

Drawing and the Non-Verbal Mind

A Life-Span Perspective

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Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo, Delhi

Cambridge University Press

The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org

Information on this title: www.cambridge.org/9780521872058

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First published 2008

Printed in the United Kingdom at the University Press, Cambridge

A catalogue record for this publication is available from the British Library

Library of Congress Cataloguing in Publication data

Drawing and the non-verbal mind / [edited by] Chris Lange-Küttner, Annie Vinter.

p. cm.

Includes index.

ISBN 978-0-521-87205-8 (hardback)

1. Drawing, Psychology of. 2. Visual perception. 3. Cognition. I. Lange-Küttner, Christiane, 1957– II. Vinter, Annie. III. Title.

BF456.D7D73 2008

153-dc22 2008015933

ISBN 978-0-521-87205-8 hardback

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13 Benefits of graphic design expertise in old age: compensatory effects of a graphical lexicon?

Ulman Lindenberger, Yvonne Brehmer, Reinhold Kliegl and Paul B. Baltes

The research of Lindenberger, Brehmer, Kliegl and Baltes into the cognitive decline-compensating effects of expertise is based on the difference between fluid and crystallized intelligence. While fluid intelligence measures such as speed and capacity are more biologically determined and thus decline with age, crystallized intelligence measures encompass culture-based skills and factual knowledge, and are more resilient to ageing-induced decline. Would the graphic expertise of professional older designers protect them against cognitive decline compared to young designers and two age- and intelligence-matched control groups? This was tested in a training study using the Method of Loci where visualization and imagery is essential, as recall of words is cued by previously associated landmarks. As expected, graphic designers showed better performance on spatial tests than controls, but this was even more pronounced in the older group, where the designers had consistently higher scores than their age peers. While older graphic designers could not match the performance of the young groups, they did fare better than their age-matched controls in the post-training Method of Loci memory assessment. It is concluded that although graphic expertise could not entirely compensate for the biologically determined reduction in fluid intelligence, there was a positive effect on episodic memory.

COGNITIVE functioning in later periods of the adult lifespan is characterized by a dynamic interdependence between knowledge-related increments and senescent declines. To capture this interdependence, two-component models of cognition separate a biology-based component from a culture-based component of intellectual functioning (e.g. Baltes, 1987; Cattell, 1971). According to Baltes (1987), the 'mechanics' of cognition reflect the speed, accuracy and coordination of elementary cognitive processes, such as processing speed, inhibition, attention, memory

capacity and reasoning. The efficacy of this component shows a monotone decrease during adulthood and early old age, and an accelerated decline in old age, probably because of aging-related changes in the brain. In contrast, the cognitive pragmatics reflect biographically acquired culture-based skills and factual knowledge, such as verbal fluency or mental arithmetic. Performance on tasks assessing this component remains invariant or even increases further with age during adulthood. In contrast to the mechanics of cognition, this component is more resilient to the effects of brain aging (Baltes, 1987; Li, Lindenberger, Hommel, Aschersleben, Prinz and Baltes, 2004).

Within the pragmatics, normative bodies of knowledge that are taught in school and relevant for all members of society, such as verbal knowledge and number facility, can be set apart from more specialized bodies of knowledge reflecting professional expertise or other less invariant aspects of a person's biography. Research in the domains of cognitive aging and expertise has emphasized the influence of these non-normative or idiosyncratic forms of pragmatic knowledge to between-person (interindividual) differences and within-person (intraindividual) changes in cognitive functioning. Age-comparative studies with individuals differing in their levels of expertise have been conducted in such diverse domains as typewriting (Bosman, 1993; Salthouse, 1984), chess (Charness, 1981, 1989; Jastrzembski, Charness and Vasyukova, 2006), Go playing (Masunaga and Horn, 2001), air-traffic control and piloting (Morrow and Leirer, 1997; Morrow *et al.*, 2003), Mastermind (Maylor, 1994), crossword-puzzle solving (Rabbitt, 1993), management skills (Walsh and Hershey, 1993), piano playing (Krampe, Engbert and Kliegl, 2001; Krampe and Ericsson, 1996) and visual identification (Viggiano, Righi and Galli, 2006). In addition to questions regarding the causes and origins of expert knowledge and expert performance in specific domains of functioning, two issues have attracted the interest of developmental researchers: (a) Do individual differences in person-specific pragmatic and expert knowledge influence the developmental pathway of the mechanics of cognition (Krampe and Ericsson, 1996; Salthouse, 1991)? (b) To what extent does biographically acquired knowledge compensate for declines in the mechanics of cognition in old age (Bosman and Charness, 1996; for review, see Krampe, 2002; Krampe and Baltes, 2003)?

