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Effect of distractors, age, and level of education upon psychomotor task learning

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Abstract

Learning new manual assembly or procedures in the presence of distractions is common across industry. This research investigated the impact of age and years of formal education upon learning a manual assembly task in the presence of visual and auditory distractors in males and females ranging in age between 18 and 65 years. Subject age was significant in all analyses of learning metrics, with the oldest subjects' performance particularly affected by the dual distractor condition. Learning, as evidenced by significant regression functions, was demonstrated only in the no distraction condition. Results indicate that reduction or elimination of irrelevant verbal or visuospatial distractors, comparable to those studied, could benefit older workers during early learning of psychomotor tasks.

Relevance to industry

With greater numbers of adults changing careers in mid to late-life, the ability to efficiently learn novel skills will become increasingly important. Determination of resistance to distractors during these early phases of learning manual assembly or psychomotor tasks will aid industry professionals in designing worker selection protocols, work design, distractor mediation strategies or training programs for all ages of workers.

Keywords: Aging worker; Learning; Assembly; Distraction

1. Introduction

Learning of manual assembly tasks or procedures in the presence of distractions is common across industry. Learning motor tasks depends on selective or focused attention, information processing, working memory rehearsal and other cognitive processes that are potentially sensitive to distraction and aging (Beaman, 2005; Craik and Byrd, 1982; Hasher and Zacks, 1988; Park and Schwarz, 2000; Zacks and Hasher, 1997). Differences in psychomotor skill capacity and the ability to selectively focus attention and tolerate distractors are thus important determinants to psychomotor learning and performance capacity. In spite of the ubiquity of these learning requirements, the interplay between distractors and age-mediated changes in cognitive and psychomotor performance has received inadequate study.

The workforce is aging. Americans age 55 years and older are anticipated to represent 34% of the population and 41.2% of the labor force by 2014 (Toossi, 2005). Numerous occupations requiring cyclical learning of new or modified psychomotor performance tasks are likely to be populated by an ever-aging workforce. Older workers may face greater learning demands because they may have changed careers or may be working in a new discipline for the first time (Braddock, 1999). If the interplay of aging and distraction is a determinant to work quality or quantity, then such information would be useful in developing worker selection protocols, work design, distractor mediation strategies and, if necessary, workforce performance assessment protocols.

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Auditory and visual distractors compete for sensory and cognitive resources and, as such, can disrupt learning at the perception, working memory, association and recall stages of learning, and preempt resources required for planning, executing and monitoring motor performance. Competition for such resources can be more problematic with aging because of potential independent or interactive decrements in visual and auditory sensory systems, information processing rates, or motor skills.

Attentional control may decline with increasing age, disrupting performance that is dependent upon focused attention (Rogers and Fisk, 2001). Declines in distractor resistance could allow the introduction of irrelevant information that competes for available cognitive resources, resulting in a confusing mosaic of relevant and irrelevant information (Hasher and Zacks, 1988; Zacks and Hasher, 1997).

Although the effects of noise on human performance have long been studied by human factors researchers, some recent articles have sought to clarify the sometimes conflicting viewpoints (Beaman, 2005). Banbury et al. (2001) found that tasks involving seriation are particularly vulnerable to exposure to irrelevant sound. Taylor et al. (2004) found that the effects of noise enhanced or degraded inspection task performance. Random and intermittent noise was shown to contribute to performance decrements for an easy task. A single source noise enhanced performance on a more difficult task. Wingfield et al. (2005) reported that a distractor consisting of meaningful speech caused interference effects in recalling target speech in older but not younger adults.

Self-reported presence of higher levels of environmental distractions was associated with lower perceived support for creativity at work and job satisfaction (Stokols et al., 2002). This work suggested that distractor-initiated psychosocial changes may have to be considered as mediators in task learning.

Changes to working memory may affect the efficiency of the learning process. Working memory, a component of short-term memory, involves manipulation, storage, and transformations of information over short time spans (e.g. mental calculations). See Park and Schwarz (2000) for a detailed discussion. Information retained in short-term memory is often taxonomized as spatial or verbal-phonetic in nature (Baddeley, 1986). Age-based decrements in working memory can be substantial and are thought to result from a decline in attentional resources (Craik and Byrd, 1982), processing speed (Salthouse and Somberg, 1982), or the inability to inhibit irrelevant information (Hasher and Zacks, 1988). Whatever the bases for such observations, working memory capacity appears to decline as one ages; increasingly so when task demands are heavy (Park and Schwarz, 2000).

