Adaptation of Sources of Inspiration in Knitwear Design

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ABSTRACT: In an experimental study of designing by adaptation, professional and student knitwear designers were videotaped designing sweaters based on a Persian rug or a 19th century tapestry. The designers used a range of source-triggered and goal-directed adaptation strategies to create adaptations ranging from the closest possible translations into the medium to radical transformations of abstract characteristics. While each strategy sometimes led to each type of adaptation, the source-triggered strategies were predominant for the easy-to-adapt source (the rug) and typically led to close adaptations; while the goal-directed strategies were more common for the more difficult source (the tapestry), and more often led to more radical transformations of the source. The professional designers made more use of goal-directed strategies than the student designers. The study supports the view that creative behavior can usefully be described in terms of consistent patterns resulting from both task demands and from cognitive capacities and learned skills.

All visuospatial design activities draw ideas from both previous designs and other sources of inspiration. The influence of various kinds of ideas on designed products is a central theme in cultural studies of design. But how designers use these sources of inspiration has been a relatively neglected question. What roles do different types of source play in the design process? What roles do sources of inspiration play in design thinking? What adaptation strategies do designers use? Do they employ a limited number of category prototypes as opposed to a multiplicity of individual category instances? This paper reports an experimental study of creating designs by adapting sources of inspiration, in which we observe knitwear designers employing rational problem-solving strategies for constructing design subproblems and making design moves.

The selection and adaptation of sources of inspiration is a vitally important and openly acknowledged part of commercial knitwear design. We have conducted an extensive observational study of the knitwear design process in industry, combining ethnographic methods drawn from the social sciences with knowledge acquisition techniques from artificial intelligence (see Stacey & Eckert, 1999, for our methodological approach). We observed and interviewed over 80 designers and technicians in 25 companies in Britain, Germany, and Italy; these companies spanned the full range from downmarket mass fashion manufacturers to fashion leading designer-label companies, and included a number of direct competitors producing equivalent products. We have developed a detailed process model of knitwear design (Eckert, 1997b) and an analysis of the
communication problems from which it suffers (Eckert, 1999b, 1999, 2001; Stacey, Eckert, & McFadzean, 1999), as well as an analysis of how the design process is influenced by the differing business models of different companies (Eckert & Demaid, 2001). We have proposed managerial strategies (Eckert, 1999; Eckert & Demaid, 1997) and computer support techniques (Eckert, 2001; Eckert, Cross, & Johnson, 2000) for making the communication of knitwear designs more effective.

The objectives of the Mechanisms of Inspiration in Novel Design (MIND) Project at the Open University were to understand the roles that sources of inspiration of different types play in the design process and how sources of inspiration are transformed into designs, focusing on knitwear design as an example domain with interesting characteristics. As well as the experiment reported here, the project also included further interviews and observations of designers working in industry, from which we have developed an analysis of how knitwear designers use sources of inspiration to actively construct their design context and formulate design problems, as well as create individual designs (Eckert & Stacey, 2001, 2003).

It is well recognized that designs are not created out of nothing, and the processes of designing have attracted more interest in architecture and engineering than in fashion and textiles. Persistent themes in research on architectural design have included the role of its environment in guiding the design of a building (Darke, 1979), the role of precedents in the application of techniques and styles (for instance Goldschmidt, 1995, 1998), the form and role of architects’ knowledge and experiences (for instance Gero, 1990; Oxman, 1990; Schön, 1988), and the part architects’ own sketches play in stimulating idea generation (notably Goel, 1995; Goldschmidt, 1991, 1992, 1994; Schön, 1983; Schön & Wiggins, 1992; see Purcell & Gero, 1998, for a review). Similarly, much of engineering design is producing variants of existing designs (see for instance Otto & Wood, 2000), and facilitating design reuse is a major research area (see Finger, 1998). In tailoring, developing a garment design by creating new blocks rather than modifying old ones is now a rare or eccentric activity—computer-aided design (CAD) systems for tailoring are designed around adaptation as the primary activity.

Although most research has focused on the adaptation of similar previous designs, designers, especially in knitwear design, draw ideas from a wide variety of other sources, for instance, the rhubarb leaf that inspired Ove Arup’s design of the Kingsgate footbridge in Durham, England (Walker, 1983). Le Corbusier’s design for the chapel at Ronchamp adapted the forms not just of North African windows and Greek roof turrets, but also the shell of a crab Le Corbusier had collected years before (Broadbent, 1973; see Goldschmidt, 1998).

We describe how sources of inspiration are used in the knitwear design process in industry in the next section, before discussing the source adaptation experiment itself. We report three main sets of results: the types of adaptation we have identified, the strategies designers use to adapt a source in creating a single design, and statistical analyses of how the designers in our experiment used these adaptation strategies to produce adaptations of different kinds.

**Uses of Sources of Inspiration in Knitwear Design**

Knitwear designers use previous garments and other sources of ideas throughout the aesthetic design of a garment, from initial design research and collection planning to the development of the conceptual designs of individual garments that are handed over to knitwear technicians for detailed design and implementation (Eckert & Stacey, 2003). (The technicians also make use of programs for previous garments and swatches of fabric when developing programs for new garments.) Sources of inspiration play two major roles in aesthetic design:

1. Defining the themes, topics, cultural connotations, and moods of particular fashions; and delineating the spaces of acceptable designs within those fashions. Both designers and ordinary people identify styles and trends in what they see, abstracting from the similarities between individual garments as well as interpreting other information, such as written descriptions and associating styles with times and situations. Our interview evidence indicates that designers reason about whether striking features of individual garments are unique or are exemplars of categories forming new trends. They also reason explicitly about the development of the forms, cultural associations, and acceptability of their most general, labeled categories includ-
ing the historical styles that may reappear. Thus, sources of inspiration contribute to the formulation of design problems—intentions to create designs with particular relationships to the spaces of fashionable garments (see Eckert & Stacey, 2001).

2. Supplying aspects of individual designs through processes of adaptation, transformation, and combination. The research reported in this article examines the second of these uses in isolation, but they cannot be so clearly separated in industrial practice. When they are planning collections, many designers (who have vivid and powerful visual imaginations) think in terms of concretely imagined individual garments. These serve as placeholders for categories to be included in a collection, though some of these might be developed into finished designs and manufactured. Sources of inspiration used in collection planning may be reused in the design of individual garments.

The Design Process

The commercial knitwear design process shares many features of engineering design, though on a smaller scale. It involves considering a variety of aesthetic and technical factors and meeting tight deadlines and cost targets. It is made complex by the subtle interaction between the structure of complex knitted fabrics and their appearance: An apparently small change to the structure may have a radical effect on the appearance, whereas an apparently small change to the appearance may make a design much more expensive to produce or completely infeasible. Knitwear design is a team activity divided between the knitwear designers, who are responsible for the conceptual design of the garment, and the knitwear technicians, who do a lot of detailed design in the course of using sophisticated CAD systems to program knitting machines to manufacture the garment. The interaction between these two is problematic primarily because communicating knitted structures is inherently very difficult (Eckert, 1997b, 2001; Stacey, Eckert, & McFadzean, 1999) and because designers, technicians, and managers in industry fail to recognize communication problems or realize their significance (Eckert, 1997b, 1999; Eckert & Demaid, 1997). Moreover, designers and technicians are very different in background, education, and interests as well as expertise (Eckert & Stacey, 1994). The designers hand their designs over to the technicians in the form of technical sketches. These comprise a brief verbal description, a freehand sketch, and parameter values for the dimensions of the garment—called measurements—that may be inaccurate, incomplete, and inconsistent. Often the only feedback the designers get on their designs are finished sample garments.

Figure 1 shows the major stages in the knitwear design process up to the hand over from the knitwear designer to the technician. This is an outline summary of the very much more detailed process analysis presented by Eckert (1997b). In terms of the activities and the connections between them described in that analysis, the knitwear design process was identical in all the companies we studied throughout the industry. However, companies differed significantly—according to their market sector—in how much effort was invested in each activity and in how much or how often the process involved iteration and backtracking to earlier steps—typically the more upscale companies were willing to invest more effort in individual designs. Companies also differed in the attention paid to particular types of sources of inspiration and other informa-
tion inputs. Moreover, designers in Britain, Germany, and Italy differ in their training and attitudes, if not in the stages of their design processes; we have no data about other countries (see Eckert, 2001). The assertions made in this article about the behavior of designers refer to commercial knitwear designers, and apply as nearly universally as we can judge from our observations.