In this chapter, we report and further analyse and interpret results from an age-comparative memory training study that investigated graphic design expertise in relation to episodic memory performance (Lindenberger, Kliegl and Baltes, 1992). Lindenberger *et al.* (1992) investigated younger and older expert graphic designers' serial word recall after instruction and training in the use of an imagery-based mnemonic

strategy, the Method of Loci. This strategy involves the use of a highly familiar ordered sequence of locations (i.e. a mental map) as a cognitive structure for encoding and retrieving new information (cf. Bower, 1970; Kliegl, Smith and Baltes, 1989). To-be-encoded items are successively linked with locations from the mental map through the use of visual imagery. At recall, the ordered locations are mentally revisited, and the visualized items are retrieved and decoded if necessary. Evidence from different lines of research suggests that the effective use of visual imagery is a critical component in memory functioning with the Method of Loci (e.g. Baddeley and Lieberman, 1980; Kliegl, Smith and Baltes, 1990; Logie, 1986; Richardson, 1985). In comparison to the original report provided by Lindenberger *et al.* (1992), we will take a closer look at two covariates administered in the original study, a subtest of the Torrance Tests of Creative Thinking: Thinking Creatively with Pictures (Torrance, 1966a, 1966b) and the Card Rotation Test from the ETS battery (Ekstrom, French and Harman, 1976). We will argue that the Torrance test of visual creativity was well suited to capture central aspects of graphic designers' expert knowledge of graphical forms, and will speculate about the compensatory function of this knowledge in old graphic designers.

During the past three decades, several studies have investigated lifespan gradients in the cognitive mechanics of episodic memory with a testing-the-limits approach to instruction and training of the Method of Loci (Baltes and Kliegl, 1992; Brehmer, Li, Müller, Oertzen and Lindenberger, 2007; Kliegl, Smith and Baltes, 1986, 1989; Lindenberger and Baltes, 1995; Lindenberger *et al.*, 1992; Stigsdotter Neely and Bäckman, 1993; Verhaeghen and Marcoen, 1996). From a developmental perspective, the testing-the-limits procedure aims at 'compressing' time by providing a high density of experience and arranging for an improved measurement context in order to identify an individual's latent potential in a particular domain of functioning. Typically, individuals of different ages are first given instructions for a performance-enhancing memory strategy that they were not familiar with beforehand. After large amounts of training and practice, interindividual differences in upper limits of performance (developmental reserve capacity) can be estimated with some confidence.

With respect to episodic memory, testing-the-limits studies have shown (a) that cognitively healthy younger and older adults (at least up to their 80s) can improve their performance relative to a no-instruction baseline; and (b) that performance gains and maximum performance levels decrease substantially with advancing adult age (Baltes and Kliegl, 1992; Brehmer *et al.*, 2007; Kliegl *et al.*, 1989, 1990; Rose and Yesavage, 1983; Singer, Lindenberger and Baltes, 2003; Thompson and Kliegl,

1991). Because negative adult age differences were magnified after training, Kliegl *et al.* (1989) concluded that the effects of cognitive aging may be more clearly identifiable at performance conditions near the upper limits of reserve capacity, or cognitive plasticity, than at baseline performance conditions (Baltes and Kliegl, 1992).

The Lindenberger *et al.* (1992) study, which is summarized and further interpreted in the present report, combined the testing-the-limits paradigm with research on the relation between professional expertise and adult age changes in cognitive functioning. To this end, the authors investigated older adults with a high amount of task-relevant pre-experimental practice, knowledge and ability ('talent') in order to investigate whether the combination of professional expertise and talent is able to mitigate or even eliminate negative adult age differences in upper limits of episodic memory performance (Baltes and Kliegl, 1992; Kliegl *et al.*, 1989).

Assuming that visual imagery is a critical component in memory functioning with the Method of Loci, Lindenberger *et al.* searched for a profession that places a high emphasis on the generation of visual images in the context of verbal material. The profession of *graphic design* was deemed to meet this requirement. Graphic designers working as freelance artists create posters, art catalogues, and advertisements in newspapers and news magazines, as well as other kinds of pictorial representations. They communicate pictorial representations both verbally and visually, and are experts in integrating desired information into their design. Frequently, they need to create easily detectable and recognizable pictograms that tie concepts and emotional states to the target product. It appeared plausible to assume that the kind of creative visual imagery needed to achieve expert levels of performance in this type of professional activity would facilitate the acquisition and use of an imagery-based mnemonic strategy such as the Method of Loci.

