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Abstract
The purpose of this study was to develop a test that measures spatial skills relative to product development and apparel design. To provide some support for content validity, the test included components of spatial products, spatial storage, and spatial thought. As evidence of the type of spatial ability measured by the test, an established test that measures spatial relations (Differential Aptitude Test—Space Relations) (DATSR) was correlated with the newly developed test. To provide preliminary statistical data regarding the test, a between-subjects design study was conducted with clothing construction/patterning training (none, some) as the independent variable. Dependent variables were the Apparel Spatial Visualization Test (ASVT) and the DATSR. To evidence content validity of the test, scores on the ASVT should reflect improvement in spatial abilities as a function of training. Students with some training scored higher on the ASVT but did not differ in their scores on the DATSR compared to those with no training. This provides some evidence that the ASVT measures spatial skills specific to apparel design and product development. The ASVT and the DATSR were not significantly correlated.


There are hundreds of tests available to measure a variety of spatial abilities, including spatial relations, spatial orientation, and spatial visualization (Eliot & Smith, 1983). However, these tests are intended to measure general spatial abilities. The challenge for clothing and textiles educators and researchers is to identify and measure specific spatial abilities needed for mastering apparel design and product development. The purpose of this study was to develop a test that measures spatial abilities relative to apparel design and product development.

Product development is an important component of apparel merchandising. As defined by Frings (1996, p. 185), "Product development is the process of market and trend research, merchandising, design, and development of the final product." Kadolph and Langford (1998, p. 8) defined product development as "the design and engineering of a product so that it has the desired serviceability characteristics, appeals to the target market, can be made within an acceptable time frame for a reasonable cost, and can be sold at a profit." Glock and Kunz (1995) provided a similar definition for product development. They noted that preadoption product development includes developing designs, sketching, precosting, making first patterns, designing samples, testing materials, reviewing samples, determining design specifications, estimating costs, and standardizing fit.

The size and nature of the firm and its fashion orientation determine how product lines are developed (Jarnow & Dickerson, 1997). In large apparel manufacturing firms,
merchandisers may develop new lines and plan the overall fashion direction. Designers are part of the product development team and execute creative aspects of product development. In small apparel manufacturing firms, product development tasks may be performed by the owner or lone designer. Resident buying offices may employ design staffs to develop private label merchandise for client stores. Some retail firms create private label merchandise as a function of product development departments (Jernigan & Easterling, 1990). Other retail firms have expanded the responsibilities of the merchandising division to include product development; thus, buyers and merchandisers may have the title and associated responsibilities of a product development manager (Glock & Kunz, 1995). According to these descriptions, then, product development is a multi-faceted process of which designing is one component.

A variety of sources contain descriptions of the skills and abilities needed for success in a career in the creative arts, such as apparel design or product development. Dolber (1989, p. 12) noted that "the designer is a talented artist with a strong sense of color and line. The designer must be knowledgeable about fabrics and trimmings and be familiar with the patternmaking, fitting, draping, sewing, costing, and production process for each garment." In addition, the designer must be "imaginative and have an unusual flair for clothing and fabrics" (Dolber, 1989, p. 13). According to Dolber (1989), programs that train designers "generally include courses in drawing, pattern making, draping, sewing, fabrics and trimmings, principles of color and design, and the production and costing of garments" (p. 13). Mauro (1996) regarded creativity, curiosity, talent, and focused observation skills as crucial to success in a fashion career. Further, this author contended that the duties of a designer "encompass many disciplines, including sketching, patternmaking, and sewing" (p. 11), and require an eye for detail and an aesthetic appreciation for fashion as an art form. Mauro (1996) noted that an ideal curriculum would include "courses in art history, sketching, life (anatomical) drawing, garment construction, draping, pattern-making, textiles, and merchandising" (p. 17). To summarize, apparel design and product development require a foundation of specific knowledge, abilities, and skills that can be used in creative thinking, problem solving (inherent in the creation of every design), and development of design concepts.

Creative thinking, conceptual problem solving, and concept generation are associated with spatial abilities (Roth, 1993). According to Humphreys, Lubinski, and Yao (1993), individuals who scored high on tests of spatial abilities, compared to those who scored high on verbal or mathematics abilities, reported greater participation in hobbies which involved creating, shaping, or transforming objects in some way (e.g., sewing, drawing, and painting). MacDonald and Franz (1989) investigated whether math, logical reasoning, and spatial tests could predict success in a clothing construction course and found that the spatial relations test was the best predictor of course performance. Franz, MacDonald, and Grocott (1985, p. 38) noted that it was "clear from evaluating the tasks involved in fitting and clothing construction that a number of important cognitive skills are essential which enable the student to create an abstract image of the finished garment from the flat pattern." Thus, spatial abilities would seem to be important to designers, patternmakers, and other professionals involved with product development.