Types of Sources

Any object or image or scene can be a source of ideas for a designer, and any abstract idea might suggest a usable image. But some kinds of objects are more commonly used as sources in knitwear design.

**Garments.** Aspects of existing garments can be adapted more directly than other types of source. Looking at the real thing provides much more detailed information, especially about how a feature is constructed, while images of garments provide more context, especially suggestions of moods and cultural connotations.

**Other textiles.** Designers frequently draw motifs from printed fabrics and other media such as carpets. These are often translated into knitted form with the least possible amount of alteration, though other features or aspects might be passed through more radical and abstract transformations.

**Other designed products.** Artifacts such as mosaics sometimes provide adaptable motifs, while three dimensional artifacts like buildings and stonework can provide design elements that can be translated into a two dimensional form.

**Works of art.** Artworks, mainly paintings, can supply indications of mood and cultural associations as well as color schemes, motifs, and suggestions of shapes.

**Natural objects.** Objects such as flowers or shells supply both shapes for motifs and color combinations.

**Natural phenomena.** Images of scenes such as thunderstorms or tropical beaches are often used as sources of color schemes as well as indicators of moods and cultural associations.

Many designers keep collections of source materials including art and craft books, exhibition catalogues, fashion magazines, postcards, pictures torn out of magazines, and so on. They regard collecting potential sources as an important part of their job, and most complain that their companies do not recognize the importance of source collecting or provide enough resources for it (Eckert, 1997a; Eckert & Stacey, 1998).

Mental Representations of Garment Designs

Experienced designers have commented to us that the ability to visualize garments is the most important attribute of a good designer. Most of the knitwear designers we have talked to tell us that they see their designs mentally as detailed, realistic images of garments, similar to photographs. How complete and detailed these mental images really are is hard to assess; research on imagery indicates that details in subjectively rich mental images may often not exist until people focus on a particular area or detail (for instance Kosslyn, 1980, 1994; Logie, 1995). But it is quite common for knitwear designers to create, evaluate, and discard designs in their heads, sketching only to communicate. (This seems to be relatively rare, though not unknown, among architects. Frank Lloyd Wright made few freehand sketches and advocated completing designs in one’s mind before committing pen to paper; see Goldschmidt, 1995.) We suspect that in much industrial practice the information missing from knitwear designers’ mental images concerns details and aspects of designs that designers leave to their technicians to sort out for them.

While we have only verbal report evidence about knitwear designers’ mental representations of individual garments and garment categories, we can make inferences from the large body of psychological research on learning, memory, and expertise. Knitwear designers possess a technical understanding of the structures of garments, enabling them to create highly structured mental representations; they see huge numbers of garments, and many report being
able to remember a large number in vivid detail. For the knitwear designers we have studied, mental representations of types, trends, and spaces of acceptable garments within a fashion are visuospatial. Successful designers have both aptitude and skill for understanding fashion and how their own and others’ garments fit into it. While they reason explicitly about the development of fashion, their understanding is largely tacit and perceptual: Designers recognize appropriateness within particular fashions.

Although designers’ memories include details of both exact form and context, research on perceptual learning (see Goldstone, 1998) and expertise in, for instance, radiology (for instance Myles-Worsley, Johnson, & Simons, 1988), chess (for instance Gobet & Simon, 1998), and electronics (Egan & Schwartz, 1979), as well as mental imagery, indicates that visuospatial representations are highly structured, incorporating categorizations of both structural features and emergent visual features. Aiken (1978) presented evidence that architects’ memories for architectural drawings depend on schematic encoding of drawing chunks. It is difficult to assess how much of the mental representation of a garment is unique to it and how much is reconstructed from representations of more general categories. The structure and redundancy in mental representations enables details to be reconstructed from sparse mental descriptions. Studies of memory for drawings of faces (Wulf, 1922) and for stories (Bartlett, 1934) have shown that unusual features that are perceived as significant are highlighted and exaggerated, whereas other unusual features are smoothed toward what is standard for the category (see Koriat, Goldsmith, & Pansky, 2000). Perceptual recognition of an object or scene as a member of a category (which involves the use of the category representation to construct a representation of the individual) can distort what people perceive, highlighting salient unusual features and minimizing others, as well as enabling them to perceive the object or scene as a configuration of particular components (see Goldstone, 1998).

The sources of the ideas designers use furnish them with a language for describing their designs to their colleagues. We have observed that knitwear designers talking amongst themselves (rather than to technicians or managers) refer constantly to previous designs, their own and those they have seen in shops or in fashion magazines, describing new design ideas in terms of modifications and combinations of elements of previous designs. At least in knitwear design, this is a significant feature of the design culture (Eckert & Stacey, 2000). Knitwear designers have a vocabulary for garment features, but the range of available verbal labels for garment categories is very much smaller than the range of possible categories. Designers’ use of reference-based descriptions, and their reports of having vivid and detailed memories of large numbers of garments they have seen, indicates that their mental representations of the space of possible garment designs primarily comprises very many garment instances serving as exemplars of subtly differentiated subcategories that can only be referred to by their origins.

Designers in other fields make comparable use of memories for both generalizations and individual designs: Schön (1988) describes functional types and references as forms of architectural design knowledge. Drawing on the cognitive theory of dynamic memory (Schank, 1982; Schank & Abelson, 1977), Oxman (1990) argues that precedents are used in design as prototypes, through a process of typification—in which individual designs and problems are used to create and refine more abstract generalizations—and are indexed in memory by these generalizations.

Sources of Inspiration in Collection Planning

Before the knitwear designers we have studied work systematically on designing individual garments, they plan the collections their companies will offer for a particular season. Designers begin their work on a new season by researching coming trends. This is done by looking at materials produced by fashion forecasting bureaus, fashion trend publications such as Book Moda and Zoom on Fashion Trends, fashion magazines such as Vogue, and at garments produced by haute couture designers and more upscale high street producers, as well as those of their direct competitors (see Eckert & Stacey, 2001, 2003). Their objective is to understand the envelopes of acceptable garments within particular fashion trends and the cultural connotations of garments in particular parts of each space of fashionable garments. Designers can then select some fashion trends for their own collections and decide what kinds of garments they want within each fashion trend in relation to the garments that both upscale
trend-setting companies and their competitors will produce. Fashion is an emergent consequence of all the world’s designers performing essentially similar research activities, aiming to produce distinctive but similar designs (see Eckert & Stacey, 2001).

At the end of the research stage of the design process in industry, knitwear designers create descriptions of the ranges they intend to produce. They comprise brief verbal specifications of the categories the designs should belong to, often accompanied by sketches of designs that serve as placeholders for categories. Usually very brief and informal written notes or sketches serve as cryptic cues for much richer mental representations. The categories of garments that designers decide to include in ranges define not just the functions of garments, but what themes they fit into, and—in qualitative categorical terms—their shapes, the features they include (pockets, collars, buttons and so on), and their decoration. These category descriptions include the intended overall visual and tactile effects, and how the types of stitch structures and design elements are to be arranged to achieve them, but usually not any details of the decorative elements. For some companies (see Eckert & Demaid, 2001), briefs from buyers determine the categories, but these briefs must be fleshed out by fashion research.

Our interview evidence shows that garment categories are fundamental to design thinking; they cover the entire search space of possible garments, and the more abstract and general categories provide the only way designers have to describe garments verbally. Designers think about how decorative elements—motive-can be placed and combined, in terms of a small finite set of options (see Table 1). Thinking of different arrangement options for a motif is a natural action. Motifs can occur singly, as the horse does in the front view in Figure 2, or repeated to form overall patterns, or horizontal or vertical stripes (called borders) in various locations, as the horse does in the back view in Figure 2. Different motifs can also be combined or juxtaposed to achieve a combined effect. Thus, motifs can take a variety of structural roles in a design. In our experiment, many designers used the horse in the rug and the main leaf swirl in the tapestry as single motifs. (Some simple borders and overall patterns are designed as borders of indefinite length or as fill patterns rather than composed from individual elements, for instance, the vertical borders in Figure 2.)

