



# HHS Public Access

Author manuscript

Memory. Author manuscript; available in PMC 2017 January 01.

Published in final edited form as:

*Memory*. 2016 January ; 24(1): 89–97. doi:10.1080/09658211.2014.985591.

## Divergent Thinking and Constructing Episodic Simulations

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### Abstract

Divergent thinking likely plays an important role in simulating autobiographical events. We investigated whether divergent thinking is differentially associated with the ability to construct detailed imagined future and imagined past events as opposed to recalling past events. We also examined whether age differences in divergent thinking might underlie the reduced episodic detail generated by older adults. The richness of episodic detail comprising autobiographical events in young and older adults was assessed using the Autobiographical Interview. Divergent thinking abilities were measured using the Alternate Uses Task. Divergent thinking was significantly associated with the amount of episodic detail for imagined future events. Moreover, while age was significantly associated with imagined episodic detail, this effect was strongly related to age-related changes in episodic retrieval rather than divergent thinking.

### Keywords

episodic memory; autobiographical; aging; divergent thinking; simulation; prospection

### Introduction

Divergent thinking – the ability to generate ideas by comparing and combining disparate forms of information in new ways – is closely linked to imagination (Durdell & Wetherick, 1976; Mednick, 1962). Divergent thinking is related to the quality of imagination in children (Russ, 2003), and mental imagery in adults (Durdell & Wetherick, 1976; Forisha, 1978; Schmeidler, 1965). We suggest that divergent thinking is also associated with the ability to create detailed simulations of autobiographical events, such as possible future experiences.

Akin to divergent thinking, simulation is a form of “productive imagination” (Burnham, 1892), involving the extraction of details from various episodic autobiographical memories which are recombined to create novel scenarios (for reviews of supporting evidence, see Addis & Schacter, 2012; Schacter et al., 2012; Szpunar, 2010). According to the constructive episodic simulation hypothesis, access to details in episodic memory is associated with the amount of episodic detail comprising simulations (Schacter & Addis, 2007). Indeed, the level of detail comprising memories of past events is strongly correlated

with that of simulations (see Schacter, Gaesser, & Addis, 2013, for a review). However, retrieving details from memory is not sufficient; one has to organize disparate elements of information into a coherent form (Addis & Schacter, 2012), which may require recruitment of creative thought processes (Khatena, 1978), such as divergent thinking. Thus, the aim of this study is to investigate whether divergent thinking abilities are associated with the construction of detailed simulations over and above the ability to access detailed memories.

Little research has investigated the potential links between divergent thinking and autobiographical simulation. Ononye, Blinn-Pike and Smith (1993) found that performance on the Consequences Task (Guilford, 1967), which requires the generation of possible consequences and responses to non-personal futuristic problems (e.g., everyone suddenly loses the ability to read and write), was significantly associated with that on the Future Problem-Solving Task, in which participants generated solutions for personal future problems (e.g., a dream job in a distant city). It is possible, however, that the similar structure of both tasks could explain, at least in part, the correlated performance. Moreover, while this study focused on the quantitative aspects of future thinking, divergent thinking may contribute to the *quality* of simulations – and may be particularly important for the richly detailed scenarios that typify episodic simulations (Schacter & Addis, 2007). The present study attempts to address this issue.

An additional question is whether divergent thinking is similarly related to the simulation of *any* autobiographical episode, whether the imagined event is located in the future or the past. We have previously found imagined past events to be similar to future simulations, both in terms of the amount of episodic detail (Addis, Musicaro, Pan, & Schacter, 2010) and neural correlates (Addis, Pan, Vu, Laiser, & Schacter, 2009). However, these events may differ in terms of opportunity for flexible, divergent thought. Although the imagined future is somewhat constrained by past experiences and plans, it can still be conceived as many branching possibilities (Goldie, 2009), while imagined past events are likely more constrained by what has actually occurred.

We also assessed whether previously-documented differences between young and older adults in the amount of episodic detail comprising imagined events (cf., Addis, Wong, & Schacter, 2008; Addis et al., 2010; Cole, Morrison, & Conway, 2013; Rendell, Bailey, Henry, Phillips, Gaskin, & Kliegel, 2012; for review, see Schacter et al., 2013) is associated with the ability to retrieve episodic details from memory, or whether divergent thinking might also be relevant. Age-related declines on the Alternate Uses Test have been reported (e.g., Alpaugh et al., 1982) and age is a significant predictor of divergent thinking (Hendricks, 1999), but it remains unexplored whether declines or cohort differences in divergent thinking are important non-mnemonic factors in understanding age-related changes in the simulation of episodic events.

