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Auditory and Visual Distractor Decrement in Older Worker Manual Assembly Task Learning: Impact of Spatial Reasoning, Field Independence, and Level of Education

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ABSTRACT

This study examined the impact of age on manual assembly task learning in the presence of visual and auditory distracters. Manual assembly task learning (e.g., number of learning trials needed to obtain consistently accurate assembly and near asymptote performance times) was studied in men and women between 18 and 65 years of age. Higher spatial reasoning capabilities were associated with fewer trials to reach the learning criterion, faster manual assembly times, and material prophylaxis for the type of distractors addressed in this study that are likely to be encountered in the workplace. Years of formal education and field independence showed no impact on distractor-based decrements in task learning. For the oldest group of subjects (>50 years), concomitant presentation of visual and auditory distractors that are commonly encountered in industry were associated with a greater number of learning trials that were needed to achieve asymptotic manual assembly task learning. Spatial reasoning and field independence measures were lower in the older than in the younger age groups ($p < 0.05$). When spatial reasoning was treated as a covariate, however, nearly all age differences found in learning performance in the face of distractors were removed. The findings suggest that selection of workers based on spatial reasoning ability, rather than age, would yield better manual task learning in the face of visual and auditory distraction. © 2009 Wiley Periodicals, Inc.

1. INTRODUCTION

Distractions, external events or phenomena that disrupt performance, have long been a concern of persons who are interested in human learning and performance (Dulsky, 1932). Investigators have speculated that aging exacerbates the effects of distractors upon psychomotor performance and learning (Gottlob & Madden, 1999; Haarmann, Ashling, Davelaar, & Usher, 2005; Lawson, Guo, & Jiang, 2007; Schwerha, 2004; Tun, O'Kane, & Wingfield, 2002; Verhaeghen, Vandenbroucke, & Dierckx, 1998). Given that our workforce is aging and workers 55 years of age or older are projected to represent 30.0% of the population and 36.8% of the American labor force (Fullerton, 1999), interest in this issue is mounting (Braddock, 1999).

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Small batch manufacturing, or competitive service industries, inevitably require cyclic or frequent learning of psychomotor performance tasks. Such activities often occur in the presence of auditory, visual, or combined distractive stimuli. If aging and distractions interact to challenge learning or execution of psychomotor tasks, then such information would be useful in developing workforce selection, work design, or workplace distractor mediation strategies.

A previous study in our laboratory (Schwerha, Wiker, & Jaraiedi, 2007) showed that older subjects experienced more errors and required greater time to learn a noncontextual psychomotor task when subjected concomitantly to irrelevant verbal discourse and a mirror-imaged frontal view of dissimilar manual assembly tasks. However, wide variations in individual subject performance within and across age groups were observed, suggesting that some subjects had greater resistance to distractors than did others. Resistance to distractors has been attributed to individual field independence (Lavie, 2005), whereas learning manual–spatial tasks has been associated with spatial reasoning capacity (Salthouse, Fristoe, McGuthry, & Hambrick, 1998; Salthouse, Hambrick, & McGuthry, 1998; Salthouse & Miles, 2002; Salthouse, Mitchell, Skovronek, & Babcock, 1989). The goal of this study was to assess the comparative importance of aging, spatial reasoning, and field independence upon learning a representative manual assembly task when exposed to auditory and or visual distractors.

2. BACKGROUND

Perception of germane auditory and visual stimuli is requisite for learning. Yet, irrelevant auditory or visual information can compete for working memory and other cognitive and motor resources (Wickens, 1992). Degradation of visual and/or auditory perception with aging appears to increase the difficulty of learning complex psychomotor tasks (Welford, 1985), and immersion of older subjects in distracting environs has produced decrements in a variety of performance metrics.

2.1. Aging Decrements in Learning Psychomotor Tasks

Performance in working memory tasks degrades through adulthood, and task difficulty appears to play a role in the degree of age-related decrements (Park & Schwarz, 2000). These findings are thought to result from a diminished attentional resources (Craik & Byrd, 1982), processing speed (Salthouse & Somberg, 1982), or the inability to inhibit irrelevant information (Hasher & Zacks, 1988).

Age decrements in information processing may result from overall organic neurological degradation that affects global cognition or from differential slowing of components within the system (Birren & Schaie, 1990). Cross-sectional and longitudinal laboratory tests have found age-associated slowing of task performance and increases in errors in certain types of responses, particularly in simple and complex reaction time tests (Salthouse, 1984; Whitbourne, 1996). Reductions in attentional resources produced by slowing central nervous system processing capacity have been proposed (Whitbourne, 1996). If tasks become more complex, age differences should become more pronounced, reducing the ability to reject irrelevant information (Hasher & Zacks, 1988; Whitbourne, 1996; Zacks & Hasher, 1997).

2.2. Distractor Effects

A wealth of studies exist related to the impact of distractors upon the learning performance of children with, and without, attentional deficit disorders, social disorders, or some form of central nervous system pathology (Baving, Rellum, Laucht, & Schmidt, 2004; Kenner, 1992; Ozonoff & Strayer, 1997; Wetzel, Berti, Widmann, & Schroger, 2004). Results from these studies have not been consistent and probably reflect variations in methodologies, differences in the similarity of distractor-task characteristics, learning demand or experience with the primary tasks and the distractors, statistical power, and perceptual–information processing–motor workloads.