The ways motifs are combined are governed by changes in fashion, just as are shapes and color schemes, and designers often set out to create designs that have motifs in particular structural roles within a predefined plan. For instance, a very fashionable style for men’s sweaters designed in Britain in 1993 and sold in 1994 and 1995 was overall color patterns comprising several horizontal bands (borders) of relatively complex pattern on a uniform background color. The design shown in Figure 2 would have been very fashionable in the mid-1980s, but very unusual when the experiment was conducted in 1997. Large single motifs and figurative designs were out of fashion for winter 1998–1999 and summer 1999, which were the

<table>
<thead>
<tr>
<th>Single motif</th>
<th>Location</th>
<th>Central</th>
<th>Off center</th>
<th>On pocket</th>
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<tbody>
<tr>
<td>Border pattern</td>
<td>Direction</td>
<td>Horizontal</td>
<td>Vertical</td>
<td>Diagonal</td>
</tr>
<tr>
<td>Location</td>
<td>Central</td>
<td>Left/top</td>
<td>Right/bottom</td>
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<td>Symmetry on garment</td>
<td>Symmetric</td>
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<td>Connectedness</td>
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<td>Overall pattern</td>
<td>Arrangement</td>
<td>Stripes</td>
<td>Regular</td>
<td>Pseudo-random</td>
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Figure 2. Single motif design with asymmetric shapes.
collections the professional designers were working on when they participated in the experiment, but are returning early in the next decade.

Yarns and color schemes are selected very early in the design process (see Eckert & Stacey, 2003). Color schemes are strongly influenced by the ranges provided for each season by the yarn manufacturers, who are guided by the fashion forecasts produced by the Color Marketing Council. Designers draw color schemes from images with appropriate cultural connotations, often ones showing colors typical of some culture or geography, for instance, photographs of surfers riding waves for garments with nautical or summery associations. Such images are included in mood boards with sketches of garments and swatches of fabric to convey the cultural associations of intended garments and garment categories as well as their form.

Conceptual Design of Individual Garments

Commercial knitwear designers focus their creative efforts almost exclusively on meeting the needs identified by their collection plans for garments of particular types within particular themes (the only requirements specification they ever have). Other garments are the primary sources of shapes and structural features, and of emergent aesthetic effects to be achieved, but knitwear designers frequently look elsewhere for sources of decorative motifs (see Eckert & Stacey, 2003). Once the themes for a new season have been identified, designers look for sources of inspiration within a particular theme. For example, if the theme is “Persia,” they might look at a book on Persian rugs.

This search can be for a source the designer has seen previously and remembers, or for a source resembling something remembered. More typically it will be a search that is focused by the desire to find a source that suggests a garment with some particular characteristic. This characteristic might be a motif of a particular category, such as a tulip, or it might be an emergent perceptual property, such as “aquaticness.” For instance a designer might look for a particular carpet or for a carpet containing a rich dark orange with blue. But designers often search simply for something that strikes their imagination (though their imagination is sharply tuned to their brief or collection plan). As we have observed in the experiment reported here, designers are either driven by a plan—specifying the arrangement of the elements of the design, and some of the emergent aesthetic effects of these elements, in selecting sources to adapt—or they look for a source that will inspire them to generate a plan. Designers may make several rounds of searches for sources of inspiration for different elements of a design, when partial designs suggest the need for other design elements of particular types.

Occasionally, designers see a source and, in what they experience as a single leap of inspiration, conceive a design for a garment that they subjectively experience as complete and detailed. As we note previously, it is not obvious what content a “subjectively complete” mental representation of a design actually has. This is a striking phenomenon that is sufficiently widespread that designers comment on it frequently, but it is relatively rare in industrial practice, compared with more sequential processes of design generation illustrated in Figure 3. Designers typically begin with an idea, search for and select a source of inspiration they can use to realize that idea, adapt the source, and evaluate the resulting design; however, sources of inspiration frequently trigger the creation of design ideas. If the design is unsatisfactory, the designers can go back to the source to create a different adaptation, or select a new source, or discard the idea.

Figure 3. Adaptation of a source of inspiration for an individual design.
and find a new one. Once the design is carried forward into detailed design, backtracking will only go as far as changing the adaptation of the source; once the design is prototyped, only the detailed design will be changed to overcome problems (Eckert & Stacey, 2003).

The elements that are extracted from sources of inspiration require translation into the medium in which the design is created. Motifs are often used in knitted patterns with the minimum possible amount of modification, but as knitwear has a low resolution (a single stitch is quite large) and a limited set of colors, almost all motif sources require some simplification. Creating a gridded pattern from a finer-resolution image is not a mechanical process. The results depend on who does it. The knitwear designers we have observed seem not to be very conscious of this and often delegate creating gridded patterns to their technicians. By contrast, carpet designers, who also create gridded patterns from finer-resolution sources, are very well aware of how subjective and variable this is (A. Demaid, personal communication, July, 1996).

The Experimental Study

We conducted an experiment to observe the use of a source of inspiration in the conceptual design of individual knitted garments to supplement the MIND Project’s observational study of the use of sources of inspiration in industrial practice. The experimental subjects, who were either professional knitwear designers or experienced students completing knitwear design degrees, were given a source of inspiration (a picture of a Persian rug or of a 19th century tapestry) and asked to use it to create designs for sweaters.

Our aim was to investigate the actions and reasoning processes involved in adapting sources to gain a more detailed understanding of part of the process of designing by adaptation. We started from the assumption that the adaptation process was rational. The experiment was intended to test the hypothesis that knitwear designers use a repertoire of identifiable strategies for creating adaptations and to reveal these strategies. We also aimed to assess designers’ use of goal-directed reasoning in design by adaptation and to assess the role of the designers’ sketches in the development of their designs. In the following sections, we describe the range of adaptations made by designers and the strategies designers employed to generate designs from the source. The primary objective of the experiment was to identify the range of different patterns of behavior followed by the designers; obtaining useful statistics was only a subsidiary objective. We conclude by describing some statistical analyses of the frequency of the different behavior patterns, but the results can only be regarded as tentative.

The Experimental Task

The designers were given several copies of a garment outline printed on sheets of A4 paper and an image (either the rug shown in Figure 4 or the tapestry shown in Figure 5) as a source of inspiration. They were offered a pencil and eraser and a packet of 12 colored pencils; however many of the designers brought and used their own pens. The designers were given the following brief and were allowed to work uninterrupted for about 30 min. The experimenter observed the designing silently, and then conducted a debriefing interview. The subjects were videotaped throughout the experiment and the debriefing.

This is a picture of a rug/tapestry. I would like you to use it as a source of ideas and inspiration for designing sweaters. I would like you to design one or more menswear t-sleeve sweaters with turtle-necks. They can be as close to the source as you like, or as different as you like. Just draw whatever designs you want. You can use the outline shape or a blank piece of paper. Don’t worry too much about details, but if you feel you need to work something out in detail, you can use the graph paper. Just keep going until you’re happy that what you’ve drawn expresses what you want it to express. It would be great if you could talk about what you’re doing as you go along, but don’t let that interfere with your designing. Don’t worry if it does not happen. You have got about 30 minutes.

We did not explicitly state a topic or fashion theme in the experimental design, so as not to constrain the designs more than necessary. However, some of the subjects asked the experimenter what the topic was. For the rug task the topic was named as
“Persia.” For the tapestry, the topic was given as “Morris,” even though the tapestry was not designed by Morris himself. Seven of the nine professional designers and three of the student designers were given both sources of inspiration; the order was alternated between subjects. Two of the professional designers participated when they were too busy to have time for both tasks.

External Validity of the Experimental Design

All but two of the subjects enjoyed doing the experiment and appeared to be motivated to produce designs that fitted the brief. They were comfortable working to the brief, and found it a reasonably natural experience. Two of the students did not like the experiment, even though they were paid to participate in it; so far as we could tell this was because they resented being given a design brief. They were motivated to produce good designs, but not restricted by the brief. Working to a brief and designing against one’s personal taste is a normal part of a professional designer’s experience.

Although the subjects were not given any constraints on what sort of sweaters they designed other than the garment shape (which a few chose to modify), they almost invariably produced color pattern designs using stripes and motifs drawn in various ways from the sources. Creating complex color pattern designs using elements adapted from sources is a very common activity in commercial knitwear design, which all our subjects were familiar with, even though our professional designers would not normally produce them in the normal course of their work in 1997, when they participated in our experiment.

