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Comparison of Reweaving and Reknitting Techniques with Textile Conservation Repair Methods

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COMPARISON OF REWEAVING AND REKNITTING TECHNIQUES WITH TEXTILE CONSERVATION REPAIR METHODS

BY

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Abstract

Reweaving and reknitting techniques rebuild losses in textiles by replacing damaged yarns to duplicate original structures and patterns. Traditionally viewed as restorative methods used mainly for consumer clothing and household furnishings, reweaving and reknitting have much potential for adaptation to the repair and stabilization of historic and collectible textiles.

Standard textile conservation repair and stabilization techniques utilize hand-sewn underlay and overlay patches and adhesive-coated underlay supports. Although these techniques can provide practical and time-saving approaches for a wide variety of situations, problems with these techniques can sometimes develop over the long term when issues of structural integrity and appearance are concerned. While reweaving and reknitting techniques can provide superior aesthetic and structural results, they require more time and are more costly.

This study evaluated the possibility of expanding the use of reweaving and reknitting techniques in the repair and stabilization of damaged textiles to meet textile conservation challenges. The research involved a panel review of actual textiles that had received various stabilizing treatments and a statistical analysis of the evaluation data. This report includes detailed instructions outlining basic reweaving and reknitting techniques and a discussion of applying these and traditional treatments to woven and knit fabrics.

Three different reweaving or reknitting techniques, applying an underlay with hand stitching, and attaching an adhesive-coated backing were used to repair damaged fabrics. The textiles treated represented a range of woven and knitted structures

including a plain weave / low thread count, plain weave / high thread count, twill weave, patterned weave, stockinet knit, double knit, and patterned knit. Each of the three treatments was applied to each of the seven fabrics.

The 21 fabric / treatment combinations were examined by a panel of reviewers and evaluated with respect to specific qualities of visual appearance, structural integrity, and effect of repair on drape. They recorded their rating on a Visual Analogue Scale.

The evaluators (n = 49) of the treated fabrics gave the reweaving and reknitting treatments statistically significantly higher ratings in all of the three qualities reviewed compared with the treatment samples repaired with standard textile conservation repair and stabilization techniques. These repairs took the longest time to complete with average completion times ranging from 2.63 to 17.50 hours per sample.

The treatment samples repaired with the textile conservation techniques of applying an underlay with hand stitching and an adhesive-coated backing received the lowest ratings in all of the three qualities with no statistically significant difference between the means of these two conservation techniques. Both textile conservation techniques took the least time to complete with average completion times ranging from 0.88 to 2.00 hours.

The high ratings that the reweaving and reknitting treatment samples received in this research suggest the need for curators and conservators to be aware of the benefits of reweaving and reknitting and consider using these techniques to repair objects that merit the time and expenditure required. This research confirmed the lack of current, thorough information on reweaving and reknitting techniques and negligible commentary in the textile conservation literature to explain the application of these methods; this seems to indicate their minimal use or consideration in the field.

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Preface

This thesis has been written in the manuscript format as described in the University of Rhode Island Graduate School Format Guidelines for Theses and Dissertations. The manuscript has been written to satisfy guidelines for manuscripts submitted to the Journal of the American Institute for Conservation. Appendices include a review of literature, treatment samples summary, test data, textile repair evaluation form, and evaluation panel comments. Photographs noted in the List of Figures are included in a separate CD included at the end of the thesis.

The Journal of the American Institute for Conservation is a periodical published three times a year for its members and others within the conservation field. Articles submitted for publication are reviewed by the editor, an associate editor in the appropriate specialty, and two reviewers.

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1.0 Introduction

When determining repair options to stabilize damaged textiles, textile conservators face a dilemma unique to textile conservation. The visual image of a textile or costume, whether in terms of design and pattern or of cut and construction, cannot always be separated from the medium. In a woven structure such as a tapestry, the construction and the design are one and the same. No distinction exists between a support canvas, medium, and representation, as with a painting, for example. For this reason, any missing part of a textile, whether it is large or small, represents a loss of both material and image. This is a basis of a major problem for textile conservators – how to integrate the two parts of the work (Brooks, et al. 1994; Giannatiempo Lopez 1994; Hutchinson 1990-91; Shore 1993).

Two conflicting opinions exist when determining treatment options to repair damaged textiles that share the same concern – that the style and character of the textile must be preserved. The first opinion (conservation) supports the idea that honesty with respect to the observer and to the artist who originally created the textile must be maintained and that the repairs done must be distinguishable from the original textile (Lodewijks and Leene 1972, 137-138). The second opinion (restoration) holds that any repair work done should be as invisible as possible on the condition that all repairs are fully documented by photographs and detailed reports (Lodewijks and Leene 1972, 137-138).

Reweaving and reknitting techniques have a long history of use as preferred methods in the repair of expensive textiles and apparel for the superior results they can provide in terms of aesthetics and structural stability. However, reweaving and reknitting in textile conservation have experienced limited application compared with other repair and stabilization techniques such as applying backings with either hand stitching or adhesives. In addition, while commercial literature contains basic information on reweaving and reknitting, no U.S. textile conservation literature exists that provides specific information on these techniques.

Repair techniques of reweaving and reknitting are greatly undervalued and underutilized and have more potential than is currently recognized in textile conservation practice (Lodewijks and Leene 1972; Perkins et al. 1990-91; Shore 1993). These techniques rebuild losses in textiles by replacing yarns to duplicate structure and pattern. Traditionally viewed as restorative methods used mainly for consumer clothing and household furnishings, reweaving and reknitting have much potential for repairing and stabilizing historic and collectible fabrics. They provide enhanced visual appearance and structural integrity more than commonly used textile conservation techniques (Fabricon 1993a, 95; Francis 1999; Perkins et al.1990-91).

The purpose of this study was to compare rewoven and reknitted textile samples with textiles repaired and stabilized by traditional conservation techniques to explore the potential for expanding the use of reweaving and reknitting in textile conservation. The potential of the repair techniques used to repair the treatment samples for this research was judged in terms of aesthetics or appearance of the finished repair, its structural integrity or stability, and the compatibility of the repair with the drape of the original textile.

The study used two reweaving techniques and two reknitting techniques. The two reweaving techniques used on the woven treatment samples were French reweaving and side weaving. A basic reknitting technique of replacing individual knit stitches and a knit- grafting technique were used to repair the knit fabrics. The basic textile conservation techniques of attaching an underlay patch with hand stitching and the use of an adhesive-coated backing were the two traditional textile conservation repair and stabilization methods used.

1.1 French Reweaving

French reweaving is a method of repairing losses in textiles by the actual weaving of individual replacement warp and weft yarns to replicate the original textile weave structure. The basic reweaving method of yarn replacement to repair damaged textiles has a history practically as old as that of hand-woven textiles (Shore 1993). The art of reweaving grew into a highly developed specialty by the Middle Ages when "invisible reweaving" repaired textiles of artistic and historic value belonging to the Church and nobility (Benford, Marino 2002, 6). Commercial reweaving methods still are used widely in the repair of expensive apparel, household textiles, and upholstery. Textile and paintings conservators generally do not use reweaving as a general loss compensation technique with the exception of treating tapestries, carpets, and paintings canvases (Deralian 1987; Heibert 2003; Shore 1993).

1.2 Side-weaving

An alternative to French reweaving is side-weaving which involves reweaving a patch of cloth to cover an area of loss instead of reweaving individual warp and weft yarns. A patch of matching cloth is cut to cover the area of loss, and the sides are unraveled to form fringed edges. The fringed edges then are rewoven into the fabric with a latch type needle. The side-weaving technique is especially useful when repairing large areas of loss when French reweaving might be impractical.

1.3 Reknitting

The basic concept of reknitting to repair areas of yarn loss involves obtaining replacement yarns comparable in fiber, as well as yarn structure, diameter, texture, and color. Individual replacement yarns are reknitted into an area of loss to duplicate the original knit stitch structure.

1.4 Knit-grafting

The knit-grafting technique involves knitting a patch of matching knit fabric to fill in an area of loss. This reknitting technique is useful for repairing large areas of loss, double knits, and patterned knits.

1.5 Underlay patch attached with hand stitches

Attaching an underlay patch with hand stitches is a standard textile conservation repair and stabilization method. The technique involves cutting an underlay patch of an appropriate support fabric, placing the patch underneath the damaged fabric to be stabilized, and then attaching the patch to the damaged fabric with hand stitches around the outer edges of the patch and then along the edges of the loss area. This is a practical and time-saving method that can be used in a variety of applications.

1.6 Attaching adhesive-coated backing

The use of an adhesive-coated backing is another standard textile conservation repair and stabilization method. A backing support fabric is cut to the size of the damaged textile and an application of adhesive is applied to the backing fabric and allowed to dry. The backing fabric then is adhered to the damaged textile with the application of heat. Adhesives are used in instances when other repair and stabilization techniques may not be possible or practical.

2.0 Reweaving and Reknitting Techniques

What follows are detailed instructions outlining basic reweaving and reknitting techniques. French reweaving and side-weaving are the two methods discussed that were used in this research. The reknitting techniques of repairing a ladder or run, repairing a small hole in stockinet knit, repairing a larger hole with guideline threads or needles, and knit-grafting repair techniques are included after the reknitting techniques.

2.1 French Reweaving

The French reweaving technique involves the reweaving of individual warp and weft yarns with reweaving needles to replace missing or damaged yarns and rebuild original weave structure and pattern.

2.1.1 Needles

Needles of all types share the same basic structural features: shaft, point, and eye (Kurella 2001). Needles made specifically for French reweaving are recommended over other types of needles as they have larger eyes and narrower diameter shafts for easier threading and manipulation of the reweaving yarns through the fabric. Blunt tips allow the needles to slip in between the yarns of the fabric to avoid penetrating and damaging them (Fabricon 1993a).

As shown in Table 1, reweaving needles come in sizes 2 to 12, with 12 being the smallest (Table 1) (Fig. 1). The appropriate size of needle for a reweaving project is determined by yarn diameter and fabric count of the textile to be repaired (Table 2).

Sizes 2 through 4 are useful for the heaviest weight fabrics with large diameter yarns. Sizes 5 through 8 work on medium weight fabrics with smaller diameter yarns. Sizes 9 through 12 are best on lightweight fabrics with the smallest yarn diameters. Beading needles and yarn darners can be modified for reweaving medium to heavy weight textiles by running the point of the needle over an emery board to blunt the tip, but it must be smooth so that it will not catch on the fibers. Using the correct size needle is essential for ease of threading and minimum distortion of yarn alignment in the repair area.

Table 1 Comparison of French Reweaving Needles

Needle Size	Length (millimeters)	Shaft Width (millimeters)	Eye Size (length x width) (millimeters)
2	46.87	1.04	1.94 x 0.95
3	42.68	0.90	1.60 x 0.71
4	37.21	0.97	1.62 x 0.57
5	33.15	0.85	1.46 x 0.52
6	40.33	0.72	1.33 x 0.45
7	29.75	0.66	1.24 x 0.52
8	34.82	0.54	1.13 x 0.52
9	32.56	0.41	1.02 x 0.46
10	28.46	0.57	0.93 x 0.46
11	31.15	0.39	0.86 x 0.33
12	29.41	0.34	0.78 x 0.30

Fig. 1. French reweaving needles / size range

2.1.2 Counting out weave pattern

The process of "counting out" is an important first step in reweaving (Fabricon 1993a; Lopatka 2003; Saunders 1958). It determines the weave pattern of warp and weft yarns in a textile to be rewoven before the start of the actual reweaving process. The technique involves analyzing the path of each weft yarn and the number of warp yarns each weft yarn is passing over (o) or under (u) until a total assessment of the weave pattern is confirmed. A basic plain weave, for example, is written: U1, O1, U1, O1 for the first weft yarn; O1, U1, O1, U1 for the second weft yarn; U1, O1, U1, O1 for the third; and O1, U1, O1, U1 for the fourth. By counting out along four weft yarns, the complete progression of a plain weave pattern is confirmed before the actual reweaving begins (Fig. 2).

Table 2 Treatment Fabric Characterization

Weave / Knit Structure	Fiber	Yarn Construction (simple / ply)	Direction of Spin / Twist (S / Z)	Yarn Width (millimeters)	Yarn / Wale Count
Plain weave /low thread count	Wool	Warp and weft: simple single	Warp and weft: z spin	Warp: 1.65 Weft: 1.70	Warp: 5 yarns / cm Weft: 5 yarns / cm
Plain weave /high thread count	Wool / polyester blend	Warp and weft: simple single	Warp and weft: z spin	Warp: 0.45 Weft: 0.43	Warp: 16 yarns /cm Weft: 15 yarns /cm
Twill weave	Wool	Warp: 2-ply Weft: simple single	Warp: S twist Weft: z spin	Warp: 1.11 Weft: 0.63	Warp: 10 yarns /cm Weft: 12 yarns /cm
Patterned weave	Wool	Warp and weft: both 2-ply	Warp and weft: S twist	Warp: 0.77 Weft: 0.68	Warp: 14 yarns /cm Weft: 12 yarns /cm
Knit /stockinet	Wool	Two 2-ply	S twist	1.32 / both plys	3.5 wales / cm
Knit /patterned	Polyester blend	One 2-ply	Z twist	0.45	NA
Double knit	Wool	Two 2-ply	S twist	1.02 / both plys	6 wales/cm

Fig. 2. "Counting out"

2.1.3 Preparation of damaged area and replacement yarns for reweaving

The second step of French reweaving is cutting away damaged portions of original yarns so that they will not obscure the reweaving process. Care also should be taken to thoroughly examine the textile immediately surrounding the damaged areas(s) for additional "hidden" damage such as grazing from moth activity, which can significantly weaken yarns and weave structure. Confirming the location of the topmost damaged yarn and starting the reweaving process beginning with or above that yarn is important. Leaving a partially damaged yarn could cause problems either later in the process or after the reweaving is complete.

Yarn ends from the fabric should extend no more than 1/8 inch into the area to be rewoven. The preparation process of removing damaged yarns is known in the reweaving trade as "teasing out" (Fabricon 1993a) (Fig. 3). During the teasing process the ends of yarns along the damaged area are teased away from the intact fabric so that they can be trimmed later. When removing damaged yarns from areas of extensive loss, the trimmed yarn ends are "stair stepped" with replacement yarns to eliminate bulkiness of overlapping yarns around the repair area (Fabricon 1993a; Saunders 1958) (Fig. 4).