Variations in distractor tolerance may result because 1) not all apparent extraneous stimuli are distractive (Dulsky, 1932), 2) the interplay among distractors and task performance resources may be nonlinear in nature (Welford, 1962), 3) diagnostic errors exist in clinical disorder classification and severity gauging, 4) use of chronological aging was used as a metric of organic aging, 5) differences in perceptual, cognitive, and motor demands of learning psychomotor tasks may appear comparable, and 6) unmeasured differences exist in spatial reasoning and field dependence among subjects within and across studies that could produce differential impact upon task complexity and attentional demands.

Selective or focused attention, information processing, rehearsal in working memory, and other cognitive processes involved in learning are potentially sensitive to both the aging process and to distraction phenomena. Laboratory results have shown that irrelevant speech can disproportionately affect older adults (Rouleau and Belleville, 1996), and research on the deleterious effects of visual stimuli have been reported since the 1960s (Rabbitt, 1965). Older adults have also performed poorer than young adults in tasks that require activity recall and in motor activities that require effortful processing at high speeds (Lichty, Kausler, & Martinez, 1986; Park & Schwarz, 2000; Ratner, Padgett, & Bushey, 1988; Wishart, Lee, Murdoch, & Hodges, 2000).

Maylor and Lavie (1998), studying age differences in selective attention, found that older subjects were disproportionately affected by visual distractors when recall set size or perceptual loads were smallest. Their results suggest that older adults differentially suffer from the effects of distractors when perceptual loads are low enough to allow attentional resources to be diverted to the distractors.

Schwerha et al. (2007) found concomitant presentation of irrelevant verbal discourse and slightly dissimilar and potentially confusing manual assembly videos resulted in degraded learning rates for noncontextual manual assembly tasks. Subjects aged between 50 and 65 years experienced an increase in both the number of learning trials and associated task cycle times of 25.0% and 31.1%, respectively. When comparisons across distractor conditions were made, learning trials increased 150.0% and cycle times increased 54.3%.

The aforementioned studies indicate that distractors can affect human learning performance and that older adults, in some circumstances, experience greater decrements in task learning in the presence of certain types, magnitudes, or combinations of distractors. Those studies did not examine potential mediators of either aging or distractor effects upon learning industrially relevant psychomotor tasks that are likely to be assigned to an aging labor force.

2.3. Spatial Reasoning

Psychomotor performance, which relies materially upon spatial organization or assessment capacity (such as manual assembly of parts or subassemblies) has benefited when performed by subjects with higher spatial reasoning ability (Jacewicz & Hartley, 1979; Shepard & Metzler, 1971; Vandenberg & Kuse, 1978). Significant differences in spatial reasoning capacity occur within the general population, and test–retest reliabilities of assessment instruments have been good ($r > 0.83$; Chen, 1991).

Gaylord and Marsh (1975), studying age differences in the spatial–cognitive performance, determined that older subjects required 84% more time to perform spatial reasoning tasks. Cerella, Poon, and Fozard (1981) found age-associated increases in mental rotation times between younger and older women of 96%. In contrast, Jacewicz and Hartley (1979) reported no age differences in spatial reasoning ability.

Older adults may be able compensate for deficits in spatial reasoning if supportive cues are available. Clarkson-Smith and Halpern (1983), using descriptive and nonsense labeling of spatial figures, found that mental rotation errors increased with age only between the middle-age (mean = 54.7 years) to oldest group (mean = 74.2 years). The number of errors was materially reduced when informative labeling was used.

Spatial reasoning capacity may be an important mediator in the availability of attentional resources and, thereby, proffer greater resistance to distraction. Workers who perform assembly tasks across from one another are exposed to potential visual distraction when coworkers perform similar mirror-imaged or dissimilar manual activities.

2.4. Field Independence

The term "field independence" is often used to describe the ability to separate an item from an organized field and, theoretically, one's capacity to avoid or mitigate distraction (Bertini, Pizzamiglio, & Wapner, 1986). This ability is typically measured using the Rod and Frame Test (RFT), Body Adjustment Test (BAT), Rotating Room Test (RRT), or by tests that evaluate one's ability to identify an item that has been embedded within a field (Embedded Figures Test, EFT). Field independence scores (FIS) are scalars with no arbitrary threshold for classification. The notion that field independence allows a person to selectively attend to certain information within an attentional field, while ignoring other irrelevant information, has led to the exploration of whether field independence is related to the ability to resist distractions.

Bloomberg (1965) found that field-independent subjects were less affected by distractors in a reversible perspective task. Blowers (1974, 1976) concluded that field dependence didn't affect reaction time performance in the face of distractions. In a factor-analytic study, Karp (1963) found that figure-embeddedness tests loaded materially upon different factor structures than did distraction metrics even though those factors tended to be moderately correlated with distractor factors. Makkar, Malhotra, and Jerath (1999) found that field-independent subjects were less susceptible to distraction in short-term memory tests.

Field dependence appears to decline from 8 to 15 years of age, stabilizes, then in later life appears to increase (Panek, 1985; Schwartz & Karp, 1967; Witkin, Oltman, Raskin, & Karp, 1971). Men between 60 and 75 years of age, who were still working, have been reported to be significantly more field independent than their retired cohorts (Karp, 1967). Yet, other studies have found no significant differences in field dependence between younger and older adults (Panek, 1985; Schwartz & Karp, 1967).

Although bases for these findings and apparent disagreements remains unclear, there is adequate evidence to argue that study of age-based differences in field dependence should be considered as potential covariates when examining age-mediated resistance to decrements in psychomotor task learning when immersed within distractor fields.

3. METHODS

3.1. Subjects

Sixty-six male and female subjects between the ages of 18 and 65 years participated in this study on an informed consent and unpaid basis. The age range of subjects was selected to represent the current adult working population. See Table 1 for descriptive anthropometric and demographic data for subjects.

