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Age and Experience Effects on the Interpretation of Orthographic Drawings of Three-Dimensional Objects

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Adults of different ages and experience levels attempted to recognize wire-frame drawings of 3-dimensional objects originally displayed in orthographic views. Although only slight age relations were evident on a measure of decision accuracy in the criterion task, increased age was associated with poorer performance on several tasks hypothesized to assess component processes. Furthermore, there was no significant alteration in any of the performance measures by statistically controlling for amount of relevant experience, and there was no evidence that people of different ages, or different levels of experience, relied on different abilities to perform the criterion task. These results seem to imply that experience neither mediates nor moderates age-related influences on certain measures of relatively basic cognitive processes.

In several recent projects, my colleagues and I (e.g., Salthouse, Babcock, Skovronek, Mitchell, & Palmon, 1990; Salthouse & Mitchell, 1990) found that age-related influences on measures of spatial visualization ability were largely independent of the amount of experience the research participants had received with relevant activities. This was true in comparisons restricted to practicing architects in the Salthouse et al. study and when the research participants were categorized with respect to the amount of experience they reported with activities presumed to require spatial abilities in the Salthouse and Mitchell study. The apparent implication of these results is that experience neither mediates nor moderates age-related differences in certain measures of spatial ability. However, a potential limitation of the earlier studies is that the measures of spatial ability were not deliberately selected to be similar to any particular occupational or leisure activity. Instead, the measures were based on conventional psychometric tests or computer-controlled variants of those tests. The primary purpose of the present project was to examine interrelations of age and experience on measures of spatial ability derived from specially created tasks postulated to be very similar to activities performed by many engineers.

The criterion task in this project consisted of the recognition of three-dimensional objects portrayed initially as sets of three orthographic drawings and, subsequently, as single, wire-frame drawings (see the top panel of Figure 1 for an illustration). A strong argument can be made that the interpretation of these kinds of technical drawings of three-dimensional objects is a critical skill for many engineers because technical drawings are necessary for the transition from the design to the construction of nearly all objects. Moreover, accuracy in both producing and interpreting drawings is extremely important in the engineering profession because the drawings frequently function as a legal document specifying exactly what is to be constructed, and a failure of either representation or interpretation could result in time-consuming delays or possibly even expensive litigation.

Although engineers may not be required to produce drawings at all stages of their careers, graphical comprehension is likely to be important throughout one's professional life. Giesecke, Mitchell, Spencer, Hill, and Loving (1969, p. 7) have even asserted that an engineer deficient in the ability to understand technical drawings is "professionally illiterate." A further indication of the importance of technical drawings in engineering is evident in the fact that nearly all engineering curricula include at least one course on mechanical drawing or engineering graphics and that items related to the interpretation of technical drawings are often included in exams for the professional certification or licensing of engineers. These considerations all suggest that the interpretation of technical drawings is an activity with considerable relevance to the practicing engineer.

The most widely used method of representing three-dimensional objects is the orthographic projection system in which the object is portrayed by two-dimensional views of the top, front, and right surfaces of the object. The strategy often recommended in textbooks (e.g., Giesecke et al., 1969; Hoelscher, Springer, & Dobrovolny, 1968; Luzadder, 1968; Rodriguez, 1990), and preferred by instructors of engineering graphics courses (Salthouse & Rodriguez, 1990), for determining the three-dimensional object represented by the three orthographic views is to project each surface onto an outline box and then to mentally cut out the extraneous regions. For example, application of this strategy to the set of orthographic drawings in the top left panel of Figure 1 would involve folding the top view down and back along its front horizontal axis into the picture plane and folding the right view back along its left vertical axis into the picture plane. This should result in a three-di-