## Materials and Methods

Thirty-six participants (18 young: 9 males;  $M_{age}=21.89$  years,  $SD_{age}=3.61$ ; 18 older: 7 males;  $M_{age}=74.89$ ,  $SD_{age}=5.56$ ) who had participated in another study examining imagined future, imagined past, and remembered past events (Addis et al., 2010) came back into the

laboratory for additional testing of divergent thinking. Participants gave informed written consent for all testing sessions in a manner approved by the Harvard Institutional Review Board. Participants were fluent in English, had no history of neurological or psychiatric impairment; all older adults had a mini-mental state examination score of 27 or higher, excluding dementia. Older adults had completed more years of education than younger adults (Older:  $M=16.39$  years,  $SD=2.62$ ; Younger:  $M=14.56$ ,  $SD=2.09$ ;  $p=.026$ ).

For a detailed description of the episodic simulation task used during Phase 1 of this experiment, see Addis et al. (2010). Briefly, during session 1, participants retrieved 35 memories from the past 5 years, and specified 3 details for each: a person, object, and location. In session 2, participants completed an adapted version of the Autobiographical Interview (AI, Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002) with three conditions: imagine-future, imagine-past, recall-past. On each trial, they were shown sets of details from their own memories recalled in session 1. For “past-recall” trials (4 trials), the detail set comprised a person, location, and object from one memory and participants recalled the specified event. For past-imagine (4 trials) and future-imagine trial (4 trials), a set of person, location and object details drawn from different memories were shown<sup>1</sup>, and participants generated a plausible personal experience involving the specified details. For all conditions, events were required to be temporally and contextually specific (i.e., episodic) and located within five years from the present. General probes were given when needed to clarify instructions and encourage as much description of details as possible within the three minutes allocated for each trial. Trials were blocked according to condition; order was counterbalanced across participants. Transcribed interviews were scored using the standardized AI scoring procedure (Levine et al., 2002; for more information, see Addis et al., 2010): each distinct detail was classified as *internal* (episodic information relating to the central event being described) or *external* (non-episodic information including semantic details, extended events and repetitions). The average number of internal and external details for each participant in each condition was used in these analyses.

Approximately one month ( $M=27.42$  days,  $SD=36.79$ ) after session 2, participants were invited to the laboratory to complete session 3; this delay did not differ between groups ( $p=.265$ ). Divergent thinking was assessed using the Alternative Uses Task (Guilford, 1967). Participants were instructed to generate as many uses as possible for a given item within a minute. Six items were used: eyeglasses, shoes, keys, button, wooden pencil and automobile tire. Participant responses were recorded and scored for standard measures of divergent thinking: *Fluency* (total number of possible uses generated); *flexibility* (the number of distinct categories or groupings the responses could be divided into); *appropriateness* (appropriate uses received a score of 1 and inappropriate responses a score of 0); *elaboration* (0 points were given for brief descriptions of the use, e.g., “a doorstop”; 1 if more detail was given, e.g., “a doorstop to prevent a door slamming”; and 2 points if even further detail was given, e.g., “a doorstop to prevent a door slamming in a strong wind”); *originality* (calculated by comparing each response generated by a participant to the

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<sup>1</sup>Note that in the original study, there were additional imagine trials in which details came from one or two memories (i.e., a recombination load manipulation). However, in order to match trial numbers across memory and imagine trials for this analysis, we only included data from the imagine trials in which recombination of details was maximal.

responses of all other participants; a score of 3 was assigned if less than 5% of other participants generated that response, 2 if 5–10% of other participants had the response, 1 if 10–15% of other participants had that response, and 0 if more than 15% of other participants gave that response). Flexibility, appropriateness and elaboration were scored by three independent raters blind to group membership (fluency and originality scores were not subjected to an inter-rater reliability analysis as these scores were based on counts of responses or the distribution of responses across participants). Inter-rater reliability of these three divergent thinking measures was high; using a two-way mixed model, the standardised Cronbach's  $\alpha$  was greater than .86 for each measure. As performance across the five measures was significantly inter-correlated ( $r$  values, .604 to .998), scores were mean-centred and collapsed into a mean divergent thinking score for use in the regression analyses.