3.2. Apparatus

Subjects performed a manual assembly of nine large red, blue, green, and yellow Lego Duplo™blocks in nonsense configurations. The blocks were chosen for their size to reduce potential age-related problems with grip and hand dexterity. Color and size blocks and the spatial organization of the assembly tasks were noncontextual and nonhierarchical to reduce environmental support in task learning. The standard assembly time for different assembly configurations studied were matched and predicted, using the Maynard Operation Sequence Technique (MOST) (Zandin, 2003), and resulted in an average standard time of 19.44 s.

Blocks were stored in color-sorted bins that were positioned at equal distances of 30 cm from the center of the assembly platform. Two storage bins were located on the left of the assembly platform and two on the right of the assembly platform. See Figure 1 for the testing station organization and Figure 2 for an example of a typical completed assembly.

Four distractor conditions were presented to subjects as described in detail by Schwerha et al. (2007). The auditory distractor consisted of a running commentary, using a woman's voice at 68–70 dBA, about weather, after work plans, and other noncontextual topics that might be encountered in the workplace. The visual distractor was a mirror-image video presentation of a slightly dissimilar assembly of the same type and color blocks, to emulate a coworker performing different assembly operations in front of the subject. The video display was presented directly in the subject's line of sight when performing the manual assembly task as shown in Figure 1.

TABLE 1. Subject Descriptive Demographic, Spatial Reasoning, and Field Dependence Characteristics

Age Group	Measure	Mean	*SD*
18–29 years	Age	23.3	2.0
($N = 22$)	Field independence score	13.0	4.1
	Spatial reasoning score	21.8	9.6
	Years of formal education	16.7	1.0
30–49 years	Age	44.9	3.6
($N = 21$)	Field independence score	9.4	5.5
	Spatial reasoning score	16.0	8.1
	Years of formal education	16.4	2.1
50–65 years	Age	56.6	5.0
($N = 23$)	Field independence score	8.7	4.3
	Spatial reasoning score	11.8	7.9
	Years of formal education	15.8	2.8

SD = standard deviation.

Figure 1 Test station organization and layout showing video distraction monitor placement.

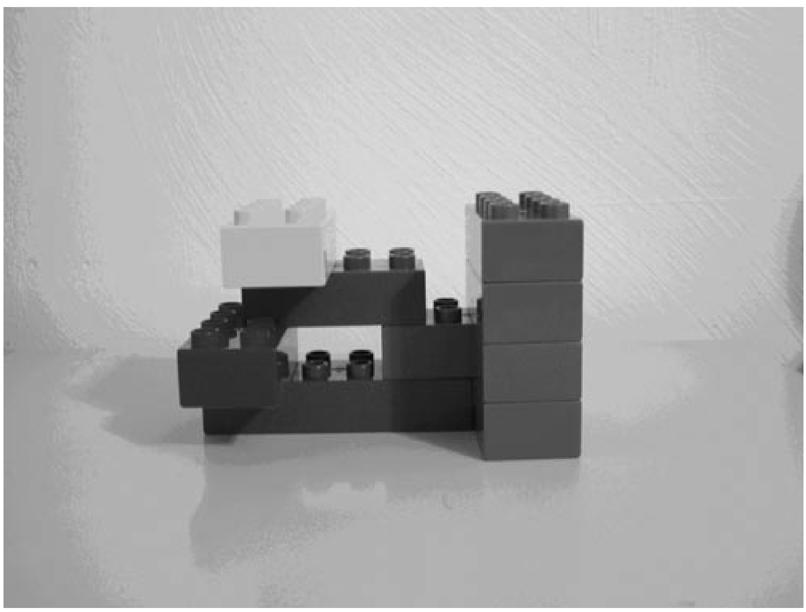

Figure 2 Example of noncontextual block assembly performed by test subjects.

A standard Group EFT was administered to subjects to obtain a measure of field independence following the methods described by Vandenberg and Kuse (1978) (see *Figure 3*).

The Vandenberg Mental Rotation Test was administered to gage spatial reasoning ability following the methods outline by Bertini et al. (1986). See Figure 4 for a representative image.

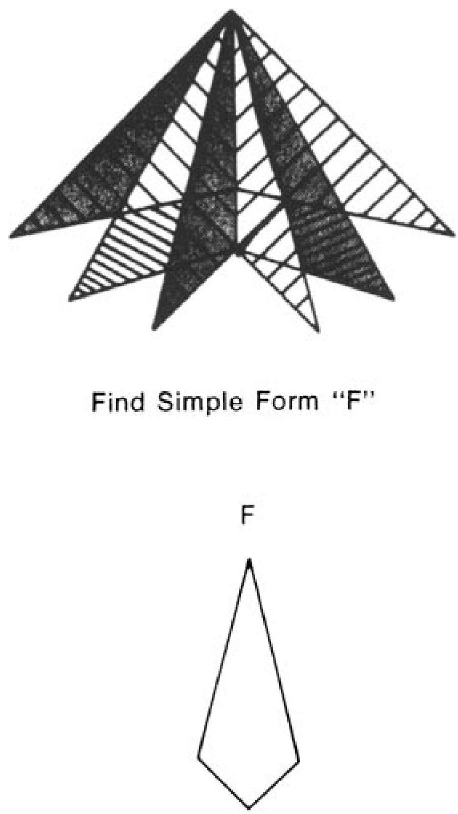

Figure 3 Example of embedded figure test used to assess field independence. Reproduced by special permission of the Publisher, MIND GARDEN, Inc., 855 Oak Grove Ave. Suite 215, Menlo Park, CA 94025 USA, www.mindgarden.com, from the **Group Embedded Figures Test**, Copyright 1971, 2003, Philip K. Oltman, Evelyn Raskin & Herman A Witkin. Further reproduction is prohibited without the Publisher's written consent.