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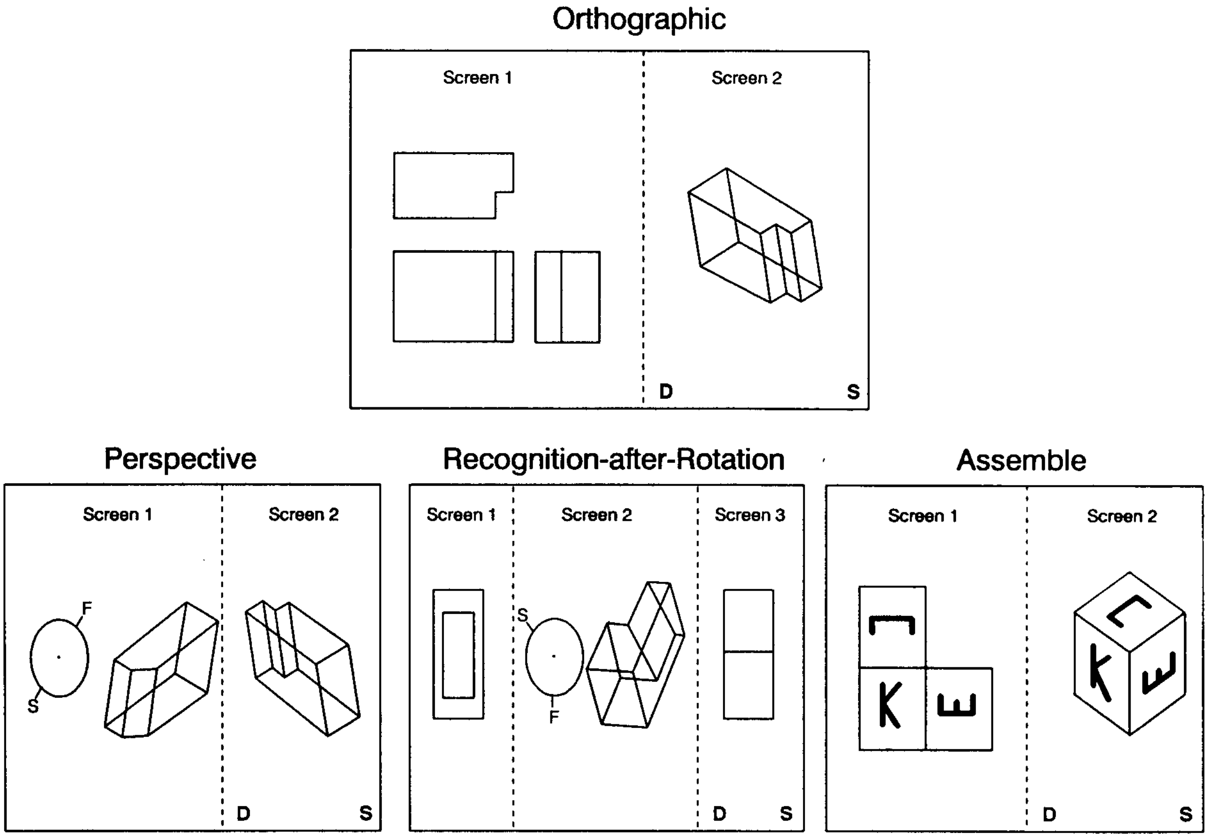

Figure 1. Illustration of displays in successive screens of trials in the four experimental tasks. (The labels of the screen number were not presented in the actual tasks, and the letters D and S in the bottom of the screens were replaced by the words *different* and *same* in the actual tasks as reminders of the response assignment. S = starting viewing point; F = final viewing point.)

mensional representation resembling the object portrayed in Screen 2.

Analysis of this recommended strategy suggests that it involves at least three distinct components. The first is deciding how an object or surface would look when viewed from a different perspective; the second is preserving the altered perspective of one surface while transforming another object or surface; and the third is the coordination and assembly of the information from the different perspectives into a coherent three-dimensional object. The tasks created to assess these hypothesized components are illustrated in the bottom panel of Figure 1.

The task labeled *perspective* was designed to evaluate the ability to recognize an object after it had been rotated or spatially transformed a specified amount. The first display on a trial in this task illustrated the object that was to be rotated and also contained a display of the starting (S) and final (F) viewing points of the object. Instructions indicated that the respondent should imagine that the object was viewed from the position on the circle marked *S* and that he or she then walked around to the point marked *F.* The task was to decide, with a same–different response, whether the object represented in the second display corresponded to how the object in the initial display would appear if viewed from the new perspective.