Fig. 3. "Teasing out"

Fig. 4. Stair stepping of trimmed yarn ends

Ideally, replacement warp and weft yarns for reweaving are acquired from undamaged portions of the textile to be repaired, so that these yarns will match the textile in color and texture. When this is not possible, replacement yarns of compatible color, texture, structure, size, and fiber content must be acquired from other textiles. If yarns of the correct color are not available, they could be dyed. Warp and weft yarns usually are not used interchangeably in reweaving due to the different strength and structural properties of each (Fabricon 1993a).

2.1.4 Dipping

The technique of dipping anchors the beginning and end of a replacement weft or warp yarn and involves taking one long stitch of about ½ inch in length which floats along the underside of the fabric with a reweaving needle threaded with the replacement yarn before beginning to reweave and making a similar stitch after reweaving. The replacement yarn is placed in alignment over the broken yarn with each end of the replacement yarn worked into the weave structure over the ends of the broken yarn (Fabricon 1993a; Lopatka 2003; Saunders 1958) (Fig. 5). The tips of each end of the replacement yarn should protrude at least ½ an inch above the top fabric surface and are trimmed after the reweaving repair is complete.

Fig. 5. "Dipping"

The replacement yarns are in turn stair stepped with the trimmed yarn ends of the damaged area. Reweaving literature generally recommends that dips for the first three replacement yarns be placed at progressively farther distances from the damage. The dip for the fourth replacement yarn is placed at the same distance as the first, followed by the same progression of distance for the first set of yarns. This progression is repeated for every set of three replacement yarns. The stair stepping of dips also is necessary for the placement of the "joinings," discussed next (Fabricon 1993a; Lopatka 2003; Saunders 1958) (Fig. 6).

Fig. 6. Stair stepping of dips

2.1.5 Joining

"Joining" involves weaving the replacement yarn through the intact portion of the fabric beginning with the end of the dip and continuing along the yarn to be replaced up to the point where the damaged yarn end has been teased out at the edge of the damaged area. The replacement yarn is continued along the line of damage to the opposite broken end, and rewoven into the intact portion of fabric on the other side of the damage for a distance of approximately five yarns to complete the second joining. A final dip is made on back of the other side to complete the reweaving of the replacement yarn (Fabricon 1993a; Lopatka 2003; Saunders 1958). Joinings are placed at the beginning and end of each row to secure the beginning and end of a replacement weft or warp yarn on both sides of the damaged area. The length of the joining can vary depending on the size of the yarns and thread count (Fig. 7). Joinings are generally longer in length for lower thread count fabrics with wider diameter yarns and shorter in length for high thread count fabrics with narrow diameter yarns.

Fig. 7. "Joining"

Multiple yarn joinings for areas of loss larger than three warp or weft yarns are stair-stepped in the same manner as described for dipping. This stair-stepping arrangement of the dippings and joinings distributes the bulk of the overlapping yarns in such a way that the double thickness of yarns at the edges of the repair area are scattered and the ends do not form a sharp line (Fig. 8).

Fig. 8. Stair stepping of dips and joinings

The first four steps of French reweaving previously described 1) counting out, 2) preparation of textile and yarns, 3) dipping, and 4) joining, apply to the repair of damaged textiles where either the warp or weft yarns are damaged or when both warp and weft yarns need to be replaced. These four steps position the replacement yarn for the actual reweaving across the area of damage.

2.1.6 Reweaving sets of warp or weft yarns

When reweaving individual or multiple sets of warp or weft yarns, the damaged area usually is positioned so that the yarns to be rewoven are running in a horizontal alignment to the reweaver, with the reweaving progressing from right to left, beginning with the top-most damaged yarn for a right-handed reweaver. After the dipping and joining of a replacement yarn are completed at the right hand edge of the damage, the threaded reweaving needle is worked through the existing set of warp or weft yarns across the area of damage per the weave structure formula counted out in the first step (Fig. 9). Once the left edge of the damage is reached, the joining and dipping steps are completed on the left side of the damage to complete the reweaving of the individual replacement yarn. The yarn ends of the original damaged yarn and tips of the replacement yarn protruding above the textile surface then are trimmed closely to the textile surface to finish the reweaving process (Fig. 10).

Fig. 9. Reweaving individual or multiple warp or weft yarns

Fig. 10. Trimming damaged and replacement yarn ends after reweaving is complete

2.1.7 Reweaving sets of both warp and weft yarns

The same steps discussed in the reweaving of individual or multiple warp or weft yarns apply to reweaving damaged textiles in which both warp and weft yarn sets must be replaced. When reweaving areas of warp and weft damage, the reweaving literature specifies that the replacement weft should be inserted first, then the warp (Fabricon 1993a; Lopatka 2003; Saunders 1958).

After the replacement weft yarns are placed in position following the basic steps, the damaged weft yarn ends that were teased out then can be trimmed back closely to the top textile surface. This technique makes seeing the reweaving work more clearly as lost warp yarns are replaced (Fig. 11).

Fig. 11. Trimming damaged yarn ends after reweaving replacement weft yarns and before reweaving replacement warp yarns

Once the damaged weft yarn ends are trimmed, the fabric is turned clockwise so that the rewoven weft yarns are running in a vertical direction (Fig. 12). The replacement warp yarns to be rewoven next will now be in a horizontal orientation, with the reweaving progressing from right to left, beginning with the top-most damaged yarn following the weave pattern determined during the counting out process (Fig. 13). After the reweaving of the replacement warp yarns is complete, the damaged warp yarn ends then are trimmed back closely to the textile surface (Fig. 14).

Fig. 12. Turning of reweaving with replacement weft yarns prior to reweaving warp yarns

Fig. 13. Reweaving of replacement warp yarns

Fig. 14. Trimming damaged warp yarn ends after reweaving replacement warp yarns

2.1.8 Trimming replacement weft and warp yarn ends

When a damaged area has been completely rewoven and the ends of the original damaged weft and warp yarns have been trimmed, the ends of the replacement weft and warp yarns at the beginning of the first dips and at the end of the second dips then are trimmed. After cutting, the slight tension placed on each yarn before cutting lessens, allowing the cut ends of the yarns to spring back and bury themselves in the textile so that they do not show on the textile's surface. The trimming of the replacement yarn ends completes the French reweaving process (Fig. 15). Pressing the finished reweaving finishes the procedure (Fig. 16).

Fig. 15. Trimming replacement weft and warp yarns to complete French reweaving repair

Fig. 16. Completed French reweaving repair

2.1.9 Pressing

Pressing the completed reweaving is an important finishing procedure. The basic pressing method involves placing a heavy press cloth that has been moistened with water over the rewoven area. A preheated iron is pressed down on the press cloth to create steam. The press cloth then is removed, and the reweaving allowed to dry in place. The pressing method varies according to the fiber content and yarn and weave structure of the rewoven textile. Fulled or textured fabrics such as camel's hair coating and woolens are steamed with a heavy moistened press cloth with the heated iron resting lightly on the cloth long enough to steam it thoroughly, but not long enough to dry out the pressing cloth. Silk fabrics and fabrics with a crepe-weave structure are pressed with a press cloth wetted just enough to create steam. The iron is placed close enough to the pressing cloth to steam the fabric underneath, but the full weight of the iron is never placed on the fabric nor is the press cloth allowed to dry out, as this will make the silk or crepe fabric shiny. Light-colored fabrics and those that have a tendency to water spot are pressed dry on the wrong side of the fabric to prevent the formation of shiny spots. Hard-finished worsted suit fabrics and similar fabrics are pressed on the right side with a pressing cloth moistened just enough to create steam. These fabrics are pressed until the pressing cloth is almost dry (Saunders 1958).

2.2 Side-Weaving

The side-weaving technique involves reweaving an actual patch of fabric over a damaged area of a textile instead of reweaving individual yarns. The patch is cut from fabric that matches the original damaged textile in both color and weave structure. The edges of the patch are unraveled prior to reweaving, and the resulting freed yarns of the patch are woven into the original textile. The patch actually covers the area of loss, with the warp and weft yarn alignment of the patch being parallel to the weave structure of the original textile. Any size damage can be repaired with this technique as long as the replacement patch matches the original textile in color, pattern, yarn structure, and weave.

2.2.1 Needles

A specially designed latch needle is used for weaving in the replacement patch. The latch needle has a curved spear point and movable latch: the shank of the needle is secured in a plastic, metal, or wood handle. The latch, which is screwed to the base of the curved spear point, is designed to drop over the tip of the spear point. It closes to form an eye when the needle is withdrawn from the textile (Fig. 17). Latch needles are made in three sizes: fine, medium, and heavy. The smallest needle has a very fine spear point and latch for picking up single yarns. The fine needle is for lightweight fabrics; the medium needle is suitable for medium weight fabrics such as serge and gabardine; and the heavy latch needle is designed to hold coarser yarns found in tweeds and heavyweight textiles. The delicate needle mechanism of any size latch-type needle must never be overloaded because of the danger of breaking the latch.

Fig. 17. Side-weaving – latch needle

2.2.2 Counting out

As with the French reweaving technique (section 2.1.2), counting out is an important first step to determine the entire pattern of a weave structure before the actual reweaving begins.

2.2.3 Preparation of textile for reweaving

In contrast with the French reweaving method, in side-reweaving the damaged portion of the original textile is not trimmed back prior to side reweaving. Trimming enlarges the damaged area and weakens surrounding yarns thus requiring a larger replacement patch (Fabricon 1993b).

2.2.4 Placement of guideline stitches

Guideline stitches are small temporary running stitches that are placed around the damaged area prior to reweaving using a fine sewing needle and contrasting color sewing thread. Guideline stitches serve two important purposes: they help mark the position of the replacement patch to be placed over the damaged area, and they indicate the point where each of the unraveled yarns of the replacement patch is to be drawn into the textile. Guideline stitching generally is not placed closer than one quarter of an inch to the damaged area to ensure that all of the weakened yarns are covered by the replacement patch (Fabricon 1993b).

The guidelines are stitched around all four sides of the damaged area, usually forming a square or rectangle. The guideline stitches should be small, even, no longer than one eighth of an inch in length and must be put in with great care to ensure accurate placement of the replacement patch (Fig. 18).

Fig. 18. Placement of guideline stitches

2.2.5 Preparation of replacement patch

The replacement patch must match the pattern and weave structure of the original textile and be large enough to extend at least one-quarter of an inch beyond the damaged area with an additional three-quarters of an inch allowance for anchoring threads. For example, if the damaged area is one inch wide by one inch long, the replacement patch must be at least three inches wide and three inches long (Fabricon 1993b) (Fig. 19).

Fig. 19 Preparation of replacement patch

The replacement patch is placed over the damaged area so that the patterns of the original textile and replacement patch align exactly. It is pinned securely to the textile along the left edge with straight pins. The right-hand edge of the replacement patch is folded back until the right-hand guideline is visible. The corresponding yarn in the edge of the fold of the replacement patch that lays over the right-hand guideline will mark the edge of the replacement patch and the starting point for unraveling yarns along the right-hand side of the replacement patch that will be woven into the textile (Fabricon 1993b) (Fig. 20).

Fig. 20. Positioning of replacement patch

2.2.6 Unraveling edge of replacement patch

The pointed tip of a straight pin or sewing needle is used to unravel warp yarns from the right-hand edge of the replacement patch. Yarns should be gently unraveled one at a time so that the replacement patch and textile are not pulled out of shape. This will produce a fringe of horizontal weft yarns on the right-hand side of the replacement patch (Fig. 21). The warp yarn in the replacement patch that corresponds to the right-hand guide line that has been stitched to the right of the damaged area of the textile is not unraveled at this point. The right-hand edge of the replacement patch is usually unraveled first. Only one side of a replacement patch is unraveled at a time. The yarn ends tend to come apart easily when they are unraveled, so yarns should not be unraveled until they are to be woven into the textile.

Fig. 21. Unraveling edge of replacement patch

2.2.7 Anchoring the first yarn

The pointed tip of a straight pin or sewing needle is used to straighten the yarns in the fringe of the replacement patch along the right-hand side. All the yarns in the fringe should be about three-quarters of an inch in length. They should all be parallel and lay smoothly on the top surface of the textile (Fig. 22). The upper right-hand corner of the replacement patch is lifted to expose the top horizontal guideline. The first horizontal or weft yarn at the top of the fringed right side of the patch should lay directly over this top horizontal guideline (Fig. 23). The first fringed yarn is separated from the other yarns in the fringe and gently pulled backwards and held down with the thumb of the left hand (Fig. 24).

Fig. 22. Fringed right side of replacement patch

Fig. 23. Alignment of top guide thread with first fringed yarn

Fig. 24. Separating first fringed yarn of replacement patch

The latch-type needle is inserted into the textile from the face side of the textile between the warp yarns at a point about five-eighths of an inch to the right of the right-hand guideline in line with the first fringed yarn. The needle should be inserted only until the tip of the latch is visible from above (Fig. 25). A small dip stitch approximately 3/8 inch in length is first made to anchor the fringe tip of the patch yarn in place once it is pulled through, comparable to the French reweaving method. The handle is tilted towards the textile, and the tip of the needle is slid over three or four cross yarns that are directly under the horizontal yarn that extends to the right from the top horizontal guideline at the right hand edge of the repair area (Fig. 26). The tip of the needle is brought to the top of the textile between the vertical right-hand guideline and the yarn in the replacement patch that is directly to the right of the guideline (Fig. 27). The tip of the latch-type needle passes through the textile and the fringe of the replacement patch; it should not pass through the replacement patch itself.

Fig. 25. Inserting latch needle to reweave first fringed yarn

Fig. 26. Underside of fabric showing needle placement

Fig. 27. Reweaving first fringed yarn of replacement patch

The latch needle is pushed through the textile until the latch has passed completely to the top surface of the textile. The first fringe yarn that was held back is placed into the hook of the needle (Fig. 28). The needle is drawn back carefully through the textile, over the cross yarns that lay under the first horizontal yarn, and up through the top surface of the textile at the point where the needle was originally inserted.