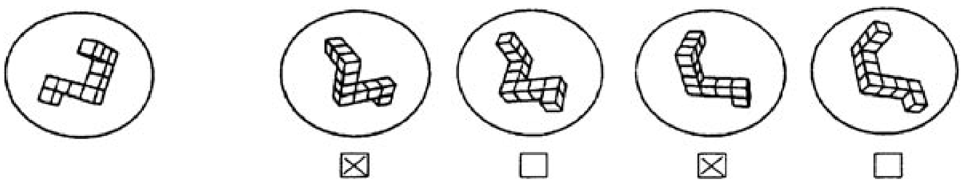

Figure 4 Example of rotated visual stimuli that were used to gage mental rotation gage of spatial reasoning ability.

A computer program was constructed to 1) run the experiment using a microcomputer, 2) present the instructional videos and distractions to the subjects, 3) time subject performance, and 4) record the data in a systematic fashion. The computer program randomized trial sequences and presentation of distractors.

3.3. Procedures

Following a standardized description of the experimental objectives, paradigm, procedures, and completion of informed consent form, subjects were randomly assigned to one of the distractor conditions. The subject sat at the assembly station and was given an opportunity to practice reaching for the block, positioning the hand, grasping a block, moving the block to the assembly pad or subassembly in front of him or her, and positioning and inserting the block onto the designated set of connectors. This practice period was very short to avoid perturbation of the subsequent learning trials.

Upon completion of self-paced practice, the subject was shown a video of the desired block assembly task. The instructional video showed a person building the assembly without audio and provided a "subject's eye" perspective of the step-by-step assembly task. Learning trials followed immediately.

Subjects were instructed to complete the noncontextual manual assembly task as quickly and as accurately as possible. The task required subjects to assemble the nonsense block configuration matching both spatial and color configuration. As soon as a subject erred in either the spatial or color configuration of the assembly process, the trial was stopped and the subject restarted a learning trial after reviewing the training video. Subjects were permitted to vary the sequence of operation, but not the spatial or color organization of block assembly. Subjects were not required to review the instruction video if they felt that they understood the assembly process and had simply made a "slip." Once a subject completed three error-free trials with no significant reduction in assembly task times across the three trials, the learning criterion was met and the session was stopped by the computer. Both number of trials and final cycle times were recorded for analysis.

All subjects were exposed to a single distractor test condition to avoid significant learning or positive transfer effects across distractor conditions. Experimental learning trials ranged between 20 and 50 minutes, with a typical trial taking approximately 30 minutes before the psychomotor learning task had reached the stopping criterion.

The EFT for Field Dependence and the Vandenberg Mental Rotations Test for Spatial Ability required 30 minutes to complete and were administered on a subsequent date to avoid fatigue and motivational artifacts.

4. RESULTS

The number of error trials completed before three consecutive correct assemblies were achieved and the period of time required to complete the assembly for the third consecutive correct trial were analyzed using an analysis of covariance (ANCOVA). The ANCOVA model used years of formal education (YFE), FIS, and spatial reasoning scores as covariates. Inspection of the data showed that by the third consecutive accurate assembly trial performance times were at or approaching asymptotic levels. After subjects reached the stable learning criterion, their average cycle or performance times were comparable to those predicted by predetermined time system tables.

The experiment and analysis were not extended beyond the stopping criterion because we presumed that initial stages of learning would be most sensitive to distraction. If distraction effects were encountered, then their impact upon later stages of the learning process would be mitigated by sustained rehearsal and reduced attentional resource requirements with progressive- or over-learning of the motor task.

Material negative correlations between error trials and performance times would be expected if subjects elected to not follow the instruction set and pursued a speed–accuracy tradeoff. For the subjects as a group, no such correlations were found. Weak negative correlations were found in the youngest and oldest subject populations as shown in Table 5.

An analysis of variance was performed to determine that there were no differences in educational background (YFE) ($F(2, 63) = 1.0$, mean square error (MSE) = 4.4, $p < 0.38$), decreased spatial reasoning scores ($F(2, 63) = 7.7$, MSE = 565.5, $p < 0.001$), and decreased FIS ($F(2, 63) = 5.5$, MSE = 118.6, $p < 0.01$) between the youngest and oldest age groups. Post hoc Tukey paired-comparison tests were performed to determine if age group differences existed. As shown in Table 2, the youngest subject group possessed greater field independence than the oldest group. That group also possessed the highest spatial reasoning scores in comparison with the other age groups.

No differences were found between middle-aged and our oldest subject groups in spatial reasoning or FIS (see *Figure 5*).

Means and standard deviations for numbers of learning trials and trial performance times are provided in *Figure 6* and 7, respectively. An ANCOVA was performed on the number of learning trials needed to reach the stopping criterion and cycle time for the last error-free assembly trial using subject education, spatial reasoning, and field independence as covariates. FIS and YFE were not found to be statistically significant covariates for number of learning trials (FIS $F(1,50) = 0.18$; MSE = 12.9; $p > 0.05$; YFE $F(1,50) = 3.1$, MSE = 8.9, $p > 0.05$) or performance times (FIS $F(1,50) = 0.30$; MSE = 9.1; $p > 0.05$; YFE $F(1,50) = 0.1$, MSE = 9.1, $p > 0.05$). Thus, FIS and YFE were removed as covariates, and the ANCOVA was recomputed using only spatial reasoning as the covariate, increasing the statistical power of our tests. See Tables 3 and 4, respectively.