Older adults may also experience reductions in perceptual or motor bandwidth capacity. Slowing rate of information sampling can produce aliasing of inputs and result in confusion or misinterpretation of the sensory state. Age-associated reductions in information processing may result from a generalized organic neurological degradation that slows either components or the entire cognitive system (Birren and Schaie, 1990). The "generalized slowing hypothesis" suggests that age-related changes in information processing rates are due to general reduction in capacity rather than any specific type of stage of information processing. Cross-sectional and longitudinal studies have found that both simple and complex reaction times are slower and less accurate with aging (Salthouse and Somberg, 1982; Welford, 1985).

Task perceptual load may affect the impact of a distractor. Low perceptual or cognitive workloads may increase tolerance of irrelevant sensory input or baseline elevations in cognitive workload imposed by potential age-induced organic changes. Maylor and Lavie (1998) found that older subjects were disproportionately affected by an irrelevant letter distractor when set size, or perceptual load, was small in a letter-search task. Their interpretation was that older adults may only differentially suffer from the effect of distractors when perceptual loads are low enough to allow attentional resources to be devoted to the distractors.

Performance decrements on tasks performed in the presence of distractors may also be dependent upon distractor mode and type of task (e.g. visual distractor with spatial task). The multiple resource theory (MRT, Wickens et al., 1987) predicts: (a) subject performance will be more disrupted when inputs are similar in mode and compete for the same sensory input channel, and (b) sensory input and resource time sharing will be more efficient when sensory information is presented using different modes (e.g. visual vs. verbal) and processed along different channels. When information processing approaches capacity in both channels, the information processing speed of the entire system appears to slow. Wickens et al. (1987) reported that time-sharing ability does not differ between age groups (ages 20–65 years) for tracking and memory search tasks that tap the speed and capacity of the human information processing system. However, their study used tasks that were both visual and auditory, subjects were not required to create and manipulate three dimensional objects, and they performed in a time-sharing task rather than a task where they were forced to perform in the face of distractors. Older adults have been shown to experience difficulty selectively attending to relevant information when it and the irrelevant information are both presented concomitantly in the same modality (McDowd et al., 1991).

Finally, age-related assembly performance decrements have been reported. Hancock (1967) found that learning times for manual assembly tasks became substantially longer for persons over the age of 40 unless the older person had previous related experience. Others have reported that motor performance slows with age, particularly with increased task difficulty (Ketcham and Stelmach, 2001).

Presentation mode and task complexity have been found to affect the learning rate for electronic assemblies (Goldman and Hart, 1965). Older adults may retain more knowledge and perform faster when instructions are provided in video form rather than in written form (Mykityshyn et al., 2002).

The goals of the study were to examine age-mediated resistance to visual, auditory and combined visual and auditory distractions during learning trials for a representative psychomotor or manual assembly task. Specifically, the objectives of the study were to determine if: (a) industry-relevant visual, auditory, or a combination of such distractors led to greater learning errors, total learning trials or performance times, (b) age had an effect upon learning manual assembly tasks, and (c) age mediated any distractor-based decrements in task learning metrics examined (e.g. number of learning trials and task completion times).

2. Methods

2.1. Subjects

Forty-two females and 24 males ($N = 66$), ranging between 18 and 65 years of age, participated in this study on an informed consent and unpaid basis. Subjects were grouped into three age categories: 18–28 years, 40–50 years, and 51–65 years. This design was intended to compare young subjects with two groups of older working age groups. The age group from 29 to 39 was not studied because we had no reason to believe performance would materially differ from the previous decade and because of economic constraints. One subject had extraordinarily poor learning performance and was dropped. Years of formal education reported by subjects were recorded. Gender of subject was not analyzed because it was not the purpose of the experiment and sample size limited such an investigation. Subjects were asked if: (1) they felt that their motor skills were on par with others from their age group, (2) they had any vision problems that prevented them from reading or performing tasks with their hands, and (3) they had any hearing problems that prevented them from conversing with their friends. Only subjects who answered "yes" to question 1 and "no" to questions 2 and 3 were permitted to participate in the study. See Table 1 for relevant demographic information.