The task labeled *recognition-after-rotation* involved three successive displays. The first and third displays were of a single orthographic view of an object, which the respondent was to judge as either the same–different with respect to one another. The second screen in the trial contained a wire-frame view of a different object and a reference circle indicating the S and the F perspectives for viewing the object. The respondent was instructed to try to rotate the object on the screen such that it would appear the same as if it were viewed from Position F on the reference circle. As much time and rotation manipulations as needed were allowed for this rotation process. Note that this task really involves two distinct activities—the primary requirement of making a same–different judgment to the orthographic drawing in the third display, and the interpolated activity of rotating the different wire-frame object in the second display.

The task labeled *assemble* involved two displays and required a same–different decision regarding whether the orthographic views in the first screen and the three-dimensional drawing in the second screen could represent the same object. Familiar symbols on the faces of a cube were used as the stimulus material in this task to emphasize the integration or assembly component, rather than the ability to deal with potentially novel spatial materials.

Two independent studies were conducted with different groups of participants. Only college students participated in the first study because its primary goal was to examine the relations between the experimental measures and measures of performance on standardized tests of three potentially relevant cognitive abilities. The second study involved adults of different ages and experience levels to investigate the interrelations of age and experience on the performance of the experimental tasks. Because the experimental tasks were identical in both studies, the general method is described first.

Method

All participants performed the four tasks illustrated in Figure 1 in the following order: (a) orthographic, (b) perspective, (c) recognition-after-rotation, and (d) assemble. Each of the tasks was presented on a microcomputer, with the first screen displayed for 4.5 s, and the second (or third in the recognition-after-rotation task) screen displayed for an unlimited time to allow the subject to respond. Responses were depressions of the "slash" (/) key on the keyboard for same and of the *Z* key for different. Rotation of the wire-frame object in the second screen of the recognition-after-rotation task was carried out by depressions of the left and right arrow keys on the keyboard.

The stimulus materials used in the tasks were orthographic and wire-frame drawings of relatively simple three-dimensional objects. Approximately 150 pairs of similar objects were identified, and complete (orthographic and wire-frame) sets of drawings were created for each member of the pair. Selection of the drawings eventually included in the experimental tasks was based on several successive pilot tests and accompanying item analyses. Pairs of similar objects were needed so that the corresponding drawings for the other member of a given pair could be used as the incorrect or as the different alternative (for 50% of the trials) in the orthographic, perspective, and recognition-after-rotation tasks. The different alternatives (also on 50% of the trials) in the assemble task were created by altering the orientation of one of the letters from a correct set of drawings.

Each task was preceded by a brief description of the instructions and the examiner's offer to answer any questions left unclear by the instructions. The participant then performed a set of five practice trials as many times as desired (with feedback on accuracy after each set) until he or she felt comfortable about the nature of the task. A total of 30 different experimental trials were presented, with accuracy feedback provided after each response. The accuracy feedback consisted of the words *correct* or *incorrect* for the same–different decisions. Additional feedback for the rotation component in the recognition-after-rotation task consisted of a display of the reference circle with portrayal of the S, desired F, and actual F viewing positions. The average accuracy achieved across the 30 experimental trials was also displayed after each task.

Immediately before the first task, each participant answered a set of questions about his or her recent experience with several activities and rated his or her ability with each activity. The experience information was reported in terms of the average number of hours per month spent performing the activity during the last 6 months, and the ability ratings were on a 5-point scale ranging from 1 (*high relative to the average adult*) to 5 (*low relative to the average adult*). The activities included in the questionnaire are listed in Table 1, along with the means and standard deviations of the responses in the two samples. Several activities assumed to be unrelated to proficiency with spatial tasks were included to allow general response tendencies to be differentiated from reports of specific experience and abilities.