Neither the number of learning trials nor cycle time at the learning criterion was affected by age and the introduction of either verbal or visual distractors. An exception occurred with an introduction of the visual distractor in the oldest subject group, resulting in a 16.2% increase in completion or cycle times.

TABLE 2. Tukey Multiple Comparison Tests for Differences Between Subject Age Groups in Spatial Reasoning and Field Independence Test Scores and Level of Formal Education

Metric	Age Group (*I*)	Age Group (*J*)	Mean Difference (*I*–*J*)	*SE*	*p* <	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Spatial reasoning score	18–29	30–49	5.89	2.62	0.07	−0.41	12.14
	18–29	50–65	9.99	2.56	0.01	3.86	16.13
	30–49	50–65	4.13	2.59	NS	−2.08	10.34
Field independence score	18–29	30–49	1.42	1.42	0.03	0.22	7.02
	18–29	50–65	1.38	1.38	0.01	0.98	7.63
	30–49	50–65	1.40	1.40	NS	−2.67	4.05
Years of formal education	18–29	30–49	0.65	0.65	NS	−1.21	1.91
	18–29	50–65	0.63	0.63	NS	−0.64	2.40
	30–49	50–65	0.64	0.64	NS	−1.01	2.07

SE = standard error; NS = not significant.

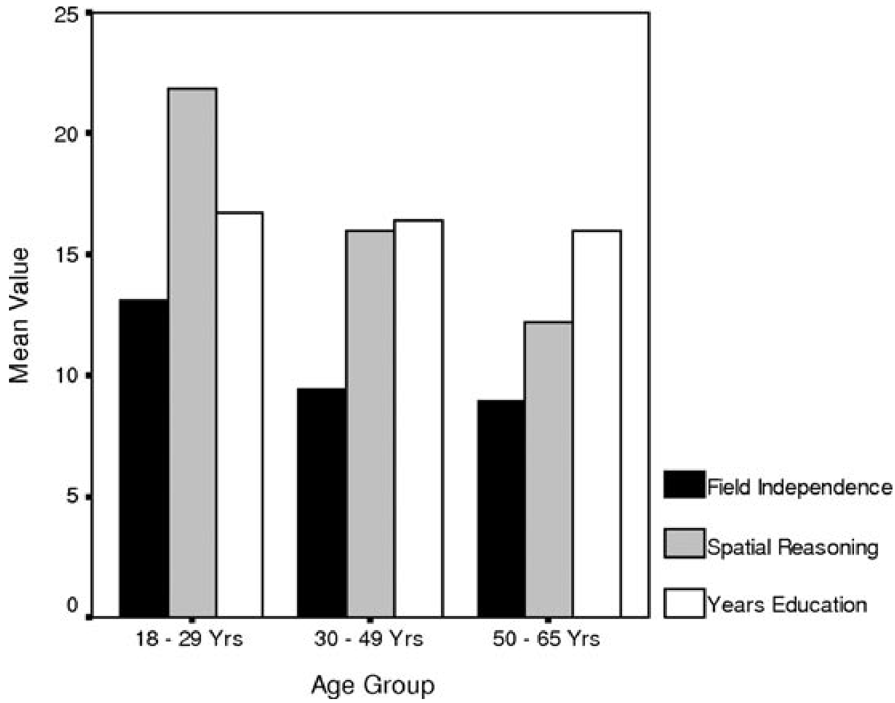

Figure 5 Mean field independence and spatial reasoning scores and number of years of formal education across age groups.

Pearson Product-Moment correlations showed statistically significant but weak associations between subject age and number of learning trials ($r = .28$, $N = 66$, $p < 0.05$) and cycle times ($r = .43$, $N = 66$, $p < 0.05$) across all subjects. When correlations were computed within each age group, as shown in Table 5, mild associations were found with improved learning performance and subject spatial reasoning and FIS in younger subjects. The oldest subject group also demonstrated a mild inverse association between spatial reasoning capability and fewer errors before reaching the learning criterion. Unlike the youngest and middle-age groups, the oldest age group showed a moderately positive association between spatial reasoning and field independence.

Plots of the combined verbal and visual distractor set against spatial reasoning for each age category suggest that differences in spatial reasoning within and across subject age groups were stronger mediators of learning performance than was chronological age. See *Figures 8* and 9.

A principal components factor analysis produced three factors that collectively accounted for approximately 67% of the total variance. Inspection of Table 6 shows that the first factor was loaded by decrements in task learning, reductions in spatial reasoning scores and FIS, and subject age. Joint distractor impact loaded on a separate factor as well as a general improvement in performance associated with YFE.

5. DISCUSSION

Schwerha et al. (2007) reported that subjects who were 50 years of age or older were distracted by concomitant exposure to noncontextual verbiage and visual display of manual