## Results

### Episodic Simulation

We conducted a 3 (Condition: Past-Imagine, Future-Imagine, Past-Recall)  $\times$  2 (Detail: Internal, External)  $\times$  2 (Group: Young, Older) mixed factorial ANOVA with repeated factors of Condition and Detail and between factor of Group. Although this analysis was reported in Addis et al. (2010), we repeated the analysis here with the subset of imagined events used in the current study. The same effects of interest as those previously reported were also evident here, and the average internal and external detail scores according to condition and age-group are provided in Table 1A. A main effect of Detail,  $F_{1,34}=82.39$ ,  $p<.001$ , reflected more internal than external details generated when describing events. There was also a crossover interaction of Detail and Group,  $F_{1,34}=25.79$ ,  $p<.001$ , where young adults generated more internal details than older adults ( $p=.005$ ) and older adults generated more external details than young adults ( $p=.005$ ). The main effect of Condition,  $F_{2,68}=39.11$ ,  $p<.001$ , was driven by more detail generated for recalled events than imagined past and future events ( $p$  values  $<.001$ ). Internal details were strongly correlated across the three conditions ( $r$  values  $>.68$ ;  $p$  values  $<.001$ ), as were external details ( $r$  values  $>.59$ ;  $p$  values  $<.001$ ).

### Divergent Thinking Measures

We conducted a series of independent sample  $t$ -tests to determine whether there were age differences in the divergent thinking measures (see Table 1B). These analyses revealed that age did not affect performance on any of the five measures: Fluency ( $t_{34}=1.14$ ,  $p=.26$ ), flexibility ( $t_{34}=1.51$ ,  $p=.14$ ), appropriateness ( $t_{34}=1.10$ ,  $p=.28$ ), originality ( $t_{34}=.24$ ,  $p=.81$ ), elaboration ( $t_{34}=.07$ ,  $p=.95$ ), or the mean of these divergent thinking measures ( $t_{34}=.71$ ,  $p=.49$ ).

### Relation between Divergent Thinking and Episodic Simulation

We were interested in whether divergent thinking abilities would be associated with the ability to generate detailed episodic simulations. We computed Pearson's product-moment correlations between the five divergent thinking measures and imagine-future, imagine-past and recall-past internal detail scores. As shown in Table 1B, all five measures were

significantly correlated with the amount of internal episodic details comprising imagined future events. The elaboration score was also significantly correlated with the internal detail score for imagined past events, and exhibited a trend for recalled past events ( $p = .065$ ). None of the divergent thinking measures significantly correlated with the external detail score (all  $p$  values  $>.084$ ).

We conducted hierarchical linear regression analyses to determine whether the mean divergent thinking score could predict the amount of episodic detail comprising imagined future, imagined past and recalled events, even when age differences were controlled for (see Table 2A). First, age (in years) was entered into the models and was a significant predictor of the internal detail score for all event conditions, explaining approximately 14–26% of the variance in internal detail scores across the conditions. This finding is consistent with the age-related decreases in internal detail scores evident in the ANOVA analyses. In contrast, mean divergent thinking was only a significant predictor of the number of internal details generated for imagined future events, explaining an additional 11% of variance over and above age. It is possible that divergent thinking may be a significant predictor of internal details for the past-imagine and past-recall conditions if age is not already entered into the model. However, another set of regression analyses (Model 1 in Table 2B) with mean divergent thinking as the only predictor in the model indicated that this was not the case; once again, divergent thinking was a significant predictor of future-imagine internal detail only. We also ran this second set of regression analyses (Table 2B) to determine whether age could account for significant variance in the internal detail scores over and above divergent thinking. Indeed, this was the case for all conditions; even in the future-imagine condition, where mean divergent thinking was a significant predictor, age still accounted for a further 21% of variance.