A designer uses spatial abilities when sketching a flat two-dimensional style, taking into account the garment's three-dimensional construction, drawing the garment's spatial divisions in proportion to the human body's spatial divisions, and including spatial details (e.g., darts, seamlines, trimming). A two-dimensional working sketch may be supplemented with notes regarding three-dimensional construction (e.g., shirring at waist to be in a 3:1 proportion) and one-, two-, and three-dimensional measurements of garment details (e.g., belt is 1" wide; pocket is 3" X 4"; the pant leg should resemble a bell with a circumference of 24" at the hem and 12" at the knee). Space, then, is an integral part of the structure of any three-dimensional garment and is a fundamental element in apparel design (Davis, 1996).

Space as a Fundamental Element in Apparel Design

Apparel design and product development involve spatial products, stored spatial information, and spatial thought. Spatial products are external products that represent space in some way (Liben, 1981). Spatial products in apparel design include any kind of external portrayal of a fashion object in any medium (e.g., working sketches, fashion illustrations, flat paper patterns, draped muslins, garments, advertisements of clothing, computer displays, and verbal descriptions of garments).

Spatial storage is any information about space contained "in the head" of an individual and of which he or she is unaware (Liben, 1981). Spatial information is stored as (a) truth propositions, (b) pure relations, (c) stimulus-response bonds, or (d) other formats (Liben, 1981). In apparel design, spatial storage might include truth propositions, such as "the angle of the dart legs remains constant without regard to its location around the pattern's outline" (Armstrong, 1995, p. 96). A flat pattern principle related to pure relations is that "a dart may be transferred to any location around the pattern's outline from a designated pivotal point without affecting the size or fit of the garment" (Armstrong, 1995, p. 82). Knowledge stored as stimulus-response bonds might include the steps and outcomes associated with the slash and spread or pivotal transfer methods of patternmaking. Spatial knowledge is sometimes stored in other formats, one of which is abstract, proposition-based memory representations. For example, application of the expressive qualities of the design elements and principles requires abstract proposition-based memory representations. By the end of a draping or flat pattern design class, students should have spatial knowledge specific to apparel design stored as easily accessible information. Both novice and expert designers should be able to apply spatial information to problem-solving situations (e.g., when creating a new style). Once an individual contemplates stored spatial information, it becomes spatial thought (Liben, 1981).

Spatial thought is concerned with or makes use of space in some way (Liben, 1981). For example, stored spatial information is reflected upon or manipulated in spatial problem solving or spatial imagery. Strategies involving spatial thought include (a) a relatedness search, (b)
stimulus analysis, and (c) checking (Baron, 1978). A relatedness search refers to searching memory for items that are related in some way to the spatial problem to be solved or manipulation of an object (e.g., remembering the shape of a pattern piece and how the finished garment piece made from that pattern piece looked). Stimulus analysis refers to evaluating a stimulus (i.e., a style) in terms of its component parts (e.g., enumerating the component parts—sleeves, skirt, bodice, collar). Checking refers to reexamining an initial response to evaluate other possibilities (e.g., “It looks as if the skirt is cut on the lengthwise grain; is it cut on the bias?”).

Spatial Abilities

Because of the requirements of working with space in both two- and three-dimensional visual shapes and form, professionals in product development and apparel design need highly-developed spatial abilities. One apparel company tested marker makers and discovered that predictors of marker maker job performance included at least three spatial abilities: spatial relations, spatial orientation, and spatial visualization (both two- and three-dimensional) (Lounsbury & Gibson, 1987).

Spatial relations ability involves identification of relatively simple stimuli after mental rotation (Salthouse, Babcock, Mitchell, Palmon, & Skovronek, 1990). For example, when a dart is rotated to a new position, a patternmaker should be able to imagine the shape of the resulting pattern. The ability to discern the arrangement of elements within a visual stimulus pattern involves spatial relations (Miller & Bertoline, 1991). For example, in the visual stimulus pattern of an apparel design there are many elements in a distinct arrangement, including darts, seams, edges, hems, openings, gathers, trims, and so forth.

Spatial orientation is “the comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude for remaining unconfused by the changing orientations in which a configuration may be presented, and the ability to determine spatial relations in which the body orientation of the observer is an essential part of the problem” (McGee, 1979, p. 4). For example, when draping garments, designers may stand the dress form in front of a mirror and analyze the design in the mirror for a different perspective. Viewing a mirror image requires changing the body orientation of the designer. Spatial relationships can be changed by altering the position of the observer, such as viewing a garment in a mirror, on a mannequin or a model, or on the self.