Rug designs are a common source of inspiration in industrial practice, as collections of pictures of rugs contain large numbers of relatively coarse-grained and easily adaptable motifs. Several of our participants commented on having used rugs as sources in the past. With the exception of the two participants who disliked the experiment, our participants thought that the rug was a very good choice of source that they liked and found easy to work with, and that they might choose to use it. The tapestry was chosen as a very different but comparably rich image. It proved very much less successful as a source. Our subjects found it difficult to work with, and most said that they would not choose it themselves. Only two said they preferred the tapestry condition of the experiment to the rug condition, as they found it more of a challenge. One reason for the unpopularity of the tapestry (we believe the major one) is that the smooth curves of the leaf pattern do not lend themselves to the construction of coarse-grained grid patterns, though many of our subjects thought the leaf pattern tapestry too feminine for menswear. The brief specified a man’s t-sleeve sweater because menswear is more restricted than ladieswear in shape, patterns, and material, and we wished to focus the designer’s activities on using design elements from the source images. All our professional designers designed or had designed men’s sweaters for a living, or had worked closely with menswear designers and participated in decision making about menswear collections. Shape outlines of the sort supplied in the experiment are commonly used in industry.

The major difference between our experimental task and designing color pattern garments in industrial practice is that working designers usually choose their own sources, with practical needs and aesthetic objectives clearly in mind; they are free to select or discard sources that meet previously formulated needs. Formulating the right needs, to create garments that fit into the context of contemporary fashion and match a company’s target market, is a professional knitwear designer’s most important skill, and selecting the right sources is a crucial part of the creative process (Eckert & Stacey, 2001; Eckert, Stacey, & Clarkson, 2000). Our experiment gave our subjects no need or opportunity to exercise this skill. While designers look at sources to see what they suggest, they select only the most suggestive rather than the images other people think would be effective.

Therefore, the constraints and direction imposed by the source in the experiment are much more arbitrary. We would expect this to cause designers to put more effort into thinking “what can I do with that?” than they would in a comparable situation in normal industrial practice, when it would normally be more cost-effective to look for another source that could be adapted more easily and directly to create the desired effects. This certainly colored our participants’ reactions to the tapestry. However designing garments with branded characters as motifs, with much tighter constraints than in our scenario, is a major task for a significant number of knitwear designers producing children’s clothes.
The Participants

We piloted our experimental procedure with the authors themselves and a number of colleagues and friends, most of whom had no experience whatever of designing knitted garments. In the subjective opinions of the authors, the designs produced by most of these amateurs were not noticeably inferior to those of the less inspired professionals and students; however the experiment did not require or enable the experts to use their key skill of knowing how to fit their designs into the context of contemporary fashion. We compared two groups of experimental participants.

Experienced students. The experiment was conducted with 11 student designers. All had worked as knitwear designers in one-year industrial placements between the second and final years of their degree courses. The first three students were taking a postgraduate MA in Knitwear Design at Nottingham Trent University. Two of these were the subjects who disliked the experiment, one of whom was the only male participant. The second group comprised five apparel design students at De Montfort University in Leicester, who participated in the experiment shortly before the end of the final year of their degree course. These participants volunteered for the experiment when the first author approached their whole class after a lecture. Two further students at Brighton University were approached at their degree show at the end of their undergraduate course. One participant, from the University of Derby, was a placement student at the first company mentioned in the following section. The Brighton University students and the placement student did the experiment with both sources of inspiration.

Professional designers. Nine of the ten professional designers who participated in the experiment worked at the two companies that had been most cooperative in our observational study of design practice. In one large supplier to a large and well-known British retail chain, six designers took part, including the head designer, who had volunteered her colleagues for the experiment. One of these designers was a freelance designer working as maternity cover. These designers worked as a close team, and all had at least three years professional experience. Three designers at a Scottish manufacturer of own-label golf wear took part. One of these had to be excluded from the analysis reported here because she drew several design ideas onto one sketch, making it impossible to reconstruct individual design ideas from what she produced; she also appeared extremely preoccupied during the experiment. A further participant had previously run her own knitwear company, and now worked in design management.

The analysis is thus based on the performance of 11 student designers and 9 professional designers.

Data Collection

All but one of the professional designers and five of the students were asked to think aloud during the experiment to generate concurrent verbal protocols of their conscious thoughts during designing. All of the protocol participants were asked to talk aloud while counting the windows in their parents’ house as a warm-up verbalization task. All of the designers were debriefed after the experiment using the same set of questions (listed in the Appendix); the debriefing lasted between 15 min and 1 hr, and involved the participant talking the experimenter through her designs. The analyses reported in this article were drawn as far as possible from the concurrent verbal protocols, supplemented by examination of the participants’ sketches and their subsequent descriptions of what they did. Comparison of the participants’ debriefing descriptions of what they had done with their think-aloud protocols produced at the time revealed that the debriefing descriptions were frequently inaccurate. They appeared to be post-hoc rationalizations.

Using Verbal Protocols to Study Design Thinking

Studying problem solving behavior by getting participants to think aloud and analyzing their verbal protocols—to identify the participants’ goals, foci of attention, mental representations, and the content of their mental actions—is a well-established and much discussed technique in psychology (see Ericsson & Simon’s, 1993, seminal methodological account). It has been extensively used to study designing (for instance Akin, 1987; Goel, 1995; Goldschmidt, 1991, 1994)—
the literature on protocol studies of architects and engineers creating designs is far too large to survey here (see Purcell & Gero, 1998, for a survey of protocol studies of sketching in design). Cross, Christiaans, and Dorst (1996) present 20 papers on different aspects of designing by different authors, based on the same verbal protocols—the experimental task was to design a luggage rack for a bicycle. The use of verbal protocols to study visuospatial reasoning, especially designing, is problematic and remains controversial. Jonathan Schooler and his colleagues have demonstrated that verbalization does not disrupt activities that can be verbalized readily, but can interfere with recall of perceptual memories and other nonreportable nonverbal mental activities. They attribute this to verbal overshadowing—verbal processing taking away attention from nonverbal configurable processing (for instance Fallshore & Schooler, 1995; Schooler & Engstler-Schooler, 1990; Schooler, Fiore, & Brandimonte, 1997). The activities that are degraded by verbalization include insight problem solving, but not noninsight problem solving (Schooler & Melcher, 1994; Schooler, Ohlsson, & Brooks, 1993). Moreover, trying to verbalize visual stimuli or mental images has been found to interfere with visuospatial problem solving in situations where verbal labeling leads to counterproductive effects of mental set (Brandimonte & Gerbino, 1993; Brandimonte, Hitch, & Bishop, 1992a, 1992b). Visser (1992), in her discussion of the applicability of protocol analysis methodology to design, notes that Ericsson and Simon (1980) remark that producing verbal reports of information directly available in propositional [i.e. language or verbal] form does not change the course and structure of the cognitive processes. However instructions that require subjects to recode information in order to report it may affect these processes” (p. 235) and “Only information in focal attention can be verbalized” (p. 235).

Davies (1995), discussing an experiment on software design, and Lloyd, Lawson, and Scott (1995), discussing an experiment designing a bicycle rack, present evidence that verbal protocol experiments distort normal design behavior. However, their arguments have more force against the use of experimental setups that give the designers tasks embodying unnatural constraints and requirements than against the use of protocol methods. Lloyd et al. point out that experiments force designers to work to shorter deadlines than normal and to avoid understanding–enriching activities like looking at similar products, as well as unrelated displacement activities (enabling incubation).

Our observations of our participants’ behavior in this experiment, and our subjective experience of doing it ourselves, suggest that people verbalize the aspects of visuospatial problem solving that can easily be described in words. When thinking about objects or other visuospatial aspects of designs that defy easy verbal description, such as the shapes of motifs, people remain silent or describe their actions in general terms. The research previously cited by Schooler and his colleagues (cited previously) on the effects of verbalization on imagery and insight suggests that the effort involved in timesharing between verbalization and nonverbal visuospatial thinking might disrupt the nonverbal thinking, reducing designers’ abilities to recognize nonobvious perceptual characteristics of the source materials and their designs, and perform spatial manipulations. But we were not able to assess this from our experimental data. Of course, in our experimental situation, and in much of commercial knitwear designing, thinking about visuospatial entities that cannot be named or easily described is an important part of the task. Thus, the protocols generated in the experiment were a lot more informative about goals and strategies than about thinking about the subtleties of shapes and spatial relationships. As many other experimenters have found, our subjects differed enormously in how easily they could verbalize and how happy they were doing it. For some, generating a protocol in the experiment was entirely natural thinking aloud. Others found verbalizing unnatural and uncomfortable; one designer seized the opportunity to observe the 2 min silence at 11 o’clock on Armistice Day as an excuse to stop talking.