After completing the experimental tasks, the participants were asked to rate how familiar the tasks and stimulus materials appeared. Ratings were made on a 5-point rating scale ranging from 1 (*very unfamiliar*) to 5 (*very familiar*).

Study 1

Participants in the initial study performed the experimental tasks just described and six paper-and-pencil tests often used as markers of spatial visualization, inductive reasoning, and perceptual speed abilities. The purpose of these additional measures was to allow a determination of the factor-loading pattern of the new measures by reference to established abilities.

Method

Subjects. Participants in the study were 121 college undergraduates, 82 women and 39 men, with a mean age of 20.0 years. (No significant gender differences were evident in any of the experimental measures, and consequently this classification variable was ignored in all subsequent analyses.) Compensation for participation in the 2-hr session consisted of credit toward a course requirement.

Procedure. Before performing the experimental tasks, the participants in Study 1 were administered six paper-and-pencil tests. The six tests, and their respective time limits, were as follows: paper-folding (3 min), surface development (6 min), letter sets (7 min), series completion (5 min), number comparison (1.5 min), and finding As (2 min). All tests were from the Educational Testing Service Kit of Cognitive Reference Tests (Ekstrom, French, Harman, & Dermen, 1976), except the series completion test, that was from the Shipley Institute of Living Scale (Shipley, 1986). Each test was administered according to the published guidelines, and performance was represented by the number of items answered correctly.

Results and Discussion

Means and correlations among the experimental measures are summarized in Table 2. Three points should be noted about the values in this table. The first is that the mean levels of performance are near the middle of the effective performance range (i.e., chance is 50% with a two-alternative, same–different decision), indicating that most scores were probably not limited by floor or ceiling restrictions. The second point is that although the estimated reliabilities are not as high as one might hope, they are nevertheless acceptable for the present purposes. And third, although all the correlations between the experimental measures were positive, none of them was very large. This suggests that the measures were not all assessing exactly the same construct.

Table 3 contains the results of the factor analysis with varimax rotation conducted on the data from the six paper-and-pencil psychometric tasks and from the four experimental tasks. Three factors had eigenvalues greater than 1.0 and were retained in the final factor solution. The loading patterns for these factors suggest that the first factor corresponds to spatial visualization ability and that the third factor reflects perceptual speed. The second factor can probably be interpreted as reflecting reasoning, but it is more complex than the other factors because the reasoning tests load nearly equally on all three factors.

The most interesting aspect of the results in Table 3 is that the experimental measures load exclusively on the first 2 factors, with measures from the orthographic and perspective tasks loading on the Spatial Visualization factor and measures from the recognition-after-rotation and assemble tasks loading on the mixed factor, which probably consists mainly of Reasoning. It can therefore be inferred that the experimental measures are assessing abilities related to spatial visualization and inductive reasoning, but independent of perceptual speed.

Means and standard deviations of the responses to the experience and self-rated ability questions are summarized in Table 1.

Table 1
Means and Standard Deviations of Experience–Ability Questionnaire Responses

	Ability rating				Recent experience			
	Study 1		Study 2		Study 1		Study 2	
Activity	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Reading books, magazines, or newspapers	2.1	1.0	1.8	0.9	39.4	35.0	47.0	54.9
Managing or supervising other people	2.5	1.0	2.4	1.0	17.9	33.2	42.9	63.4
Developing and implementing long-term plans	2.4	0.9	2.3	1.0	13.0	18.2	18.2	29.7
Considering how an object or building would look from a different viewing position	2.6	1.1	2.4	1.2	7.0	15.7	11.1	24.0
Producing or interpreting technical drawings (e.g., blueprints) or 3-dimensional objects	2.6	1.1	2.6	1.3	10.2	22.2	15.4	36.3
Using computer-assisted design or computer-assisted manufacturing computer programs	2.8	1.1	3.3	1.4	7.1	18.8	11.1	34.1

Note. For ability ratings, 1 = high and 5 = low. Recent experience was measured in terms of the average number of hours per month that were spent performing the activity in the last 6 months.