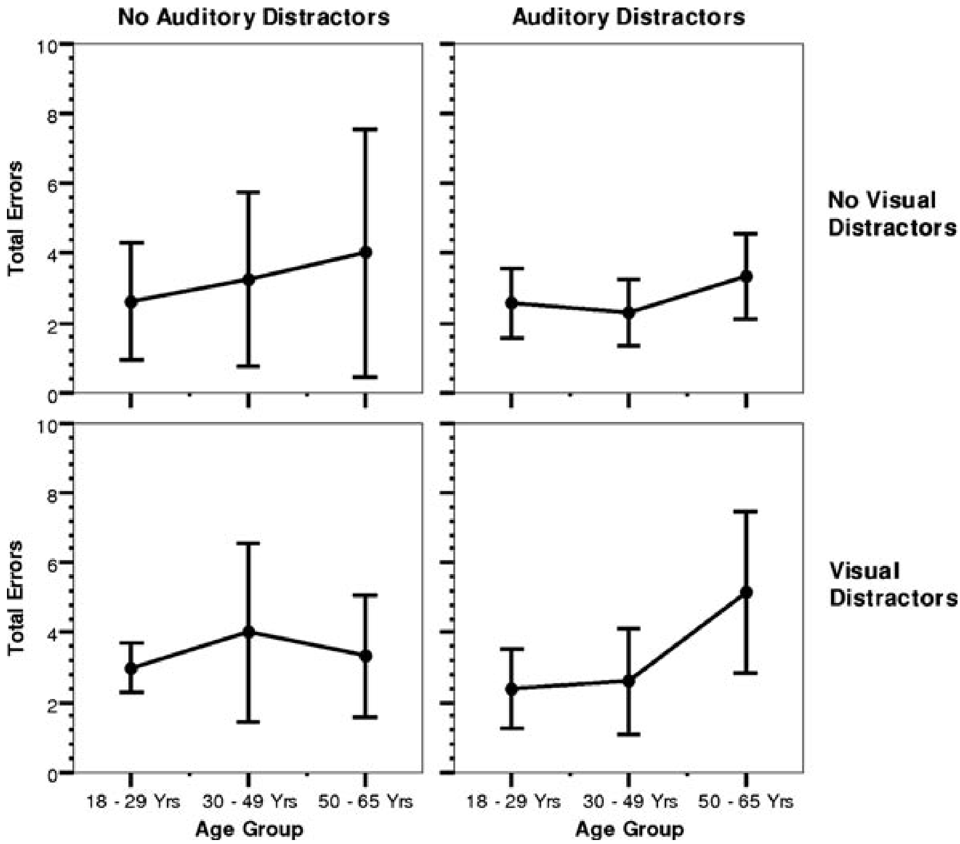

Figure 6 Means and standard deviations of the number of error trials prior to reaching the learning criterion plotted across age groups and distractor conditions.

assembly tasks that were similar to noncontextual manual assembly tasks. Large variations in manual assembly task learning performance indicated that individual differences occur in tolerance of distractors. Distractor impact upon number of learning trials was found only in our oldest subject group when they were subjected to visual distractors or when both visual and auditory distractors were presented concomitantly. The oldest group possessed lower spatial reasoning and FIS.

Although FIS values were materially lower in the older age groups, it appears that this characteristic was not a material factor in older subject resistance to distractors. Our middle aged and older subject groups did not possess different levels of field independence as groups. Although a reasonably strong association was found between field independence and spatial reasoning in the oldest group, that relationship was much weaker in the younger groups. This resulted in ineffective covariate performance of FIS in the ANCOVAs for either number of required learning trials or task performance times. Finally, factor analysis showed no material loading on the joint distractor factor.

No material correlation was found between a subject's field dependence and spatial reasoning scores across the subject population as a whole. Where correlations were found between FIS and performance metrics within different age groups, the correlations were generally weak. Factor analysis demonstrated that FIS did not load upon concurrent

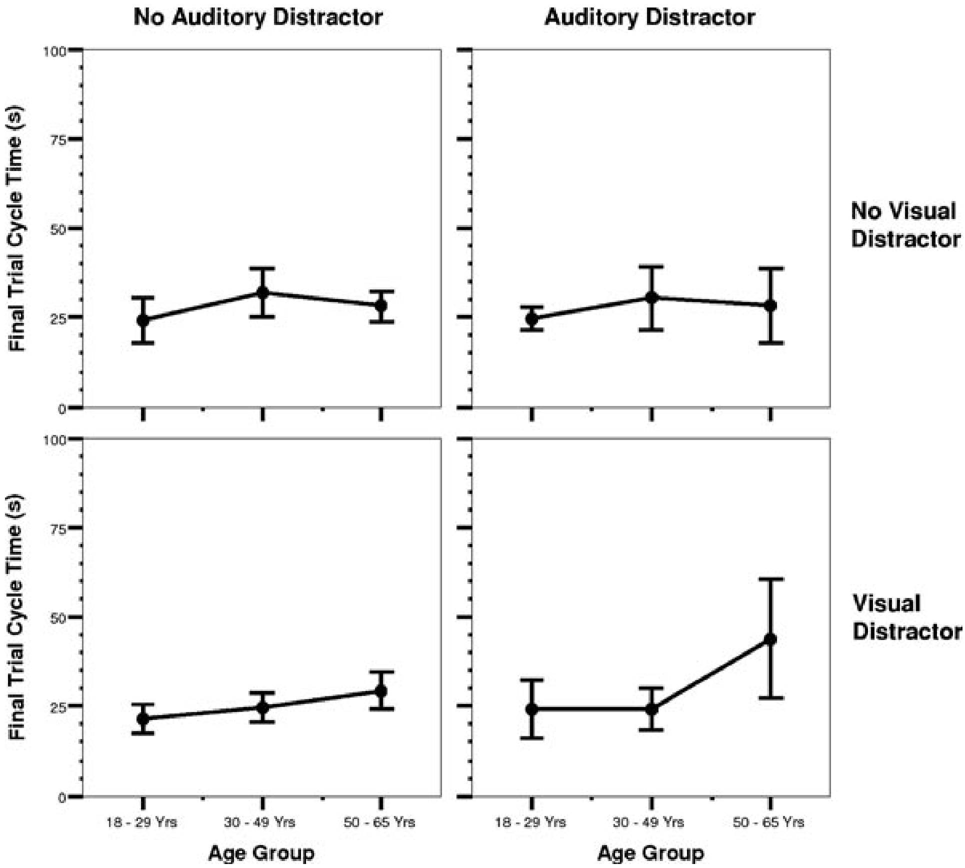

Figure 7 Means and standard deviations of final cycle times across age groups and distractor conditions.