In summary, the goal of the study of Lindenberger *et al.* (1992) was to investigate whether a group of older experts with lifelong experience in the production of visual images on the basis of verbal material would be able to reach the level of performance of younger adults with or without similar task-relevant experience. To investigate this question, age and expertise were examined at two levels in a fully crossed quasi-experimental design (i.e. younger adults versus older adults, and experts versus normal 'control' individuals). In addition to memory functioning with the Method of Loci, standard marker tests of spatial visualization and visual creativity were conducted to support the legitimacy of the contrast between experts and controls.

The inferential limitations related to the quasi-experimental design of this study should be noted at the outset. A possible superiority of

expert graphic designers over 'control' individuals may reflect professional expertise, superior ability or an interaction of the two (e.g. 'nurtured nature'). That is, it may reflect the accumulation of task-relevant experience and its coordination into a body of factual and procedural knowledge that can be brought to bear upon the task, but it may also reflect initial differences in talent or task-relevant 'abilities', or, in the case of older graphic designers, the fortunate biographical constellation of individuals who have been dwelling on their strengths throughout their professional lives. The latter effects may have been further accentuated by selective survival in the profession, as only people with certain talents may have been able to stay active in this highly demanding job into old age. Clearly, the present study cannot resolve these interpretational ambiguities.

Six older graphic designers (ages 64–81, $M = 69.9$ years), six normal older control adults (ages 64–80, $M = 70.5$ years), six younger graphic design students (ages 22–24, $M = 23.0$ years) and six normal younger control students (ages 21–24, $M = 22.6$ years) participated in the experiment, with three women and three men in each of the four groups. Except for two older graphic designers and two older normal participants with nine years of schooling, all research participants had completed approximately thirteen years of schooling. At the time of testing, all younger participants were undergraduates at Berlin universities. Those not specializing in graphic design were studying at other departments of the Free University of Berlin. Of the six younger graphic designers, five were at the end of their second year at the graphic design department of the Berlin School of Arts (Fachbereich Visuelle Kommunikation der Hochschule der Künste Berlin). The sixth participant had just completed her degree as a graphic designer at another Berlin graphic design school (Berufsfachschule für Fotografie, Grafik und Mode). All six older graphic designers were 'experts' in the sense that they had been, or continued to be, highly successful professionals. At the time of testing, five designers were still active in their fields; for more information, see Lindenberger *et al.* (1992).

Location-word pairs were used to assess episodic memory performance. The same set of twenty well-known Berlin landmarks served as location cues for all participants. The sequence of locations was geographically meaningful and corresponded to a fictitious sightseeing tour. A city map and photographs of the landmarks were used in training. A total of nine different non-overlapping twenty-item noun lists were used as to-be-learned words. The nouns of these lists had an imagery rating above 6.00 on a 7-point scale according to the norms provided by Baschek, Bredenkamp, Öhrle and Wippich (1977; see also Paivio, Yuille

and Madigan, 1968). To avoid effects related to cohort, care was taken that the nouns were neither 'dated' nor 'modern'.

In contrast with most other studies with the Method of Loci, recall was cued presenting the landmarks in the same serial order as at encoding. It was assumed that graphic designers had large amounts of professional experience in *generating* visual images on the basis of verbal material, but not in *retrieving* these images without the help of external cues. Therefore, the provision of such cues was expected to maximize the beneficial effects of graphic design expertise on serial word recall with the Method of Loci. Within groups, half of the participants received the sequence of Berlin landmarks in reverse order. For the entire duration of the experiment, it was ensured that a given landmark-noun combination was never presented more than once to a participant to avoid repetition effects.

Training programme

Participants were scheduled to participate in twenty-one sessions lasting from 60 to 90 minutes each. Sessions were administered on different days, with a minimum of one day between sessions and a maximum generally not exceeding four days.

Assessment of covariates (Sessions 1 and 2). Psychometric assessment served two main purposes: (a) to test the expectation that graphic designers would perform above the level of normal control adults on measures of criterion-relevant intellectual abilities (visual creativity and spatial visualization); (b) to check whether graphic designers and controls were comparable in general (i.e. not directly expertise-related) aspects of intelligence. In the first session, the 'Parallel Lines' subtest of the Torrance Test of Creative Thinking: Thinking Creatively with Pictures was administered (Torrance, 1966a, 1966b; for a recent review, see Kim, 2006). The second session started with tests from the Hamburg-Wechsler Intelligence Test for Adults in the following order: Forward Digit Span, Backward Digit Span, Vocabulary, and Digit Symbol Substitution (Wechsler, 1964). Thereafter, two tests of spatial visualization, Card Rotation and Surface Development, were given (Ekstrom *et al.*, 1976).