These data were also subjected to a factor analysis with varimax rotation to identify meaningful constellations of responses. Results of the factor analysis are summarized in Table 4.

The factor analysis yielded five factors with eigenvalues greater than 1.0. The loading patterns suggest that the factors represent Subjective Ability With Relevant Activities, Subjective Ability With Other Activities, Experience With Relevant Activities, Experience With Other Activities, and Experience With Computer-Assisted Design–Computer-Assisted Manufacturing (CAD–CAM) Activities. The bottom portion of Table 4 contains the correlations between each of these factors and the experimental measures. The most noteworthy aspect of the correlations is that only the negative relations between the factor representing self-rated ability with relevant spatial activities and performance in the orthographic and perspective tasks were significantly different from zero. This indicates that people who rate their abilities as higher than average (i.e., lower numbers on the rating scale) perform somewhat better in these tasks than people who rate their abilities lower.

The average rating to the postexperimental question concerning the familiarity of the tasks and stimulus materials was 2.3. The familiarity rating was not significantly correlated with any of the factors from the experience–ability questionnaire responses, but it was positively correlated with each of the experimental measures. The correlations were low (i.e., the range was .13 to .27), however, and only that ($r = .27$) with the measure of accuracy in the orthographic task was significantly ($p < .01$) greater than zero.

Table 2
Correlation Matrix for Study 1 (N = 121)

Variable	1	2	3	4	5
1. Age	—	−.01	−.10	.11	−.02
2. ORTHO		**.60**	.50*	.25*	.16
3. PERS			**.78**	.29*	.20
4. REC-ROT				**.79**	.25*
5. ASSEM					**.60**
M	20.0	72.5	75.3	87.1	83.6
SD	1.6	11.8	14.6	13.2	9.0

Note. Boldfaced numbers indicate estimated reliabilities computed by boosting the odd–even correlation by the Spearman-Brown formula. ORTHO = accuracy in the orthographic task; PERS = accuracy in the perspective task; REC-ROT = accuracy in the recognition-after-rotation task; ASSEM = accuracy in the assemble task.
* $p < .01$.

The results of this initial study were encouraging in at least four respects. First, the experimental tasks seemed to be understood by all participants and yielded measures with averages near the middle of the measurement scale and with acceptable levels of reliability. Second, the various measures were not simply alternative reflections of the same construct because the correlations between them were not very high, and they did not all load on the same factor. Third, the factor analysis revealed that the measures were related to Spatial Visualization and Inductive Reasoning abilities, but not to Perceptual Speed ability. And fourth, the experience–ability responses could be grouped into meaningful clusters reflecting Experience or Subjective Ability with Relevant Activities or with Other Activities. In light of these satisfactory results from the initial study, I decided to proceed with the major investigation of the relations of Age and Experience on these measures.

Study 2

As mentioned in the introduction, the primary goal of this research was to examine the effects of experience as a potential mediator or moderator of performance on tasks presumed to be relevant to the occupational activities of engineers. The research participants in this study therefore ranged from 21 to 80 years of age, and attempts were made to solicit the participation of individuals with widely varying levels of experience interpreting technical drawings of three-dimensional objects.

Method

Subjects. Special efforts were made to recruit participants likely to have had experience with the generation and interpretation of technical drawings of three-dimensional objects, in addition to participants with little or no experience of this type. These efforts included numer-

Table 3
Factor Analysis for Study 1: Experimental and Psychometric Measures

Measure	Factor 1 (Spatial Visualization)	Factor 2 (Reasoning)	Factor 3 (Perceptual Speed)	h^2
Paper folding	.736	.150	.096	.573
Surface development	.812	.152	.181	.716
Letter sets	.311	.449	.371	.436
Series completion	.271	.562	.442	.584
Finding As	.054	−.183	.831	.727
Number comparison	−.089	.295	.702	.588
Orthographic	.782	.148	−.145	.654
Perspective	.757	.198	−.004	.612
Recognition-Rotation	.132	.786	−.047	.638
Assemble	.162	.628	.027	.421
Eigenvalue	3.388	1.542	1.021	