Concern for the potential distorting effects on design behavior led us to run the experiment initially without concurrent verbalization. But our experiences with this experiment matched the usual methodological findings of verbal protocol research. First, that concurrent verbalization provides valid information about aspects of design thinking that are otherwise inaccessible; and second, that concurrent protocols show that retrospective accounts of behavior are often inaccurate, and so should be treated with great caution. Any distorting influence of verbalization, though possibly significant, is less important than the insight provided by the protocols.
Types of Transformation

Transforming an element of a source of inspiration into an element of a design can range from achieving the closest possible likeness to free association of ideas. Here we divide transformations of source elements into different classes, which generate design elements that differ more and more from the source. The categorization of adaptations into these classes is not clear-cut; it is sometimes difficult to decide which class a design belongs to. In the analysis of the experiment, classification has been based primarily on the designers’ intentions and the relationship of the outcome to the initial source.

“Literal” Adaptation

When a new design element is kept as close as possible to the source of inspiration, designers call it a “literal adaptation.” When a motif is designed, a knitting pattern is created with a height and width of a certain number of stitches and a small number of colors. Unless the source is already a grid pattern (for example for embroidery) this involves some simplification. However knitwear designers do not regard as simplifications the adaptations required to create a grid pattern while staying as close as possible to the original. Literal adaptation of images into grid patterns is well supported by current CAD systems, which allow the user to specify the number of colors and the grid size.

Conscious Simplification

Designers consciously simplify designs based on more complex sources by either selecting parts of the source (for example, in Figure 2 the designer has picked out the horse) or discarding parts of the source (for example, in Figure 6 the designer has left out parts of the central diamond), while otherwise keeping the design or design element as close as possible to the source. The simplified design element may play a different role in the structure of the new design (see Figure 20).

Abstraction

Designers aim to capture some essential properties of a relatively complex source while eliminating or changing others to create a relatively simple design element. These essential properties might be basic proportions, geometric shapes, color schemes, or visual emergent properties such as overall busyness or complexity. The objective might be to retain the cultural meaning of the source. In Figure 7, the overall form of the rug has been abstracted and combined with a simplification of one element of it to create a motif. In Figure 8, the designer has sought to maintain the round flowing forms of the tapestry.
Modifications to Source

Designers can introduce changes when transforming a source of inspiration into a design element. They might change details within an overall form copied from the source. For instance, many designers used the central diamond form of the rug but changed its internal structure. They may regroup elements derived from the source. For instance, some designers have placed horses within the large diamonds. Designers may also amalgamate design elements from different sources; this happens when designers have found several good sources or are planning to create very complex designs. It is difficult to distinguish modification from abstraction and simplification; we have used the criterion that the adaptation should add features beyond what is required for any degree of simplification.

Association

A source can also inspire a design by reminding the designer of another object or another design they have seen. Designers may draw an object or design element that is visually similar to the source, though not derived directly from it. For instance, a designer might draw a different rug from memory or imagination as a result of seeing the rug used in our experiment. A designer might use the source of inspiration to define a topic and create another design fitting into that topic, drawing on memory and imagination or another source of inspiration. For example, in creating the design shown in Figure 9, the designer defined “Islam” as a topic within the context created by the rug and its theme of “Persia.” Designers often exploit associations within the natural context of the source. For instance, in the design shown in Figure 10, the designer drew flowers and leaves to complement those drawn from the tapestry. Designers also sometimes develop design elements by evolution away from the original source, where an initial adaptation inspires a further transformation. For instance, one designer picked leaves from the tapestry; these reminded her of caterpillars (a process of “seeing as”; cf. Goldschmidt, 1991; Schön & Wiggins, 1992), and she developed them further into caterpillars to produce the design shown in Figure 11.

Deviation

Some designers in our experiment moved completely away from the source. Designers can take ideas from the environment they are designing in. For example, one designer took a cable pattern from Claudia Eckert’s sweater and put it into her tapestry-inspired design. Such coincidental inspirations can be quite common when designers are actively looking for a
source of inspiration within a context. Designers can also draw on ideas that they already have in mind. This might or might not be related to the source. Designers creating Arran patterns might start by drawing a classic Arran for modification. One designer drew a cardigan design that she had done previously as a starting point for her tapestry-inspired design.

Strategies for Adaptation

The designers in our experiment employed a variety of different strategies for deriving ideas from sources of inspiration. The two major approaches are (a) to form a plan for the design and then use elements of the source to populate the design with the required design elements and (b) to derive a plan for the design from the source. This section outlines the range of different adaptation strategies that were used. This analysis is based partly on a priori analysis of the adaptation problem, which gave us these two broad categories, and partly on the experimental evidence about the use of strategies to create designs based on the rug and the tapestry, from which we identified the different source-driven strategies. In the next section, we discuss the experimental evidence about which strategies were used, and by whom, in the experiment.

Evidence About Design Thinking in Our Data

Design strategies defy conventional methods of observation. Our experimental data provided limited evidence about reasoning processes in designing by adaptation. However, we were able to identify adaptation strategies as well as the types of adaptations that were created. During the experiment, our subjects created designs very quickly—between two and fifteen in half an hour—and worked on individual designs for as little as 30 sec. Some designs were sketched without any hesitation after the end of the previous sketch. In concurrent verbalization, the subjects described their goals and their actions in terms of what they were drawing and what they were looking for, but very rarely mentioned problem solving tasks or other mental activities, so we did not observe complex reasoning about the designs and how they should progress.

We conclude from our data, other research on design thinking, and our own experiences of trying the experimental task ourselves, that this is because our subjects’ design thinking was largely visuospatial, and thus not reportable except in broad terms, and too fast to be verbalized or described in real time. The evaluation of partial design sketches has been identified by many design researchers, especially in architecture, as a major component of many designers’ creative processes (most famously Schön, 1983; and Goldschmidt, 1991, 1995; see Purcell & Gero, 1998). We did not find very clear evidence for designers interactively responding to what they see in their own sketches, though we have had the subjective experience ourselves. We suspect that this is because designers’ perception of features of their designs, and of corresponding needs or possibilities for further developments, happens too quickly for clear traces to appear frequently in protocols, given that shapes and spatial characteristics are not easily described in words.

Method of Analysis

The strategies identified in this section were derived from a combination of analyses of the nature of the adaptation problem, comments made by our experimental subjects in their debriefing interviews, and analyses of their videotaped verbal protocols and actions during design episodes. The holistic “inspiration-strikes” strategy, which designers describe as an instantaneous creation of a design idea, is included because designers mention it in interviews. It cannot be tested in experiments in which designers are given a source. Unless inspiration strikes, which we believe is much rarer than is often assumed, designers confronted with our experimental task or a comparable situation can proceed according to one of these logical possibilities: (a) formulate or remember a plan for the form of the design, and use the source to supply design elements that fit into that plan; (b) derive a plan for the design from the source, and then use the source to supply appropriate design elements; or (c) derive the plan for the design from an alternative source of ideas, often a previous design based on the source or remembered from elsewhere.

The source-driven design strategies are subdivided according to the degree of conceptual change between the source and the new design. Of course, many de-
signs are created by a combination of strategies: A designer begins with one strategy, evaluates an incomplete design, and uses a different strategy to take it further. In our statistical analyses, we have associated each design with the first strategy used.

Plan Driven Design

The designer can look at a source needing a design element to fulfill a given structural role in a design when the visual effect of the design element and/or the whole design has been chosen before any details are decided on (Figure 12). The designer examines the source with the question: “What can I get from the source to create this sort of design element?”

Structural role drives source. In industrial practice, knitwear designers often aim to fit garments into particular fashions that dictate the use of particular types of motifs arranged in particular ways—for instance, the complex horizontal band sweaters of the mid-1990s. Here the designer begins with a garment category, which requires motifs to fill predetermined structural roles.

During the design phase, designers employing this strategy look systematically for sources of inspiration that supply design elements that fit the requirements imposed by the predefined structure, theme, and desired characteristics. In the experiment, designers often decided on categories of designs such as “overall border pattern,” implicitly specifying an outline plan and a set of structural roles for design elements; and looked for components of the source to fill needs, that is, for design elements that fit into the vacant slots in the structure. For example, the designer of Figure 13 wanted to create an “overall multi-colored pattern.” Different types of adaptation are used depending on the visual effect the designer wants to achieve.

Emergent need drives source. In the course of designing, the designer can perceive the need for a design element to serve a particular function, to complement existing design elements to achieve a particular overall visual effect—this is an example of what Schön and Wiggins (1992) term appreciating the characteristics of a design (Figure 14). In our experiment, designers frequently adopted this strategy when refining incomplete designs. As this is, by definition, a strategy adopted to extend a partial design, and our statistical analyses consider only the first strategy used, we haven’t included it in our measures of how frequently different strategies occurred in our experiment.