Fig. 28. Placing first fringed yarn into hook of latch-type needle

After the first yarn is pulled through the textile, about one-eighth of an inch of the yarn or "fringe tip" will show through above the top surface, approximately five eighths of an inch to the right of the right-hand guideline stitching. The length of the fringe tip should indicate if the yarn has been anchored correctly (Figs. 29, 30).

Fig. 29. Anchored first fringed yarn (face view)

Fig. 30. Anchored first fringed yarn (reverse view)

The horizontal yarn of the replacement patch that lays over the bottom guide line of the textile is the last fringed yarn end to weave in along the right edge. The remaining fringed yarn ends along the right-hand edge of the replacement patch including this last yarn end are woven into the textile in the same manner as the first yarn end.

The steps for weaving in the remaining sides of the replacement patch are the same as previously described for the first side: 1) rotate the textile counter-clockwise; 2) unravel the vertical yarns at the right-hand edge of the replacement patch up to the yarn that is directly on top of the right hand guide line; 3) weave in the top yarn of the fringe; 4) weave in the remaining yarns of the fringe up to the yarn that is directly on top of the bottom guide line; 5) repeat these steps (Figs. 31, 32, 33).

Fig. 31. Rewoven yarns of right hand edge of replacement patch

Fig. 32. Turning side weaving counter-clockwise to reweave next side of replacement patch

Fig. 33. Turning and reweaving of last side of replacement patch

2.2.8 Finishing

Once all four sides of the replacement patch are woven into the textile, the lines of resulting fringe tips visible on the top surface are trimmed with small sharp scissors, pulling each fringe tip slightly with tweezers prior to trimming to ensure the trimmed fringe tips are flush with the textile (Fig. 34). The textile then is turned over to the wrong side, and the dips visible on the wrong side are pulled out using the tip of a sewing needle or straight pin (Fig. 35). The resulting fringe of yarns on the underside of the textile is not trimmed. They are left to help anchor the replacement patch firmly; removing them would weaken the repair (Fabricon 1993b).

Fig. 34. Trimming fringe tips on face side after all four sides are rewoven

Fig. 35. Pulling out dips on reverse side

With the side-weaving technique, the damage in the textile and the reweaving work always will be visible from the underside of the textile, but from the right side, the presence of the weaving repair will be minimal (Figs. 36, 37). The repaired area should be steam pressed with a moistened press cloth after the reweaving is completed following the basic pressing techniques for French reweaving discussed in Section 2.1.9.

Fig. 36. Reverse side of completed side weaving repair

Fig. 37. Face side of completed side weaving repair

2.3 Semi-Weaving (or In-Weaving)

Semi-weaving is a variation of the side-weaving technique. This method consists of obtaining a replacement patch that matches the yarns, weave structure, and pattern of the textile to be repaired as with side-weaving, but instead of weaving each yarn separately, two or more yarns are grouped at a time and pulled into the textile weave structure. The latch needle is used as with side weaving, although a larger size is necessary since more threads are involved. This technique sometimes is used for very large areas of damage (Fabricon 1993b, Saunders 1958).

2.4 Introduction to Reknitting Techniques

A wide variety of reknitting techniques exist that can effectively repair and stabilize damaged filling knit fabrics that have been snagged, pulled, or damaged by tears, rips, runs, or burns.

2.4.1 Equipment and Materials

Reknitting techniques require only the most basic equipment. An assortment of crewel needles, basic sewing needles and crochet hooks in different sizes, sewing threads, and small sharp scissors are required. Ideally matching yarns for reknitting are acquired from an inconspicuous area of the damaged fabric being repaired. When this is not possible, compatible yarns similar in structure (number of yarns in ply, direction of twist), color, thickness, and texture are required. Dyeing the yarns sometimes is necessary.

2.4.2 Tracing

Tracing is an important first step of the reknitting process in which the specific structure and pattern of the knit stitching in a knit fabric is determined prior to the actual start of work, much as counting out is done for reweaving (Fabricon n.d., Saunders 1958). The basic tracing technique involves threading a crewel needle with a contrasting color yarn, following the horizontal path of one yarn in one row of an undamaged section of the knit fabric, and recreating the knit stitches with the yarn to confirm the exact placement of the knit stitches in relation to the rows immediately above and below the row being traced (Fig. 38). The yarn used for tracing the knit pattern is left in the knit fabric during the reknitting process to be used as a structural reference (Fig. 39). This tracing technique is carried over into the actual reknitting process, when a crewel needle is threaded with the matching yarn for the actual repair (Fabricon n.d.; Saunders 1958). The initial tracing yarn used to confirm the knit structure is removed after the reknitting repair is complete.

Fig. 38. Reknitting – Tracing technique to confirm knit structure

Fig. 39. Reknitting – Use of tracing thread as structural reference

2.4.3 The Ladder or Run

The tools and supplies required for a repair of a ladder or run in a filling knit are a crochet hook, pin, darning needle, and length of matching yarn. A ladder is created when one broken stitch causes the loops of the other stitches in a knit wale to slip out of place (Fig. 40).

Fig. 40. Catching first "rung" of unraveled wale

To repair a ladder one wale in width, the damaged fabric is turned with the knit side facing up. The crochet hook is inserted from the right side of the fabric catching the last whole loop at the bottom of the ladder. The first "rung" of the ladder is caught, pulled down through the loop and then up in front of it, forming a new loop (Fig. 40). With the crochet hook still holding the newly formed loop, the crochet hook is inserted through the next rung, and this next rung is pulled down through the loop on the crochet hook and then up. This technique is repeated until the broken yarn is reached. A pin is inserted through the last loop to fasten it in place. A length of matching yarn threaded through a darning needle is stay stitched to the wrong side of the knit fabric at the top of the ladder. The needle is brought through to the right side, and a knit stitch is taken through the last loop of the ladder repair and the first undamaged knit stitch bordering the top of the ladder to secure the top knit stitch of the ladder repair in place (Fig. 41). The pin is removed, and the yarn fastened off and trimmed on the wrong side to complete the repair (Figs. 42, 43).

Fig. 41. Stitching last loop of repair yarn to secure in place

Fig. 42. Fastening off trimmed yarn to complete repair

Fig. 43. Completed repair

2.4.4 Reknitting Small Hole in Stockinet Knit

To prepare a hole for reknitting broken single or multiple knit stitches in a single horizontal row, the tip of a needle is used to pull the broken ends of the yarn through to the back of the fabric. A clean edge to the hole is necessary to avoid frayed ends being in the way of the reknitting process. With some types of damages such as insect or burn losses, picking some of the ends out one or two stitches back from the hole to eliminate any additional weakened stitches may be necessary. The broken yarn ends must be long enough to stay pulled through to the back of the knit fabric (Fabricon n.d., Saunders 1958) (Fig. 44).

Fig. 44. Preparing edges of small hole prior to reknitting

To begin the reknitting process, the horizontal row to which the missing knit stitch or stitches belonged is located. Starting two knit stitches to the right of the hole, the length of reknitting yarn threaded through a crewel needle is fastened to the wrong side of the knit fabric by making a small stay stitch through a loop on the wrong side of the knit fabric. The yarn is pulled up almost to the end, and then another stay stitch is made through the first loop (Fig. 45). This double stay stitch method securely holds the ends of the replacement yarn and does not create any bulkiness of the yarn ends compared with knotting techniques found in hand sewing (Fabricon n.d., Saunders 1958). The crewel needle threaded with the reknitting yarn then is brought through to the right side approximately two knit stitches to the right of the hole (Fig. 46). The tracing of these two knit stitches with the threaded crewel needle is done from right to left by actually following and overlapping the two knit stitches with the repair yarn until the edge of the hole is reached. This technique of starting two knit stitches away from the edge of the hole ensures the strength of the repair and is comparable to the "joining" technique of French reweaving (Fabricon n.d., Saunders 1958).

Fig. 45. Fastening replacement yarn prior to reknitting

Fig. 46. Threaded needle at right edge of repair area prior to reknitting

The missing knit stitch or stitches are reknitted by tracing the path of the knit stitches through the loops at the top and bottom of the hole with the repair yarn. Two knit stitches then are traced to the left of the hole to secure the end of the knit repair (Fig. 47). The crewel needle is run through to the wrong side of the fabric, where the reknitting yarn is fastened off using the same stay stitch technique for securing the beginning of the repair yarn and trimmed (Fabricon n.d., Saunders 1958) (Fig. 48).

Fig. 47. Tracing two stitches to the left of repair area after reknitting first row

Fig. 48. Fastening off yarn after completion of reknitting repair

2.4.5 Reknitting Larger Hole (with two or more rows of broken yarns)

In reknitting larger losses, new stitches are put in side by side as with a single row loss, but these new stitches will not loop through the top and bottom of the hole. More than one row of stitches will need to be made to repair the loss.

The issue with multiple knit row losses is how to hold one horizontal row of new stitches in place while another new row is being reknit through it. Two methods to hold these stitches in place are discussed in the reknitting literature: 1) inserting a network of temporary guideline threads either vertically or horizontally over the area of loss, or 2) using a long needle or pin to hold the row of stitches that is inserted horizontally across the area of loss (Fabricon n.d., Saunders 1958).

2.4.5.1 Using guideline threads

Guideline threads are a temporary support for one row of replacement knit stitches while the next row is being put in. Guideline threads can be placed either vertically across a knit loss or horizontally. Whether vertical or horizontal guideline threads are used for a knit repair is mainly a matter of preference.

2.4.5.1.1 Reknitting with vertical guideline threads

Prior to installing vertical guideline threads, the damaged area is prepared for repair by picking the loose yarn ends through to the back of the knit fabric. A needle is threaded with a stiff thread of a contrasting color. The thread is fastened on the wrong side of the knit fabric one stitch away from the top right hand corner of the loss. The needle is brought through to the right side of the fabric, and the thread is taken down through both the last whole loop and the first loose loop at the bottom of the loss. The loops are caught in this manner – first two at the top then two at the bottom all the way across the loss. The vertical guideline threads are not cut and fastened after each crossing across the loss. The whole guideline network is a continuous single thread, with each loop being caught twice (Fig. 49).

Fig. 49. Vertical guidelines – Inserting vertical guideline threads

The reknitting then can be done over the vertical guideline threads. After fastening the replacement yarn end on the reverse side of the knit fabric using the fastening technique discussed in Section 2.4.4 the reknitting is begun two stitches to the right of the loss. The yarn is traced to the edge of the hole. Each new stitch is wrapped around two of the vertical guideline threads with the replacement knit row being worked horizontally from the right edge to the left edge across the area of knit loss (Fig. 50). After the row is worked across to the left edge of the original knit loss, the replacement yarn is secured using the tracing technique of reknitting through the two knit stitches bordering the edge of the knit loss (Figs. 51, 52). When the first row of reknitting is complete, the fabric is turned around so that the row completed is at the top (Fig. 53). The second row is worked from right to left.

Fig. 50. Tracing repair yarn up to right edge of repair area prior to reknitting

Fig. 51. Reknitting first row

Fig. 52. Tracing two stitches to left of repair area after completing first row

Fig. 53. Turning of knit fabric to begin next row

The reknitting is continued in this way, turning the fabric around at the end of each row so that the reknitting is always proceeding from right to left. After all the rows are reknitted and the repair yarn is fastened, the guideline threads are carefully removed with small sharp scissors and tweezers (Figs. 54, 55).

Fig. 54. Fastening off yarn at end of repair

Fig. 55. Trimming repair yarns and removing guide threads to complete reknitting repair

2.4.5.1.2 Reknitting with horizontal guideline threads

Horizontal guideline threads are of the same type of thread as vertical guideline threads. After the edges of the knit loss are prepared for repair, the row of loops edging the top of the loss is found then the thread is fastened to the wrong side of the knit fabric in this top-most row eight stitches to the right of the loss. The threaded needle is inserted under the first two stitches, over the next two, and under the next two. This will bring the needle to two stitches from the edge of the loss. The thread is brought over these two stitches across the loss through the loops of the top row and over the first two stitches on the other side. The thread is stitched under two and over two as done on the other side, then fastened and trimmed. When installing horizontal guideline threads, the guide threads must be placed to properly align the knit rows edging the right and left sides of the hole.

Each guideline thread, one for each missing row, is put in this way. The middle threads will cross directly over the loss. The top and bottom threads will hold the top and bottom loops (Fig. 56). The replacement yarn is fastened to the reverse side of the knit fabric, brought to the face side two stitches to the right side of the knit loss and traced through the two stitches to bring the yarn to the edge of the knit loss. The reknitting progresses from right to left across the knit loss as with the vertical guideline technique, but the left side of each replacement knit stitch loop is under two guide threads and the right hand side of each loop is over two guide threads (Fig. 57). When the first row of reknitting is complete, the fabric is turned around so that the row completed is at the top and the second row is worked from right to left as with the vertical guideline technique. The yarn in this row will go through the loops and over and under the guideline threads of the row above. It also will go over and under the guide thread below. Once the reknitting is complete and the repair yarn is fastened, the guideline threads are removed.

Fig. 56. Placement of horizontal guide threads

Fig. 57. Reknitting replacement stitches

2.4.5.2 Using a needle to hold new stitches

With the needle method, reweaving or darning needles are used to hold new stitches instead of thread guidelines and are inserted horizontally across the knit loss much in the same way horizontal thread guidelines are. A long reweaving or darning needle is inserted into the knit fabric approximately one quarter inch to the right of the upper right corner of the damaged area, through the exposed loops of the last row of knit stitches bordering the top edge of the hole to be reknit, and then brought up through the knit fabric approximately one quarter inch to the left of the hole.

The yarn for the first row of reknitting is threaded, secured, and traced two stitches to the upper right of the damaged area as with the other reknitting techniques previously described. A second long reweaving or darning needle then is inserted through the lower portion of the knit loops just traced and placed across the damage, keeping the needle in line with the row to be reknit, and bringing the needle back through the knit fabric at a point about two stitches to the left of the damage. The row then is reknitted with the needle threaded with the replacement yarn, continuing the tracing from the upper right of the damage to the left across the damaged area. The upper loops of the new row of knit stitches are reknitted into the loops of the upper row; the lower loops of the reknit stitches are temporarily wrapped and anchored around the reweaving or darning needle.

