those in the engagement condition, on the other hand, showed selective improvement in divergent thinking, a key ability exercised in creative problem solving. On average, then, both groups appeared to show ability-specific effects. However, moderators of change differed somewhat for those in the engagement and training interventions. Generally, those who started either intervention with a more positive cognitive profile showed more cognitive growth, suggesting that cognitive resources enabled individuals to take advantage of environmental enrichment. Only in the engagement condition did initial levels of openness and social network size moderate intervention effects on cognition, suggesting that comfort with novelty and an ability to manage social resources may be additional factors contributing to the capacity to take advantage of the environmental complexity associated with engagement. Collectively, these findings suggest that training and engagement models may offer alternative routes to cognitive resilience in late life.

Keywords: cognitive enrichment, engagement, cognitive training, divergent thinking, resilience

Age-related declines in cognition are, as starkly described by Lövdén, Bäckman, Lindenberger, Schaefer, and Schmiedek (2010), “in full view by roughly the age of 65” (p. 659). However, individuals vary in their trajectories of cognitive development through adulthood, so that by the age of 65 there is also substantial variability in cognition, with some older adults showing high levels of competence equal

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to or better than many younger adults, and others approaching a functional floor (Hertzog, Kramer, Wilson, & Lindenberger, 2008). The way in which experience impacts such variation is not well understood, though cognitive resilience in adulthood is likely a lifelong process (Stine-Morrow & Chui, 2012). Because intellectual resources are vulnerable in late life, considerable recent research has been devoted to exploring the potential for cognitive enrichment (Hertzog et al., 2008) and interventions to promote cognitive health during this period (Stine-Morrow & Basak, 2011). This literature might be understood as drawing on two different approaches: the training approach, which targets specific skills or abilities for instruction and practice (Hindin & Zelinski, 2011); and the engagement approach, in which individuals are encouraged to make lifestyle changes (Basak, Boot, Voss, & Kramer, 2008; Carlson et al., 2008; Small et al., 2006) that may offer mental exercise. In the present report, we describe the results of an investigation that contrasted these two models of cognitive enrichment in a single experimental design. By way of introduction, we consider more specifically the nature of cognitive aging and optimization, and then elaborate on these two models before developing specific hypotheses.

Cognitive Aging and Optimal Life Span Development

Age deficits in speed, reasoning, executive control, and other fluid abilities are robust, with effect sizes from cross-sectional data on the order of 1.5 to 2 *SD* between the ages of 20 to 80 (Salthouse, 2010, p. 17), and within-person declines of about 1 *SD* (Schaie, 2005, p. 121). However, functional capacity needed to manage the complex demands of adult life and work is often maintained late into life (Salthouse, 2012). There is now wide recognition that neural networks and behavior are malleable, or *plastic*, into very late life (Buschkuehl & Jaeggi, 2010; Mahncke et al., 2006; Voss, Vivar, Kramer & Praag, 2013). *Plasticity*, the potential to be shaped by experience, typically declines during adulthood, but is present through the life span (Baltes, 1987, 1997). Lövdén and colleagues (2010) characterize plasticity as the capacity of cognitive and neural systems to reconfigure themselves so as to extend the scope of flexible adaptation. They argue that increases in plasticity depend on a prolonged mismatch between the experienced demands of the environment and current functional capacity. At the same time, this mismatch must be within the current range of flexibility; if demands exceed this range, the prolonged engagement with environmental demands that is needed to enhance adaptive capacity is not possible (cf. Metcalfe & Kornell, 2005; Payne, Jackson, Noh, & Stine-Morrow, 2011; Reuter-Lorenz & Lustig, 2005). Not all learning or improvement in performance reflects an increase in plasticity. For example, domain-related knowledge or strategy training can increase performance in a narrow range of situations without affecting the more generalized capacity for adaptation. This capacity to adapt to and learn from novel situations is often thought of as "intelligence," an array of distinct abilities that contribute to adaptive functioning. Hence, the quest to find forms of enrichment that enhance plasticity amounts to the search for ways to improve intelligence (Buschkuehl & Jaeggi, 2010).

Our interest was in contrasting two models of cognitive enrichment: a training model in which particular cognitive components are targeted for instruction and practice, and an engagement model in which individuals are embedded in a rich and stimulating environment that engenders exercise of cognition in context. It is important that training and engagement should be thought of as theoretical constructs, and any particular enrichment experience—though possibly weighted toward one or the other—is likely to contain some balance of the two. The training model grows out of literature in experimental psychology in which a specific skill is trained and outcomes are assessed for skills identical or almost identical to the trained skill (*near transfer*) and skills that are very different from that trained (*far transfer*; e.g., Ball et al., 2002). By definition, then, a demonstration of *improved* plasticity involves showing far transfer. The engagement model derives from epidemiological and correlational work on lifestyle showing that individuals who invest themselves in complex work (Rohwedder & Willis, 2010; Schooler, Mulatu, & Oates, 1999), leisure (Bygren, Konlaan, & Johansson, 1996; Scarmeas et al., 2001; Schooler & Mulatu, 2001; Verghese et al., 2003; Wilson et al., 2000), and social networks (Bennett, Schneider, Tang, Arnold, & Wilson, 2006; Fratiglioni et al., 2000; Lövdén, Ghisletta & Lindenberger, 2005), or generally stay busy (Jopp & Hertzog, 2007) fare better in cognition (Jopp & Hertzog, 2007; Schooler et al., 1999), health and resistance to late-life pathology (Scarmeas et al., 2001), and longevity (Bygren et al., 1996). As such, engagement may offer promise for broad-spectrum benefits analogous to those of aerobic exercise (Voss, Vivar, Kramer, & van Praag, 2013).

What is at stake theoretically is defining the mechanisms and processes that evoke a prolonged mismatch between current levels of adaptive capacity and demand so as to increase plasticity. What is at stake for application is principled translation to programs and practices that afford lifelong cognitive resilience. Education, the primary cultural institution for drawing out intellectual potential, traditionally has depended on both of these models. On the one hand, education is defined by particular curricula that provide training in specific capacities, skills, and domains of knowledge that are presumed to be necessary for further education and independent functioning. On the other hand, education is also conceptualized as an enriched environment that offers opportunities for exploration and choice among alternatives for new experiences, social engagement, and learning new things. Both training and engagement contribute to educational models, though the balance tends to shift toward engagement with movement through the life span as the acquisition of key skills affords more choice in the nature of intellectual growth (e.g., learning to decode print early in the life span affords choice of reading material later; general education requirements in freshman year engender intellectual skills that enable wider participation in university resources). Certainly, by mid- to later adulthood, the few educational models available are more of the engagement variety (Riley & Riley, 2000).

Cognitive Training

There is a rich literature in the psychology of aging that has examined the effects of training in cognitive abilities and perceptual skills. Perhaps the best example of this approach is the ACTIVE trial, a randomized clinical trial to contrast the effects of cognitive training in speed, memory, and inductive reasoning among older adults (Ball et al., 2002; Rebok et al., 2014; Willis et al., 2006). The ACTIVE trial demonstrated robust effects that were highly specific to the trained ability with little evidence of transfer to untrained abilities. The implication is that broad change in cognition required for plasticity (i.e., "g") will depend on specialized training in a broad array of abilities.[1]

Not everyone benefits equally from training, with a number of studies reporting moderation of training effects by cognitive and motivational variables. There is some evidence that the effects of memory training are likely to be enhanced for those who are younger and begin training with more cognitive resources (Bissig & Lustig, 2007; Unverzagt et al., 2007; Verhaeghen & Marcoen, 1996; Verhaeghen, Marcoen, & Goossens, 1992). In the ACTIVE trial, the effectiveness of memory training has been shown to depend on initial cognitive profile (Langbaum, Rebok, Bandeen-Roche, & Carlson, 2009). Such Matthew Effects (i.e., the rich get richer) are typically attributed to variations in plasticity (reflected in baseline cognitive measures) that enable more cognitively robust individuals to take better advantage of training so that initial differences between better and worse performers are amplified. However, the conditions under which Matthew Effects occur are not well understood. Noncognitive resources may also play a role in enhancing the effects of cognitive training (Hess, 2014).