Spatial visualization requires mental manipulation of an entire spatial configuration often by changing the relationship of elements to one another (Salthouse et al., 1990). According to McGee (1979, pp. 3-4), spatial visualization is “the ability to mentally manipulate, rotate, twist, or invert pictorially presented visual stimuli. The underlying ability seems to involve a process of recognition, retention, and recall of a configuration in which there is movement among the internal parts of the configuration, or of an object manipulated in three-dimensional space, of the folding or unfolding of flat patterns...” In apparel design, spatial visualization ability is required to imagine the rotation of a working sketch (e.g., to imagine a back view or a side view by looking at a front view), the folding and unfolding of flat pattern pieces, and changes associated with addition, subtraction, or movement of components of a style (e.g., a yoke, seam lines, pleats, gathers, pockets).

Purpose of the Study

The purpose of this study was to develop a test that measures spatial skills specific to apparel design and product development. Content validity can be established by ensuring test items include the constructs defined in the relevant literature (Touliatos & Compton, 1988). Thus, to meet requirements of content validity, any test that purports to measure spatial abilities specific to apparel design and product development should include components of spatial products, spatial storage, and spatial thought. To determine whether the test measures spatial relations, spatial orientation, or spatial visualization, an established test that measures one of those abilities was concurrently administered and correlated with the newly developed test.

There is evidence that improvement in spatial abilities occurs as a function of practice and training (Lajoie, 1986). If training is important in fostering a high level of spatial ability, it might be expected that specialized training would result in improved performance on tests of specialized spatial abilities. A clothing and textiles curriculum generally contains a variety of courses that provide training in spatial abilities specific to product development and apparel design (e.g., clothing construction, fashion illustration, flat patternmaking, draping, tailoring). Evidence of the content validity of the test would be provided if students who had some training in clothing construction/patternmaking scored higher on the test than students who had no training.

Method

Materials

Research has shown that paper-and-pencil spatial tests can be used to measure spatial ability (Miller & Bertoline, 1991). For this study, two paper-and-pencil tests, the Apparel Spatial Visualization Test and the Differential Aptitude Test—Space Relations, were used to measure students’ spatial abilities.

The Apparel Spatial Visualization Test (ASVT) was developed by the authors to measure spatial visualization skills relative to apparel design and product development. The ASVT consists of 20 sets of pattern pieces that may be constructed in fabric to create a garment (see Figure 1). To the right of each set of pattern pieces are sketches showing the outside, front view of five garments. Students are to decide which one of the garments could be made from the pattern pieces shown (scores can range from 0-20). The ASVT includes a range of complexity; for example, the number of pattern pieces in a set ranges from two to seven. The ASVT contains elements of spatial products (i.e., flat paper pattern pieces, sketches of garments), spatial storage

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Figure 1. Example of Items in Apparel Spatial Visualization Test

(i.e., retention of details of various styles, retention of shapes of pattern pieces), and spatial thought (i.e., recall of the shape of a pattern piece and how the finished garment piece made from that pattern piece looked; a stimulus search to enumerate the component parts of each sketch).

An initial step in test validation involved comparing the ASVT with a test that measures the least complex spatial ability—spatial relations. Tests of spatial relations are less complex than corresponding tests of spatial visualization (Miller & Bertoline, 1991). The Differential Aptitude Test—Space Relations (DATSR) was chosen as a comparison measure because of its established reliability and validity.

For example, the DATSR has been found to have a split-half reliability of .77 and a low positive correlation with the following tests of spatial ability: Cube Comparisons (spatial orientation, .39), Card Rotations (spatial orientation, .44), and Paper Form Board (spatial visualization, .12) (Vandenberg & Kuse, 1978). The DATSR measures “the ability to visualize a three-dimensional object from a two-dimensional pattern, and to visualize how this object would look if rotated in space” (The Psychological Corporation, 1995, p. 161). The DATSR consists of 35 single stimulus elements (patterns) that can be folded into one of four figures located to the right of each pattern. Students are to
decide which one of the figures could be made from the pattern shown (scores can range from 0-35). The drawings always show the outside of the figures.

**Procedure**

Participants in this study were 49 women (mean age = 22.44) from two universities who were majoring in clothing and textiles. There were 10 freshmen, 2 sophomores, 14 juniors, 17 seniors, and 6 graduate students. Fourteen students indicated they had no clothing construction or patternmaking training. In classroom settings, students volunteered to participate in a study of how individuals form perceptual impressions of two-dimensional patterns and three-dimensional forms. Students first provided demographic information including age, sex, year in school, major, clothing construction and patternmaking training. Next, they completed the DATSR and finally the ASVT.