Instruction in the Method of Loci (Session 3). At the beginning of Session 3, participants were introduced in detail to the Method of Loci. First, they were told about the historical origins of the method. Then, the functioning of the method was explained to them using concrete examples. The generation of interactive visual images between landmark cues and to-be-learned words was highlighted as the critical feature of the method. Graphic designers were asked to recollect aspects of their work performance that involved different forms of interactive visual imagery, and it was suggested to them that they consider the acquisition of the Method

of Loci as a task that is related to their professional expertise. Other participants were asked to think of situations in which they used interactive visual imagery. They were told that they were expected to engage in this kind of activity in the following sessions. Next, all participants were given a form with the twenty Berlin landmarks in experimental sequence (which served as memory loci in the later sessions) and were told about their function in the Method of Loci. The experimenter provided a city map of Berlin, and participants were asked to locate the landmarks on the map in correct order.

Training assessment (Sessions 4–9). Five different lists of high-imagery nouns (i.e. twenty to-be-learned words each) were administered in each session. Within sessions, each of the five lists appeared only once. Two different presentation times (the time available to form an interactive image, linking the location cue and the to-be-learned word) were used during training (i.e. 4.5 s and 7.5 s per word). After the recall phase, the tutor commented on the participant's performance, and made suggestions for further improvement. For instance, the tutor stressed the importance of creating interactive visual images that combined landmark and noun information, and encouraged the participant to concentrate ('zoom in') on those aspects or details of a location that the participant considered to be most imageable.

Post-training assessment (Sessions 10–21). In each session, four different twenty-item noun lists were presented at one of three different presentation times (i.e. 7.5, 4.5 or 1.5 s per word). During the twelve sessions of post-training assessment, each combination of word lists and presentation times was administered four times (for details, see Lindenberger *et al.*, 1992).

Results are provided in three sections. First, group differences in psychometric tests are reported. Second, data from the training sessions (sessions 4–9) are examined to check whether participants in all groups profited from training and were able to use the mnemonic technique under easy task conditions. Third, post-training group differences in post-training assessment (sessions 10–21) are analysed to investigate whether older graphic designers were able to reach the performance level of younger participants. We focus our presentation of results on expertise-related results.

Graphic fluency and Card Rotation expertise effects

Table 13.1 displays the means and standard deviations as well as relevant statistical tests for the psychometric measures. In line with findings of large-scale normative studies of cognitive aging (cf. Salthouse, 1982;

Table 13.1 Means, standard deviations and F values for the covariates assessed in the Lindenberger et al. (1992) experiment

Tests	Younger adults						Older adults						F values		
	Control		Designers		Control		Designers		Control		Designers		Age	Expertise	Age × expertise
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD			
<i>Criterion-relevant tests</i>															
Torrance Visual Creativity	43.7	5.0	55.6	8.2	42.4	4.4	58.3	10.5	42.4	4.4	58.3	10.5	0.06	20.93	0.45
Surface Development	18.2	4.5	26.7	3.0	3.4	2.1	13.8	6.5	3.4	2.1	13.8	6.5	59.24	27.63	0.22
Card Rotation	64.5	13.6	68.8	9.9	25.2	8.2	50.2	13.4	25.2	8.2	50.2	13.4	38.14	9.76	4.84
<i>Wechsler tests</i>															
Digit Symbol Substitution	60.0	3.1	60.6	8.4	47.7	9.4	45.4	6.6	47.7	9.4	45.4	6.6	21.51	0.08	0.23
Vocabulary	70.3	2.1	67.7	7.0	70.3	8.0	63.3	7.8	70.3	8.0	63.3	7.8	0.63	3.13	0.44
Forward Digit Span	7.5	0.8	7.8	1.2	6.3	1.0	6.5	0.8	6.3	1.0	6.5	0.8	9.78	0.39	0.04
Backward Digit Span	6.2	0.8	6.7	1.4	6.5	0.8	6.3	1.0	6.5	0.8	6.3	1.0	3.62	0.58	0.14

Note. In all four age-groups, N = 6; for all F values, dfs = 1,20. Values significant at the .05 level are in bold. Raw scores are reported for all measures except for the Torrance Visual Creativity test. Scores on the latter measure represent the T-transformed (i.e. M = 50, SD = 10) unweighted composites of the scoring dimensions of fluency, flexibility and elaboration (cf. Torrance, 1966a, 1966b).