Because the to-be-developed skill in training is well specified, difficulty can be systematically adjusted to current skill level. Such adaptivity allows the individual to be maintained at a comfortable, but prolonged, mismatch between current level of ability and environmental demands (Lövdén et al., 2010; i.e., stay in a "zone of proximal development" (Vygotsky, 1978) or "region of proximal learning" (Metcalfe & Kornell, 2005).

Engagement

The hallmark of engagement is the availability of an enriched environment, such as work or complex leisure activities, affording opportunities for individuals to selectively invest in activities. In an engagement model, there are not typically requirements for formal training or instruction, though individuals may seek out instruction to meet demands of the complex context. While the goal of training is explicitly self-enhancement, the goals of engagement can be varied (e.g., motivated by generativity, curiosity, or pleasure) so that self-enhancement motives can be quite ancillary. Relative to training, engagement requires higher levels of self-regulation to initiate and sustain activities, as well as withdrawal from activities that are not satisfying. As noted earlier, the bulk of the evidence for this view is correlational or epidemiological, and therefore, causally ambiguous in being vulnerable to selection effects (i.e., complex lifestyles may engender cognitive resilience, or it may be that people who are cognitively intact, by virtue of genetic endowment and/or early life experience, create more complex lifestyles). However, Rohwedder and Willis (2010) took advantage of nationally representative samples from an array of countries (e.g., HRS-AHEAD in the United States) in which the financial consequences of retirement vary, showing that citizens in countries that incentivize retirement show earlier cognitive declines. Assuming that individual control over national retirement policies is minimal, this provides somewhat more solid evidence of a causal role for engagement in cognitive enhancement.

The causal pathways through which engagement might impact cognition are not obvious. Consider three possibilities that are not mutually exclusive. Engagement might train many abilities at once by creating opportunities for sustained implicit practice of task-relevant skills (e.g., in a book club in which a book is analyzed and used as a springboard to discuss other books, events and personal experiences, one might exercise working memory, reasoning, divergent thinking, as well as spatial skills in navigating to a new location each month). Alternatively, an engaged lifestyle might exercise some core capacity (e.g., executive control) because of the requirements to manage many activities. Finally, an engaged lifestyle might promote cognitive growth because the social context of engagement provides a meaningful socioemotional and cultural context that motivates individuals to exercise multiple capacities to achieve personally significant goals.

Unlike in a training model of enrichment, adaptivity is more difficult to achieve in an engagement model. Rather, complex environments require that the individual self-regulate so as to maintain the optimal mismatch between the current level of flexibility and external demands. Self-regulation in such environments is complex, requiring both intellectual resources and skills in managing the social environment. Thus, there are good reasons to be skeptical about the efficacy of an engagement model of cognitive enrichment.

The Senior Odyssey Project

The Senior Odyssey project was motivated by two large concerns. First, it was an experiment to explicitly contrast training and engagement models of enrichment given the tenuous causal link between engagement and resilience (Stine-Morrow & Payne, in press). In fact, while animal experimentation has shown that an enriched environment can engender neurogenesis, there is evidence that these effects are driven entirely by increases in physical activity (Mustroph et al., 2012). An equally plausible account of the engagement-cognition relationship, then, is that healthy and cognitively resilient individuals select into complex environments (Gow, Corley, Starr, & Deary, 2012; Hultsch, Hertzog, Small, & Dixon, 1999; Scarr & McCartney, 1983; Small, Dixon, McArdle, & Grimm, 2012). Thus, whether embedding oneself in a complex environment that presents habitual mental stimulation has an effect on cognition is entirely an open question.

The challenges to experimentally manipulating changes in lifestyle to test the causal hypothesis are daunting (Salthouse, 2006), though there are examples of short-term interventions with small samples (Konlaan et al., 2000; Small et al., 2006). With a global

[1] Another account of how training could enhance plasticity is that instruction and practice in some core ability central to intellectual functioning may produce broad transfer (Stine-Morrow & Basak, 2011). This is actually a notion that took center stage in debates early in the history of psychology in the form of the "doctrine of formal discipline" (DFD), the idea that exercising mental abilities by learning some formal system (e.g., Latin, mathematics, or logic) would discipline the mind so as to make it more nimble in new episodes of learning. In spite of the early dismissal of this idea by James and Thorndike, it has continued to resurface in different guises, with some empirical support (Hewins, 1916; Lehman, Lempert, & Nisbett, 1988). Contemporary versions of the DFD include training in working memory, interference control, and executive function, the logic being that the ability to manage the flow of information in working memory is tantamount to intelligence (Kane & Engle, 2002). Training in this core ability would thereby be expected to expand adaptive capacity in a range of circumstances (Buschkuehl & Jaeggi, 2010; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008), a notion that remains highly controversial (Shipstead, Redick, & Engle, 2012).

increase in the aging population and growing popular interest in “brain training” (Begley, 2007; Marx, 2013), there is no shortage of programs designed to promote late-life cognitive fitness (Hartman-Stein & LaRue, 2011). However, rigorous test of whether these programs positively impact cognitive function is largely lacking. There are some important exceptions. One is the Experience Corps project that randomly assigned socioeconomically disadvantaged elders to a program in which they were trained to serve important support roles in Baltimore schools, and then placed to work with children in the classroom or with school staff. In capitalizing on generativity motives in later adulthood, the project made available meaningful social roles that also required engagement in mentally challenging routines, producing an increase in executive control (Carlson et al., 2008). Another example is the Synapse project, in which older adults who were randomly assigned to engage in digital photography lessons showed improvement in episodic memory (Park et al., 2013).

A second concern was that the program be rooted in existing social institutions so that it would have the potential to endure. Sociologists have argued for some time that American culture is “age-segregated,” in that the availability of social roles related to education, work, and leisure are constrained by age (Riley & Riley, 2000). In fact, the availability of high-quality educational programs diminishes past young adulthood (National Research Council, 2012). To the extent that investment in intellectual pursuits may enhance cognition, what may appear to be normative age-related declines in cognition may be indirectly caused by the lack of opportunity for educational engagement. Thus, the project was developed with an eye toward age-integration, establishing the program in the context of an existing social institution, Odyssey of the Mind (OOTM; Stine-Morrow & Parisi, 2011; Stine-Morrow, Parisi, Morrow, Greene, & Park, 2007; Stine-Morrow, Parisi, Morrow, & Park, 2008), that could offer ongoing opportunities for educational engagement for an age-diverse population.

OOTM (*www.odysseyofthemind.org*) is an enrichment program in schools designed to build skills in creative problem solving. Teams collaborate to prepare for tournament competition in two areas of ill-defined problems: Spontaneous Problems (SPs), in which teams are presented with a novel problem for which they must develop a solution (or solutions) on the fly; and the Long-Term Problem (LTP), in which teams present a prepared solution to a problem (e.g., build a weight-bearing structure out of balsa wood to certain specification, create a retelling of an historical event with certain narrative or performance elements) in the form of a short presentation. Processes for creating problems, defining scoring criteria, and judging performance are well established. For both sorts of problems, creative rather than typical, solutions are favored and rewarded. Teams are encouraged to generate multiple solutions as a pathway to developing creative solutions. A pilot project in which the Senior Odyssey program was contrasted with a waitlist control showed that older adults gained in speed, inductive reasoning, and divergent thinking, and a cognitive composite (Stine-Morrow et al., 2008).