After the first row is complete, the work is turned around so that the reknitted first row is at the bottom of the repair area. The long reweaving or darning needle originally inserted through the loose knit stitches edging the top of the hole is removed and inserted one quarter inch to the right of the next row to be reknit and placed across the damage as before. The replacement yarn for the second row of reknitting is traced two stitches to the right of the row; the loops for the new row of knit stitches are looped through both the new stitches in the row below and around the long needle placed across the row above. Alternating the two needles secures the exposed loops of each row of replacement stitches as they are reknit across the hole. The completed reknitting is secured on the left side of the repair area by tracing two stitches to the left of the last row of reknitting and securing the yarn.

I found the needle method to hold new stitches a very awkward and clumsy technique. The needles slip out of the knit fabric quite easily, resulting in dropped stitches. In addition the needle method is inadequate in providing a proper, consistent tension to ensure an even replacement knit stitch formation.

2.4.6 Knit-Grafting

The basic knit-grafting reknitting technique involves cutting and inserting a patch of knit fabric that matches the fabric to be repaired into the loss area and then reknitting the patch to the loss area around all four edges.

2.4.6.1 Double knits / bonded knits

With double knit fabrics, two separate layers are machine knit together to form a double thickness. Reknitting double knit fabrics involves treating each thickness separately.

The basic reknitting technique for the grafting repair of double knit fabrics consists of cutting and inserting a patch of matching fabric into the loss area and then reknitting the patch to the loss area around all four edges for each separate layer. Before the actual grafting can be done, preliminary steps prepare the replacement patch and loss area to ensure an accurate fit and placement of the patch.

The first step in preparing the loss area edges prior to grafting involves the placement of guideline threads. Beginning with the right side of the fabric, contrasting color thread guidelines consisting of short evenly spaced running stitches approximately 1/8 inch in length are placed across the line of loops one row above the edge of the loss area. A similar row of running stitches is put in across the lower side, one line below the bottom edge of the loss area (Fig. 58). The upper and lower rows of the double knit fabric that are directly in line with the guide threads then are carefully unraveled to provide straight, uniform rows of loops to work with and to square off the loss area (Fig. 59).

Fig. 58. Double knits – Placement of guidelines along loss area edges

Fig. 59. Preparation of loss area edges

The number of horizontal knit rows and vertical knit wales to be replaced in the damaged area then is counted. The replacement patch will have two horizontal rows less than the actual size of the loss area to allow space for the two rows of reknitting that will attach the top and bottom edges of the patch to the loss area. The number of vertical wales, though, will be the same due to the technique used for grafting the left and right sides. This is a very important step to ensure the accurate fit of the replacement patch. A patch of matching double knit fabric then is cut to the size of the loss area (Fig. 60). Matching yarns are unraveled from an extra section of the knit fabric for reknitting (Fig. 61). The replacement patch is placed inside the damaged area so that the loops along the upper and lower edges of the loss area and the loops along the upper and lower edges of the patch are aligned with each other and lay flat (Fig. 62).

Fig. 60. Preparation of replacement patch

Fig. 61. Unraveling replacement yarns for reknitting

Fig. 62. Placement of replacement patch

The actual reknitting and grafting then can be done. A reweaving or crewel needle is threaded with an eight-inch length of the unraveled yarn. The repair yarn is fastened two stitches to the right of the repair area using the fastening technique as previously described in Section 2.2.4. The patch is reknit into the damaged area with the threaded needle using the appropriate knit stitch to reknit the loops of the upper and lower edges of the patch with the corresponding loops of the upper and lower edges of the damaged area working from right to left for each row (Fig. 63). The reknitting yarns are fastened off at the end of each row (Fig. 64).

Fig. 63. Reknitting upper and lower edges of replacement patch

Fig. 64. Fastening off reknitting yarns at end of each row

The left and right sides of the patch and the damaged area then are grafted together using the stoting technique which connects the edges of fabrics with a series of small, regularly spaced stitches that are concealed beneath the surfaces of the fabrics being joined. Stoting the edges of two fabrics together results in a smooth, flat, almost imperceptible join.

To stote two fabric edges together, a fine sewing needle (size 10 or 12) is threaded with a general purpose sewing thread (size 50) in a matching color. The sewing thread is fastened beneath the surface at the top edge of the repair area. The stoting stitching is worked beneath the surface of the patch and edges of the repair area, working small horizontal stitches that connect the edges of the horizontal knit row of the repair area edge with the edge of the patch. A small vertical stitch is taken to proceed to the next row where the next stoting stitch is taken. This progression of horizontal stoting stitches alternated with vertical stitches is continued until the lower edge of the repair area is reached and the stoting thread fastened and trimmed (Fig. 65). The stoting of the left and right sides of the repair area completes the reknitting and grafting repair of the face side of the double knit fabric (Fig. 66). The underside of the double knit fabric is reknit and grafted in the same manner. After the grafting and reknitting of the underside is complete, the guideline threads are removed, and the reknitting and stoting yarn and thread ends are trimmed to finish the work. Bonded knits also can be repaired using this technique (Fabricon n.d.).

Fig. 65. Grafting sides of replacement patch

Fig. 66. Completed double knit reknitting repair

2.4.6.2 Patterned knits

The knit-grafting technique can be adapted successfully to repair larger damages for a wide variety of patterned knits. The basic idea is to define the basic knit repeat pattern so that the edges of the loss area and replacement patch can be prepared.

The edges of the loss area are carefully unraveled and trimmed (Fig. 67). A replacement patch that matches the portion of the pattern to be repaired is cut from extra fabric and its edges unraveled (Fig. 68). The edges of both the area of loss and replacement patch must be carefully prepared so that the corresponding knit loops and edges of each will fit exactly. The replacement patch then is placed inside the loss area, and the edges of the patch grafted to the edges of the loss area using a combination of knit stitches appropriate for the patterned knit being repaired (Figs. 69, 70). Trimming of yarn and thread ends after the grafting is complete finishes the work (Fig. 71).

Fig. 67. Patterned knit / grafting – Defining edges of repair area

Fig. 68. Preparation of replacement patch

Fig. 69. Placement of replacement patch

Fig. 70. Grafting edges of replacement patch to edges of repair area

Fig. 71. Completed grafting repair

2.4.7 Ribbed knits

Ribbing has alternate knit and purl stitches instead of all knit stitches. Each rib may have any number of stitches, usually one or two. On a ribbed knit fabric, the smooth or knit ribs stand out, and the purl ribs recede. When repairing a basic knit-one, purl-one ribbing, for example, alternate knit and purl stitches are used (Fig. 72). The basic reknitting methods previously described also can be used for ribbed knits.

Fig. 72. Ribbed knits – Alternate knit and purl stitch structure

3.0 Procedure

The purpose of this study was to compare rewoven and reknitted textile samples with textiles repaired and stabilized by traditional conservation techniques to explore the potential for reweaving and reknitting in textile conservation.

Three different techniques (1) reweaving or reknitting; (2) attaching an underlay with hand stitches; and (3) supporting with an adhesive-coated backing were used to repair damaged fabrics. The textiles treated represented a range of textile weave and knit structures including (1) plain weave / low thread count; (2) plain weave / high thread count; (3) twill weave; (4) patterned weave; (5) stockinet knit; (6) double knit and (7) patterned knit (Figs. 73-79). Each of the three treatments was applied to each of the seven fabrics for a total of 21 fabric / treatment combinations.

Fig. 73. Treatment sample – Plain weave / low thread count

Fig. 74. Treatment sample – Plain weave / high thread count

Fig. 75. Treatment sample – Twill weave

Fig. 76. Treatment sample – Patterned weave

Fig. 77. Treatment sample – Stockinet knit

Fig. 78. Treatment sample – Double knit

Fig. 79. Treatment sample – Patterned knit

Each of the 21 fabric / treatment combinations was examined by a panel of reviewers and evaluated with respect to specific qualities of (1) visual appearance; (2)

structural integrity; and (3) effect of repair on drape (Appendix F). A Visual Analogue Rating Scale (VAS) system was used to evaluate the treatment samples. The VAS rating scale model consists of a horizontal scale labeled 0 on the left (undesirable) and 10 on the right (best). The VAS system was used since the data is continuous and can be statistically analyzed.

3.1 Preparation

New fabrics representing each of the seven weave and knit structures were selected for treatment. Three 4 x 6 inch samples of each of the seven fabrics were cut. The woven fabrics then had warp and weft yarns cut to create a 1 x 1 inch hole in the center of each sample. The knit fabrics had yarns cut in a 1 x 1 inch square to create holes and dropped stitches in the center of each sample.

A firmly padded work surface was constructed using a 10 x 10 inch polyester fiberfill cushion that was covered with a laundered, high thread count plain weave cotton fabric. All four sides of the cushion were held in place with bean-bag style weights filled with lead shot to provide a solid, non-moveable base of support for the fabrics being worked on (Fig. 80). A 4 x 2 inch piece of Volara® polyethylene sheet foam was attached to the cushioned work surface with archival double-sided tape to provide a firm, yet flexible, work surface. Straight pins held the treatment samples in place.

Fig. 80. Cushioned work surface

3.2 French Reweaving

The French reweaving technique of individual warp and weft yarn replacement was used on three woven fabric samples: (1) plain weave / low thread count, (2) plain weave / high thread count, and (3) twill weave. Adequate quantities of warp and weft yarns were unraveled from extra fabric for each of the samples to provide matching yarns for reweaving.

Both reweaving and tapestry needles in various sizes were selected for reweaving the warp and weft yarns. A size 22 tapestry needle worked best for reweaving the plain weave / low thread count samples because it had the longest eye, which was necessary to accommodate the bulkiest yarn (Table 2). The blunt tip of the tapestry needle also made it ideal for reweaving. The narrow diameter yarns of the plain weave / high thread count samples required a size 10 reweaving needle. A size 5 reweaving needle worked well for reweaving the twill samples.

After counting out the weave structure pattern, individual replacement yarns were woven in following the traditional French reweaving steps of damaged yarn end preparation, stair-stepping, dipping, and joining discussed in sections 2.1.3, 2.1.4, and 2.1.5 of the "Techniques" section (Figs. 2-8). Reweaving literature specifies that replacement weft yarns be woven in first followed by replacement warp yarns (Fabricon 1993a).

After the damaged areas were completely rewoven, the ends of the original damaged yarns and ends of the replacement yarns were trimmed following the trimming techniques outlined in 2.1.7 and 2.1.8 to complete the French reweaving process (Figs. 14-15). Each of the rewoven samples then was steam pressed following the pressing techniques outlined in Section 2.1.9.

3.3 Side-weaving

The side-weaving technique discussed in sections 2.2.1 through 2.2.8 was used to repair the patterned weave sample. A patch of fabric that matched the weave structure and color of the damaged fabric was prepared for insertion into the area of loss instead of individual yarns. The 1 x 1 inch hole in the patterned weave sample required a 3 x 3 inch patch (¼ inch + ¾ inch + 1 inch + ¼ inch + ¾ inch per side). After counting out the weave structure, a 3 x 3 inch patch of matching fabric was cut (Fig. 19).

Thread guideline running stitches ⅛ inch in length were placed ¼ inch away from all four sides of the damaged area using a fine needle and contrasting color sewing thread following the technique for stitching guidelines outlined in section 2.2.4 (Fig. 18). The patch was placed over the damaged area and pinned to the textile along the left edge with straight pins, taking care to ensure that the woven pattern of the patch and damaged sample aligned exactly (Fig. 20). Prior to beginning the actual side weaving, the vertical yarns of the right hand edge of the patch were unraveled up to the yarn that lies directly on top of the right hand guide line following the technique outlined in Section 2.2.6 (Fig. 21). The fringed horizontal yarns along the right hand edge of the patch then were woven into the damaged fabric using a small size latch-type needle following the side-weaving technique described in section 2.2.7 (Figs. 22-31).

After the right hand edge of the patch was complete, the sample was rotated counter-clockwise moving the completed right edge up to the top, and the next edge to be woven to the right hand side. The remaining three edges of the patch were woven into the fabric repeating the same steps followed for the first edge discussed in sections 2.2.6 and 2.2.7 (Figs. 32-33).

After all four sides of the replacement patch were woven into the textile, the lines of fringe tips on the top surface were trimmed with small sharp scissors and tweezers so that they were flush with the textile (Fig. 34). The repaired textile then was turned over to the wrong side. The temporary guideline stitches were removed using small sharp scissors to cut the stitching thread at regular intervals and tweezers to pull out the stitching threads. The dips visible on the wrong side were pulled out using the tip of a straight pin (Fig. 35). The fringe tips on the underside of the textile were not trimmed so that they can anchor the replacement patch firmly (Fig. 36). The repaired area then was steam pressed on the right side following the pressing technique described in section 2.1.9 to complete the side-weaving repair process (Fig. 37).

3.4 Reknitting the loss of two or more rows

The stockinet knit sample was repaired by the basic method of reknitting larger knit losses using vertical thread guidelines threaded through the wales edging the loss to hold each replacement knit row in place. The equipment and materials required for the repair was a size 12 sharp sewing needle, a size 22 tapestry needle, replacement yarns for the reknitting, and brightly colored sewing thread for the guidelines. Preparation of the edges of the damaged area prior to reknitting was done by using the tip of a needle to pick the broken yarn ends through to the back of the damaged fabric. This initial step was necessary to avoid having the damaged yarn ends being in the way during the reknitting process (Fabricon n.d.) (Fig. 44). After preparing the damaged fabric, the tracing technique confirmed the knit structure as outlined in section 2.4.2 (Fig. 38).

A support foundation of brightly colored vertical thread guidelines were put in place for each wale interrupted by the hole covering the entire loss area following the technique for establishing vertical thread guidelines in section 2.4.5.1. The guideline structure that covered the entire area of loss consisted of two vertical thread guidelines per wale holding the exposed loops along the top and bottom edges in place (Fig. 49).

Matching replacement yarns were unraveled from extra sections of the knit fabric. Humidification straightened the crimp in the unraveled replacement yarns to make them easier to manipulate during the reknitting process. The unraveled yarns were saturated with distilled water, gently pulled out to full length, sandwiched between layers of heavy-weight acid-free blotting paper, and weighted until the yarns were dry (Fig. 81).