Source Driven Design

A source of inspiration can trigger the development of a design, which might be based closely on it or distantly derived from it. The development of the design is typically a sequential process involving the application of a strategy. Here we outline the qualitatively distinct source-driven strategies that we have identified in our experiment.

Holistic idea. In interviews, designers often comment that they come across a source of inspira-

Figure 12. Structural role drives source strategy.

Figure 13. Structural role drives source design.
tion by chance and are instantly struck by an idea for a design (see Figure 15). For example, one designer commented to us that she saw a piece of tree bark and immediately translated it mentally into a knitted fabric. Many designers have explained to us that during design research they look at many different stimuli and often translate these immediately into designs, many of which are discarded just as quickly.

Our analysis of our experimental data did not reveal any holistic idea designs—all the designs appeared to be incrementally developed from ideas for partial designs. But in our experimental setup, it is impossible to clearly distinguish the instantaneous generation of holistic ideas from other source-driven strategies. (“Aha!” statements describing a complete idea before any sketching would be suggestive evidence, but we cannot safely draw the reverse inference from the absence of such clear statements.) However, it is remarkable that many designers began drawing almost as soon as they saw the source of inspiration and did not hesitate during the sketching of one design idea.

**Salience priority.** Several designers in our experiment began creating designs by placing a direct adaptation of the most visually salient feature of the source onto the garment design in the most similar available structural role. Only then did they appear to reflect on what else the design might need. A design created in this way could be sufficient as it is, be extended using the emergent need drives source strategy, or be extended by recalling a garment category that fits the initial design element and applying the structural role drives source strategy. For example, the three center diamonds are right in the middle of the rug; several designers placed it in the center of their sweater designs. Some designers did this in a first design as a starting point for other designs, others did it when they had (temporarily) run out of ideas, whereas others commented that they wanted to avoid doing this because it would be too obvious.

Here again, we encountered serious difficulties with classifying the designs produced in the experiment, as the salience priority strategy can be viewed as a special case of either of the two following strategies. Either the salient feature is used in the new design in the same structural role as it takes in the original source (as in the sweater design shown in Figure 16; see Figure 17), or it is transformed into a design element taking a different role. We classified as salience priority designs that appeared to be created by the immediate translation of a very salient source element either without reflection or explicitly as a starting point.

**Source drives same structural role.** Designers applying this strategy position features of the source in the same relationships to the overall form, or other features of the new design, as they have in the source (see Figure 18). They have the implicit goal to use parts of the source directly without active alteration of their associated structural roles, but with explicit consideration of what’s there and how to use it. This strategy is used either to create a new design composed of selected elements of the original source or to supply design elements that complement other parts of the new design.
that have already been created. For example, in the design shown in Figure 19, a border in the rug is adapted into a border in the sweater.

Source drives different structural role. Designers employing this strategy adapt features in the source to fill structural roles in the new design that are different from the roles they play in their original contexts (see Figure 20). They have the implicit goal to adapt parts of the source by actively considering alternative relationships between these parts and other features of the design or the overall form of the design. This may be motivated by dissatisfaction with the aesthetic effect achieved by a feature in its existing role. However knitwear designers have only a limited set of ways in which they can use motifs (see Table 1), and imagining the feature in each possible role is a natural activity for them. In Figure 2, the horse is used as a large single motif, but in Figure 21 it appears as a repeated motif in a border across the chest.

Analysis of source. Designers employing this strategy identify relatively abstract emergent characteristics of their sources, and construct traditional patterns embodying those characteristics (see Figure 22). For example, the designer who created the sweater design shown in Figure 8 picked up on the tonal richness of the tapestry and the flowing layered effect of the elements within it, and translated this into a rounded cable pattern on a background of multicolored wool. Other designers in our experiment reacted to more general properties of the sources, for example seeing the rug as rich or the tapestry as flowery, and tried to capture this in a design, for instance in Figure 10. In these cases, the designers fall back on traditional patterns or designs that they have seen as sources of structures to adapt to implement the emergent characteristics that they have taken from the source.

Designing From Other Sources

Designers both in real life and in our experiment sometimes base their designs on sources of ideas other than the visual stimuli they are considering. These may be associations with the theme or recollections of designs that provide a starting point for design by modification, adapting the structural characteristics of the foundation design to include features from the source, or achieve its emergent aesthetic properties.

Design evolution. Designers often go from one design to the next without referring back to the source. They are using their own sketches as sources of inspiration for subsequent design ideas that are evolved from their initial ideas rather than to the source (see Figure 23). This is a phenomenon that has frequently been observed in studies of architectural design (Schön, 1983; Schön & Wiggins, 1992; see Purcell & Gero, 1998).
In our experiment, a few designs were created that had no obvious connection to the source provided in the experiment. In their debriefing interviews, the designers commented that they had these designs in mind from previous designs of their own or from designs they had seen elsewhere (see Figure 24)—a somewhat different situation from the rational adoption of a plan to fit into a particular fashion space. We view these designs as evidence for fixation on previous designs (sources of inspiration outside the brief given in the experiment) influencing what our subjects created. (See Jansson & Smith, 1991, and Purcell & Gero, 1996, for experimental studies of fixation in product design.)

**Legacy design.** In our experiment, a few designs were created that had no obvious connection to the source provided in the experiment. In their debriefing interviews, the designers commented that they had these designs in mind from previous designs of their own or from designs they had seen elsewhere (see Figure 24)—a somewhat different situation from the rational adoption of a plan to fit into a particular fashion space. We view these designs as evidence for fixation on previous designs (sources of inspiration outside the brief given in the experiment) influencing what our subjects created. (See Jansson & Smith, 1991, and Purcell & Gero, 1996, for experimental studies of fixation in product design.)

**No direct relationship with the source.** In the experiment, some designers created designs without making any discernible reference to the source, or to any obvious alternative source of ideas. Some very basic designs such as simple stripes were derived from the categories of the designs the designers wanted to produce without reference to any source, as the form of the design elements are determined by and implicit in the general form of the designs.

**Combinations of Strategies**

Simple designs such as that shown in Figure 19 can be created by the application of a single strategy. But many more complex designs, such as that shown in Figure 2, are created through the application of a combination of strategies. In the latter case, the designer was initially attracted by the horse. (She had picked it out for previous designs but not used it.) She began the new design by sketching the big horse, applying the **salience priority** strategy. She then looked at her horse and searched the source for a suitable border pattern, applying the **structural role drives source** strategy. She picked out the step pattern, and looked again and picked out the diagonal boxes.

Designers in our experiment who used combinations of strategies began with either plan or a source-driven strategy, and started sketching. They looked at the sketch and thought about what might be missing. They then either formed a plan and looked for an element of the source with which to realize the plan, or drew an idea from elsewhere. Sometimes they derived new ideas directly from the sketch.
Patterns in Strategy Application

The study was designed to identify the strategies used by designers, not to provide sufficient quantitative data to support strong inferences about relative frequencies. The difficulty of securely differentiating between categories of strategies means that our numerical results should be treated with some caution, but, nonetheless, some interesting patterns emerge from statistical analysis.

All the strategies previously described have been observed in the rug and tapestry experiment, with the exception of holistic creation. In this section we examine (a) differences between the task conditions—the rug is both more typical and more tractable as a source of inspiration than the tapestry, and this appears to influence the strategies used to adapt it; (b) the differences between the student designers and the professionals, who appear to make more use of plan-driven strategies; and (c) the relationship between the adaptation strategies used and the types of transformations that are produced.

Method of Classification

For the purpose of this analysis, the designs have been classified according to the strategy applied for the most salient feature of the design. This was invariably the first pattern feature drawn by the designers, though some designers changed the given shape before they began to draw the pattern. A few designs that had no clear relationship to the source were excluded from the analysis. Claudia Eckert identified the initial strategy by (a) design intentions stated in verbal protocols, for example “I will design an overall stripe pattern” was classified as \textit{structural role drives source}, and “I like the horse” followed by immediate drawing of the horse was classified as \textit{salience priority}; (b) comments made in the debriefing in answer to the question, “How did you come up with this design?” and (c) looking at the design itself.

It is extremely difficult to assign a design securely to one category. This is partly because some category boundaries are fuzzy, for instance between \textit{salience priority} and \textit{source drives same structural role}, and between \textit{salience priority} and \textit{source drives different structural role}. It is also impossible to ensure equal treatment of designs produced with and without concurrent verbalization.