In the current project, there were two experimental arms, one that operationalized an Engagement model of cognitive stimulation as the classic OOTM program, and another that operationalized a Training model using an adaptation of home-based inductive reasoning training (Margrett & Willis, 2006), which were compared with a Waitlist Control. Thus, both interventions were expected to exercise problem solving skills. In contrast to the earlier pilot (Stine-Morrow et al., 2008), the inclusion of the Training condition provided a cognitive placebo against which to test the Engagement model. Individuals in both the Engagement and Training groups were enrolled as Odyssey participants with equal status (in “Odyssey-Troy” and “Odyssey-Ithaca,” respectively), and had expectations of improved cognition. This was a parametric design (Willis, 2001), which controlled for expectancy effects, time allocated to program activities, and to some extent, social interaction with lab staff, but in which groups were hypothesized to show differential improvement in abilities. As such, our study provided a relatively rigorous test of the effects of engagement.

There were three questions of interest: (1) Can engagement produce any effect at all on cognition? In contrast to training, in which instruction and practice are explicit, engagement offers opportunities for activities and mental exercise in which there is no explicit instruction. Against the backdrop of an educational literature suggesting the importance of guided instruction for learning (Mayer, 2004), we were interested in whether growth in ability was possible via engagement. (2) How do engagement and training compare in their overall effectiveness in boosting cognition? Assuming that engagement broadly stimulates the intellect, we expected the Engagement group to show generalized improvement across the abilities measured, but based on the literature showing ability-specific effects from training, we expected the Training group to show selective improvement in inductive reasoning. (3) Do different sorts of people benefit from engagement and training? We expected those with stronger cognitive ability at pretest to show more responsiveness to the intervention (i.e., a Matthew Effect reflecting the fact that flexibility enhances the potential for plasticity; Lövdén et al., 2010), but as discussed earlier, we also anticipated that the two types of enrichment might be differentially beneficial for different sorts of people. For example, we wondered whether the highly social nature of the engagement model might reduce the moderating effect of initial cognitive status, but heighten the influence of baseline social resources. Also, given the need for flexibility in working in teams (as well as the focus of program activities on creativity), we also wondered whether individuals with higher levels of Openness to Experience and Mindfulness would show greater benefits from the Engagement program.

Method

Participants

Volunteers were recruited from the communities of Champaign, Urbana, and Danville, Illinois, through newspaper ads; presentations to senior groups; an information booth at a local farmer’s market; posters and pamphlets at grocery stores, doctor’s offices, and local businesses; and open house parties at a Senior Odyssey space at a local shopping mall. Participants were screened to exclude those with a history of dementia or other neurological impairment, cancer treatment, stroke, those with a Mini-Mental Status Exam (MMSE; Folstein, Folstein, & McHugh, 1975) score <24, and those with 15 hr or more of scheduled activity per week (e.g., work, volunteer commitments). Participants were screened through an initial phone interview (or occasionally, on their initial appointment). During the telephone interview, volunteers were told about the time commitment for the project, which prompted many not to pursue participation. Ultimately, we were able to randomly assign about a third of the individuals initially assessed for eligibility (Figure 1). Recruitment and random assignment were conducted across four annual cycles of the program, which ran synchronously with OOTM. The final sample consisted of 461 adults (60 to 94 years of age; $M = 72.6$ years), who were generally healthy but relatively inactive.

Participants were randomly assigned to one of three groups: Engagement, Training, or Waitlist Control. Participants were given the option of being randomly assigned as part of a couple. A CONSORT (Consolidated Standards of Reporting Trials) diagram collapsed across the four cycles is presented in Figure 1 and charts the flow of participants from eligibility assessment to enrollment to random assignment to posttesting. In this figure, participants who dropped out of the program are distinguished from those who did not return to posttest. A description of participants is presented in Table 1. At pretest, groups did not differ in age, $F(2, 458) = 2.14$; educational level, $F(2, 458) = 1.22$; global cognitive status, as measured by the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), $F < 1$; vocabulary (standardized composite of the Educational Testing Service (ETS) Advanced and Extended Range Vocabulary subtests), $F(2, 455) = 1.02$; speed (standardized composite of the Letter and Pattern Comparison tasks), $F(2, 457) = 1.02$; gender composition, $\chi^2(2) = 1.78$; or percentage of participants assigned as a member of a couple, $\chi^2(2) = 1.23$.

Measurement Battery

The battery of cognitive measures was administered to participants across two sessions, an individual and group-based testing session, lasting approximately 4 hr in total. Participants were tested prior to the beginning of the program and then again after the program. The interval between pretest and posttest was controlled to be between 30 and 32 weeks. When possible, alternative forms were used for measures of cognition between pretest and posttest.

Measures of social context, personality, attitudes, and activity were given to participants in a booklet to complete at home. In this report, we focus on cognitive outcomes, detailed below. Because of our interest in testing hypotheses about moderation of effects on cognition by existing social context and certain aspects of personality, we also note that we included a measure of social network size (Cohen et al., 1997), measures of core personality constructs (Neuroticism, Extraversion, Openness to Experience, Agreeableness, and Conscientiousness; Goldberg, 1999), and measures of dispositions for cognitive motivation (Need for Cognition; Cacioppo, Petty, Feinstein, Jarvis, & Blair, 1996) and Mindfulness (Bodner & Langer, 2001).

Cognitive measures represented five fluid abilities. *Processing Speed* was assessed with Letter and Pattern Comparison tasks (Salthouse & Babcock, 1991) and the Finding A's task (Ekstrom, French, & Harmon, 1976), each of which involves making speeded judgments to simple stimuli ($\alpha = .72$). Five instruments were used to identify a construct for *Reasoning*. These included the Letter Sets, Number Series, Letter Series, and Word Series tasks (Ekstrom et al., 1976) and the Everyday Problem-Solving (EPS) task (Marsiske & Willis, 1995). Collectively, these tasks require participants to identify patterns in a series of items and either generate the next item in the series or decide which item does not adhere to the pattern. In the EPS task, participants must solve everyday problems (e.g., make inferences from nutrition labels) ($\alpha = .90$). Two

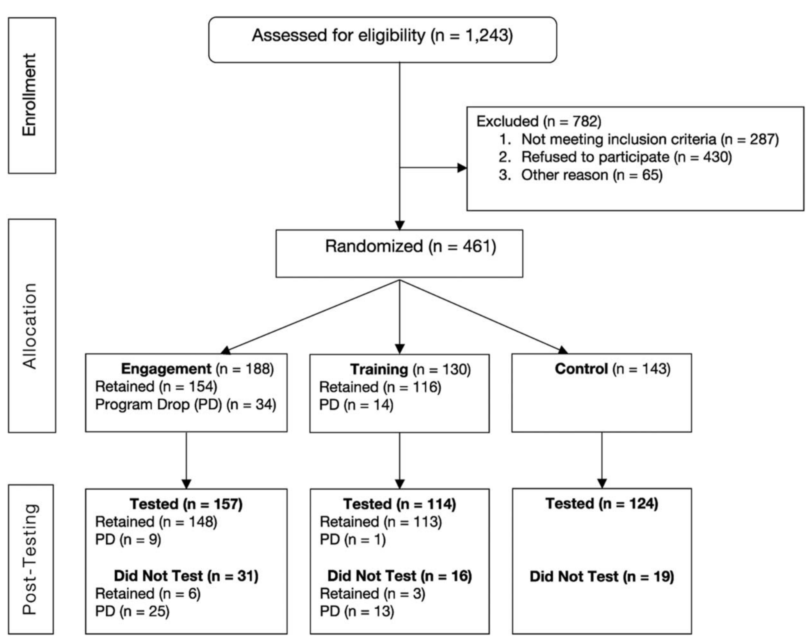

Figure 1. Consolidated Standards of Reporting Trials (CONSORT) diagram charting the flow of participants from through the study. (Note that "retained" refers to participant status in the intervention groups, regardless of whether the individual returned for testing; because our analysis as intent-to-treat, the number tested could be greater than the number retained in the program.)