Fig. 80 Humidification treatment for reknitting yarns

A length of replacement yarn approximately eight inches in length was fastened on the wrong side of the upper right edge of the knit loss two stitches to the right of the damaged area following the fastening technique described in section 2.4.4. The tapestry needle threaded with the replacement yarn then was brought up through the knit structure to the right side (Fig. 46). The tracing technique outlined in section 2.4.2 was used to trace the two stitches to the right of the area of loss with the threaded tapestry needle working from right to left, bringing the threaded tapestry needle to the right hand edge of the damaged area (Fig. 50).

The first row of replacement knit stitches was reknit with the threaded tapestry needle over the vertical guidelines. Each replacement knit stitch was formed by wrapping the replacement yarn around each pair of vertical guide threads and reknitting each stitch to connect into the loops of the adjacent knit row, working from right to left until the left side of the damaged area was reached (Fig. 51). The two knit stitches to the left side of the damaged area were traced with the tracing technique to complete the first row of reknitting (Fig. 52).

The fabric then was turned counter clockwise so that the first row completed was at the bottom (Fig. 53). The second row was worked from right to left with the same reknitting techniques of tracing and replacement knit stitch formation over each pair of vertical guideline threads. Careful attention was paid to maintaining a consistent tension on the repair yarn during the reknitting process to ensure uniformity of the replacement knit stitches with the existing knit structure.

After the last row was reknitted and the two knit stitches to the left of the last row were traced, the repair yarn was drawn through to the back of the knit fabric and fastened off with the same fastening technique used to secure the beginning of the repair yarn (Fig. 54). The excess repair yarn remaining on the wrong side of the repaired knit fabric was trimmed to approximately one-half inch in length, and the guide threads were cut and removed using small sharp scissors and tweezers to complete the reknitting process (Fig. 55). The repaired knit sample then was steam pressed with a Rowenta iron set at the wool setting. A heavy cotton press cloth moistened with distilled water was placed over the knit sample and the iron applied with a firm pressure over the entire sample. The press cloth was removed and the treated sample allowed to air dry.

3.5 Knit-Grafting

Two variations of a knit-grafting technique were used to repair the double knit and patterned knit samples. Each of these knit fabrics had unique construction aspects that required different approaches to the reknitting techniques used. Since patterned knits can vary so widely in complexity and knit structure, different techniques are used in their repair (Fabricon n.d.).

3.5.1 Double knits

Since double knit fabrics consist of two layers of fabric, reknitting double knit fabrics involves treating each layer separately. To prepare the double knit sample for reknitting, a horizontal row of contrasting color thread guideline running stitches approximately one-eighth inch in length was placed across the line of exposed knit loops one row above the damage. A similar row of thread guideline stitching was placed across the lower edge, one row below the bottom of the damage (Fig. 58). The upper and lower horizontal rows of loops along the edges of the repair area were unraveled up to the upper and lower rows of the guideline stitching to create straight, uniform edges for the next step of the grafting process. The resulting repair area created was square in shape measuring one inch by one inch (Fig. 59).

The number of knit rows to be replaced in the damaged area was counted and the correct size of the replacement patch calculated following the steps discussed in section 2.4.6.1. A square patch of matching double knit fabric was cut to the appropriate size and the edges prepared (Fig. 60). Matching yarns were unraveled from an extra section of the double knit fabric for grafting (Fig. 61). To reduce the crimp in the unraveled yarns, the same basic humidification technique used to treat the replacement yarns for the stockinet knit sample in section 3.4 also straightened the replacement double knit yarns.

The replacement patch then was placed inside the damaged area so that the loops along the upper and lower edges and the loops along the upper and lower edges of the patch were aligned and laid flat (Fig. 62). A size 20 cross-stitch craft needle was threaded with an eight-inch length of the unraveled and humidified grafting replacement yarn. The shorter length of this type of needle, combined with its longer eye and smaller width were features that made this type of needle easy to manipulate through the small loops of the double knit structure. The yarn was fastened two stitches to the right of the repair area using the fastening technique described in section 2.2.4. The patch was grafted into the damaged area with the threaded cross-stitch needle using the stockinet knit stitch technique described in section 2.4.4 to reknit the loops of the upper and lower edges of the patch with the corresponding loops of the upper and lower edges of the damaged area working from right to left for each row (Fig. 63). The grafting replacement yarns were fastened off at the end of each row (Fig. 64).

The stoting technique was used to graft the left and right sides of the replacement patch to the sides of the area of loss. A size 10 sharps needle was threaded with an eight-inch length of Coats and Clark's Dual Duty All-Purpose size 50 sewing thread in a matching color. The sides then were grafted using the stoting technique outlined in section 2.4.6.1 (Fig. 65). The guideline stitches then were removed with small sharp scissors and tweezers. The grafting yarn and thread ends were trimmed flush with the fabric surface to complete the knit-grafting repair (Fig. 66). The second thickness of the double knit fabric was grafted following the same steps as for the first thickness.

3.5.2 Patterned knits

Due to the intricate structure of the patterned knit, a variation of the basic grafting technique was developed to complete the patterned knit-grafting repair. Yarns were unraveled carefully and trimmed from the edges of the repair area to define the edges of a basic design repeat approximately one inch in diameter that would then determine the size and shape of the replacement patch (Fig. 67). A basic design repeat that corresponded with the repair area was cut from extra fabric and edges prepared so that the replacement patch would fit properly inside the repair area (Fig. 68). The loops and edges of the replacement patch and repair area had to interconnect with each other to ensure a smooth, seamless fit.

The patch was placed within the damaged area, and the edges and loops of the damaged area and patch were aligned (Fig. 69). A size 10 French reweaving needle was threaded with a six-inch length of Coats and Clark's Dual Duty All-Purpose size 50 sewing thread in a color that blended in with the multicolored knit pattern. Unraveled yarns from the patterned knit were not used for this grafting treatment because the extremely loose twist of the yarn structure and excessive crimp that did not respond well to humidification treatments made these yarns difficult to handle and ineffective for the treatment. The thread was fastened two stitches to the right of the upper edge of the damaged area using the basic fastening technique for knits discussed in section 2.4.4. The patch was grafted into the damaged area with the threaded French reweaving needle using a combination of stockinet, blanket, and overcast stitching that closely matched patterned knit structures. The loops and edges of the patch were grafted with the corresponding loops and edges of the damaged area working clockwise around the edges of the repair area (Fig. 70). The grafting thread was fastened off at the end of the repair using the same technique used for fastening the thread at the beginning. The grafting thread was trimmed flush with the surface of the fabric to complete the knit-grafting repair (Fig. 71).

3.6 Underlay attached with hand stitches

New underlay fabrics were chosen for each fabric type and laundered to remove finishes that might provide stiffness or potentially harmful soil or finishes. High thread count plain weave fabrics were selected as underlay fabrics for all the woven and knit structures with the exception of a light-weight wool and polyester blend fabric selected for the wool / polyester blend high thread count plain weave sample. The underlay fabrics were chosen based on characteristics of the textiles to be supported. The following factors were considered for choosing underlay fabrics: the amount of support provided; the texture and interaction with the original fabric (adequate friction to stabilize placement of underlay fabric); weight of the support fabric (usually the same or lighter than the original); color, sheen, and texture.

Coats and Clark's Dual Duty threads for hand sewing in sizes 50 and 60 and size 10 and 12 sharps needles were used for stitching the underlay fabrics to the fabric samples. When choosing threads for textile repair and stabilization, stability and minimum visibility were primary considerations over fiber content. Threads made for machine sewing were not considered since compared to general purpose sewing threads, machine sewing threads are more heavily coated with polymers that may have potentially damaging effects over the long term with the fibers of historic textiles (Ordoñez 2005). Today, conservators often use various weights of cotton or cotton / polyester-blend threads for different types of stabilization stitching and polyester threads for the assembly of support fabrics due to their strength and chemical stability (AIC Textiles Specialty Group 2002).

The Coats and Clark's Dual Duty Plus Extra Fine size 60 thread of a cotton-polyester blend was the smallest diameter thread locally available and was the least noticeable thread for hand stitching, used with the size 12 sharps needle. The limited color selection of this thread restricted its use for the hand sewing stabilization treatments. The Coats and Clark's Dual Duty All Purpose size 50 thread came in a wider range of colors and was used for the remaining fabrics with the size 10 sharps needle when the appropriate color in size 60 was not available, but its wider diameter made the stitches more visible.

The first consideration for choosing appropriate needle types and sizes was based on minimal disruption of yarn orientation. Using a sewing needle that is too wide in diameter for a lightweight fabric with a high yarn count can disrupt the weave structure of the fabric. A second consideration involved the human comfort and safety factor with these needles placing the least stress on the sewer's hand.

The underlay fabrics for each fabric were pressed and cut so that the total size of the underlay patch extended ½ inch beyond the edges of the damaged area (Fig. 82). The underlay patches were positioned underneath each damaged area and pinned to each fabric sample with straight pins (Fig. 83). The underlay patches were stitched to each fabric sample along all four sides of each patch using straight stitches laid perpendicular to edges of the hole approximately 1/8 inch in length for the higher thread count fabrics and 3/16 inch in length for the lower thread count fabrics (Fig. 84). Consideration was given when stitching each sample to ensure that the stitches were long enough for a number of yarns in the fabric to support each stitch. Short stitches that just cross over a few yarns are more likely to cut through a fabric than longer stitches that have more yarns to support them. Stitches that are too long are too visible and do not provide adequate support (Ordoñez 2005). The stitching along the support patch edges also had to be placed in a strong area of the fabric to assure sufficient support.

Fig. 82. Hand stitching with underlay – Preparation of underlay

Fig. 83. Hand stitching with underlay – Placement of underlay

Fig. 84. Hand stitching with underlay – Stitching edges of underlay to repair fabric

After the stitching the underlay support edges, the edges of the damaged area were stitched to the underlay support with overcast stitches sewn so that on the top surface, they laid perpendicular to the edges of the damaged area (Fig. 85). The same factors for determining appropriate stitch length and placement for the stitching of the support patches were considered for stitching the edges of the damaged area to the support. A major concern that affected stitch length and spacing for securing the edges of the damaged area was ensuring that the stitches were long enough to extend into a strong area of the fabric to provide enough support.

Fig. 85. Stitching edges of repair area to underlay

3.7 Attaching Adhesive-Coated Backing

The same underlay fabrics used in the previous treatment technique also were used for the adhesive-coated backing. Jade No. 403 adhesive was selected for the application of this technique. It is a vinyl acetate ethylene copolymer and has a neutral pH (5.5 – 8.0) after dark and light aging. Jade No. 403 is water-soluble while wet, and thermoplastic when dry. It dries clear, forms a flexible bond, and may be used for textiles (Paskausky 1998, Proctor 1994).

The backing fabrics were cut the same size as the fabric samples (4 x 6 inches) and taped face-side up over plastic sheeting to help retain alignment of warp and weft yarns during application of the adhesive. Templates of clear Mylar were prepared that corresponded in size to the damaged areas of each fabric type. The templates were temporarily adhered with archival double-sided tape to each backing fabric to cover the area of backing fabric that corresponded with the location of the damaged areas of each fabric sample (Fig. 86). The Mylar template served as a mask to prevent adhesive from being applied to that portion of the backing fabric that would show through the area of loss. Extra Mylar strips approximately 1/8 inch in width were cut and placed in vertical rows over the open areas of the patterned knit as additional masks to prevent adhesive from being applied to the open areas (Fig. 87).

Fig. 86. Adhesive-coated backing – placement of Mylar mask to backing fabric

Fig. 87. Placement of Mylar strips to backing fabric for patterned knit

Undiluted Jade 403 adhesive was applied with a four-inch foam roller to lightly coat the surface of the backing fabrics. Paskausky (1998) determined that this application technique provided the most even coverage on a variety of fabric surfaces when compared with other treatment methods of brushing, spraying, and sponging. Two applications (one in the warp direction and one in the weft direction) were applied. The adhesive was allowed to dry between applications (Fig. 88).

Fig. 88. Drying of adhesive-coated backing fabrics

The adhesive-coated backing fabrics were laid face side up on a firmly padded surface that was covered with silicone release paper; each of the damaged fabrics was placed face side up over its backing fabric, matching the area of loss over the non-adhesive area of the backing fabric (Fig. 89). The backing fabrics were bonded to the back side of each fabric sample with a Rowenta iron tested with a TIF™ 7000 pyrometer to confirm when a bonding temperature of 180° F. was reached. The iron was placed in position and a firm downward pressure applied for ten seconds. The fabrics were returned to room temperature before being moved (Paskausky 1998) (Fig. 90).

Fig. 89. Placement of damaged fabric over adhesive-coated backing

Fig. 90. Adhesive-coated backing – Completed treatment sample

3.8 Evaluation Panel's Review of Treatment Samples

A total of 55 panel members representing students, staff, and faculty members from the Textiles, Fashion Merchandising, and Design Department of the University of Rhode Island in Kingston participated in the treatment sample review and rating process. The viewing space was open to participants during regular daytime class hours for one day, and students, staff, and faculty were invited to participate in the review process at a time during the day that was convenient for them. Panel participants represented a wide diversity of experience and knowledge of textiles.

3.8.1 Viewing Space Setup

The space selected for the viewing and evaluation of the treatment samples simulated basic textile gallery viewing conditions. A long cork backboard spanning the length of the viewing area was set at an approximate 110° viewing angle and covered with a matte black knit fabric. The exposed width of the counter provided the ideal gallery viewing distance for the panel evaluators.

The treatment samples to be viewed and evaluated were randomly assigned numbers one through twenty-one to determine their placement order. The treatment samples were pinned to the fabric-covered cork backboard with straight pins and labels placed below them to indicate their assigned numbers (Fig. 91).

Fig. 91. Viewing space setup

A digital light meter was used to help measure and adjust viewing space lighting levels to textile gallery viewing conditions of 50 lux. Two flood lamps were set up at each end of the viewing space to reflect light off the ceiling to provide indirect incandescent lighting. Natural sunlight coming into the space through three windows was controlled by adjusting the opening of the Venetian blinds covering the windows. The lighting levels were monitored with the digital light meter on a regular basis throughout the viewing period and adjusted when necessary.

3.8.2 Viewing Procedure / Evaluation Method

Each evaluation panel participant was given an evaluation form and asked to rate each treatment sample based on three qualities: appearance, structural integrity, and effect of the repair on fabric drape. The panel members rated each quality for each sample using a Visual Analogue Scale (VAS) (3 qualities for 21 samples making a total of 63 VAS lines per panel member). Each evaluator placed a single vertical mark along a ten-centimeter horizontal scale labeled 0 on the left (undesirable) and 10 on the right (best) (Appendix F). Panel members maintained the gallery viewing distance described previously and were allowed to handle the treatment samples without unpinning them.