In the following analysis, we discuss the results in terms of how much reasoning about the form of the design different strategies require. We group \textit{structural role drives source} with \textit{analysis of source} as more complex strategies involving more reflection about how to use the source to achieve design objectives; and group the source-driven strategies (\textit{salience priority}, \textit{source drives same structural role}, and \textit{source drives different structural role}) as less complex strategies. It would be a mistake to regard the former as “better” or “more sophisticated.” In real life, many simple designs involve a lot of thought and effort in deciding exactly what is required by fashion. If designers know what they want, it pays them to search for a source that they can adapt directly, employing the \textit{salience priority} strategy or the \textit{source drives same structural role} strategy, because this minimizes the effort involved in adapting the source.

Differences Between Sources

A total of 123 designs were created by 20 participants. The number of designs per designer ranged from 2 (using one source) to 21 (using both sources). The rug is a typical source of inspiration for knitwear design. Its rich geometric patterns are easy to adapt and can be used in many different themes. The tapestry was selected as being equally rich, but its organic round shapes are very difficult to adapt into knitwear, and the flowery motifs were seen by many designers as being too feminine for menswear. Table 2 shows the number and relative frequency of the strategies employed by the professionals and students using the rug. Table 3 shows the same information for the tapestry condition.

As Figure 25 suggests, the designers in our experiment employed adaptation strategies with different frequencies in the rug and tapestry tasks. The significance of this observed difference was tested by grouping the strategies used by the professional designers as shown in Table 4. With the strategies grouped into more complex and reflective (\textit{structural role drives source} and \textit{analysis of source}) and simpler and more source-driven (\textit{salience priority}, \textit{source drives same structural role} and \textit{source drives different structural role}), as shown in Table 4, a $2 \times 2 \chi^2$ test gives $p \leq 0.02$. With \textit{structural role drives source} and \textit{analysis of source}
source treated as separate groups, a $3 \times 2 \chi^2$ test gives $p \leq 0.01$. In both cases, the more conservative Yates correction to the $\chi^2$ analysis gives $p \leq 0.05$. (There were not enough student tapestry designs for the same comparison to be made for the student subjects.) These results indicate that designers use source-driven strategies more when they like the source and find it easy to use, and that they use more reflective goal-driven strategies when the source proves relatively intractable. This is what one would intuitively expect. The evidence of concurrent verbal protocols and debriefings indicates that when designers have difficulties with the source and feel that they cannot reuse its components directly (the flowers and leaves of the

<table>
<thead>
<tr>
<th>Tapestry Task</th>
<th>7 Professionals</th>
<th></th>
<th>3 Students</th>
<th></th>
<th>10 Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Role $\rightarrow$ source</td>
<td>10</td>
<td>40</td>
<td>1</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Salience priority</td>
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<td>2</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>Source $\rightarrow$ same role</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Source $\rightarrow$ different role</td>
<td>6</td>
<td>24</td>
<td>4</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>Analysis of source</td>
<td>6</td>
<td>24</td>
<td>1</td>
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</tr>
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<td>1</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Legacy</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Total of designs</td>
<td>25</td>
<td>100</td>
<td>10</td>
<td>100</td>
<td>35</td>
</tr>
</tbody>
</table>

**Table 2. Number and Frequency of Strategies Used with the Rug Source**

**Table 3. Number and Frequency of Strategies Used with the Tapestry Source**

**Comparison between Tapestry and Rug Task for Professional Designers**

![Comparison between Tapestry and Rug Task for Professional Designers](image)

**Figure 25.** Professionals: Strategy frequencies in rug and tapestry tasks.
tapestry were seen by many as too feminine, and they had shapes that are difficult to translate into grid patterns except at a very large scale), they either form a plan within which they can employ elements of the source or try to capture the characteristics of the source in another way.

**Differences Between Professionals and Students**

Even though all the student participants had at least one year of industrial experience, the numerical data shown in Table 5 and illustrated in Figure 26 suggests a marked difference between the students and the professionals in how frequently they employed the different strategies.

Table 5 shows the number of times the more complex strategies (structural role drives source and analysis of source) and the less complex strategies were used by professional and student designers, aggregating across the rug and tapestry tasks. A $2 \times 2 \chi^2$ test gives $p \leq 0.02$, with a Yates adjustment of $p \leq 0.05$. A 3 $\times$ 2 $\chi^2$ test separating structural role drives source and analysis of source gives $p \leq 0.01$, with a Yates adjustment of $p \leq 0.02$. However, the validity of results aggregating over the two tasks is limited by the conflation of differences in strategies employed by the students and the professionals, with the difference in the total number of designs generated in each condition by the students and the professionals. For the rug alone (Table 6), a $2 \times 2 \chi^2$ test gives $p \leq 0.05$, with a Yates adjustment that is not significant at the $p \leq 0.05$ level. The $3 \times 2 \chi^2$ test is not valid because both groups produced only one design in the analysis of source category. Only 3 students did the tapestry task, so there were insufficient tapestry-based student designs for a valid $\chi^2$ test comparing professional and student tapestry-based designs.

These results indicate that the student designers stuck more closely to the source, while the professional designers were more likely to use more elaborate goal-directed strategies. They support the conclusion that experienced professional designers are more skilled at bypassing the obvious ways to adapt source materials and at finding ways to use source materials that do not suggest designs. Although this can be attributed partly to the professional designers having more experience, we interpret this as being a consequence of the professionals having developed different skills and habits to

**Table 4. Professionals: Occurrences of Strategies in the Rug and Tapestry Tasks**

<table>
<thead>
<tr>
<th>Professionals</th>
<th>Role Drives Source</th>
<th>Analysis</th>
<th>Structural Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tapestry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 participants</td>
<td>10</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Rug</td>
<td>9 participants</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 5. Occurrences of Strategies Used by Professionals and Students (Excluding Evolution Designs)**

<table>
<thead>
<tr>
<th>Total of Designs</th>
<th>Role Drives Source</th>
<th>Analysis</th>
<th>Structural Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professionals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 participants</td>
<td>23</td>
<td>7</td>
<td>32</td>
</tr>
<tr>
<td>Students</td>
<td>11 participants</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>37</td>
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</tbody>
</table>
cope with different task demands (see Eckert, Stacey, & Wiley, 1999; Stacey, Eckert, & Wiley, 2002). Throughout their training, British-educated design students do fairly free projects, within which they are free to select their own sources of inspiration and interpret briefs how they wish. Their training is influenced by the belief, widespread among British design educators as well as in the knitwear industry, that creativity is harmed by tight constraints (Eckert & Stacey, 1994). This has the consequence that students gain no experience in designing within tight constraints. Working professional designers learn to design within much tighter constraints imposed by customers’ briefs and time pressure. Using the structural role drives source strategy to create designs with a particular predetermined form is a normal part of our professional subjects’ working lives; they may also have a richer source of plans and more strongly learned procedures for using them, and thus be more prone to fixation. Moreover, many professional designers are restricted in their access to source material and have to make do with what they have, which they experience as a significant limitation (Eckert & Stacey, 1998).

**Table 6. Occurrences of Strategies Used by Professionals and Students in the Rug Task (Excluding Evolution Designs)**

<table>
<thead>
<tr>
<th>Total of Rug Designs</th>
<th>Role Drives Source</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professionals 9 participants</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>Students 10 participants</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

**Figure 26.** Frequencies of strategies used by professionals and students.

Relationships Between Strategies and Transformation Types

The designs produced in the experiment were analyzed to test the hypothesis that different adaptation strategies used by the designers in our experiment were associated with different types of transformations.

The designs generated in the experiment were classified according to the adaptation strategies their designers used to create them and the types of transformations they embodied. Table 7 shows the number of designs for each combination of adaptation strategy and transformation type. The most complex and goal-directed strategies, structural role drives source and analysis of source, frequently led to the most radical and indirect type of source transformation, association. The simpler and more direct adaptation strategies, salience priority, source drives same structural role and source drives different structural role, led to a much higher proportion of straightforward, close transformations. Although there are differences in frequencies, most of the source-related design strategies led to designs employing most of the different types of transformation.

As classifying designs is difficult, and to some extent subjective, this numerical data should be treated with some caution; statistical analysis nonetheless supports the view that different transformation types are associated with particular strategies. A χ² analysis of the data in Table 7 gives ρ ≤ 0.001, with a Yates adjustment of ρ ≤ 0.02. A χ² analysis of the data for the source-related strategies and transformations (the inner box in Table 7) gives ρ ≤ 0.001, with a Yates adjustment of ρ ≤ 0.001. Table 8 shows the number of designs produced with direct versus complex and plan-driven strategies, and with close versus complex transformations. A χ² analysis of
the data in Table 8 gives \( p \leq 0.02 \), with a Yates correction of \( p \leq 0.02 \).