Table 1
Participant Characteristics

	Engagement	Training	Waitlist
N	188	130	143
Mean age	71.7	73.4	72.9
SD	8.0	7.5	7.4
Range	60–92	60–94	60–91
Mean educational level (years)	15.7	15.2	15.4
SD	2.6	2.7	2.5
Range	9–20	10–20	11–20
Mean MoCA	26.0	26.1	25.9
SD	2.9	3.0	3.0
Range	18–30	14–30	16–30
Vocabulary	0.03	0.00	0.00
SD	0.96	0.99	0.94
Speed	0.01	−0.06	0.09
SD	0.80	0.90	0.92
% Female	71	77	76
% partnered	26	22	22

Note. MoCA = Montreal Cognitive Assessment. Measures of Vocabulary and Speed are standardized *z*-score composites.

instruments were used to identify a construct for *Visual-spatial processing* (VSP), Card Rotation and Hidden Patterns (Ekstrom et al., 1976), in which participants identify visual patterns in an array in which spatial rotation and/or visual transformation is required. (α = .72). *Divergent Thinking* was assessed with the Alternate Uses task (Reese et al., 2001) and the Opposites task (Ekstrom et al., 1976), which require ideational fluency in generating new exemplars from a stimulus item (α = .71). *Verbal Episodic Memory* was measured using two indicators derived from performance on the Hopkins Verbal Learning Test (Benedict, Schretlen, Groninger, & Brandt, 1998), total number of words remembered over three trials (HVLT-Tot) and the delayed recall score (HVLT-DR), and proportion of correct propositions recalled in an immediate sentence free-recall task (Stine-Morrow, Milinder, Pullara, & Herman, 2001; α = .76). The battery as a whole formed a reliable composite of fluid ability (α = .87).

Procedure

In the interest of implementing a true age-integrated model of engagement (Riley & Riley, 2000), the intervention was conducted on the calendar of the Odyssey of the Mind program. In fact, those in the Engagement intervention participated as full-fledged members of Odyssey of the Mind under the auspices of the University of Illinois. For each cycle, pretesting was conducted in late summer and early fall, and data on age, vocabulary, cognitive status, and speed were compiled so that we could ensure that randomization was successful in balancing individual differences across conditions. Individuals in the Engagement and Training groups participated in their respective programs from fall into spring. Recall that participants were allowed to be assigned with a partner; block random assignment assured that no condition had a disproportionate number of participants requesting partners. Each intervention consisted of 16 program weeks that were spread out through the season to accommodate winter holidays and weather-related cancellations. After participants completed a year of the program to which they were randomly assigned, they were given the opportunity to return as “alums” to either the “Troy” or “Ithaca” program.

Engagement program (“Odyssey-Troy”). In the pretest session, participants were presented short summaries of the OOTM LTPs for that year and asked to rank-order their preferences. Teams of 5 to 7 individuals were assembled based on these preferences, with minor adjustments made to accommodate scheduling constraints for meetings. Weekly meetings (~1.5 hr each) were held on the University of Illinois campus and in a local mall, both in spaces dedicated to this purpose. Each team was guided by an undergraduate coach, who received training through the OOTM organization and by our staff. Coaches led each of the 16 meetings using a standard set of slides to present SPs. A task analysis (Luczak, 1997) was used to verify that that SPs over a season exercised reasoning, VSP, divergent thinking and fluency, and memory.[2] Team meetings focused primarily on SPs early in the season, with details and constraints of the LTP introduced gradually. Individuals were asked to engage in a total of 15 hours per week of Odyssey activities (including team meetings, preparing the LTP, and certain games) for which they kept logs that they submitted to their coach at the weekly meeting. Points were awarded for time spent in these activities (in half-hour blocks) and cashed in for prizes. A core value of the program was the focus on creative problem solving. Alumni members were distributed among teams according to preference for the LTP, and served as a resource for new members in learning the program.

Reasoning training (“Odyssey-Ithaca”). The training intervention consisted of home-based instruction in inductive reasoning (Margrett & Willis, 2006), the ability to identify patterns and infer progressive sequences. This program constituted 10 weekly lessons and was supplemented with 6 packets of crossword and Sudoku puzzles, to equate the duration of Training to that of Engagement. The mix of crosswords and Sudoku provided some variety and are believed by many to support cognitive health; Sudoku puzzles rely in part on reasoning skill and so were consistent with training, and crosswords were not expected to have substantial effects on cognition (Hambrick, Salthouse, & Meinz, 1999). Difficulty was systematically incremented across lessons, adapting to participants’ growing skill.[3] Participants came into the lab each week to return their completed packet, check their an-

[2] All units were reviewed by two members of our lab to identify the cognitive skills (verbal ability, inductive reasoning, visual-spatial, divergent thinking and fluency, flexibility, and (working) memory) needed to process and solve the SPs. Across the four cycles of the program, participants were presented with an average of 15.2 SPs per session in group format (on average, 243.8 SPs per season). SPs very often exercised more than one cognitive component. Across the four cycles, verbal ability/production was required in 65% of the SPs; inductive reasoning, 36%; visuospatial processing, 19%; divergent thinking, 27%; mental flexibility, 48%; and (working) memory, 34%.

[3] For example, the first packet of reasoning training introduced the concept of a repeated pattern through physical actions (e.g., knock, knock, clap, knock, knock, clap, knock, knock, ?) and drawing lines between repetitions in a written sequence (e.g., Monday Monday Friday/Monday Monday Friday/. . .); across packets, patterns grew more complex (e.g., b c d b c e b c ?) and were extended to practical situations, such using a phone book or a bus schedule. We assembled a file of puzzles graded in difficulty so that participants were matched early in the season to puzzles within a comfortable range and allowed to choose more challenging puzzles as they were ready.

swers, and pick up a new packet of activities. The time commitment for Training participants was closely matched to that of those in the Engagement intervention.

Waitlist Control participants experienced no intervention during the cycle, but participated in testing as a control for retest effects, which can be substantial (Yang & Krampe, 2009). For the first three cycles of the program, Waitlist participants who returned for the next year were randomly assigned to either Engagement or Training; these data are not reported here.

Data Analysis

We used second-order multiple-group latent change score models, also known as multiple-indicator latent change score models (McArdle, 2009; McArdle & Prindle, 2008; Schmiedek, Lövdén, & Lindenberger, 2010), to determine the effects of the intervention on cognition, and to examine moderators of change within intervention. Models were fit separately for each cognitive ability. Manifest variables were standardized to a *T* score distribution ($M = 50$, $SD = 10$) based on the baseline mean and *SD* of the sample. For each ability, multiple measures were used to define latent factors for initial level and posttest performance, and a latent slope factor, representing the amount of individual change from pretest to posttest. We constrained for strong measurement invariance in our models across groups and time. Factor loadings, residual variances, and intercepts were held equal across time and group. In addition, residual variances were correlated across each item from pretest to posttest. Absolute model goodness of fit was assessed using the Comparative Fit Index (CFI) and the Root Mean Square Error of Approximation (RMSEA). Nested model comparisons were used to evaluate whether latent change estimates reliably differed between groups. Cross-group equality constraints were imposed on latent change means, and likelihood ratio tests were used to evaluate whether constraining latent change estimates to be equal across groups resulted in significantly worse model fit. Analyses were conducted as intent-to-treat, so that participants who dropped from the program were invited back for posttest, and data were included for posttested participants even if they had dropped from the program (Lachin, 2000). Full-information maximum likelihood was used to estimate parameters from all data available within time of measurement (Graham, 2009). Supplementary analyses examined potential moderators of training gains by correlating estimates of latent change within each intervention group with baseline individual differences and estimates of intervention adherence (e.g., attendance).