3.8.3 Statistical Analysis Method

A total of 55 completed evaluation forms were collected from the panel of reviewers. Six forms had to be disqualified because they were either incompletely or incorrectly filled out. For each of the 49 acceptable evaluations, the responses on the VAS lines (a total of 63 VAS lines per evaluator) were quantified by measuring the distance in centimeters from the 0 endpoint of a VAS line to the mark placed by the evaluator.

The resulting dataset was analyzed using the Minitab ANOVA (Analysis of Variance) one-way analysis unstacked method with Tukey's 95% Simultaneous Confidence Intervals for All Pairwise Comparisons to determine the statistical results of the evaluation panel ratings, basing the analysis on the null hypothesis that no significant difference exists in the means of the three repair techniques: reweaving / reknitting (R), attaching an underlay with hand stitches (U), and supporting with an adhesive-coated backing (D) with respect to Appearance (1), Structural Integrity (2), and Effect on Drape (3).

The data comparing the evaluation results of the reweaving treatments with the underlay and adhesive techniques on woven fabrics were analyzed separately from the evaluations of the reknitting treatments compared with the underlay and adhesive techniques used on the knit fabrics.

4.0 Results

4.1 Statistical Results

What follows is a summary of the statistical results for the appearance, structural integrity, and effect on drape resulting from reweaving and reknitting treatments compared with attaching an underlay with hand stitches and supporting with an adhesive-coated backing.

4.1.1 Woven Fabrics

Initially the following box plots suggested that the mean of the panel member ratings for reweaving with respect to appearance (R1) might be significantly different from the means of woven fabric samples with a sewn underlay (U1) and an adhesive-coated backing (D1).

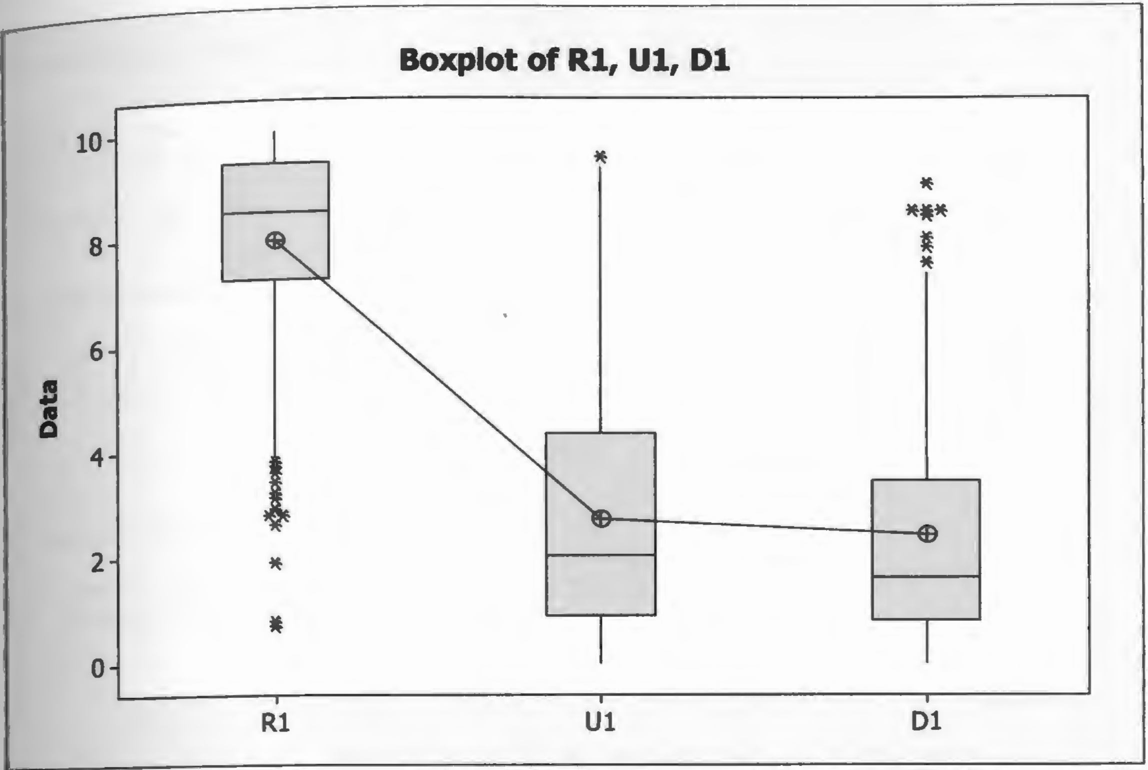

Fig. 92. Displays of appearance data for the three treatments on woven fabrics

To test this definitively, the ANOVA output below shows that three sample means (R1, U1, and D1) are not identical ($p < 0.0001$). To find out which pairs of means are different, Tukey's 95% Simultaneous Confidence Intervals for All Pairwise Comparisons determined that the mean for R1 was significantly different from both U1 and D1, and that U1 and D1 were not significantly different.

One-way ANOVA: R1, U1, D1

```
Source   DF       SS       MS       F      P
Factor    2  3841.35  1920.68  426.71  0.000
Error   585  2633.15     4.50
Total   587  6474.51

S = 2.122   R-Sq = 59.33%   R-Sq(adj) = 59.19%


                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level    N   Mean  StDev  -------+---------+---------+---------+--
R1     196  7.963  1.967                                  (-*-)
U1     196  2.697  2.248    (-*-)
D1     196  2.398  2.140  (-*-)
                          -------+---------+---------+---------+--
                               3.2       4.8       6.4       8.0
```

```
Pooled StDev = 2.122


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons

Individual confidence level = 98.04%


R1 subtracted from:

     Lower  Center   Upper    +---------+---------+---------+---------
U1  -5.768  -5.266  -4.765     (--*-)
D1  -6.067  -5.565  -5.064    (-*--)
                              +---------+---------+---------+---------
                           -6.0      -4.0      -2.0       0.0


U1 subtracted from:

     Lower  Center  Upper     +---------+---------+---------+---------
D1  -0.801  -0.299  0.203                                (--*-)
                              +---------+---------+---------+---------
                           -6.0      -4.0      -2.0       0.0
```

A similar pattern was observed for the analysis of Structural Integrity and Effect on Drape of woven fabrics (Appendix C).

4.1.2. Knitted Fabrics

Similar to the results of the woven fabrics, the following box plot again suggested that the mean of the panel member ratings for reknitting with respect to appearance (R1) might be significantly different from the means of both samples with a sewn underlay (U1) and an adhesive-coated backing (D1) on knitted fabrics.

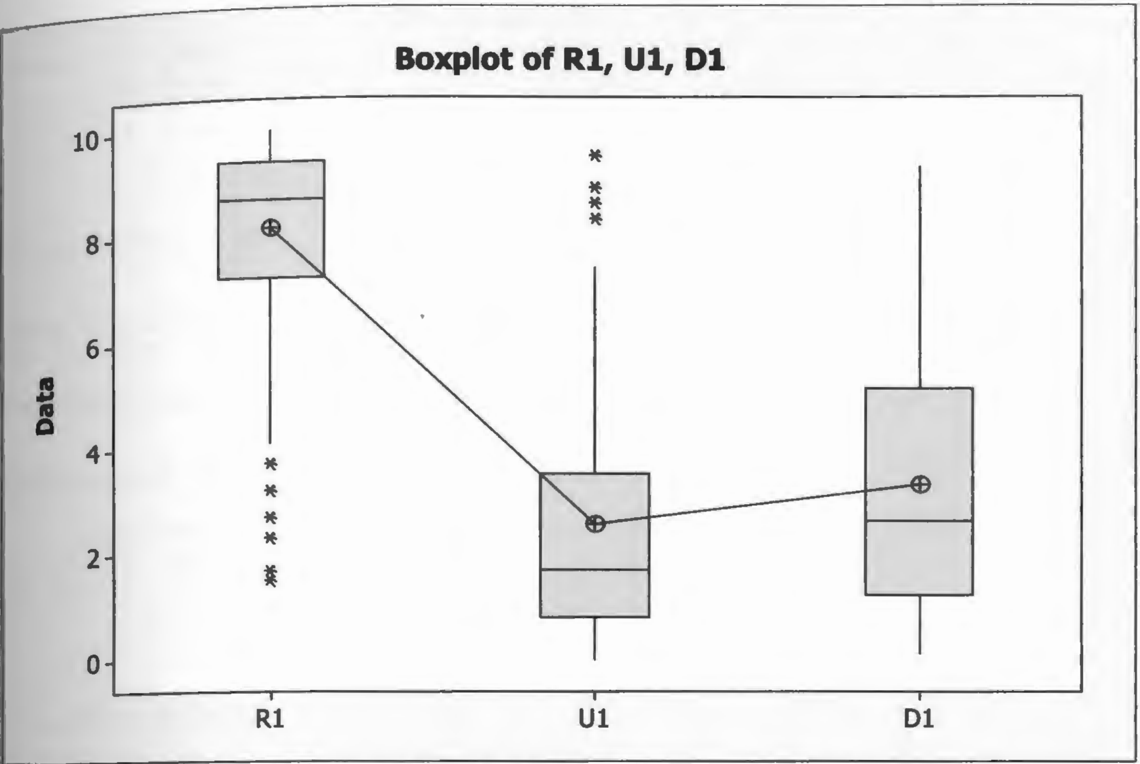

Fig. 93. Displays of appearance data for the three treatments on knitted fabrics

The results for the knitted fabrics are similar to those of the woven fabrics. The ANOVA output below reveals that three sample means (R1, U1, and D1) are not identical ($p < 0.0001$). Tukey's 95% Simultaneous Confidence Intervals for All Pairwise Comparisons determined that the mean for R1 was significantly different from both U1 and D1, and that U1 and D1 were not significantly different. A similar pattern was observed for the analysis of Structural Integrity and Effect on Drape of the knitted fabrics (Appendix D).

One-way ANOVA: R1, U1, D1

Source	DF	SS	MS	F	P
Factor	2	2739.38	1369.69	280.97	0.000
Error	438	2135.21	4.87		
Total	440	4874.60			

S = 2.208   R-Sq = 56.20%   R-Sq(adj) = 56.00%

Individual 95% CIs For Mean Based on

```
                              Pooled StDev
Level    N    Mean   StDev   ------+---------+---------+---------+---
R1     147   8.161   1.810                                      (-*-)
U1     147   2.541   2.289   (-*-)
D1     147   3.285   2.471       (--*-)
                             ------+---------+---------+---------+---
                                  3.2       4.8       6.4       8.0

Pooled StDev = 2.208


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons

Individual confidence level = 98.03%


R1 subtracted from:

     Lower  Center   Upper    -+---------+---------+---------+--------
U1  -6.222  -5.620  -5.017    (--*--)
D1  -5.478  -4.876  -4.273        (--*--)
                              -+---------+---------+---------+--------
                            -6.0      -4.0      -2.0       0.0


U1 subtracted from:

     Lower  Center  Upper   -+---------+---------+---------+--------
D1   0.141   0.744  1.347                                  (--*--)
                            -+---------+---------+---------+--------
                          -6.0      -4.0      -2.0       0.0
```

4.2 Evaluation Panel Comments

Panel participants were invited to include additional comments and observations in a comments section at the end of the evaluation form. Twelve of the participants contributed additional comments (Appendix G).

The majority of comments focused on comparing the appearance of the different treatment samples. Most of the comments seemed to favor the appearance of the reweaving and reknitting treatment samples. One panel participant commented that "the reweaving, re-threading, and re-looping are the most aesthetically pleasing of all repair techniques." Another panel participant thought that "some of the repairs were imperceptible and (I) think they were most successful visually and in hand."

The reknitting technique used to repair the multicolored knit fabric was the preferred technique for a panel participant who commented that "with the multicolored knit stripe, only the reknit sample was visually acceptable" adding that "solid color fabrics, both knit and woven that use a similar color backing are acceptable visually." The knit-grafting techniques used for the double knit and patterned knit fabrics were favored techniques for two other panel participants, rating the samples "excellent on all counts" and "perfect." Another panel participant felt that "the reweaving and reknitting jobs look best, but (I) wonder how costly and time consuming the work is."

The treatment samples repaired with the underlay and adhesive-coated backing techniques were not the preferred techniques for another panel participant who commented "couldn't tell if some holes were fixed or not." Another panel member commented on these treatment techniques as well, feeling that "visually the ones with black underlays were distracting." Another panel participant felt that "the repair is too obvious" for the underlay with hand stitching repair of the patterned knit. Another panel member agreed that the underlay with hand stitching and adhesive-coated backing repairs were visually distracting, commenting that "color (value and hue) differences in some samples could have been better – especially value more than hue."

Structural integrity of the repairs seemed to be more difficult for some of the panel participants to rate. One panel participant noted "could not judge repair's effect on structural integrity by just looking at it." Another panel member felt that "the structural stability was hard to evaluate" also adding "plus a knowledge of conservation practice can bias one's opinion" acknowledging how textile conservators and non-textile conservators may view and rate the textile treatments with differing criteria based on individual experience and preferences. The same panel participant felt overall that the reweaving and reknitting treatments were "Impressive, though."

Panel participants were more critical of the effect on drape for the treatment samples repaired with the hand-stitched underlay and adhesive-coated backing techniques. A panel member was critical of the knit fabrics' being stabilized with a woven fabric, noting "woven to repair a knit – different drape." Another panel member was critical of the adhesive-coated backing repairs and commented "extra layer makes sample stiff." Still another panel participant felt that "it may be easier to compare drape if a non-treated fabric is included as a reference."

One panel member commented on the overall rating procedure suggesting that "a demonstrated '555' (e.g.) would have made this a lot easier." This observation seemed to be reflected in several of the evaluation forms where the scoring for some of the treatment samples did not correlate with the general overall consensus of the panel. Providing a set of untreated samples for the panel to examine and compare with the treated samples could have helped with this evaluation.