Li *et al.*, 2004) younger adults had higher scores than older adults on indicators of the mechanics of cognition (i.e. Digit Symbol Substitution, Forward Digit Span, and marginally also for Backward Digit Symbol Span), and on both tests of spatial visualization. As expected, negative adult age differences were absent for the marker test of the pragmatics (i.e. Vocabulary). The absence of significant age differences in the Torrance Visual Creativity Test contrasts with earlier studies that report adult age differences in creative performance favouring the young (Alpaugh and Birren, 1977; Ruth and Birren, 1985).

Of particular interest is the investigation of possible expertise effects in criterion-relevant and more general measures of intellectual functioning. Graphic designers scored significantly higher on the two tests of spatial visualization and the Torrance Visual Creativity Test than control participants. With the exception of Card Rotation in younger participants, group differences between graphic designers and control participants were also significant when tested within age-groups. No significant effects of expertise were found on the Wechsler tests. The presence of differences between experts and control participants on the criterion-relevant ability markers, together with the absence of such differences on other measures of intellectual ability, was consistent with our expectations.

The inspection of raw data from the 'Parallel Lines' subtest of the Torrance Tests of Creativity is especially instructive, as expertise effects were particularly pronounced for this test, whereas age effects were not reliable. Participants were asked to provide as many different meanings to two parallel lines as possible, either by adding detail, giving the lines a verbal title, or both. The participant with the highest score, and whose test sheet is reproduced in Figure 13.1, was an older graphic designer, and three of the four best-performing individuals were older graphic designers (see Figure 13.2). Possible mechanisms that may explain older graphic designers' remarkable levels of graphical fluency will be addressed in the discussion.

For the other criterion-relevant test, Card Rotation, we observed main effects of age (higher performance in younger adults compared to older adults) and expertise (higher performance of graphic designers compared to normal controls). Interestingly, the Age \times Expertise interaction was also reliable, reflecting larger expertise effects among older adults than among younger adults (see Figure 13.3). Though a firm inference is rendered impossible by the cross-sectional nature of the data, this pattern of findings is consistent with the claim that professional expertise may attenuate age-related decline in those aspects of the mechanics that are presumably closely related to professionally relevant skills.