Results

Adherence and Drop Out

Engagement participants attended an average of 11.0 out of 16 session ($SD = 4.8$) and Training participants completed an average of 12.9 modules out of 16 ($SD = 5.2$); this difference in adherence was significant, $F(1, 317) = 11.42$, $p < .001$. Retention in both the Engagement and Training programs was very good in absolute terms, with rates of 82% and 89%, respectively. Those who dropped out did not differ from those who were retained in age, educational level, MoCA, or pretest measures of speed or vocabulary, all *F*s <1.2. Of those who were pretested and randomly assigned, 84% in Engagement, 88% in Training, and 88% in the Waitlist Control returned for posttest. Those who returned for posttest did not differ from those who did not in age, educational level, or pretest measures of speed, all *F*s <1.9. However, those who returned for posttest scored higher on the MoCA, (26.2 vs. 25.0), $F(1, 453) = 7.99$, $p < .01$), and vocabulary (.09 vs. −.45), $F(1, 452) = 17.42$, $p < .001$, at pretest, but neither of these effects varied across experimental assignment, $F < 1$ for the interactions.

Overall Group Differences in Cognitive Change

Figure 2 plots change in individual measures, and latent change in Reasoning, VSP, Divergent Thinking, and Episodic Memory, from pretest to posttest, represented in *T* score units (i.e., 10 = 1SD) based on pretest mean and *SD*. Model fits for each cognitive construct are presented in Table 2. The latent change model for Speed in the Training group did not converge to a proper solution, so we could not test for group differences in change at the construct level. However, none of the individual speed measures showed an advantage for Engagement or Training relative to the Waitlist Control (cf. Figure 2), so we have no reason to believe that a construct-level analysis would change the picture. Initial model fitting for Divergent Thinking produced a small negative variance estimate for change within the Training group, so the model was reestimated with this variance set to zero (Chen, Bollen, Paxton, Curran, & Kirby, 2001; Gerbing & Anderson, 1987; Wothke, 1993). With this constraint, the latent change score model converged normally.

Consistent with expectations that training effects would be specific to the targeted ability, Training participants showed improvement in Reasoning relative to the two other groups. Likelihood ratio tests for group differences in latent change in Reasoning verified that Training participants showed more change than both Engagement, $\chi^2(1) = 23.30$, and Waitlist, $\chi^2(1) = 15.64$, participants, and that the Engagement and Waitlist groups did not differ from each other, $\chi^2(1) = .21$. Change in the Training group was also specific to the trained ability, in that any changes in Speed, VSP, and Memory did not exceed those in the other two groups (multiple group test of equality of latent change score means for VSP, $\chi^2(2) = 1.26$, and for Memory, $\chi^2(2) = .54$).

By contrast, the Engagement group showed improvement in Divergent Thinking. Neither the Waitlist nor the Training group showed significant retest effects on this measure, and the change in Divergent Thinking in the Engagement group exceeded that in both the Training, $\chi^2(1) = 17.61$, and Waitlist, $\chi^2(1) = 23.78$, groups. The Engagement group showed some improvement in Reasoning and Memory, but these changes were no greater than that in the Waitlist Control (as shown in the multiple group test previously), suggesting that these were simply retest effects. Thus, contrary to expectations that engagement would produce broad effects in cognitive ability, effects at the group level in the Engagement group were targeted rather than generalized across domain. As a group, Engagement participants showed change in the skill that was most practiced, valued, and rewarded in creative problem solving.

Both groups, then, showed selective improvement in individual skills. Relative to the Waitlist, the Training group showed about a fifth of a *SD* improvement in Reasoning, less than the .48 effect size shown in the ACTIVE trial (Ball et al., 2002). Relative to the

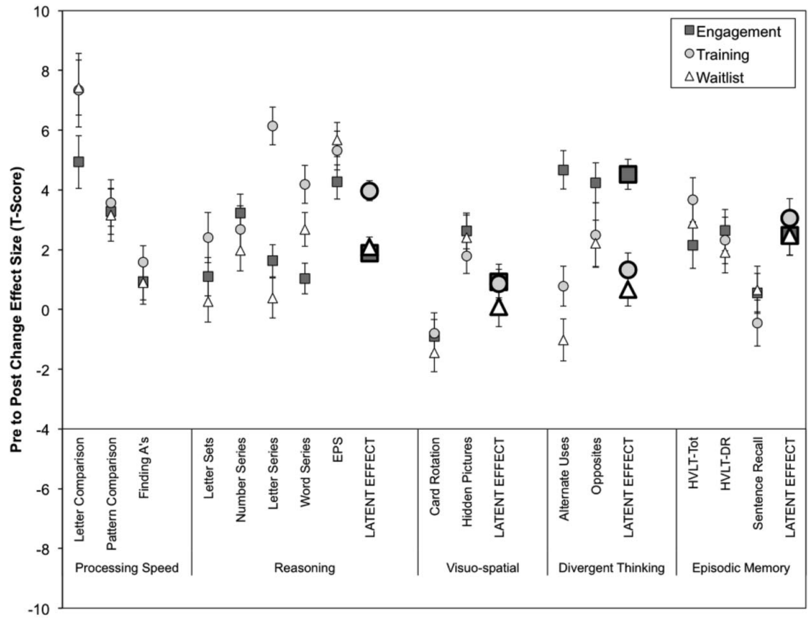

Figure 2. Pre- to posttest change in manifest variables and latent constructs. Error bars represent *SE*s. Change in latent constructs is highlighted with slightly larger symbols.

Waitlist, the Engagement group showed about three-tenths of a *SD* improvement in Divergent Thinking.

Who Benefits From the Intervention? Moderators of Change

In spite of these group differences, there was also substantial variability in change. Given the ability-specific effects of both interventions, we focused our analysis of moderation on these cognitive targets. Table 3 presents the correlations between baseline measures—age, MoCA, education, verbal ability, dispositional traits (i.e., the Big Five (including Openness), Mindfulness, and Need for Cognition), and social network size—and estimates of latent level and change for Divergent Thinking in the Engagement group; and for Inductive Reasoning, in the Training group. Consistent with the expectation of a Matthew Effect, those who were more cognitively intact at baseline, as measured by the MoCA, showed more gain in both Engagement and Training. However, this was a stronger relationship in the Training group than in the Engagement group. Note that cognitive growth was not engendered by high levels of education or by crystallized ability (as measured by vocabulary level) for either group; rather, those with higher verbal ability gained less.