2.2. Apparatus

A microcomputer with a 43.2 cm diagonal computer video display terminal presented a full screen instructional video to subjects using a screen resolution of 640×480 dpi.

Table 1
Demographic characteristics for subjects

Age group	Females	Males	Mean age (SD)	Mean years of education (SD)
18–28	10	12	23.3 (2.0)	16.7 (1.0)
40–50	16	5	44.9 (3.6)	16.4 (2.1)
51–65	15	7	56.7 (5.1)	16.0 (2.7)

The instructional video presented a required spatial and color configuration of nine red, blue, green and yellow four to 12 connector Lego Duplo^{TM} blocks. These blocks were 1.9 cm tall $\times$ 3.2 cm wide and either 3.2, 6.4, or 9.5 cm long. The blocks were chosen for their size to reduce potential age-related problems with grip and hand dexterity. Color and size of blocks and the spatial organization of the assembly tasks were noncontextual or hierarchical to avoid environmental support. Using the predetermined time system MOST^{TM}, the standard time for the task studied was 19.44 s. See Fig. 1 for a representative block assembly.

Blocks were organized and stored in bins according to color at equal distances of 26 cm from the center of the assembly platform. The assembly platform was 37.5 cm long, 25.4 cm wide, and 15.2 cm high above the supporting table. Two storage bins (5.4 cm high, 12.4 cm wide and 15.9 cm long) were located on the left of the assembly platform and two on the right. Bin tops were flush with the assembly platform surface.

The experimental task setup and view of the distractor monitor is provided in Fig. 2. Subjects sat approximately 45 cm from the screen. The visual angle for the instructional video was approximately 20° below the line of sight. A visual basic program was written to operate and monitor the experimental protocol in a systematic matter, to present the instructional videos and distractions to the subjects, and to document times for manual assembly performance.

2.3. Procedures

Following a standardized description of the objectives of the experiment, paradigm, procedures, health questionnaire and completion of informed consent form, a subject was randomly assigned to one of four distractor conditions. The four distractor conditions, constructed to be

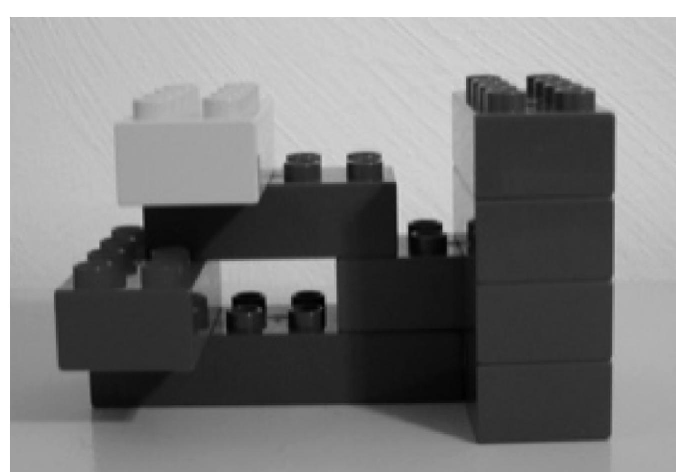

Fig. 1. An example of random block and color combinations that subjects learned to assemble.

Fig. 2. Subject seated at learning station and looking at learning videos that were presented on the monitor.

representative of the types of distractions that are encountered in industry, are described below:

1. *No distractors*. A digital picture that showed the same person as was seen in the video portion was shown full screen.
2. *Auditory distraction*. A female voice presented continuous, running commentary about weather, social functioning, work demands, etc. Verbal recordings were approximately 27 s in duration, cycled as a continuous loop, and consisted of, on average, 98 words in ten-word sentences that were presented at 68–70 dBA SPL. Four different verbal recordings that were used were presented across trials on a random-order basis.
3. *Visual distraction*. A video of an unrelated block assembly task, displayed as a mirror image, was presented in front of the subject to resemble an image of a worker sitting across from the assembly station performing a different assembly task. The video played the assembly task continuously until the experimental trial was completed.
4. *Combined auditory and visual distraction*. Both distractors were presented concomitantly.

These distractors were chosen to represent environmental distractors that could be present in the workplace. The auditory distractor can be considered to be "irrelevant speech" as it is discussed in the literature (Beaman, 2005). The video distractor was meant to simulate a person sitting across from the subject. This presentation has not been found in the literature for this type of experiment.