TABLE 3. Analysis of Covariance of Number of Error Trials Completed Before Reaching Learning Goal Using Spatial Reasoning as a Covariate

Source	SS	*df*	MS	F	*p*
Spatial reasoning	30.80	1	30.80	10.53	0.002
Age (A)	3.27	2	1.64	0.56	0.525
Auditory distractor (AD)	0.45	1	0.45	0.15	0.698
Visual distractor (VD)	2.53	1	2.53	0.86	0.357
A × AD	12.50	2	6.25	2.14	0.128
A × VD	3.77	2	1.88	0.64	0.530
AD × VD	1.05	1	1.05	0.36	0.551
A × AD × VD	2.43	2	1.22	0.42	0.662
Error	152.16	52	2.93		
Total	878.00	65			

SS = sums of squares; *df* = degrees of freedom; MS = mean square.

TABLE 4. Analysis of Covariance of Trial Completion Time Upon Reaching Learning Goal Using Spatial Reasoning as a Covariate

Source	SS	*df*	MS	F	*p*
Spatial reasoning	657.09	1	657.09	21.76	0.000
Age (A)	89.64	2	44.82	1.48	0.236
Auditory distractor (AD)	71.95	1	71.95	2.38	0.129
Visual distractor (VD)	20.21	1	20.21	0.67	0.417
A × AD	18.65	2	69.32	2.30	0.111
A × VD	642.26	2	321.13	10.63	0.001
AD × VD	61.92	1	61.92	2.05	0.158
A × AD × VD	0.34	2	0.17	0.01	0.994
Error	1,570.54	52	30.20		
Total	52,316.54	65			

SS = sums of squares; *df* = degrees of freedom; MS = mean square.

TABLE 5. Pearson Product Moment Correlations Stratified Across Age Groups

Age Group	Metric	Total Errors	Final Cycle Time(s)	Field Independence Score
18–29	Total errors	1		
	Final cycle time(s)	0.39	1	
	Field independence score	−0.44	−0.45	1
	Spatial reasoning score	−0.54	−0.57	0.41
30–49	Total errors	1		
	Final cycle time(s)	−0.23	1	
	Field independence score	−0.14	−0.07	1
	Spatial reasoning score	−0.29	−0.32	0.28
50–65	Total errors	1		
	Final cycle time(s)	0.25	1	
	Field independence score	−0.14	−0.37	1
	Spatial reasoning score	−0.45	−0.33	0.75

Correlations > 0.43, $p < 0.05$.

presentation of our distractors. This finding is in agreement with Karp (1963), who reported that figure embeddedness test scores loaded upon different factor structures than did distraction metrics. These results do not rule out the importance of field independence as a potential mediator of distraction, just for the industrially relevant levels of visual and verbal stimuli that were examined in this effort.

As with FIS, we found no relationship between YFE and resistance to distractor effects. Principal components analysis did show moderate loading of education level with the number of errors or learning trials needed to achieve the learning criterion. However, there was no loading of YFE upon the distractor factor, and this indirect correlate of learning skill failed to demonstrate any value as a covariate in our ANCOVAs of learning performance metrics.

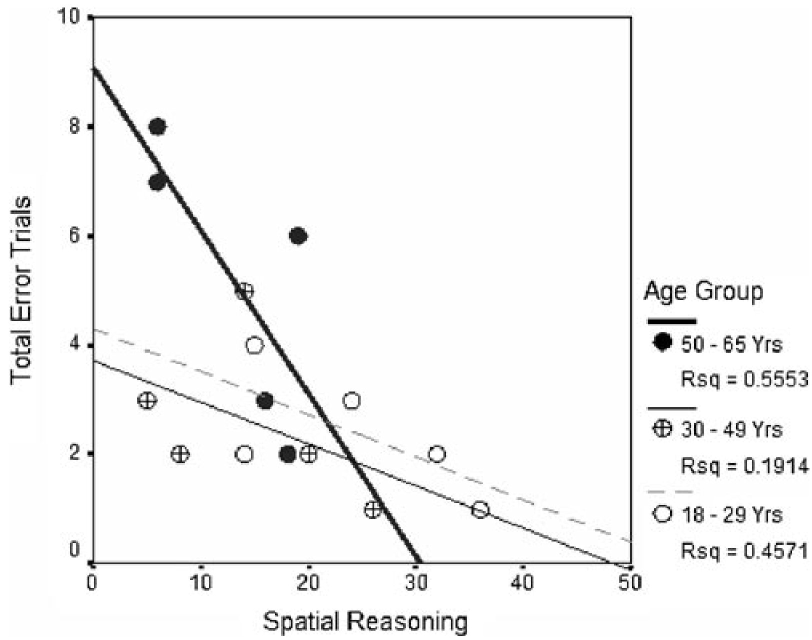

Figure 8 Relationships between subject spatial reasoning and age in number of learning trials required to reach the learning criterion in the presence of both verbal and visual distractors.