ous letters and phone calls to local engineering companies; CAD–CAM organizations; faculty members in mechanical, civil, and aerospace engineering departments; and letters sent to 1,800 graduates of the Georgia Institute of Technology with degrees in mechanical engineering. The final sample consisted of 132 men between 21 and 80 years of age. (Only men were included in the final sample because women made up a very small proportion of the relevant population, and consequently not enough women volunteered to allow meaningful analyses of possible gender, Gender × Age, or Gender × Experience effects.) Although most participants had engineering backgrounds, level of experience was evaluated by responses to the experience–ability questionnaire and was not based on occupational classification. The mean level of health, as rated by the participants on a 5-point scale, ranging from (1) *excellent* to (5) *poor*, was 1.40, with an age correlation of .25. The mean number of years of education was 16.2, with an age correlation of .12. Compensation for the approximately 1.5-hr session was $10.

Procedure. All participants completed the experience–ability ques-

Table 4
Factor Analysis of Experience–Ability Responses (Study 1)

Variable	Factor 1 (Relevant Subjective Ability)	Factor 2 (Other Subjective Ability)	Factor 3 (Relevant Experience)	Factor 4 (Other Experience)	Factor 5 (CAD–CAM Experience)	h^2
Self-rated ability						
Reading	.149	.628	−.121	−.103	−.161	.468
Managing	.169	.792	.155	.109	.211	.737
Planning	.038	.775	.155	−.319	−.009	.728
Perspective	.760	.174	−.077	−.020	.140	.633
Technical drawing	.803	.093	−.164	.018	.111	.692
CAD–CAM	.655	.108	.057	−.206	−.224	.537
Hours per month						
Reading	−.121	−.111	.034	.795	−.116	.673
Managing	.362	−.227	.344	.067	−.627	.698
Planning	−.010	−.081	−.041	.789	.106	.642
Perspective	−.196	.036	.822	−.001	−.020	.717
Technical drawing	.014	.094	.836	−.023	.072	.714
CAD–CAM	.286	−.134	.260	.030	.741	.718
Eigenvalue	2.497	1.770	1.450	1.229	1.012	
Correlations						
Age	.05	−.02	.08	.05	.04	
ORTHO	−.38*	.03	.16	.02	.06	
PERS	−.30*	−.01	.20	.14	.02	
REC-ROT	−.18	.06	.06	.00	−.07	
ASSEM	−.11	.05	−.05	.05	−.00	

Note. ORTHO = accuracy in the orthographic task; PERS = accuracy in the perspective task; REC-ROT = accuracy in the recognition-after-rotation task; ASSEM = accuracy in the assemble task; CAD–CAM = computer-assisted design or computer-assisted manufacturing.
* $p < .01$.

tionnaire, performed the four experimental tasks, and answered the postexperimental question concerning the familiarity of the tasks and stimulus materials. In addition, approximately 5 min at the end of the session was devoted to the performance of two computer-controlled versions of a digit-symbol substitution task. Results from these tasks are not described here because of plans to report them in the context of a larger study explicitly concerned with age differences in digit-symbol substitution performance.

Results and Discussion

The correlation matrix illustrating the correlations between the age of the research participant and the experimental measures is presented in Table 5. As in Study 1, the reliabilities of the measures are in the moderate range, and the correlations between measures are low to moderate. However, the greater range of participant ages in Study 2 resulted in significant negative correlations between age and the recognition-after-rotation and assemble measures. Perhaps because of lower reliabilities, the age correlations with the orthographic and perspective measures were not significantly different from zero, although they were in the same direction as the correlations with the other measures. Controlling amount of education or self-reported health status had relatively little effect on the age relations, as the age correlations after partialing education were −.17, −.18, −.41, and −.26, for the orthographic, perspective, recognition-after-rotation, and assemble tasks, respectively; and those after partialing health status were −.12, −.15, −.35, and −.27, respectively.