Given the hypothesized link between retrieval of episodic detail and the amount of detail comprising imagined events, we also repeated the above hierarchical linear regressions for the imagined event conditions but included past-recall internal detail score as an additional variable in the model (see Table 3A). Again, age emerged as a significant predictor for internal details, but only when the sole predictor in the model. Once the past-recall internal detail score was entered, age was no longer a significant predictor, suggesting that the effect of age may be strongly related to reduced access to episodic detail. The past-recall internal detail score, however, was a highly significant predictor of the amount of imagined internal detail, explaining 27–34% of variance over and above age. Importantly, even with this highly significant variable in the model, mean divergent thinking still emerged as a significant predictor of imagined internal detail, but again only for future events. We also re-ran these regression analyses (Table 3B) adding age as the last predictor, to determine whether age could significant account for variance in imagined internal detail over and above recalled internal detail and mean divergent thinking. Age was not a significant predictor for either of the imagine conditions. Interestingly, in the future condition, where divergent thinking was already entered as a significant predictor, the past-recall internal detail score still explained an additional 44% of the variance in internal detail (Table 3B, Model 2). In fact, for both imagined conditions, the model with divergent thinking and past-recall internal detail as predictors (Table 3B, Model 2) explained 51–59% of the variance in

imagined internal detail, much higher than the model with divergent thinking and age as predictors (19–36% variance explained; Table 2, Model 2).

The pattern of results suggests that while divergent thinking is related to the amount of internal detail comprising imagined future events, this relationship is not evident for imagined past events. In order to explore the significance of this apparent interaction, we ran a 2 (Condition: Past-Imagine, Future-Imagine) ANCOVA with three covariates (Age Group, Past-Recall, Divergent Thinking) on the number of internal details. The key finding was that the Condition  $\times$  Divergent Thinking interaction was not significant ( $F_{1,32}=0.42, p=.52$ ), indicating that the relationship between divergent thinking was not significantly stronger for imagined future events relative to imagined past events.

## Discussion

The primary aim of this study was to determine whether divergent thinking abilities are associated with the construction of detailed future simulations over and above the ability to access episodic details, and if so, whether similar associations would be evident for imagined past events. We also explored whether previously documented differences between young and older adults in the amount of episodic detail comprising simulations are associated with age, memory ability, and/or divergent thinking. While we found support for the hypothesis that divergent thinking is a significant predictor of the imagined internal detail score over and above memory for episodic details, this finding applied most strongly to imagined future events. Although it was not clearly evident for imagined past events, the fact that we failed to observe a significant interaction between imagination condition and divergent thinking in the model that included future and past imagination as dependent variables and divergent thinking, past recall, and age as covariates indicates that we cannot draw strong conclusions concerning differences between future and past imagination. Moreover, while age was associated with the amount of detail comprising simulations, it appears that this effect may be strongly related to age-related changes in retrieving episodic detail.

However, our results do show clearly that divergent thinking abilities are strongly associated with future episodic detail. Importantly, the regression analyses showed that the predictive value of divergent thinking for future episodic detail was still evident even when variance due to age and retrieval of episodic detail (as indexed by the past-recall internal detail score) were accounted for. This observation is consistent with previous work linking divergent thinking with many of the cognitive processes required for future simulation, including mental imagery (e.g., Durnell & Wetherick, 1976), narrative abilities (e.g., Albert & Kormos, 2004) and associative processes (e.g., Mednick, 1962), as well as recent fMRI evidence (Benedek et al., 2014) that divergent thinking recruits some of the same default network regions typically linked with future simulation (e.g., Schacter, Addis, & Buckner, 2007; Schacter et al., 2012). It is notable, however, that many of these processes are thought to be required when imagining past events, and to some extent when recalling past events – and divergent thinking was not clearly associated with these conditions. Other investigators have also reported differences in imagining *future* scenarios compared with imagining atemporal scenarios, with age-related deficits exaggerated during the former compared with



the latter (Rendell et al., 2012; for more general discussion, see Schacter et al., 2012). Although beyond the scope of this study, further work is needed to tease apart what aspects of the episodic content of future events (e.g., visuospatial content, narrative complexity) are most strongly related to particular forms of divergent thinking. Moreover, future work could address whether this relationship between divergent thinking and future simulation is still evident once individual differences in other related processes (e.g., general knowledge and vocabulary) are controlled for.