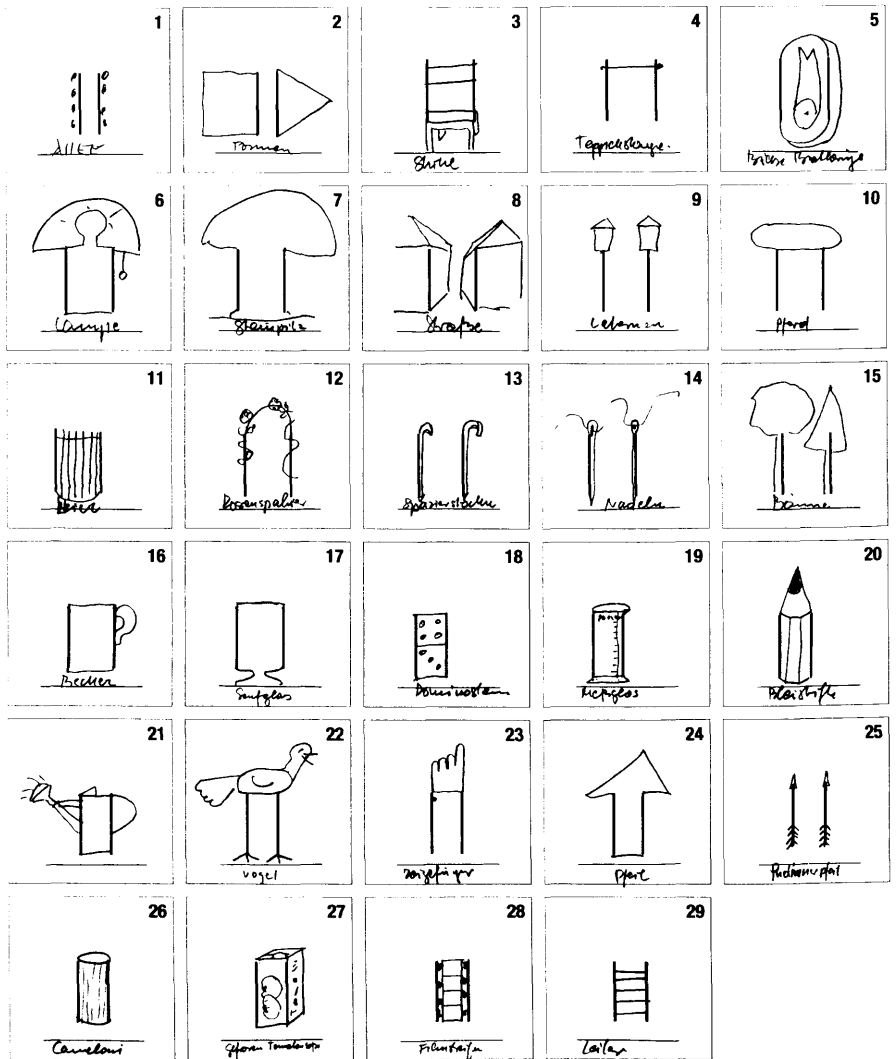


Figure 13.1 The performance of one older graphic designer in the Parallel Lines subtest of the Torrance Test of Creative Thinking: Thinking Creativity with Pictures, Form A (Torrance, 1966a, 1966b). The participant obtained the highest score on this test (see Figure 13.2).

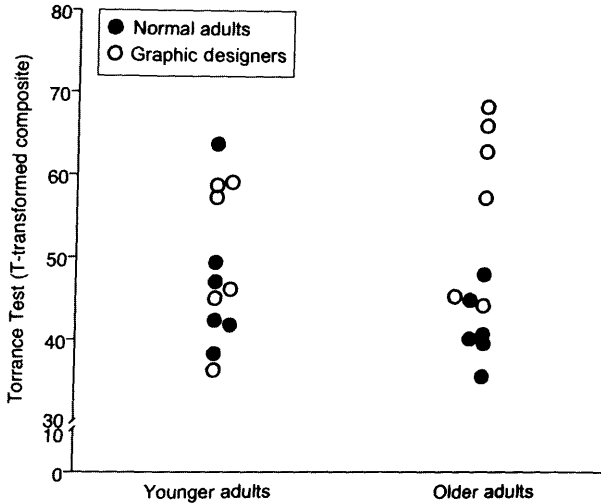


Figure 13.2 Performance of the Torrance Visual Creativity Test as a function of age-group and expertise. Scores represent T-transformed unweighted composites of the scoring dimensions of fluency, flexibility, originality and elaboration (cf. Torrance, 1966a, 1966b). Each dot refers to one participant.

Acquisition of mnemonic skill

Participants in all groups improved their performance in the course of the seven training sessions. Time did not interact with age-group or expertise, indicating that gains in recall performance did not differ across groups. Average performance levels across the training phase showed that younger control participants ($M = 17.6$, $SD = 1.4$), younger graphic designers ($M = 17.4$, $SD = 1.0$) and older graphic designers ($M = 12.3$, $SD = 2.0$) were profiting from the use of the mnemonic strategy because their performance levels after training were clearly above the range of performance in cued serial word recall generally found in adults without instruction and training in a memory skill. The situation is somewhat less clear in the case of the older control participants, who recalled on average 6.3 words ($SD = 3.0$) in correct serial position. This level of performance is somewhat higher than the level observed in older samples under similar task conditions but without imagery instructions (cf. Kliegl *et al.*, 1989; Treat and Reese, 1976). For instance, Kliegl *et al.* (1989) found that a comparable sample of older adults recalled about 4 out of 30 words prior to mnemonic instructions under very similar task conditions.

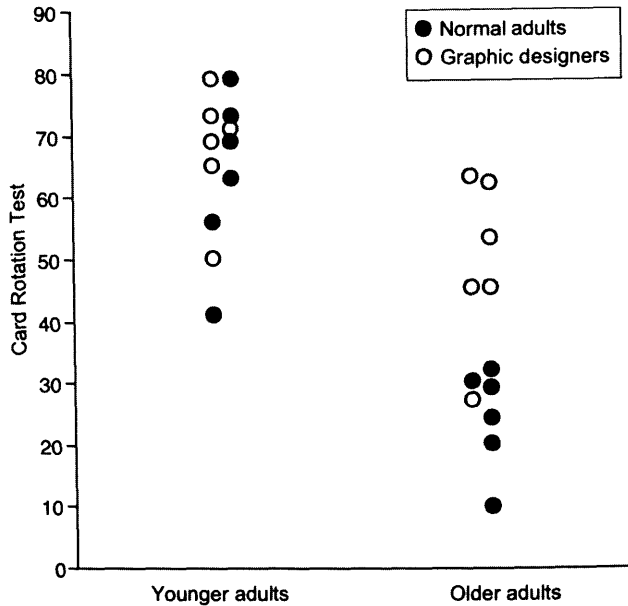


Figure 13.3 Performance of the Card Rotations Test from the ETS as a function of age-group and expertise. Each dot refers to one participant.