4.3 Practical analysis of treatment techniques

I encountered a variety of issues when initially practicing the reweaving and reknitting techniques prior to completing the actual samples used for the panel evaluation. Following the original reweaving and reknitting techniques as they appear in the literature was comparable to following a recipe with just the basic steps, but not the critical details needed for success. What follows is a description of these issues and the solutions that I developed.

4.3.1 French reweaving

The French reweaving technique can be applied to a wide variety of fabric yarn and weave structures. However, this method requires much experience and practice to recognize the issues involved with different fabrics and how to work with them.

4.3.1.1 Plain weave / low thread count

Determining the proper tension of replacement warp and weft yarns and maintaining a consistent tension throughout the reweaving process was one of the more challenging issues and involved much experimentation and practice. The wide diameter bulky yarn of the low thread-count fabric was the primary factor influencing tension. Improper yarn tension affected the alignment of both the replacement yarns and edges of the repair area, making the reweaving much more visible when compared with other rewoven fabric samples where a proper balance of tension was achieved (Fig. 94).

Fig. 94. Plain weave / low thread count – distorted reweaving structure

Initial experiments confirmed that a looser tension of replacement weft yarns is needed when working with these bulkier yarns to ensure adequate replacement weft yarn length to accommodate the replacement warp yarns that are to be woven in next. Too tight a tension of either replacement weft or warp yarns results in a pulling up or rippling effect of the reweaving and distortion of yarn alignment. Too loose a tension results in a distortion of yarn alignment resulting in crooked yarns and uneven weave structure. Steam pressing a reweaving repair in which the tension of the replacement yarns is too tight or too loose further accentuates the yarn alignment distortion.

A proper tension for reweaving the low thread count yarns was achieved by weaving in the first set of weft yarns with a loose enough tension to allow a replacement warp yarn to slide easily through. Proper weft and warp yarn alignment was maintained throughout the reweaving process by gently straightening and pulling each replacement yarn into a straight configuration with tweezers after reweaving. This process for adjusting yarn tension was not included in the published directions I reviewed.

4.3.1.2 Plain weave / high thread count

Fraying of warp and weft replacement yarns and broken yarn ends edging the repair area was so extreme as to obscure the reweaving process and added to the time needed to complete the reweaving repairs. The fraying was caused by a combination of the yarns being made of short staple fibers that tend to untwist easily and the yarns rubbing against each other during the reweaving process, which accelerated the fraying even more. This combined with the high thread count of the fabric further complicated the procedure. A high thread count linen initially was selected for the reweaving, but had to be replaced since the fraying of yarns distorted the reweaving creating a fuzzy, matted appearance that obscured the weave structure (Fig. 95). Immersing replacement linen yarns in a heavy starch solution and treating the edges of the repair area with the starch only temporarily alleviated the fraying problem. The friction of the yarns moving over each other during the reweaving process may have rubbed off the starch coating enabling the fraying to continue (Fig. 96).

Fig. 95. Plain weave / high thread count (linen) – fraying yarns

Fig. 96. Plain weave / high thread count (linen) – Starch treatment of reweaving yarns

A high-thread count wool and polyester blend was selected to replace the linen. A minimal amount of fraying of the wool and polyester yarns was experienced during the reweaving process. Applying distilled water to the replacement yarns before reweaving temporarily lessened the fraying, although the finished reweaving had a slightly fuzzy surface appearance from the frayed yarns (Fig. 97). The fraying experienced with this fabric also could have been caused by short staple fibers of replacement yarns untwisting during the reweaving process. Shrinkage of the finished reweaving after steam pressing was an issue with initial experimentation, which resulted in the pulling in and distortion of yarn alignment (Fig. 98). This problem was remedied by maintaining a looser tension of the replacement yarns during the reweaving process and not trimming the fringed tips of the reweaving yarns until after steam pressing the reweaving to allow extra yarn length needed to pull yarns into proper alignment.

Fig. 97. Plain weave / high thread count (wool blend) – Frayed yarns obscuring weave structure

Fig. 98. Plain weave / high thread count (wool blend) – Yarn shrinkage from steam finishing distorting weave structure

4.3.1.3 Twill weave

The warp yarns for the twill samples were woven in first in contrast to what is recommended in the reweaving literature due to the delicate nature of the single-ply, loosely twisted yarn structure of the weft yarns and concern for minimizing the possibility of weft yarn breakage or splitting during the reweaving process. Achieving proper tension of the replacement yarns was a major issue with this fabric also. Initial attempts to pull the warp and weft yarns into a straight alignment with the same tension created a weave structure that was too straight and distorted in appearance compared with the surrounding weave structure (Fig. 99). Achieving a looser tension of the replacement weft yarns and tighter tension and more straight alignment of the warp yarns corrected the problem (Fig. 100).

Fig. 99. Twill weave – Improper tension of reweaving yarns distorting weave structure

Fig. 100. Finished French reweaving sample with proper tension

4.3.2 Side-weaving

Similar issues of tension and shrinkage were experienced with the side-weaving technique but required the development of different methods to work with a fabric patch instead of individual replacement yarns.

4.3.2.1 Patterned weave

Achieving proper tension of fringed yarn ends and dealing with shrinkage of yarns after steam pressing were primary issues encountered with the side-weaving process. During initial side-weaving attempts, the fringed yarn ends were pulled in too tightly around all four sides of the replacement patch, and the fringed yarn tips were trimmed before steam pressing. When the finished side-weaving repair was steam pressed, the edges of the inserted patch shrank and pulled in distorting the weave structure and pattern (Fig. 101). Maintaining a looser tension of the fringed yarn ends and not trimming the fringed yarn tips until after steam pressing resulted in sufficient yarn length of the fringed yarn ends and no distortion of the patterned weave pattern (Fig. 102).

Fig. 101. Patterned weave – Weave structure shrinkage and resulting distortion

Fig. 102. Finished side-weaving sample with proper tension

4.3.3 Reknitting of loss of two or more rows

The reknitting technique of using vertical guideline threads for the repair of larger knit losses with individual replacement yarns was successfully adapted to repair the stockinet knit sample. This method requires much practice to gain proficiency with the different steps involved. Achieving proper tension was a major issue with this technique.

The knit grafting techniques were successfully adapted to repair larger knit losses by grafting patches of matching knit fabric to the areas of loss. Knit grafting techniques are very adaptable with working with either more intricate knit structures or smaller scale knit stitches.

4.3.3.1 Stockinet knit

The vertical thread guideline technique was very helpful in keeping the rows and wales of the stockinet knit repair area in proper horizontal and vertical alignment. The threads used for the guidelines were, however, sometimes difficult to work with. When reknitting the replacement knit stitches around them, they sometimes twisted due to their pliable nature. Using a stiffer thread such as a size 40 quilting thread or treating the thread with some type of stiffening agent might help with this problem.

Achieving proper tension of both the vertical guideline threads and reknitting stitches was challenging and required much experimentation and practice. The vertical guideline threads had to be pulled tightly enough to keep the rows and wales in alignment but not so tightly that they distorted the surrounding knit structure. The replacement reknitting stitches had to be gently manipulated around the guideline threads and pulled into place with tweezers to maintain a consistent tension and uniformity of knit stitch size. The most unsatisfactory aspect of using the vertical guidelines reknitting technique was the bulkiness around the edges of the finished reknitting repair caused by the overlapping of the replacement reknitting yarns from the tracing technique with the repair area edges (Fig. 103). Additional experimentation is needed to resolve this issue.

Fig. 103. Bulkiness of finished reknitted repair edges

4.3.3.2 Knit-grafting

The knit-grafting techniques used resulted in very successful repairs for the double knit and patterned knit fabrics. Variations of the knit-grafting technique were adapted for each of these fabric types.

4.3.3.2.1 Double knits

An important aspect of the knit-grafting technique encountered with the double knit fabric was in identifying the differences of directional patterning of the knit on the face and reverse sides prior to the repair work. Initial attempts with the technique did not take this into account and resulted in a grafting repair with the reverse side of the patch being grafted to the face side of the sample fabric (Fig. 104). The final grafting repair with the proper positioning of the patch and following the basic grafting technique for double knits was very successful with no major issues encountered (Fig. 105).

Fig. 104. Double knit – Differences in directional patterning of face and reverse sides

Fig. 105. Double knit – Finished sample with proper patterning alignment

4.3.3.2.2 Patterned knit

A variation of the knit grafting technique was developed for the repair of the patterned knit. Since patterned knits vary so widely in pattern and knit structure, reknitting techniques for repairing patterned knits will vary on a case-by-case basis.

Identifying the basic design repeat of the repair area and preparing an insert patch from matching fabric with edges and stitches that interlocked smoothly with the prepared edges of the repair area were key initial steps to ensure a successful grafting repair of the patterned knit. Another important factor with this repair was in determining the appropriate types of stitches to use that would correspond to the patterned knit structure. The grafting technique adapted for the patterned knit repair was very successful in terms of structural integrity and strength of the completed repair and visual aesthetics (Fig. 71).

4.3.4 Attaching an underlay with hand stitches

The most difficult aspect of using underlay fabrics was in being able to find fabrics in colors and textures compatible with the fabric treatment samples. In most instances a "compromise" underlay fabric had to be chosen for the treatment samples because matching colors and more harmonizing textures were not available. Choosing underlay fabrics of a single color for the treatment fabrics that had multicolored yarns and patterning in weave and knit structures was especially difficult. In the very few instances where an underlay fabric in a closely matching color could be found, the contrast between the texture of the high thread count plain weave cotton of the underlay fabric and the textured weave or knit of the treatment fabric was visually distracting. This depth problem was apparent with all of the thicker more textured treatment sample fabrics.

4.3.5 Supporting with an adhesive-coated backing

Since I used the same fabrics for the hand-stitched underlay treatments as for the adhesive-coated backing treatments, the same problems concerning texture, hue, and value contrasts of the backing fabrics with the treatment samples discussed in the previous section were encountered. In addition to the depth problem due to the differences in thickness of the more textured treatment samples with the underlay fabrics, the adhesive treatments for these fabrics were not sufficient and required additional hand stitching around the edges of the repair area and outer edges of the treatment sample to stabilize the repair. The stiffening resulting from adhering two layers of fabric together also changed the hand of the treatment samples and was especially noticeable with both the woven and knitted lighter weight fabrics.

4.4 Technique Time Comparison

A time log was maintained to record the length of time spent to complete repairs using each of the techniques (Table 3). Two to four treatment samples were completed for each technique, and a time estimate was calculated by averaging the treatment times for each technique.

Table 3
TECHNIQUE TIME COMPARISON

Time (hours) Classified by Technique and Fabric

Technique	Sample No.	Plain weave / low thread count	Plain weave / high thread count	Twill weave	Patterned weave	Stockinet knit	Double knit	Patterned knit
Reweaving / Reknitting	1	2.75	10.25	5.00	19.50	7.00	5.25	3.50
	2	2.50	9.25	6.00	17.00	6.75	5.25	2.75
	3	2.75	10.50	6.50	16.00	*	4.50	*
	4	2.50	*	7.75	*	*	*	*
	Mean	2.63	10.00	6.31	17.50	6.88	5.00	3.13
Hand Stitching with Underlay	1	1.75	1.25	1.75	1.00	1.50	1.25	1.25
	2	1.50	1.00	1.00	0.75	1.50	1.25	1.00
	3	*	*	*	*	*	*	*
	4	*	*	*	*	*	*	*
	Mean	1.63	1.13	1.38	0.88	1.50	1.25	1.13
Adhesive-Coated Backing	1	1.00	1.00	1.50	1.00	1.25	1.50	2.00
	2	1.00	1.00	1.50	1.00	1.25	1.50	2.00
	3	1.00	1.00	1.50	1.00	1.25	1.50	2.00
	4	*	*	*	*	*	*	*
	Mean	1.00	1.00	1.50	1.00	1.25	1.50	2.00

Additional Comments:

* Four treatment samples not completed for every fabric / treatment type in order to save time during the sample preparation process.

4.4.1 French reweaving

The plain weave / low thread count fabric took the shortest length of time to complete a 1 x 1 inch size French reweaving repair with an average repair time of 2.63 hours. The twill weave with a higher thread count followed with an average repair time of 6.31 hours. The plain weave / high thread count took the longest time to repair using the French reweaving technique with an average repair time of 10 hours.

4.4.2 Side-weaving

The side-weaving repair of the patterned weave took considerably longer than the French reweaving repairs, with an average repair time of 17.50 hours to repair a 1 x 1 inch size hole. The side-weaving technique actually took the longest time to repair a 1 x 1 inch size damage compared with all of the other reweaving, reknitting, and conservation repair and stabilization techniques. A primary cause was the intricate structure of the patterned weave.

4.4.3 Reknitting

4.4.3.1 Stockinet knit / use of vertical guidelines

The repair of the stockinet knit using the vertical guidelines technique took an average time of 6.88 hours to repair a 1 x 1 inch size hole. This technique took longer than the average repair times for the knit-grafting techniques.

4.4.3.2 Knit-grafting

The patterned knit took the shortest length of time of all the reknitting techniques to repair a 1 x 1 inch size hole with an average repair time of 3.13 hours. The double knit took more time, with an average repair time of 5.00 hours to repair a 1 x 1 inch size hole.

4.4.4 Attaching an underlay with hand stitches

The average repair time using the underlay with hand stitching technique varied from 0.88 hours for the patterned weave to 1.63 hours for the plain weave / low thread count. The average times for the other fabric types were evenly spaced in between the smallest and largest average times (Table 4).

4.4.5 Supporting with an adhesive-coated backing

The repair of all the fabric types with the adhesive-coated backing took considerably less time when compared with the reweaving and reknitting techniques used on the same fabrics (Table 4). However the average repair times of the underlay with hand stitching repairs were very comparable with the adhesive-coated backing time averages.

5.0 Discussion

5.1 Reweaving

Both the French reweaving and side-weaving techniques can result in successful repairs in terms of appearance, structural integrity, and effect on drape but only with practice and an understanding of the basic conditions and parameters can these techniques be effectively applied. The panel of evaluators preferred the reweaving treatments over the traditional textile conservation treatments because the reweaving treatments resulted in repairs that were aesthetically pleasing, structurally sound, and duplicated the original drape of the original treatment fabric. These two techniques received statistically significantly higher ratings than the two underlay treatments on woven fabrics.