Interestingly, however, we did find one important similarity between imagined past and future events: that access to episodic detail was a strong predictor for both forms of imagination. This finding is consistent with reports that a number of amnesic patients who cannot access episodic details show some impairment in imagining events (Hassabis, Kumaran, Vann, & Maguire, 2007; Klein, Loftus, & Kihlstrom, 2002; Kwan, Carson, Addis, & Rosenbaum, 2010; Tulving, 1985; for review, see Addis & Schacter, 2012). Moreover, recent evidence (Duff, Kurczek, Rubin, Cohen, & Tranel, 2014) indicates that a group of five amnesic patients were impaired in performance of the Torrance Tests of Creative Thinking, which tap divergent thinking processes. It is possible, however, that the degree of detail generated on these tasks reflects a general narrative style that is common to remembering and imagining any autobiographical episode. Speaking against this interpretation, we have previously found that episodic detail is associated with imagined detail even after controlling for narrative ability (Gaesser, Sacchetti, Addis, & Schacter, 2011), and recent data indicate that access to episodic details on tasks that tap remembering and imagining can be dissociated from performance on a narrative description task (Madore, Gaesser, & Schacter, 2014).

Once the past-recall internal score was entered into the model, age was no longer a significant predictor of imagined episodic detail, suggesting that the reduced ability of older adults to retrieve episodic details may underlie the age-related deficits in the episodic content of imagined events (Schacter et al., 2013). However, we did recently report in another aging study examining future simulation that even after recalled episodic detail was entered into the regression model, age still predicted a small but significant portion of variance in the amount of future detail generated (Gaesser et al., 2011). A key difference between the two studies is that Gaesser et al. provided participants with detailed visual stimuli in the recall and imagination conditions, and it is possible that this externally-provided detail may have slightly decreased the reliance on details retrieved from memory, allowing other age-related factors to emerge.

Although our findings demonstrate that divergent thinking abilities are associated with the generation of detailed future events, our results also suggest that age-related differences in future simulation are not simply due to cohort differences or age-related decline in divergent thinking abilities. We did not find any age-differences in divergent thinking despite previous findings to the contrary (e.g., Alpaugh, Parham, Cole, & Birren, 1982; McCrae, Arenberg, & Costa, 1987). Moreover, even when divergent thinking was entered into the model first, a significant age effect was still evident and the  $R^2$  change was similar in magnitude to when age was entered into the model first. This pattern suggests that other group differences are likely more important in explaining age-related reductions in episodic content – such as

retrieval of episodic detail. This interpretation, however, does not negate the finding that divergent thinking is an important individual difference to consider when assessing future simulation abilities, irrespective of age.

Finally, another important question for future work concerns whether future simulation is also related to convergent thinking – the ability to generate the best single solution to a particular problem – or whether the link is selective to divergent thinking. Recent evidence indicates that associative false memory effects in the Deese-Roediger-McDermott (DRM) paradigm, where presentation of multiple associated words that converge on a non-presented lure word results in a high false alarm rate to the lure word on a subsequent recognition test (for review, see Gallo, 2010), are linked with convergent but not divergent thinking (Dewhurst, Thorley, Hammond, & Ormerod, 2011). Based on the present results and our characterization of future simulation as involving the generation of multiple alternative scenarios, we expect that future simulation will exhibit the opposite pattern, i.e., though related to divergent thinking, it will not be significantly related to convergent thinking abilities.

In summary, the current study confirms that individual differences in divergent thinking are associated with the capacity for imagining future episodes. Although imagining a detailed scenario strongly relies on mnemonic factors, such as the retrieval of episodic details, divergent thinking is an important ingredient for future episodic thought across the lifespan.

## Acknowledgements

We thank Ryan Hunt, Melissa Inger and Jessica Mitchell for scoring of the Alternate Uses Test data, and Lucia Lee and Lara Markstein for transcribing and scoring AI data. This research was supported by National Institute on Aging grant AG08441, awarded to DLS. DRA was supported by a Rutherford Discovery Fellowship (RDF-10-UOA-024).