The subject sat at the assembly station and was given an opportunity to practice reaching for, moving and assembling the blocks in various patterns. Upon completion of self-paced practice, the subject was shown an instructional video of the block assembly task. The instructional video showed a person building the assembly. The instructional video provided a subject's eye view of the step-by-step assembly task and ran silent with no verbal instruction. When the instructional video stopped, the video disappeared from the screen.

The subject was instructed to complete the task as quickly and as accurately as possible and was then cued to start at the signal. If the subject made an assembly mistake (configurational or used the wrong colored block), the trial was stopped immediately. At this point, the participant had the option of watching the video again, or if they believed they understood the assembly process, they would just start another trial. Once a subject completed three consecutive error-free trials, the learning criterion was reached and the experiment was stopped by the computer. The distractions presented, started, and stopped with the assembly trials; distractions were not present during viewing of the instructional video.

Each subject saw only one distractor condition. Time to complete the psychomotor learning trials typically ranged between 20 and 25 min.

2.4. Analyses

An analysis of covariance (ANCOVA) model was used to test the effects of age and distractor condition upon number of initial error trials, total number of trials needed to complete the experiment, and final trial completion time as separate dependent metrics. Because higher levels of education have been associated with greater levels of cognitive maintenance across age, years of formal education was included as a covariate (see Albert et al., 1995 for model discussion). The model for the ANCOVA was used for all dependent metric tests and is shown below:

$$Y_{ijlkm} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\beta\gamma)_{jk} + (\alpha\beta\gamma)_{ijk} + \delta_l + \varepsilon_{ijklm}. \quad (1)$$

Index for gamma is k, where Y is the dependent metric (either number of initial error trials, total number of trials needed to complete the experiment or final trial completion time), μ the intercept, α the effect of age group, β the effect of auditory distractor, γ the effect of visual distractor, δ the covariate (years of formal education), $i = 1, 2, 3$, $j = 1, 2$, $k = 1, 2$, $l = 1, 2, \ldots, n$, $m = 1, 2, \ldots, n$.

For effect sizes of 20%, the experiment was designed to have at least 90% power for all main and/or interaction effects.

The rate of learning across age group and distractor conditions was determined for the short initial stage by analyzing learning curves for each subjects' first three consecutive correct trials. Logarithms of the original variables were used so that a linear statistical model would be appropriate. The logarithm of trial time was regressed against the logarithm of trial number and full and reduced regression models were compared (Neter et al., 1996). Using this analysis, any significant results would indicate differences in learning between the various distractor conditions. Regression equations for the full (2) and reduced (3,4,5,6) models are shown below.

Full model:

$$Y = \beta_0 + \beta_1 x + \beta_2 z_A + \beta_3 z_B + \beta_4 z_C + \beta_5 x \times z_A + \beta_6 x \times z_B + \beta_7 x \times z_C + \varepsilon, \tag{2}$$

where Y is the logarithm of trial time, X the logarithm of trial number, $z_A = 1$ if auditory distractor is present and 0 if otherwise, $z_B = 1$ if visual distractor is present and 0 if otherwise, $z_C = 1$ if both distractors are present and 0 if otherwise, ε the random variation.

Reduced models:

No distractor : $Y = \beta_0 + \beta_1 x + \varepsilon.$ (3)

Auditory distractor only:

$$Y = (\beta_0 + \beta_2) + (\beta_1 + \beta_5)x + \varepsilon. \tag{4}$$

Visual distractor only:

$$Y = (\beta_0 + \beta_3) + (\beta_1 + \beta_6)x + \varepsilon. \tag{5}$$

Both distractors:

$$Y = (\beta_0 + \beta_4) + (\beta_1 + \beta_7)x + \varepsilon. \tag{6}$$

The hypothesis to be tested to see if distractors or their interaction have a significant effect is

$$H_0 : \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = 0. \tag{7}$$

3. Results

3.1. Initial error trials

The ANCOVA for number of initial error trials indicated significant main effects for age and the interaction effect of age × auditory × visual distractor condition (see Table 2 and Fig. 3). Pairwise comparisons indicated that older subjects between 51 and 65 years of age took significantly more trials than either the middle age or