Group differences in cued recall

We now turn to the question whether older graphic designers were able to reach the level of recall performance of younger adults. Data from the twelve post-training sessions were used to address this question. Figure 13.4 shows the average performance in post-training assessment for each of the twenty-four research participants. Cronbach's alpha for this score, which was based on forty-eight trials (12 sessions \times 4 lists each session), was .99 in the total sample, .95 in younger control participants, .93 in younger graphic designers, .98 in older control participants, and .87 in older graphic designers.

Younger participants recalled more words in correct serial position than older participants, and graphic designers recalled more words correctly than control subjects. The interaction was not significant. In follow-up *t*-tests, it was found that older graphic designers performed above the level of older control participants, but below the level of younger control participants; see Table 13.2. The difference between younger graphic designers and younger control participants was not significant.

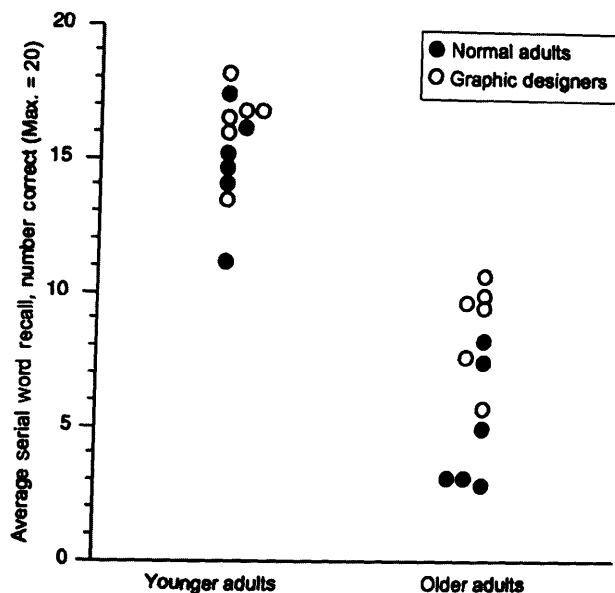


Figure 13.4 Performance during the test phase of mnemonic training as a function of age-group and expertise. Each dot refers to one participant.

An inspection of the data shown in Figure 13.4 reveals that none of the older graphic designers was able to reach the level of performance of younger adults. This perfect separation is highly unlikely by chance, $p = (1/18!) \times (12! \times 6!) = 5.39^{-5}$. The highest-scoring older graphic designer remembered an average of 11.1 words in correct serial position, whereas the lowest-scoring younger subject remembered 11.3 words. Note, however, that the four older adults with the best scores were graphic designers (see Figure 13.4). Also, though the corresponding interaction was not reliable, it seems that the performance of younger experts and younger control subjects was much more intermixed than the performance of older experts and older control subjects.¹

Two further results deserve to be mentioned. First, the pattern of group differences was stable throughout post-training assessment. The stability of individual differences within and across groups (indexed by the high internal consistencies reported earlier) and the absence of group-by-session interactions in post-training assessment render it unlikely that additional exposure to the Method of Loci would have allowed older graphic designers or older adults in general to reach the level of cued

Table 13.2 Means, standard deviations and post hoc t-tests for cued serial recall of twenty-item noun lists during the twelve-session test phase of the Lindenberger et al. (1992) experiment

Rate	Younger adults				Older adults				t values	
	Normal		Designers		Normal		Designers			
	M	SD	M	SD	M	SD	M	SD		
7.5 s/word	17.3	1.8	18.6	1.1	6.6	3.0	12.4	2.3	Older graphic designers versus younger control participants	3.73 ***
4.5 s/word	16.9	2.5	18.3	1.0	5.7	3.0	10.3	2.2	Older graphic designers versus older control participants	3.14 **
1.5 s/word	10.7	2.4	12.0	2.5	2.9	1.4	4.4	1.3		1.88 *

* $p < .10$. ** $p < .05$. *** $p < .01$

serial word recall displayed by younger adults. Second, the authors compared older graphic designers with older control adults to investigate whether group differences in recall performance difference were related to individual differences in criterion-relevant tests of visual creativity and spatial visualization. Statistical control for differences in visual creativity or spatial visualization turned out to eliminate group differences in cued serial recall between the two groups completely. This finding supports the hypothesis that the recall advantage of older graphic designers over older normal adults was related to the visual image generation component of the Method of Loci.