These results support the intuitive hypothesis that designers are more likely to use elements of the source directly when applying strategies that are driven by the visual elements of the source. When designers choose more complex and less direct strategies, they are more likely to change the source elements significantly or be guided by associations. Designers choose less direct strategies either when the source material appears unsuitable for direct adaptation—because its elements do not lend themselves to satisfactory close transformations—or because the close transformations they afford are rejected as too easy or obvious.

**Conclusions**

Creating a new design by transforming one or more sources of inspiration is a ubiquitous process in knitwear design. It has clear parallels to designing by modifying previous designs and other sources of ideas in many other fields, such as fashion design, architecture, and engineering (Eckert et al., 2000). This article reports a study of designing by transforming a source. Nine professional knitwear designers and 11 experienced knitwear design students were given a brief to design one or more men’s t-sleeve sweaters based on a given source of inspiration and a picture of a Persian rug or a 19th century tapestry. They were videotaped, in most cases were asked to produce concurrent verbal protocols, and were asked about their design thinking in subsequent debriefing. Creating designs for knitted garments by adapting such a source of inspiration is a common activity familiar to the participants in the experiment, who were also accustomed to designing to a brief specifying particular needs. However, in industrial practice designers can normally choose their own sources; they usually only select those that yield design elements that meet their needs through simple and direct adaptations, whereas in this experiment they were pushed harder than usual to think about what they could do with sources that did not immediately suggest designs.

Analysis of the videotape data and the designs themselves shows that both the designers’ strategies for creating a design by adapting a source and the designs themselves can be described in terms of clearly identifiable patterns.

A source, or one element of a source, can be transformed in one of the following ways. (Though some designs produced in our experiment bore no relation to the given source that either Claudia Eckert or the designers themselves could identify.)

- **Literal adaptation.** The source element is translated into a component of a knitwear design as accurately as the medium will allow (that is,
with a limited number of stitches and a few colors).

- **Simplification.** The source is consciously simplified in the process of translating it into an element of a knitwear design.
- **Abstraction.** Some but not all of the visual properties of the source are used to create the corresponding element of a knitwear design.
- **Modification.** The source element is altered to create an element of a knitwear design that is more suitable for the medium of knitwear or to the context of the design, but the design is still clearly visually related to the source.
- **Association.** The source element supplies visual properties, emergent features, or cultural contexts that are used indirectly to create a new design.

Transformed design elements can be used with the same relationship to other elements and the overall design as their originals, or they can be used in different combinations and take different structural roles in the overall form.

When adapting a source of inspiration into a new design, designers employ distinct strategies. These can be described most succinctly in terms of motivating questions (implicit in the designers’ actions, rather than consciously articulated).

- **Structural role drives source.** “How can I create that visual effect that I want with this source?”
- **Salience priority.** “This is the most striking feature of this source. How can I make use of it?”
- **Source drives same structural role.** “How can I apply this feature of the source in the same way in my design as it appears in the source?”
- **Source drives different structural role.** “What else can I do with this feature of the source?”
- **Analysis of source.** “How else can I create a design that captures the overall visual appearance of the source?” (Or a particular aspect of the visual appearance of the source.)
- **Design evolution.** “How can I develop this idea further?”

In the experiment, designers also created designs that were unconnected to the given source by sketching ideas that they already had in their minds. During interactions and observations of designers working in industry, as well as in the debriefings at the end of our experiment, designers often comment that they are sometimes struck by an idea as soon as they see a source. When this happens they usually experience this subjectively as an entire design appearing fully formed in their minds. Although this is very memorable, it is quite infrequent, so it is unsurprising that it never occurred in our experiment.

The study was designed to generate data from which the strategies employed by designers could be identified and analyzed, not to generate enough designs for frequencies of strategies and transformations to be measured and compared. Nevertheless, some interesting, if unsurprising, statistically significant patterns appeared. The adaptation strategies were classified as direct source-driven strategies (salience priority, source drives same structural role, source drives different structural role), or as indirect goal-driven strategies (structural role drives source, analysis of source). Statistical tests support the following intuitive hypotheses.

- When the source of inspiration is well suited to adaptation into knitwear design elements and well suited to the brief, and the designers like it, they are more likely to be guided by the visual properties of the source. When the source is less suitable, the more likely designers are to use less direct goal-driven strategies.
- Students are less likely than professional designers to use the less direct goal-driven strategies. We attribute this to the professionals having more experience of designing with tighter sets of constraints, in particular working with briefs and sources they did not choose and do not like, as well as having more experience of doing plan-driven rather than inspiration-driven design.
- Although any adaptation strategy can lead to any type of transformation, direct source-driven adaptation strategies lead to a higher proportion of close translations, while the less direct goal-driven adaptation strategies lead to a higher proportion of radical modifications and abstract transformations.

This study supports the view that designing and other creative behavior can be analyzed in terms of
consistent patterns that result both from the intrinsic demands of the creative tasks and the cognitive characteristics and learned skills of designers. Both the experiment reported in this article and our observations of the knitwear industry indicate that much, if not all, of knitwear design is the rational application of identifiable strategies both for formulating design problems and creating visual and mental contexts (Eckert & Stacey, 2001), and for generating appropriate designs.

References


C. M. Eckert and M. K. Stacey

Appendix: Debriefing Questions

Personal data
- Name
- Age
- Courses taken
- Placement
- Career ambition
- What do you like most in knitwear?
- What skill do you think is most important in a knitwear designer?

Unstructured information
- Would you like to talk me through your sketches?
- Please tell me about the decisions you made when you were designing and what you saw in your head

What is the agenda?
- What effect do you want to achieve?
- How does this relate to the source?
- How much are you influenced by your own taste?
Sketches
- Do you normally produce sketches when you design?
- Could you do the same designs without sketching?
- Do you sketch each design that comes to mind?
- What percentage do you sketch?
- How do you evaluate which ones to sketch?
- Do you think you are a good sketcher?
- Does this matter?
- Do you think sketching is important to your thought process?

Design Steps and Problem Spaces
- What were the steps?
  - Single?
  - Multiple?
- What problem spaces?
- What goals have they got?
- How is problem behavior influenced by goals?
  - Do you set yourself a detailed problem specification before you begin a design?
  - How do these change?
  - What transformations did they do?
  - What do they think is a complete solution? Might visualize complete garment, but not see complexity, i.e., Subjective feeling of complete solution is not equal to completely worked out solution

Visualization
- What do you see for each sketch?
- Do you see garment on person?
- Can you focus in on design detail?
- Can you rotate the image in your mind?
- Can you see a person moving in the garment?

Schön Questions
- How does your sketch influence your design?
- Do you change the plan or your mental image of the design as you go along?
- What makes you change it?
- Do you draw a design that you imagine?
- Do you decide what to do next by responding to your sketches?

Vividness of image
- Do you see color?
- Can you vary the colors?
- Can you see knitted structures?
- What does the mental model look like?

Design decisions
- Why did you select … ?
- Which decision did you make?

Evaluation
- When did you do evaluation?
- How did you evaluate?
- Do you also evaluate a mental image?
- Do your evaluations coincide with your decision points?

Design progression
- How do you get from one design to the next?
- How do you know you have arrived at a satisfactory design?

Concurrent Verbalization
- What do you think about the concurrent verbalization?
- Did it change the design process?
- Did it change the way you think?
- What did you talk and what did you not talk about?
- What happened in your mind while you did not talk?

Thinking style questions
- Do you talk to yourself when you are designing?
- Do you talk to yourself when you are thinking normally?
- Do you see pictures in your mind when you are thinking?
- When do you see pictures?
- For example when you are planning what to cook for dinner, how do you think about it? Do you see images of the food or ingredients?

Sources of inspiration
- How typical is the task I have given you?
- How do you normally use sources of inspiration?
- How do you select them?
- What are you taught about the use of sources of inspiration?
Creativity

- What do you consider creative behavior?
- Which type of people do you consider creative?
- How could creativity be taught?

Design Culture

- How typical is this use of sources of inspiration for work in industry?
- How relevant was what you learned in college in your placement?

- How typical was your placement experience compared to your classmates’?

Collection

- What will you do for your collection?
- How are you going to go about planning it?
- What inspiration will you use?