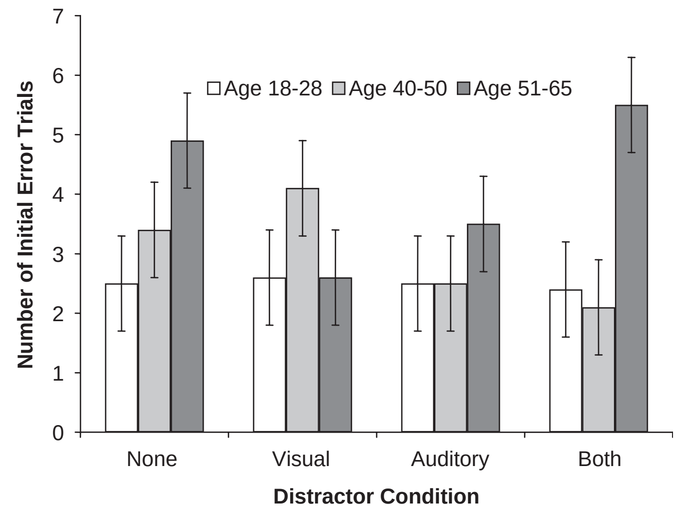

Fig. 3. Adjusted mean number of initial error trials by age group and distractor condition. The error bars represent standard errors.

younger subjects to learn to complete a correct assembly (regardless of distractor condition). Additionally, oldest subjects who were exposed to both visual and auditory distractors required approximately twice the number of error trials before being able to complete a correct trial when compared with the youngest subject group. Middle age subjects performed significantly different from older subjects, but similar to younger subjects.

Table 2
Analysis of covariance for the number of initial error trials

Error trials source	SS	df	MS	*F*-ratio	*p*
Corrected model	60.65	12	5.05	1.60	0.12
Intercept	2.79	1	2.79	0.88	0.35
Covariate (YFE)	18.47	1	18.47	5.84	0.02
Distractor audio (DA)	0.91	1	0.91	0.29	0.59
Distractor visual (DV)	0.00	1	0.00	0.00	0.99
Age (A)	27.82	2	13.91	4.40	0.02
DA × DV	3.83	1	3.83	1.21	0.28
DA × A	12.26	2	6.13	1.94	0.15
DV × A	0.28	2	0.14	0.04	0.96
DA × DV × A	18.73	2	9.37	2.96	0.06
Error	164.49	52	3.16		
Total	878	65			
Corrected total	225.14	64			

Note: YFE is years of formal education.

3.2. Total trials needed to reach the learning criterion

This experiment required subjects to complete three consecutive error free trials before learning trials were stopped. In many cases, subjects completed a number of incorrect trials before completing the assembly correctly. In those cases the total number of trials equaled the number of error trials plus three. However, in other cases subjects would complete a correct trial, and then make a mistake on the following trial before returning again to error-free performance. In those cases the total number of trials did not equal the number of error trials plus three because subjects actually completed more than three correct trials.

Many of these subjects who wavered between incorrect and correct performance belonged to the oldest age group. Members of the oldest subject group made an error trial after having already completed a correct trial approximately three times more often than did the youngest subjects. This outcome produced a 43% increase in learning trials when compared against the youngest subjects. As with the number of initial error trials, middle age subjects performed similar to younger subjects in total learning trials. The total number of required trials was greatest in the oldest subject groups when both distractors were present (see Table 3 and Fig. 4). Again, middle age subjects exposed to both distractor conditions performed significantly different from older subjects and similar to younger subjects.

Table 3
Analysis of covariance for the total number of trials needed to reach the learning criterion

Error trials source	SS	df	MS	F-ratio	p
Corrected model	178.68	12	14.89	3.016	0.03
Intercept	1.15	1	1.15	0.23	0.63
Covariate (YFE)	45.85	1	45.85	9.29	0.01
Distractor audio (DA)	11.07	1	11.07	2.24	0.14
Distractor visual (DV)	0.79	1	0.79	0.16	0.69
Age (A)	73.65	2	36.82	7.46	0.01
DA × DV	16.79	1	16.79	3.40	0.07
DA × A	20.17	2	10.08	2.04	0.14
DV × A	22.03	2	11.02	2.23	0.12
DA × DV × A	66.77	2	33.38	6.76	0.01
Error	256.76	52	4.94		
Total	3537	65			
Corrected total	435.45	64			

Note: YFE is years of formal education.