Although the instructions in each task emphasized accuracy, and not speed, of the decisions, the time participants took to make decisions in each task was also analyzed. These decision times averaged between 2.05 and 3.15 s across the four tasks, and all were significantly ($p < .01$) correlated with chronological age (i.e., the correlations ranged from .32 to .48). Angular error in the rotation phase of the recognition-after-rotation task was also analyzed and was found to correlate (.34, $p < .01$) with chronological age of the research participant. These results indicate that, in each task, increased age was associated with significantly slower decisions, in addition to somewhat less accurate decisions.

Means and standard deviations of responses to the experience–ability questionnaire are summarized in Table 3 and the results of the varimax rotation factor analysis performed on these data are summarized in Table 6. The factor pattern in Table 6 is generally similar to that from Study 1, with the exception that the CAD–CAM experience measure now loads on the Relevant Experience factor instead of combining with the managing experience measure to form a separate, fifth factor.

Table 5
Correlation Matrix for Study 2 (N = 132)

Variable	1	2	3	4	5
1. Age	—	−.16	−.16	−.39*	−.26*
2. ORTHO		**.63**	.40*	.33*	.26*
3. PERS			**.66**	.29*	.34*
4. REC-ROT				**.81**	.39*
5. ASSEM					**.79**
M	46.4	71.8	79.6	79.9	78.7
SD	15.6	12.0	11.5	14.5	13.0

Note. Boldfaced numbers indicate estimated reliabilities computed by boosting the odd–even correlation by the Spearman–Brown formula. ORTHO = accuracy in the orthographic task; PERS = accuracy in the perspective task; REC-ROT = accuracy in the recognition-after-rotation task; ASSEM = accuracy in the assemble task.
* $p < .01$.

Correlations of these factors with age and the experimental measures are displayed in the bottom of Table 6. Only two correlations were significantly different from zero, and both were negative. That is, increased age was associated with smaller amounts of relevant experience, and higher ratings of relevant ability (i.e., lower scores on the scale) were associated with a higher level of performance on the orthographic task.

The absence of significant correlations between the Relevant Experience factor and any of the experimental measures raises concerns that the experiential variation may have been too small to have revealed the expected main effects of experience. To explore this possibility, the research participants were divided into quartiles on the basis of their scores on the Relevant Experience factor, and then the absolute amount of experience contrasted for the 33 individuals in the top 25% and for the 32 individuals in the bottom 25%. The people in the bottom 25% reported an average of only 4.7 total hr per month devoted to the three relevant activities (i.e., considering how an object or building would look from a different viewing position, producing or interpreting technical drawings of three-dimensional objects, and using CAD–CAM programs), compared with an average of 120.5 total hr per month for people in the top 25%. Assuming these reports are valid, therefore, the individuals in the lowest 25% of the scores on the Relevant Experience factor were spending an average of a little over one half of a working day per month using relevant spatial abilities, whereas those in the highest 25% were spending an average of about 15 working days per month using these abilities. Despite these substantial differences in amount of experience, the two groups did not differ significantly in any of the experimental measures. These results make it unlikely that the relations between experience and performance on the experimental tasks were attenuated by a restricted range of relevant experience.

The responses to the postexperimental question concerning the familiarity of the tasks and materials are also informative about the validity of the experience ratings. The mean rating was 2.3 ($SD = 1.1$), and it was significantly ($p < .01$) correlated with the Relevant Experience factor ($r = .26$) and with performance in the orthographic ($r = .31$) and perspective ($r = .29$) tasks. These patterns indicate that people rating the tasks and materials as more familiar report more experience with presumably relevant activities, and also perform better on two of the experimental tasks, than people rating the tasks and materials as less familiar. The only other significant correlations with the familiarity ratings were with age ($r = -.24$) and the Relevant Subjective Ability factor ($r = -.25$). Older participants, and those rating their abilities with relevant activities to be lower than average (i.e., higher values on the rating scale), therefore rated the tasks and materials lower in familiarity than did younger participants or participants with average or high ratings of their own ability on relevant activities.