Revisiting the two-component model: disentangling expertise effects on the mechanics and pragmatics of cognition

This study explored relations between adult age, professional expertise and skilled memory performance after instruction and training in an imagery-based mnemonic skill. Concluding, we would like to summarize the main findings of this study, and point to open questions that need to be addressed in future work.

The main finding from the Lindenberger *et al.* (1992) study is that age-related declines in upper limits of episodic memory performance during adulthood are not easily altered by task-relevant lifelong experience. The choice of graphic designers as the expert group in the Lindenberger *et al.* (1992) study was based on evidence suggesting that interactive visual imagery is an important mediator affecting memory functioning using the Method of Loci (Baddeley and Lieberman, 1980; Richardson, 1985). Of course, we cannot exclude that a different group of older experts would have reached higher levels of mnemonic skill. For example, older professional mnemonists may show more substantial expertise-related experiential benefits in episodic memory performance than older graphic designers. In the former case, however, the domain of expertise would be almost identical to the criterion task, so the scope of the assessed expertise effect would be very narrow.

On a more positive note, graphic designers, and especially older graphic designers, showed higher levels of performance than age-matched control participants on tasks assumed to benefit from graphic design expertise, and they reached higher levels of skilled episodic memory performance using an imagery-based memory skill than their same-aged peers. Overall, graphic designers appear to be better able to produce and transform visual representations than their age-matched control participants. On the Card Rotation and Surface Development tests from the ETS, older

graphic designers did not show the typical very low levels of performance commonly observed in this domain of performance among older adults (e.g. Jenkins, Myerson, Joerding and Hale, 2000). On the Parallel Lines subtest of the Torrance, differences between graphic designers and control participants were substantial, and age-based differences were not reliable.

Given the selective advantages of graphic designers over control participants, one may wonder how these differences map onto the two-component model of lifespan cognition introduced before. Unfortunately, the cross-sectional nature of the data and the lack of process models for the target tasks (cf. Krampe, Engbert and Kliegl, 2001; Krampe and Ericsson, 1996) does not permit an unambiguous attribution of expertise-related differences to the mechanics or the pragmatics of cognition. Nevertheless, we would like to offer some speculations and suggestions for further research.

In principle, two scenarios are possible. According to the first, the advantageous performance profile of older graphic designers reflects, to some extent, experience-induced alterations in the mechanics of cognition. In our judgement, the performance of older graphic designers on the Card Rotation test is most amenable to this kind of interpretation. The constant need to image and spatially transform visual representations in working memory may have helped graphic designers to attenuate some of the normative losses in mental rotation abilities. Recent neuroimaging findings of structural changes of the brain as a function of visuo-spatial experience suggest that such experience-dependent modulations of the mechanics of cognition may in fact be possible (cf. Draganski *et al.*, 2004; Maguire *et al.*, 2000).

According to the second scenario, older graphic designers have acquired a rich body of factual and procedural knowledge that attenuates the adverse consequences of mechanic decline in expertise-relevant functional domains without altering the course of this decline itself. In addition to episodic memory performance itself, older graphic designers' impressively high levels of performance on the Parallel Lines subtest of the Torrance is consistent with this interpretation. Specifically, we would like to propose that graphic designers have acquired a 'lexicon' of graphical forms to express and promote concepts and ideas, and have stored this repertoire of concept-form associations in long-term memory. Thus, when working on the Torrance test, graphic designers had less need to create such associations on the spot than control participants because instead they were able to retrieve such associations from long-term memory (see also Patterson and Erzinclioğlu, this volume, for the opposite extreme).

Whereas the first scenario emphasizes the experience-dependent malleability of mechanic decline, the second scenario emphasizes the compensatory function of pragmatic knowledge. It is likely that the two options co-exist and interact with each other and with maturational and senescent changes in the course of lifespan development (e.g. Lindenberger, Li and Bäckman, 2006; Li and Lindenberger, 2002). Future studies need to identify the mechanisms through which experience alters mechanic declines, attenuates their consequences, or both. The present results suggest that the experience-dependent modulation of visuo-spatial skills offers a fertile testing ground for investigating this issue.

NOTE

1. Given that older and younger participants differed in Digit Symbol Substitution performance, one may argue that the observed age differences reflected the use of speeded encoding conditions throughout the post-training assessment (i.e. 1.5, 4.5 and 7.5 s/word). However, based on further analyses reported by Lindenberger *et al.* (1992), this explanation seems unlikely, as age differences did not decrease with longer encoding times.

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