**Design**

A paper-and-pencil test of apparel spatial visualization was constructed by selecting pattern pieces and sketches of styles. Evidence for validity and reliability of the test was assessed using a between-subjects design with clothing construction/patternmaking training (none, some) as an independent variable. The dependent variables were scores on the ASVT and DATSR. Data were analyzed using descriptive statistics, correlation, and ANOVA while scale items’ internal consistency was assessed using Cronbach’s alpha.

**Results**

Scores on the ASVT ranged from 2 to 20 \((m = 12.55; \text{Cronbach's alpha} = .89)\). There was a nonsignificant correlation between the ASVT and the DATSR \((r = .3114)\).

Scores on the DATSR ranged from 9 to 35 \((m = 25.33; \text{Cronbach's alpha} = .91)\). Compared with a normative sample of over 5,300 women who were high school seniors (McGee, 1979), these scores would fall between the first and sixty-fifth percentiles with the mean between the thirty-fifth and fortieth percentile.

A one-way ANOVA with clothing construction/patternmaking training (none, some) as the independent variable and scores on the ASVT as the dependent variable revealed that those with some training \((m = 14.76, \text{SD} = 3.95)\) scored higher on the ASVT than those with none \((m = 7.57, \text{SD} = 3.55)\) (see Table 1).

A one-way ANOVA with clothing construction/patternmaking training (none, some) as the independent variable and DATSR scores as the dependent variable revealed no significant difference in DATSR scores between the group with training \((m = 25.94; \text{SD} = 8.08)\) and that with no training \((m = 23.43; \text{SD} = 6.56)\) (see Table 2).

**Discussion**

To evidence content validity of the test, scores on the Apparel Spatial Visualization Test should reflect improvement in spatial abilities as a function of training. Presumably, training in clothing construction and patternmaking includes spatial products, spatial storage, and spatial thought that are required to perform well on the test. This expectation was supported by these findings; those with clothing construction/patternmaking training compared to those with no training scored significantly higher on the ASVT.

Training versus no training in clothing construction/patternmaking did not result in significant differences on the DATSR. This suggests that spatial skills measured by the DATSR may not resemble spatial skills being taught in clothing construction and patternmaking classes.

We speculate that because the ASVT involves many stimulus elements and a number of processing operations, it may measure spatial visualization ability rather than spatial relations ability. Because the ASVT measures spatial skills specific to apparel design and product development, adding the ASVT to the battery of spatial tests used in Lounsbury and Gibson’s (1987) study might allow more accurate prediction of success among candidates for specific apparel industry positions.

The DATSR is currently used by many teachers and career counselors as a basis for advising students regarding appropriate careers. Mean scores in this study on the DATSR fell between the thirty-fifth and fortieth percentile as compared to a normative sample reported by McGee (1979). Students in the present study did not score well on the DATSR compared to the normative sample. It is not difficult to imagine these students receiving advice (perhaps erroneous) not to pursue a career in apparel design because their test scores did not show an aptitude for this career area.
As Humphreys, Lubinski, and Yao (1993, p. 259) noted, disciplines in the creative arts, in which spatial skills are particularly important, are "heavily dependent on self-selection by students and consequently, obtain smaller numbers of able students than they would if another definition of talent were accepted and implemented." Humphreys, Lubinski, and Yao suggest that such disciplines give substantial weight to students' grades in vocational courses that require creating objects. They also suggest that participation and achievement in hobbies that involve the same activities are valid indicators of a student's appropriate choice of a particular discipline. According to the latter authors, spatial tests have been used primarily to assist individuals in choosing occupations for which a high school education is considered sufficient. They suggest, however, that spatial tests could also be used in selecting students for high-level technical disciplines for which a baccalaureate degree is required (e.g., careers in the creative arts). Our study suggests that the DATSR is probably not the best spatial test to use for counseling students preparing for careers in apparel design and product development.

Limitations and Implications

Further research is being conducted to assess test-retest reliability of the ASVT. The current study offers only preliminary data on the validity and reliability of the test; additional data are necessary for further development. Due to the small sample used for developing this test, additional evidence of the test's reliability and validity with a larger and more diverse sample is needed. To determine which spatial abilities the ASVT is measuring, other tests of spatial abilities (e.g., spatial visualization tests) will be assessed for any relation to the ASVT.

The test shows promise of being a significant contribution to the tools available to measure the effects of training on skill development specific to apparel design and product development. For example, this test might be useful as a pretest-posttest for a class in flat patternmaking to measure the development of competency in apparel design analysis.

The topic of skills and abilities necessary for apparel designers and product developers is complex and multifaceted. This test measures only one ability necessary for success in apparel design and product development. More research needs to be conducted—not only with this test, but with methods of measuring other skills and abilities.

References