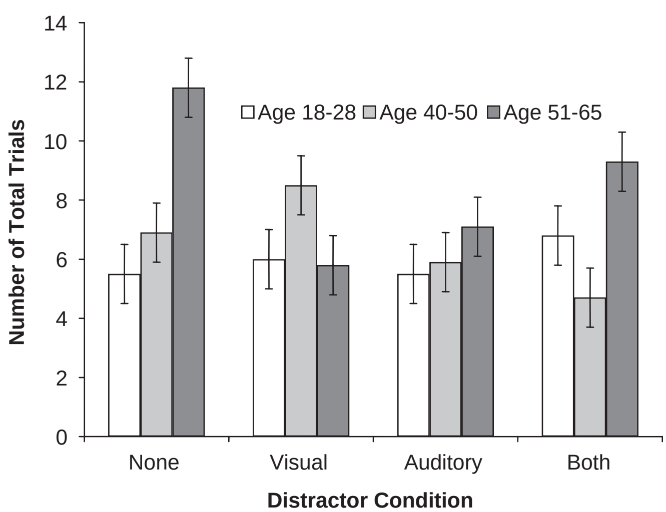

Fig. 4. Adjusted mean number of total trials needed to reach the learning criterion by age group and distractor condition. The error bars represent standard errors.

Table 4
Analysis of covariance for final trial completion time

Final trial time source	SS	df	MS	F-ratio	p
Corrected model	1140.20	12	95.01	2.26	0.02
Intercept	247.15	1	247.20	5.88	0.02
Covariate (YFE)	43.18	1	43.18	1.03	0.32
Distractor audio (DA)	41.87	1	41.87	1.00	0.32
Distractor visual (DV)	39.38	1	39.38	0.94	0.34
Age (A)	601.34	2	300.70	7.16	0.01
DA × DV	82.68	1	82.68	1.97	0.17
DA × A	87.69	2	43.84	1.04	0.36
DV × A	323.28	2	161.60	3.85	0.03
DA × DV × A	65.53	2	32.77	0.78	0.46
Error	2184.50	52	42.01		
Total	52 317.00	65			
Corrected total	3324.60	64			

Note: YFE is years of formal education.

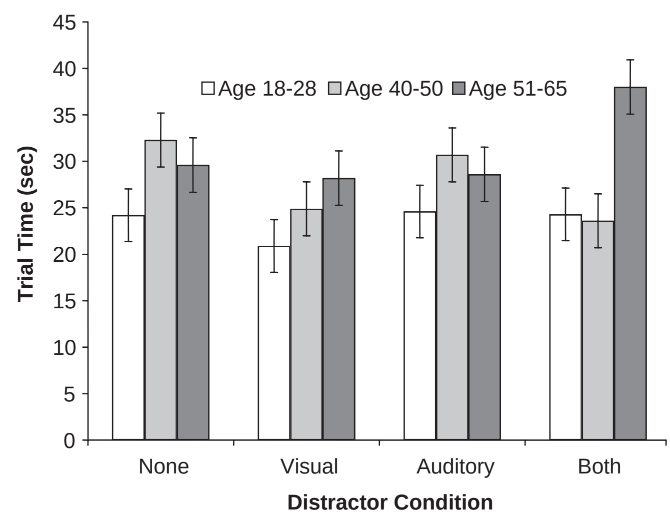

Fig. 5. Adjusted mean final learning trial completion times by age group and distractor type. The error bars represent standard errors.

3.3. Trial time at point of reaching learning criterion

Older subjects took significantly more time to complete their final trial, and older subjects' performance was more greatly affected by visual distractors than was either middle age or younger subjects' performance. Auditory distractors did not affect the performance for any subjects. Unlike the error metrics (initial error trials and total trials), middle age subjects performed similar to the oldest subjects, with middle and oldest subjects requiring significantly more time to complete the final trial than did the youngest group (see Table 4 and Fig. 5).

3.4. Learning curve

Learning curves were compared across age and distractor condition using indicator variables with full and reduced regression models (Neter et al., 1996). Logarithm of trial time was regressed against logarithm of trial for the first three consecutive correct trials by age and distractor condition. The slopes of the lines (B) were compared to determine differences in the rate of learning between the distractor conditions. No differences between regression models for age were found, but the dual distractor was found to be significantly different from the no distractor condition. Learning, as evidenced by a significant regression model, was present only in the no distractor condition. Table 5 shows regression coefficients for all data and Fig. 6 shows data points for all distractor conditions with regression functions for the no distractor and the distractor conditions.