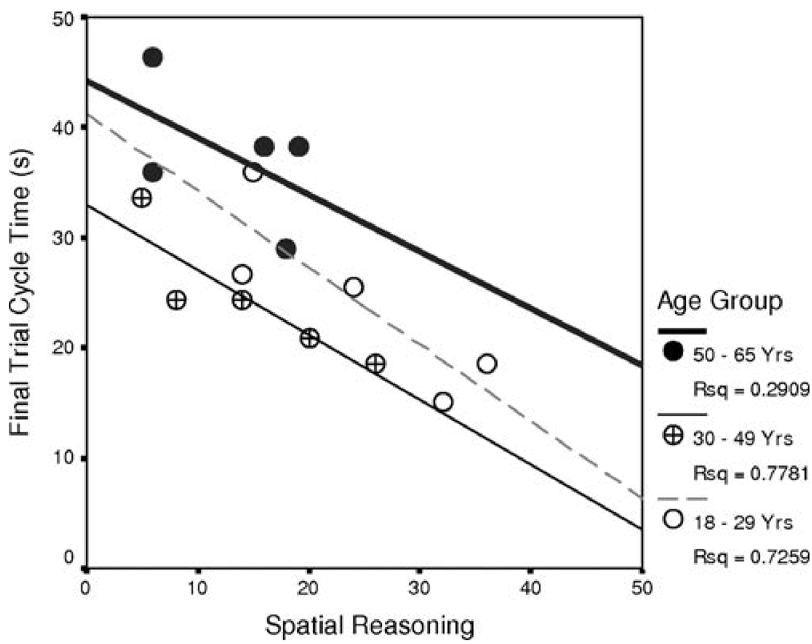

Figure 9 Relationships between subject spatial reasoning and age in final cycle or task performance times at the learning criterion in the presence of both verbal and visual distractors.

TABLE 6. Principal Components Analysis Factor Scores for Subject Learning Performance, Age, Spatial Reasoning, Field Independence, Years of Education, and Presence of Both Visual and Auditory Distractors

Metrics	Principal Components Factors		
Percentage of variance	36.3%	16.9%	14.14%
Total error trials	0.57	0.48	−
Final trial cycle times	0.70	+	+
Field independence score	−0.73	+	−
Spatial reasoning score	−0.82	−	+
Age (years)	0.70	−	−
Years of formal education	−	0.86	−
Audio and visual distractions	+	+	0.94

Component loadings below 0.40 are shown as either negative or positive values.

Spatial reasoning ability appeared to be a strong mediator of manual assembly task learning as well as resistance to our distractors. As with previous investigations, we found a benefit in motor task learning and performance in subjects who possessed high spatial reasoning scores (Jacewicz & Hartley, 1979; Shepard & Metzler, 1971; Vandenberg & Kuse, 1978). Spatial reasoning ability, on average, was lower in the oldest subjects. This finding is in agreement with previous studies of spatial reasoning ability and human performance (Cerella et al., 1981; Clarkson-Smith & Halpern, 1983; Gaylord & Marsh, 1975).

When differences in spatial reasoning among subjects was used as a covariate, age no longer proved not to be a significant effect in learning task performance and it did not interact with distractors to exacerbate decrements. Plots and tests of means showed that within older test subjects, those who possessed high spatial reasoning were more resistant to distractor effects and performed task learning approaching that of the younger groups with mixed spatial reasoning ability. This finding held regardless of distractor state.

Clearly, our distractors had an impact upon the oldest subject population when they were presented concomitantly. However, the impact of distractor exposure upon learning performance was strongly mediated by one's spatial reasoning ability. Higher spatial reasoning ability may serve to reduce working memory and other attentional resource demands and improve generalized cognitive performance capacity. Improved understanding, improved working memory rehearsal, or increased capacity for irrelevant stimulus competition for attentional resources may be enhanced by greater spatial reasoning capacity (Donovan, Queisser, & O'Leary, 1976; Salthouse, Fristoe, et al., 1998; Salthouse, Hambrick, et al., 1998; Salthouse & Miles, 2002; Salthouse et al., 1989). Older subjects who possessed higher spatial reasoning scores were better able to resist distraction and could perform competitively with younger subjects. Thus, our findings indicate that decrements in psychomotor task learning in the face of auditory and visual distractors in the oldest group were due to their lower spatial reasoning capacity rather than to a general chronological age effect.

From these results it is clear that selecting workers, at any age, based upon high spatial reasoning ability materially benefits learning of noncontextual manual assembly tasks that are found in small batch manual assembly and service industries. High spatial reasoning capacity was also associated with greater mitigation of distractor-induced decrements in learning. These findings indicate that selection or assignment of workers to such tasks should be based upon spatial reasoning ability, not simply chronological age. Reducing distractor loads upon older workers can be beneficial; particularly, if spatial reasoning abilities are low.

6. CONCLUSIONS AND RECOMMENDATIONS

Introduction of verbal and visual distractors, which are likely to be encountered in the workplace (e.g., irrelevant verbal communication from nearby workers and views of coworkers performing different and potentially confusing manual assembly operations), were associated with material decrements in learning a short-cycle noncontextual manual assembly psychomotor task in subjects whose chronological age ranged between 50 and 65 years. However, if spatial reasoning capabilities were high, then older subjects demonstrated resistance to verbal and visual distractors and performance that was competitive with younger subjects with lower spatial reasoning ability. No comparable benefits were found with greater formal education or indexes of field independence.

Collectively, our findings suggest that worker selection or assignment to minimize learning or distraction effects, based simply upon chronological age, would be less effective than focusing upon spatial reasoning capability. Higher spatial reasoning capabilities were associated with fewer trials to reach the learning criterion, faster manual assembly times, and material prophylaxis for auditory and visual distractors that are likely to be encountered in the workplace.

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