Noncognitive factors also moderated gains from enrichment. We found some evidence of an advantage among those with more social resources in the Engagement group: participants with initially larger social networks gained more in Divergent Thinking. For the sake of contrast, we note that extraversion (characterized by gregariousness and a preference for social interaction) was not a particular asset in taking advantage of the Engagement program. Finally, Engagement participants with higher levels of Openness to

Table 2
Model Fit Estimates From the Latent Change Score Models

	Reasoning	VSP	Divergent thinking	Memory
Comparative Fit Index	.96	.86	.95	.97
Root Mean Square Error of Approximation	.04	.10	.06	.05
χ^2	275	143	59	104
df	152	23	21	50

Table 3
Correlations Between Baseline Individual Differences and Latent Training Improvements

	Divergent Thinking: Engagement		Inductive Reasoning: Training	
	Level	Change	Level	Change
Age	***−0.30***	***−0.26***	***−0.41***	−0.24
MoCA	0.10	***0.34***	***0.25***	***0.59***
Education	***0.20***	0.06	0.09	−0.18
Verbal	***0.73***	***−0.30***	***0.42***	***−0.45***
Extraversion	***0.13***	−0.17	−0.06	−0.13
Agreeable	***−0.22***	0.03	0.06	−0.23
Neuroticism	0.03	−0.20	−0.08	0.08
Openness	−0.05	***0.27***	−0.11	0.15
Conscientiousness	***0.18***	−0.20	0.11	0.02
Need for Cognition	0.08	***−0.37***	***0.14***	−0.12
Mindfulness	0.04	0.18	−0.11	0.02
Social Network Index	−0.09	***0.30***	−0.02	0.18

Note. MoCA = Montreal Cognitive Assessment. Bold italicized estimates are statistically significant at $p < .05$ (uncorrected).

Experience at pretest also showed larger gains. This trend was also present in the Training group, but did not reach significance.

To contextualize these moderated effects of enrichment, we used the simple slope technique to estimate the effects of the interventions at levels of one *SD* above and below the mean of each moderator (Preacher, Curran, & Bauer, 2006). This is shown in Figure 3 for the effects of Engagement on Divergent Thinking, and in Figure 4 for the effects of Training on Inductive Reasoning. So for example, even though the average gain in Divergent Thinking in the Engagement intervention was less than a half *SD* change, relatively younger older adults (63.4 years old) showed an effect size of .7, while the older old (79.7 years old) showed a much smaller effect size, less than .2. Similarly, those 1 *SD* above the mean in Openness or Social Network Size at pretest showed a gain of almost three-quarters of a *SD*; those relatively low in these characteristics showed negligible benefit.

Adherence and Dose Response

As noted earlier, adherence in both groups was very good. Adherence to program requirements also enhanced the effects of enrichment on the targeted abilities. The correlation between the number of sessions attended and change in Divergent Thinking in the Engagement group was significant ($r = .42$, $p < .02$); for the Training group, the number of packets completed was correlated with change in Reasoning ($r = .45$, $p < .02$). In practical terms, this translated into slightly larger effect sizes for those who were relatively more engaged in the programs. For example, among those who completed at least 13 weeks of the program, the net effect size for change (experimental group change minus waitlist control change) in Divergent Thinking in the Engagement group was .44 *SD* improvement (relative to .38 in the whole sample); and in Reasoning in the Training group, .21SD improvement (relative to .19 in the whole sample).

Discussion

Engagement As a Pathway to Enrichment

The primary aim of this research was to test the efficacy of an engagement model of cognitive enrichment, contrasting it with cognitive training and a waitlist control. Both interventions created a "prolonged mismatch" between current levels of function and demands (Lövdén et al., 2010), but of very different sorts. We expected to find selective improvement in the trained ability (relative to the waitlist control), but broad-spectrum change in cognition from engagement in an intellectually and socially complex program of creative problem solving. While we replicated the selective effects of inductive reasoning training (Ball et al., 2002; Margrett & Willis, 2006; Rebok et al., 2014; Willis et al., 2006), our hypothesis of broad-based change from engagement was not borne out. Rather, we found selective improvement in divergent thinking, an ability that underpins creativity (Silvia et al., 2008). In striving to find creative solutions, participants generated multiple ideas in both the LTP and SP components of OOTM Engagement. So even though multiple abilities are exercised in an engagement model, OOTM Engagement evoked particular demands on ide-

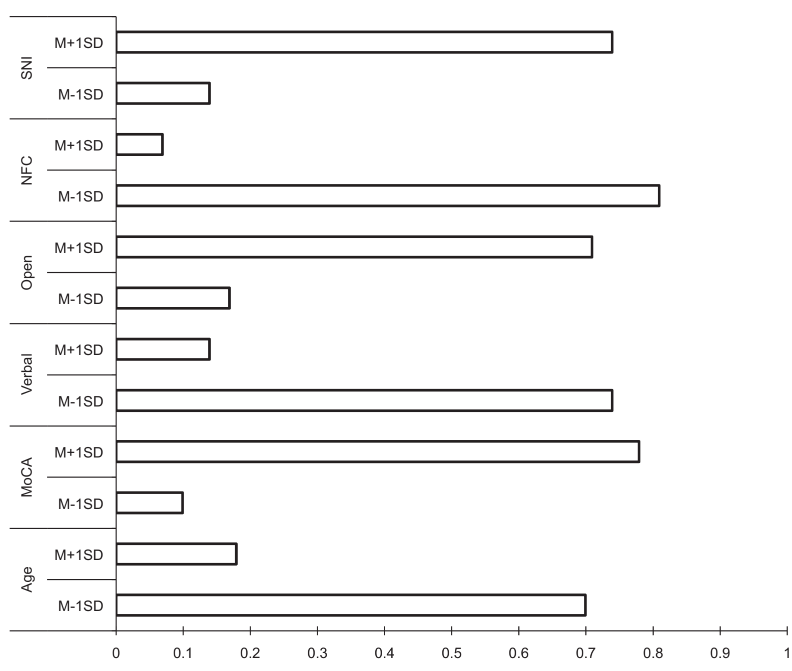

Figure 3. Model-estimated change in Divergent Thinking in the Engagement intervention as a function of age, cognitive status (Montreal Cognitive Assessment, MoCA), verbal ability, Openness, Need for Cognition, and Social Network Size.

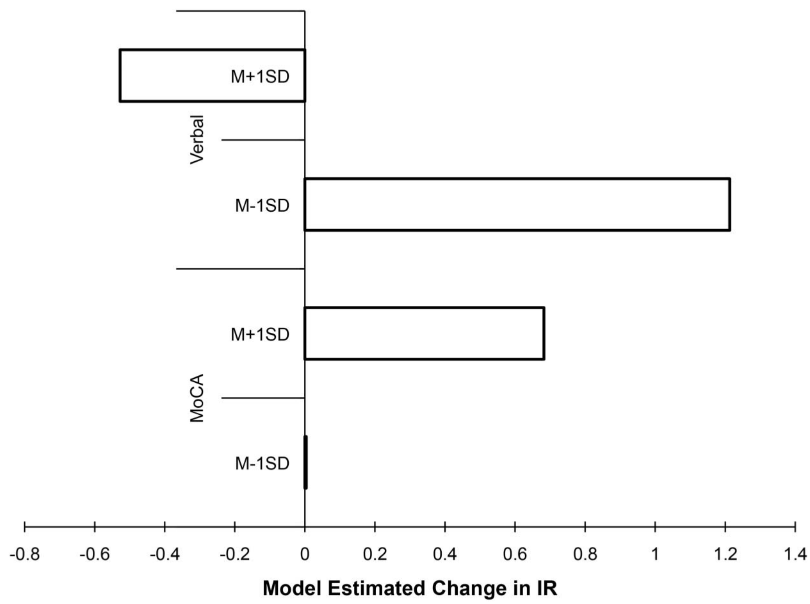

Figure 4. Model-estimated change in Inductive Reasoning in the Training intervention as a function of cognitive status (Montreal Cognitive Assessment, MoCA) and verbal ability.

ational and conceptual fluency that were threaded through activities, and were abilities that were highly valued in the community. In the absence of broad-spectrum change in intellectual function, we did not find the hoped-for pathway to enhancing plasticity.