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**Table 1**

Autobiographical Interview and Alternate Uses Test: Group Performance and Correlations

<i>A. Autobiographical Interview Scores</i>						
AI Score	Future-Imagine		Past-Imagine		Past-Recall	
	Younger	Older	Younger	Older	Younger	Older
Internal Detail §	51.75 (16.50)	32.15 (15.59)	52.58 (18.47)	39.67 (18.99)	60.56 (15.00)	45.17 (15.05)
External Detail √	16.97 (11.66)	32.15 (15.59)	15.42 (8.77)	24.69 (9.46)	25.10 (15.47)	34.20 (15.78)

*B. Alternate Uses Test Scores and Correlations with Internal Detail Scores*

AUT Measure	Mean (SD)		Correlation with Internal Detail Scores			
	Younger	Older	Future-Imagine	Past-Imagine	Past-Recall	
Fluency	6.45 (2.55)	5.52 (2.39)	.402**	.233		.097
Flexibility	4.55 (1.52)	3.833 (1.33)	.388**	.222		.110
Originality	8.37 (4.97)	7.96 (5.34)	.292*	.207		.022
Appropriateness	6.35 (2.47)	5.47 (2.40)	.413***	.247		.111
Elaboration	4.25 (2.37)	4.20 (1.81)	.374**	.304*		.258 <sup>†</sup>

Note:

§ Main effect of Group (Younger > Older), p=.005;

√ Main effect of Group (Older > Younger), p=.005;

\*\*\* p<.001;

\*\* p .01;

\* p<.05;

<sup>†</sup> p .065

**Table 2**

Linear Regression Analyses of Age and Divergent Thinking on Internal Detail Scores

<i>A. Age and Divergent Thinking on Internal Detail Scores</i>				
Model	R <sup>2</sup>	R <sup>2</sup> Change	Standardized Beta Coefficients	
			Age	DT
<i>DV: Future-Imagine Internal Detail Score</i>				
1. Age	.243	.243**	-.493**	
2. Age, DT	.357	.114*	-.461**	.339*
<i>DV: Past-Imagine Internal Detail Score</i>				
1. Age	.138	.138*	-.371*	
2. Age, DT	.185	.048	-.351*	.219
<i>DV: Past-Recall Internal Detail Score</i>				
1. Age	.260	.260**	-.509**	
2. Age, DT	.263	.003	-.504**	.057
<i>B. Divergent Thinking and Age on Internal Detail Scores</i>				
Model	R <sup>2</sup>	R <sup>2</sup> Change	Standardized Beta Coefficients	
			DT	Age
<i>DV: Future-Imagine Internal Detail Score</i>				
1. DT	.146	.146*	.382*	
2. DT, Age	.357	.211**	.339*	-.461**
<i>DV: Past-Imagine Internal Detail Score</i>				
1. DT	.063	.063	.252	
2. DT, Age	.185	.122*	.219	-.351*
<i>DV: Past-Recall Internal Detail Score</i>				
1. DT	.011	.011	.104	
2. DT, Age	.263	.252**	.057	-.504**

Note:

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DT= Divergent Thinking; DV=dependent variable.

Linear Regression Analyses of Age, Past-Recall Internal Detail Score and Divergent Thinking on Imagined Internal Detail Scores

**Table 3**

Model	R <sup>2</sup>	R <sup>2</sup> Change	Standardized Beta Coefficients		
			Age	Past-Recall	DT
<i>DV: Future-Imagine Internal Detail Score</i>					
1. Age	.243	.243**	-.493**		
2. Age, Past-Recall	.515	.272***	-.184	.606***	
3. Age, Past-Recall, DT	.607	.092**	-.168	.582***	.305**
<i>DV: Past-Imagine Internal Detail Score</i>					
1. Age	.138	.138*	-.371*		
2. Age, Past-Recall	.482	.344***	-.024	.681***	
3. Age, Past-Recall, DT	.514	.032	-.014	.667***	.181
<i>B. Divergent Thinking, Past-Recall Internal Detail Score and Age on Imagined Internal Detail Scores</i>					
Model	R <sup>2</sup>	R <sup>2</sup> Change	Standardized Beta Coefficients		
			DT	Past-Recall	Age
<i>DV: Future-Imagine Internal Detail Score</i>					
1. DT	.146	.146*	.382*		
2. DT, Past-Recall	.586	.440***	.312**	.667***	
3. DT, Past-Recall, Age	.607	.021	.305**	.582***	-.168
<i>DV: Past-Imagine Internal Detail Score</i>					
1. DT	.063	.063	.252		
2. DT, Past-Recall	.514	.450***	.181	.675***	
3. Dt, Past-Recall, Age	.514	.000	.181	.667***	-.014

Note:

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p < .05.

DT=Divergent Thinking; DV=dependent variable.