3.5. Correlations

Pearson-product moment correlation analysis showed only weak positive correlations between age and the task

Table 5
Regression coefficients for comparing regression lines between distractor conditions using indicator variables

Model	B	Std. error	Standardized coefficients	t	p
			β		
(Constant)	1.67	0.07		23.61	<0.01
None (N)	−0.23	0.09	−0.33	−2.58	<0.01
Distractor audio (DA)	−0.15	0.11	−0.52	−1.46	<0.15
Distractor visual (DV)	−0.17	0.11	−0.56	−1.66	<0.10
Both distractors (DA DV)	−0.25	0.11	−0.76	−2.27	<0.02
DA × N	0.17	0.14	0.40	1.19	<0.24
DV × N	0.16	0.13	0.39	1.17	<0.24
DA DV × N	0.33	0.14	0.78	2.36	<0.02

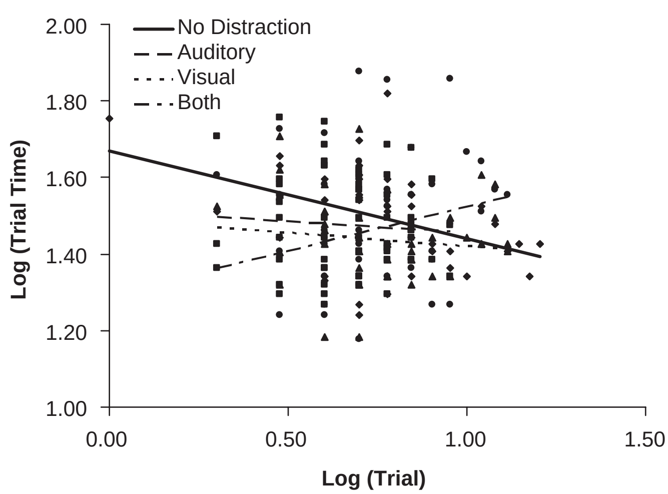

Fig. 6. Learning curves for last three consecutive correct trials for each of the distractor conditions; none (diamond), auditory (square), visual (triangle), and both (circle). Lines correspond to linear regression lines.

learning metrics (see Table 6). No significant correlations were found between age and years of formal education. No correlations were found between number of errors and trial completion times. No correlation was obtained between error rates and performance times; indicating no speed-accuracy trade-offs in the dataset.

4. Discussion

The tests given were meant to represent learning demands and distraction levels that older workers could reasonably expect to encounter in typical service or manufacturing industries; environments where cyclic learning of simple psychomotor tasks is common. The psychomotor learning task examined in this study was sufficiently limited in complexity that the number of trials needed to reach the learning criterion was low, and trial completion times were comparable to those predicted by widely used predetermined time systems. If this psychomotor learning task is representative of those found in many industries, the oldest subject group experienced

Table 6
Pearson correlation coefficients for factors, covariates, and dependent variables

	1	2	3	4	5
1. Initial error trials					
2. Total trials	0.837**				
3. Trial completion time	0.210	0.110			
4. Subject age	0.282*	0.318**	0.425**		
5. YFE	0.139	0.073	−0.030	−0.138	

Note: YFE is years of formal education.
*Correlation is significant at $p<0.05$, two-tailed.
**Correlation is significant at $p<0.01$, two-tailed.

material distraction effects only when industrially relevant levels of visual and auditory distractions were presented.

The findings presented concur with previous studies that reported a general decrement in speed-accuracy psychomotor performance in older subjects (Ketcham and Stelmach, 2001), and when older subjects are asked to learn novel tasks (Salthouse and Somberg, 1982). The oldest subject group's final trial completion times were significantly greater than the youngest group, and they were especially affected by visual distractors. This elevation occurred in the face of no effects with the youngest group. No correlation between trials needed to reach the learning criterion and final trial performance time were found, indicating that subjects complied with the instruction set and did not adopt a speed-accuracy trade-off.

These findings demonstrate that for the occupationally relevant auditory and visual distractors studied, neither distractor condition alone was sufficient to materially compete for sensory and cognitive resources that are required for learning a novel non-contextual psychomotor task examined in this study.