It is important, however, that we demonstrated domain-specific plasticity within an engagement framework. The selective improvement of divergent thinking from engagement in creative problem solving is significant for three reasons. First, divergent thinking is an often neglected part of intellectual function that shows pronounced declines with age (Reese, Lee, Cohen, & Puckett, 2001). Although relatively understudied as a facet of cognitive aging, conceptual fluency is likely an important aspect of fluid ability (Nusbaum & Silvia, 2011) that contributes to performance in diverse domains. For example, older adults with high conceptual fluency have been shown to demonstrate efficiency in language comprehension that is comparable to that of the young (e.g., Stites, Federmeier, & Stine-Morrow, 2013). Such findings have been explained in terms of neural models suggesting that predictive processing (i.e., production) is integrally related to comprehension mechanisms (Federmeier, 2007). Intellectual function in developmental research is more typically assessed with convergent approaches (i.e., requiring single correct answers), but generative processes are in and of themselves important. Thus, while it is disappointing to have not discovered a path to broad-based cognitive growth, it is nonetheless significant to have demonstrated malleability in divergent thinking.

Second, improvement in divergent thinking was found in the absence of explicit training. The finding of cognitive enhancement from engagement without formal instruction is promising in suggesting that cognitive growth is possible from informal educational experiences. There is long-standing debate as to whether people can learn when left to their own devices to explore and self-regulate in enriched environments (e.g., Mayer, 2004). Yet, this would have to be the case for work and leisure activities to impact cognition. Our data provide some experimental evidence for the proposition that cognitive growth can occur through activity engagement. Thus, even though effect sizes were small, this study serves as an existence proof that engagement in a complex environment can change ability (Finn et al., 2014). One implication is that training and engagement can offer alternative pathways to enrichment. This is a positive outcome from the standpoint of application in affording choice for late life investment in self-enhancing activities (Stine-Morrow, 2007).

Finally, our results speak to the mechanism through which an engaged lifestyle could impact cognition. Given the lack of broad-based effects of an arguably profound change in lifestyle, we can rule out a pathway of engagement effects through some "core capacity." Rather, our findings are most consistent with an account of engagement as offering ability-specific exercises.

Who Benefits From Enrichment?

We found both similarities and differences between engagement and training in patterns of moderation of gain, suggesting that the interventions might have been differentially aligned with existing functional capacities in creating a productive mismatch with demands (Lövdén et al., 2010). There is considerable evidence that enrichment can differentially benefit the initially more able (i.e., a Matthew Effect, or differential preservation; Salthouse, 2006). However, enrichment can also serve a compensatory function in enhancing performance to a greater extent among the relatively disadvantaged. In fact, both differential preservation (e.g., Unverzagt et al., 2007) and compensatory effects (e.g., Lachman, Agrigoroaei, Murphy, & Tun, 2010) of experience have been reported. Our data revealed an interesting dissociation between the effects of global cognitive status and verbal ability. Those who began either intervention with higher cognitive status (as measured by the MoCA) showed more improvement, as did those with lower verbal ability. In other words, enrichment (in both training and engagement models) showed a Matthew Effect relative to cognitive status, but serves a compensatory function relative to crystallized ability.

An explanation of this dissociation might reside in the way in which these constructs map onto plasticity. Cognitive status shares quite a bit of variance with measures of fluid ability and is related, for example, to the ability to learn from text (Payne & Stine-Morrow, in press), suggesting that it may index existing plasticity. Vocabulary, on the other hand, as a measure of crystallized ability, indexes knowledge, reflecting exposure (as well as earlier states of plasticity). Thus, we speculate that enrichment produced Matthew Effects relative to cognitive status because cognitive status is a reflection of plasticity at baseline, while enrichment was compensatory relative to vocabulary in affording opportunities for exposure to new experience. This is an interesting dissociation that deserves replication and further exploration.

Our data also showed that different sorts of people benefit from training versus engagement. Gains in reasoning training were moderated solely by cognitive indicators, as described above. However, engagement-related gains in divergent thinking from participation in creative problem solving were also impacted by pretest levels of social network size and openness to experience.

Those with more experience in navigating and managing larger social networks may have had an advantage with engagement given the strong demands for negotiating relationships among team members to accomplish the goals. Because the Engagement program embedded individuals in a socially complex environment (as is often true of engagement), it may be that those who entered the program with more experience and comfort with navigating such networks and managing multiple relationships were better able to thrive in the engagement model.

Those with higher baseline levels of Openness also showed enhanced benefit from engagement. Openness, comfort with novel situations and a preference for variety, is often found to be related to cognitive ability (Hogan, Staff, Bunting, Deary, & Whalley, 2012; Sharp, Reynolds, Pedersen, & Gatz, 2010), though growth in cognition among those with higher levels of Openness is less consistently found (Sharp et al., 2010) and the mechanisms underlying the cognition-Openness relationship are debated (Soubelet & Salthouse, 2010). It may be that it takes a certain sort of environment for open individuals to thrive, and that an open temperament was well matched to the demands of the Engagement program. Note, however, that baseline Need for Cognition was not particularly beneficial for growth in the Engagement program, but rather, was negatively related to gain. This is interesting because this construct is often found to be positively related to cognition (Baer et al., 2013; Parisi, Stine-Morrow, Noh, & Morrow, 2009), and Openness and Need for Cognition are often thought of as synonymous. In our sample, Openness and Need for Cognition were moderately correlated ($r = .67, p < .001$), as is typically found. In spite of the conceptual overlap, these constructs are subtly different (Fleischhauer et al., 2010). They share a preference for intellectual pursuits and mental stimulation, but Need for Cognition is specifically marked by enjoyment of mental effort for its own sake and persistence in achieving goals, while Openness is marked by curiosity, a preference for imaginative activities, and comfort with novelty. Even though these constructs clearly overlap (e.g., it is often challenging to engage novel situations), the more distinctive aspects of embracing novelty and imagination may have been more suited to engagement in creative problem solving, while preference for mental work was not.

Comparison With Stine-Morrow et al. (2008)

Our findings contrast with those of our initial investigation of the Odyssey program (Stine-Morrow et al., 2008), which produced gains in reasoning and speed, in addition to divergent thinking. There were a number of differences between the earlier study and the present one. Participants in this study were, as a group, less active. It may be that engagement produces broader change in cognition for individuals who are initially more active. Given the restricted range in the current sample, this is an idea that we cannot test, but this question warrants further empirical examination. The current study was also larger in terms of sample size and coaching staff, and more embedded in the community, so one concern might be that our intervention lost fidelity. We do not believe that this was an issue, given that the same program procedures were in place, and that we had a trainer who met regularly with coaches to assure that the quality of the program was maintained. If anything, as the program matured, relationships with the OOTM program were strengthened (Stine-Morrow & Parisi, 2011).

Finally, we used a parametric design, analogous to that used by the ACTIVE trial, in which intervention groups serve as active controls for one another. Participants in both branches of Odyssey expected to improve cognition, and yet they showed different patterns of improvement that aligned with the content of the programs. Unlike our earlier study, effects cannot be explained by differential expectations between intervention and control groups. This assumes, however, that expectancy has generalized effects in improving performance by enhancing motivation. Recently, Boot, Simons, Stothart, and Stutts (2013) have argued that participants in cognitive interventions can have task-specific expectations so that active control groups may not be sufficient if they produce differential expectancies. While this is an interesting idea, Boot et al. (2013) presented evidence for this only in the context of video games, which creates a relatively simple context in which participants may be able to discern what skills are being practiced. It is certainly possible that Training and Engagement participants could have developed differential expectancies that produced their distinct patterns of improvement. However, we do not think that this is plausible. We recruited volunteers to participate in the Odyssey program to investigate the "effects of activity on cognition and well-being" in which activities involved "puzzles" and "brain-teasers." Options for random assignment were characterized as two different sorts of Odyssey experiences, an "individual" version and a "team-based" version. The experiences in both were complex. Also, we showed moderation of training effects as a function of certain individual differences, and an expectancy account would have to explain such moderation.