Two sets of multiple regression analyses were conducted on the experimental measures with age and the Relevant Experi-

Table 6
Factor Analysis of Experience–Ability Responses (Study 2)

Variable	Factor 1 (Relevant Experience)	Factor 2 (Relevant Subjective Ability)	Factor 3 (Other Subjective Ability)	Factor 4 (Other Experience)	h^2
Self-rated ability					
Reading	.104	−.009	.617	−.191	.429
Managing	.244	.303	.441	−.449	.547
Planning	−.016	.067	.891	.042	.801
Perspective	−.018	.855	.138	−.098	.759
Technical drawing	−.128	.901	.044	.014	.830
CAD–CAM	−.318	.522	−.151	.291	.481
Hours per month					
Reading	−.058	.233	−.120	.684	.540
Managing	.270	−.154	−.053	.715	.611
Planning	.512	−.002	−.457	.190	.507
Perspective	.638	−.229	.282	.218	.587
Technical drawing	.848	−.169	−.057	.025	.751
CAD–CAM	.779	.009	.088	−.111	.628
Eigenvalue	2.749	2.146	1.575	1.000	
		Correlations			
Age	−.29*	.07	−.08	.12	
ORTHO	.06	−.28*	.07	.10	
PERS	.11	−.21	.04	.03	
REC-ROT	−.01	−.22	−.10	−.14	
ASSEM	.18	−.10	.08	−.09	

Note. ORTHO = accuracy in the orthographic task; PERS = accuracy in the perspective task; REC-ROT = accuracy in the recognition-after-rotation task; ASSEM = accuracy in the assemble task; CAD–CAM = computer-assisted design or computer-assisted manufacturing.
* $p < .01$.

ence factor as predictors. The first analyses were intended to determine the extent to which the age-related effects might have been mediated, or possibly obscured, by age-related variations in experience. These analyses therefore examined the influence of age after partialing the variance associated with experience. The results revealed that the age effects were very similar before and after control of the Relevant Experience factor. To illustrate, the squared multiple correlations for age before and after entering the Relevant Experience factor in the regression equation were as follows: orthographic, $R^2 = .026$ before and .023 after; perspective, $R^2 = .026$ before and .018 after; recognition-after-rotation, $R^2 = .151$ before and .166 after; and assemble, $R^2 = .069$ before and .048 after. Because the attenuation of the age relations after control of a variable reflecting amount of experience was very small, it can apparently be inferred that most of those relations are not mediated by experiential variations.

The second set of regression analyses consisted of examining interactions of age and the Relevant Experience factor to determine whether experience might moderate the age relations on the experimental measures. These analyses therefore involved entering the Age × Relevant Experience cross-product interaction terms after both the age and Relevant Experience terms in the multiple regression equations. None of the interactions were significant—that is, $F(1, 128) < 2.28$, $p < .10$—with any of the experimental measures, implying that the age relations were also not moderated by amount of experience.

A final set of multiple regression analyses was carried out to examine the possibility that the manner in which proficiency was achieved in the criterion orthographic task varied according to the individual's age or amount of relevant experience. Three multiple regression equations were therefore created to predict performance on the orthographic task: the first with only the measures from the perspective, recognition-after-rotation, and assemble tasks as predictors; the second with the experimental measures plus age and interactions of age and the experimental measures as predictors; and the third with the experimental measures plus the Relevant Experience factor scores and interactions of those scores with the experimental measures as predictors.

The R^2 values increased across the three equations with values of .210, .238, and .252, respectively. However, only the perspective measure was a significant ($p < .01$) predictor of orthographic performance, and none of the Age × Experimental Measures or Relevant Experience × Experimental Measures interactions were significant. The absence of significant interactions indicates that there is no evidence that people of different ages, or with different amounts of experience, rely on different combinations of component abilities to achieve a given level of proficiency on the criterion task of recognizing three-dimensional objects in wire-frame views from orthographic drawings.

General Discussion

The major purpose of the research reported in this article was to investigate the interrelations of age and experience on tasks created to resemble an activity performed by many engi-