When activities required effortful processing, as in learning tasks, age proved to be an important determinant of performance (Lichty et al., 1986; Park and Schwarz, 2000; Ratner et al., 1988; Wishart et al., 2000). Visual-spatial cognition has also been reported to be more age-sensitive than verbal cognition (Jenkins et al., 2000; Salthouse et al., 1990). Visual distraction decrements did occur in trial times with the oldest subject groups, while auditory distraction did not lead to performance decrements. However, no comparable results were found in the number of learning trials that were required to reach the learning criterion. When both distractors were presented, then both metrics of learning, number of trials and cycle times, were degraded. These findings suggest that the distractors were sufficiently mild that only when combined did their resource demands become problematic for the oldest subject group.

Sixty-nine percent of the 16 subjects, who erred in the assembly task after demonstrating a correct assembly trial, were in the oldest group. This event was associated with greater numbers of trials to reach the performance criterion and poorer psychomotor performance times. This finding indicates that either rehearsal or working memory maintenance is more susceptible to disruption in the oldest subjects. The aim of this experiment, however, was not to examine the effects of aging upon psychomotor performance. Increased difficulty with learning the task sequence in the presence of distractors may have contributed to elevated task assembly cycle times in that subjects had to overcome negative transfer effects in psychomotor sequences.

Analysis of learning data showed that distraction was not beneficial in the rate of learning; that was particularly true for the oldest subject group. If distractions were uncoupled or absent, then performance for the oldest subject group was not materially different from that of other subject age groups. This finding indicates that the oldest subject group could learn the tasks comparable with younger subjects if the distractor burden was limited or absent. In this case, one could either eliminate irrelevant conversation or direct view of coworkers learning or performing different psychomotor assembly tasks, or both. Each of these interventions would be required only during the training or learning phase of work, and all combinations could be easily achieved in most industries through simple separation of worker cells or avoiding direct and large visual field presentation of workers performing different manual activities.

Probationary or employment selection tests of older workers in the presence of distractors may provide false indicators of older worker capacity to learn or to perform psychomotor tasks. Such evaluation periods should evaluate initial performance capacity in the absence of combined distractors, or once tasks are learned and positive transfer effects are capitalized upon by older workers in the presence of distractor fields (Hancock, 1967).

Failure to find systematic relationships among subject age, distractor condition, and learning performance metrics, indicates that significant individual differences in other capabilities may have influenced learning performance; perhaps to a greater extent than that of age, distractors, or a combination of both. Individual differences in positive transfer of psychomotor performance, perceptual field dependence, spatial reasoning ability, and other individual differences have not been addressed in this paper. Individually or collectively those factors may have stronger impact upon worker performance than the effect of age and are currently being studied.

Final psychomotor performance or cycle times in the presence of distractors were not studied for two reasons: (1) if age, distractor or interaction effects were not found in learning trials, then one could reasonably presume that post-learning distractor effects would not be operationally meaningful, and (2) post-learning distractor effects might have psychosocial and other bases that exceeded the logistical capacity of this experiment. In this study, subjects demonstrated learning criterion performance times that were comparable to those predicted by a predetermined time system, indicating that post-learning distractor effects, if present, would not be material in nature.

5. Conclusions and recommendations

These findings corroborate previous research that found a general decrement in speed-accuracy psychomotor performance, and in learning novel tasks, in older adults. The oldest group required significantly more trials to learn the task than did the youngest subjects. Older subjects who were exposed to both auditory and visual distractors, on average, took twice the number of learning trials than did those in the youngest group.

Results indicate that elimination or uncoupling of irrelevant verbal distractors, or highly relevant but misdirecting visual-spatial stimuli, may provide material benefit to older workers during early learning of manual assembly or psychomotor tasks. The data indicate that the distractors studied are not likely to have material post-learning impact upon comparable psychomotor or manual assembly tasks examined in this study.

Worker selection based upon performance during early learning or probationary periods, or when immersed in highly distractive environs when learning tasks, may not accurately reflect older worker performance nor their resistance to or tolerance of distraction when tasks are highly practiced or over-learned. Selection decisions should be made in the absence of such phenomena, or made at the post-learning stage.

Further study is recommended to determine: (1) if individual differences in distractor tolerance (e.g. field independence) and spatial reasoning skills are more important than age or age-mediated distractor effects found in this study, (2) interaction effects between different task complexity levels, and (3) whether profound distractors can impact learned contextual or non-contextual psychomotor or manual assembly tasks.

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