An Ecological View of Enrichment

We return to the key motivation for this study, the source of the widely reported correlation between an engaged lifestyle and positive indicators of development. So why are engaged people more resilient? Reverse causation likely explains part of this well-replicated relationship (Gow et al., 2012; Hultsch et al., 1999). However, we do not believe that this is the whole story. In an experimental design, we demonstrated that individuals can show measureable improvement in an ability by being immersed in a complex environment that exercises that ability. So perhaps, one way engaged people become resilient is through implicit practice of component abilities within everyday activities. An active lifestyle might engender global cognitive resilience through sheer diversity of activities that exercises different abilities over time. In fact, correlational data show that, it is the number of different activities (not, as one might expect, intellectually challenging activities) that is the best predictor of fluid ability (Baer et al., 2013; Carlson et al., 2012).

Nevertheless, we are left with a paradox. After over 100 years of research, it is fairly clear that intelligence is a reasonably coherent construct (Deary, 2012; Deary, Penke, & Johnson, 2010; Deary, Weiss, & Batty, 2010; Kuncel, Hezlett, & Ones, 2004). It is also clear from research on behavioral and neural plasticity that we respond very narrowly to experience. Even this fairly strong test of engagement showed domain-specific effects on cognition. How is it that intellectual capacity can develop holistically when we are built to respond so narrowly and so conservatively to experience? The answer perhaps resides in the ecology of human activity. We propose that there are two forces at work, Corresponsiveness (Caspi, Roberts, & Shiner, 2005; Scarr & McCartney, 1983) and Gain-Loss Asymmetry (Hills & Hertwig, 2011).

According to the Corresponsive Principle, we select and are selected into environments based on our existing abilities and dispositions, which are then reinforced by those environments. Applied to intellectual development, this principle suggests that people are selected into environments according to ability and then these differences in ability become magnified as a consequence of differentiated engagement (e.g., consider the selection process for university and its lifelong consequences). In the current study, random assignment disrupted corresponsiveness by encouraging activity engagement without respect to initial levels of ability. Small cognitive gains, then, might lead individuals to select into incrementally more complex environments. By definition (Schooler, Mulatu, & Oates, 2004), complex environments present fluid and changing demands for which a reward structure is in place for effective performance. Such environments are likely to require the exercise of different abilities that change dynamically over time. Thus, one might resolve the paradox by assuming that opportunities to exercise abilities are randomly distributed among possible complex environments, and that ability-specific gains increase the array of complex environments into which one might select. An organism that is built to gain narrowly from experience develops intellectual function holistically because the ecology of complex environments does not allow abilities to be exercised in isolation.[4]

Another mechanism that may contribute to how gains in one domain can lead to experiences that exercise new abilities is the fundamental asymmetry between the small gain that results from persisting in one activity relative to the opportunity cost of neglecting new activities. This Gain-Loss Asymmetry (Hills & Hertwig, 2011) derives from (a) the fact that building any capacity requires an investment of effort, (b) the fact that the payoff from an investment of effort in any activity declines over time, and (c) the ecological regularity of managing multiple goals (i.e., investment must be withdrawn from one goal and another must be selected, at some cost). In other words, we are built to respond narrowly to experience so that selective allocation of effort is required to build a particular capacity, Capacity A; in order to build Capacity B, we must withdraw effort from activities related to Capacity A and invest in activities with potential to build Capacity B. We are built such that there is a negatively decelerating effect of experience on performance over time: initial investment in an activity to build Capacity A should initially produce large gains but the rate of gain will slow down over time. Persistence in activities to build Capacity A will thus create an opportunity cost for development of Capacity B (and Capacities C, D, and so on). According to the Principle of Gain-Loss Asymmetry, experience-based growth in one domain will ultimately stimulate the search for other experience because the perceived gain in the new area is more pleasurable than the small gain from persistence in the old area.[5]

[4] To test the idea that changes in intellectual capacity might encourage further engagement, we examined the choice of activities that individuals in the intervention groups made after completion of the program. Recall that after participants completed a year of the Engagement or Training program they had the opportunity to return. Of the 148 Engagement participants who completed the program and returned for posttest, 26 elected to return (18 to Engagement, and 8 to Training in the first alumni year); of the 113 Training participants, 8 returned (all to Engagement in the first alumni year). For the 34 people who continued to participate in the Odyssey (sometimes over multiple years), they averaged 3.1 packets (max = 16) in the Training program and 16.0 weeks (max = 47) of participation in Engagement. While we did not have enough participants in each intervention group to make meaningful comparisons between them, we can compare the 34 people who returned to the program with the 227 people who did not. The Corresponsiveness Principle would predict that the individuals who returned would have shown greater cognitive gains from the intervention than those who did not. While the groups did not differ in any of the pretest measures of ability, those who elected to continue with engagement in the Odyssey program showed numerically higher gain scores in all five ability composites (change in *T* score units, for those who continued engagement: $M_{\text{Speed}} = 1.41$, $M_{\text{VSP}} = 2.10$, $M_{\text{IR}} = 3.23$, $M_{\text{DT}} = 3.52$, $M_{\text{Mem}} = 3.23$; for those who did not: $M_{\text{Speed}} = .32$, $M_{\text{VSP}} = .34$, $M_{\text{IR}} = 3.03$, $M_{\text{DT}} = 3.22$, $M_{\text{Mem}} = 1.64$). The difference for the composite score approached significance ($M_{\text{Eng}} = 2.70$, $SE = .47$; $M_{\text{NoEng}} = 1.71$, $SE = .19$), $t(257) = 1.88$, $p = .06$. However, both groups were relatively high on Reasoning and Divergent Thinking, the abilities impacted by the interventions; when these scores were removed (i.e., leaving the composite of Speed, VSP, and Memory), the difference was significant ($M_{\text{Eng}} = 2.25$, $SE = .51$; $M_{\text{NoEng}} = .78$, $SE = .23$), $t(257) = 2.34$, $p = .02$. Thus, those who continued to engage in the Odyssey were those who had shown the most gains in cognition in their initial year. Interestingly, these gains were most pronounced in the nontargeted abilities. The implication is that small gains as a function of engagement can lead to the choice for further engagement.

[5] While we cannot test this idea directly in the current data set, we note that those who elected to continue with the Odyssey were those who showed more broad-based change in ability, suggesting that they may have been "switching off" in terms of exercising abilities. We also note that almost half of those who continued to engage in the program selected the program to which they had not originally been assigned during their first alumni year. So even though cognitive gain may have stimulated further engagement, it did not necessarily prompt individuals to return to the identical environment that engendered growth as a narrow conceptualization of the Corresponsive Principle might suggest.

Conclusion

We tested the engagement hypothesis that a complex and stimulating environment can broadly enhance cognition. Our findings provided only partial support for this idea. The operational model we selected for engagement, team-based collaborative problem solving, engendered gains in ideational fluency, a key capacity that has received relatively less attention in cognitive aging, but shows age declines and underpins creative activity as well as other forms of everyday cognitive activity. This finding is significant in demonstrating change in late life cognition through activity engagement that exercises capacities in the absence of explicit instruction. However, we found no evidence for broad-spectrum cognitive change from engagement in a complex environment. An important finding was that creative activities can offer avenues to cognitive enhancement, but our findings suggest that the pathway to cognitive resilience is likely to reside in serial episodes of engagement in activities that exercise particular capacities. A promising avenue of future research is to understand the principles governing regulatory strategies in activity engagement and the consequences for cognitive development in adulthood.

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