5.1.1 French reweaving

Basic issues encountered when performing the French reweaving technique included fraying, tension, and shrinkage problems. With the treatment samples used for this research, the fraying occurred most with the short staple fiber / higher thread count fabrics (the high thread count linen and wool / polyester blend plain weaves). Minimal fraying occurred with the low thread count fabrics (plain weave / low thread count and twill weave). A major factor that contributed to the excessive fraying of the short staple fiber / high thread count fabrics was the constant rubbing of the many replacement warp and weft yarns against each other as they were being rewoven into the weave structure. This constant friction pulled out short fiber ends resulting in the fraying. I have successfully rewoven higher thread count / longer staple fiber cotton and rayon fabrics with minimal fraying due to the longer length fibers. A possible remedy to counteract the fraying could be the application of a coating on the individual yarns to be rewoven and edges of the repair area. Although the application of the starch and distilled water treatments were not successful for this research, additional experimentation with other substances such as beeswax may result in an effective anti-fraying agent. The beeswax could be removed with dry cleaning solvent.

Achieving proper tension with French reweaving requires much initial practice regardless of the type of fabric to be rewoven. I determined that a primary first step to reach a proper tension is to first achieve correct alignment of the reweaving yarns so that the replacement warp and weft yarns lie in straight alignment with the warp and weft yarns of the surrounding fabric and are at right angles to each other. Once correct alignment is attained, then the tension of the individual replacement warp and weft reweaving yarns can be adjusted accordingly.

Shrinkage sometimes occurs with finished French reweaving treatments due to a combination of factors. After steam pressing a finished reweaving, shrinkage can occur if the tension of the replacement warp and weft yarns is too tight. The short replacement yarns become even shorter as they relax during the steaming and pull in resulting in a distorted reweaving repair. As a result of this research, I determined that one way to offset any possible shrinkage after steam pressing a reweaving treatment is to not trim the tips of the replacement yarns prior to steam pressing. This leaves a length of yarn that can be "let out" if shrinkage occurs. The weave structure of the reweaving then can be realigned to match the surrounding fabric, and the replacement yarn tips trimmed. Using less steam may also offset additional shrinkage.

5.1.2 Side-weaving

Problems with tension and shrinkage are primary issues that can occur with the side-weaving process. Incorrect tension of a side-weaving repair results when the fringed edges of the replacement patch are woven into the surrounding weave structure and then are pulled in through the weave structure too tightly or not tightly enough. Too tight a tension pulls in the edges of the repair area resulting in a buckling of the repair area edges. Too loose a tension results in visible floating warp and weft yarns edging the edges of the replacement patch that are from the yarns of the fringed edges of the replacement patch not being pulled in enough.

As with the French reweaving technique, steam pressing a side-weaving repair with an incorrect tension that is either too tight or too loose only further distorts the repair and the alignment of the replacement patch with the repair area. To help offset any potential tension problems while reweaving the fringed edges of the replacement patch, careful control of each fringed yarn as it is being pulled through the weave structure is essential. As with the French reweaving technique, I have determined that not trimming the fringed tips of the replacement patch edges prior to steam pressing allows more control and adjustment of tension and alignment of the replacement patch yarns if shrinkage does occur.

5.1.3 Considerations when determining type of reweaving treatment

Determining whether to use French reweaving or side weaving for a reweaving repair depends on a number of factors. The size of the repair area and thread count of the textile to be repaired are primary considerations. Especially with narrow thread diameter, high thread count fabrics, the French reweaving technique is more successful with smaller size repairs of 1 x 1 inch or less. It becomes increasingly difficult to repair larger areas of damage effectively due to the increased frequency of tension, alignment, and fraying problems that occur with repairing large areas and the resulting increase in time and cost involved. Side-weaving on the other hand is more successful with larger repair areas of 1 x 1 inch or larger and requires less time and cost to repair these areas when compared with the French reweaving technique.

French reweaving also requires obtaining adequate quantities of replacement warp and weft yarns in colors and textures compatible with the textile to be repaired. If matching yarns are not available from the actual textile, then yarns have to either be obtained from other textiles, or dyed to match the repair textile, which will add to the time and cost of the repair. A primary issue with side-weaving is in being able to obtain enough matching fabric for the replacement patch. If an adequate quantity of matching fabric is not available to make a replacement patch, then a successful side-weaving repair is not possible.

Fabric finishes are another important consideration when determining the most appropriate reweaving technique to repair a textile. Heavier fulled woolens such as camel's hair cannot be repaired with the French reweaving method because it is not possible to recreate the original fabric texture with individual replacement yarns, thus side-weaving would be the only possible repair option.

5.2 Reknitting

As with the reweaving techniques, the reknitting techniques of reknitting knit losses of two rows or larger using thread guidelines and knit-grafting can provide excellent results in terms of appearance, structural integrity, and effect on drape. As with the reweaving treatments, the panel of evaluators preferred the reknitting treatments over the traditional textile conservation treatments because the reknitting treatments resulted in repairs that duplicated the original knit structures of the damaged fabrics and were aesthetically pleasing, were structurally strong, and closely resembled the original drape of the treatment fabric. The observer's mean ratings of the reknitted samples were statistically significantly better than using a woven backing either stitched on or held by an adhesive.

Since so many variations of knit structures and fabrics exist, a basic understanding of the potential issues involved with each technique can help to determine situations when these techniques can be successfully applied in the repair of damaged knit fabrics.

5.2.1 Reknitting of large knit losses using thread guidelines

Using either vertical or horizontal thread guidelines is a very effective tool in keeping the rows and wales of the knit fabric to be repaired in correct alignment and also provides a support foundation for the replacement knit stitches, which are formed around these threads. Although whether or not to use vertical or horizontal guidelines is mainly a matter of preference, I found that it was easier to maintain a correct alignment of the knit pattern and replacement knit stitch formation with the vertical guidelines, which seem to provide a more stable foundation.

Several key issues were encountered when using the vertical guidelines technique. Maintaining correct tension of both the thread guidelines and replacement knit stitches is critical. Thread guidelines that are threaded too tightly into the knit structure result in a pulling in of the edges of the repair area, resulting in a distortion of the knit pattern and reknitting repair. Guidelines that are threaded too loosely will not be effective in providing correct alignment of the repair area and a stable foundation for the replacement knit stitches. The use of a stiffer thread such as a size 40 quilting thread for the guidelines is helpful in maintaining correct tension.

Achieving correct tension of the replacement knit stitches over the guideline threads can be very challenging and requires much practice. I found that tweezers were helpful in manipulating the reknitting yarn around the guideline threads for an even stitch formation. Shrinkage of the reknitting repair sometimes can occur after steam pressing; maintaining a slightly looser tension of the replacement knit stitches can help alleviate this problem.

A slight ridge around the edges of the repair area sometimes occurs when reknitting fabrics made of bulkier yarns. This ridge is formed as result of the tracing technique of overlapping the repair yarn with the edges of the repair area, which is necessary to secure the edges of the reknitting repair. This is the most unsatisfactory aspect of this technique and needs more experimentation to develop alternative techniques when working with bulkier yarns.

5.2.2 Knit-grafting

A successful knit-grafting repair is dependent on several factors, regardless of the type of knit structure being repaired. The replacement patch to be grafted into the repair area must fit in the repair area perfectly with no overlapping of the replacement patch edges with the edges of the repair area. A replacement patch that is either too large or too small will result in a buckling or pulling in of the replacement patch with the surrounding repair area and a very visible grafting repair.

The edges of both the replacement patch and repair area also must be prepared so that the knit loops of both sets of edges interlock smoothly. This will help to ensure a more inconspicuous grafting repair and more even knit-grafting stitch formation. Maintaining a consistent tension of the grafting stitches that connect the edges of the replacement patch with the edges of the repair area is critical in achieving a smooth, seamless repair.

5.2.3 Considerations in determining type of reknitting treatment

A number of factors must be considered when deciding whether to use the reknitting with guidelines or knit-grafting techniques for a reknitting repair. Several primary considerations include the intricacy of knit pattern to be repaired, the gauge or size of the individual knit stitches, and the overall size of the repair area.

The knit-grafting technique can be a useful, time-saving method for repairing knit fabrics with more intricately formed knit structures in which exact reproduction of individual knit stitches would be difficult and costly in terms of repair time spent. Knit-grafting is also a more practical method for repairing larger repair areas with smaller gauge knit stitching such as the double knit fabric used for this research. Obtaining a large enough replacement patch is a key factor in determining the practicality of using the knit-grafting technique for a reknitting repair.

The reknitting of individual replacement knit stitches over thread guidelines is an effective technique for repairing more simply formed knit structures such as the stockinet knit used for this research. It is a very versatile technique and can be successfully applied in the repair of small and large size repair areas. Obtaining replacement yarns in matching colors and textures is essential for a successful repair. Dyeing the replacement yarns is sometimes necessary and will add to the time / cost factor of the repair.

5.3 Underlay attached with hand stitches

Applying an underlay fabric patch with hand stitching to stabilize textile losses is an accepted textile conservation repair method, which can be adapted to a variety of repair situations. An understanding of both the positive aspects and potential limitations of this technique can ensure more successful repairs.

This method is useful in a textile conservation context for repairing and stabilizing textile losses in which the use or adaptation of other repair techniques may not be possible or appropriate. One of the more challenging aspects of this technique is in being able to find underlay fabrics in colors and textures that are compatible with the fabric to be repaired. Another aspect complicating the difficulty of finding good color matches for underlay fabrics has to do with the fact that color trends and fashions change from season to season, and specific colors and textures simply may not be readily available. Fabrics with multicolor yarns and patterning present an even greater challenge in finding appropriate repair fabrics where the use of a single color repair fabric would result in a visually distracting repair. Thick, textured fabrics present a depth problem if repaired by the underlay method when the underlay fabric lays a millimeter or more below the damaged fabric. Texture presents more of an issue when repairing knits with this technique. Using woven underlay fabrics to repair the knit treatment samples used for this research resulted in appearance, depth, and drape problems.

These problems raise the question of which is more important when selecting appropriate underlay fabrics – texture, hue, or value? I believe that in using an underlay to stabilize a loss of yarns, compatible color value of underlay fabrics is more important than hue. Compatible textures of underlay fabrics are more important for thick, textured fabrics in resolving issues with depth.

The use of spectrophotometry to match value and hue of backing fabrics to fabrics being repaired could be a more effective method of addressing the issue of compatible value and hue. In addition, the use of Munsell or Pantone color chips could be another helpful tool in matching colors. The use of various forms of digital inkjet printing on replacement fabrics to recreate original textile patterning to repair missing or damaged areas of a textile or costume object has been successfully used in a variety of applications, particularly for museum exhibitions (Britton, et al. 2006; Mailand 1993). For smaller scale projects, however, it is not practical due to its high cost, although that price will lessen in time as technology improves.

Another method of temporarily addressing the visual issues of fabric losses is with the use of color print technology to print an actual paper copy of an intact pattern repeat from the damaged fabric. The copy can be placed under the damaged area to act as a passive underlay. This method has been successfully used for preparing textiles with areas of damage for exhibition, but is not a permanent repair technique.

5.4 Attaching adhesive-coated backing

The use of an adhesive-coated backing can be an effective method for repairing textiles with extreme fracturing or splitting of weave or knit structures where the use of the other techniques discussed previously would not be practical or possible, such as with fractured silk (Paskausky 1998). The main issue when using adhesives is the unsatisfactory effect on drape that can result from two layers of fabric being joined. Incompatible backing fabrics can increase the problem. The use of backing fabrics that are too heavy in weight can result in an extreme stiffness of drape of the original textile object. Selecting backing fabrics that are too light weight will not provide adequate support of the repaired area and may not have the desired textural component.

The use of adhesives may not be an effective method for repairing thick, heavy, textured textiles. With the heavier woolens and knits used for the treatment samples for this research, the adhesive treatment was not sufficient in achieving a secure bond, and additional stitching was necessary to stabilize the repair. The use of heavier weight underlay fabrics would have resulted in an extreme stiffness of drape.

5.5 Technique Time Considerations

The reweaving and reknitting treatments took more time to complete with longer average repair times compared with the underlay and backing techniques. The longer length of time required for reweaving and reknitting repairs translates into higher costs to execute the work, which may be prohibitive when working with a limited budget. However, I feel that a better long-term investment can be achieved with reweaving and reknitting techniques because they can provide superior aesthetic and structural results and thus a longer lasting repair over the long term.

Less satisfactory results were achieved by the underlay and backing techniques but these methods took less time to complete compared with the reweaving and reknitting techniques. Although the conservation techniques are practical in a variety of situations, they may not provide the best quality repair that could last over a long period of time.

6.0 Conclusion

A successful repair to stabilize textile losses is judged in terms of its visual aesthetics to present the structure and pattern of the original textile in an understandable manner to the viewer or client; providing adequate structural stability and strength of the repair to last over the long-term; and achieving an effective drape of the repair that is compatible with the original textile structure. The potential of a specific textile repair technique to be determined as an effective repair method lies with its ability to satisfactorily provide these qualities.

The means of the evaluators' ratings of reweaving and reknitting techniques used for this research rated statistically significantly higher in appearance, structural integrity, and effect on drape than the means of the two conservation repair methods of applying an underlay with hand stitching and the adhesive-coated backing. This suggests that the repair techniques of reweaving and reknitting do have potential to be more widely used in textile conservation applications. The extra time and cost involved with the use of reweaving and reknitting techniques are additional key considerations for textile conservators in museums and private practice when working with limited time and budgetary restrictions. Time for practice must be considered.

All the repair techniques discussed in this research have advantages and disadvantages. When deciding upon the most appropriate repair technique for a specific situation, a textile conservator must consider the kind and amount of damage, availability of similar yarns or fabric, color, fiber content, yarn and fabric structure, and finishes that affect surface quality. The goals of the client or curator and planned end use of the object are key considerations. Time and budgetary constraints as well as the skills of the individual textile conservator are important factors that may determine the course of treatment. The overall condition of the object must also be considered.

With the current trend of more textile conservators going into private practice a textile conservator needs to be proficient in a wide variety of skills to serve a multi-faceted clientele who may use their textiles differently from a museum (Mathisen, Da Zara 2000). The clientele may include museums, galleries, retailers, individual collectors, cultural and religious organizations, and individual collectors. I believe that reweaving and reknitting techniques can be successfully adapted within a conservation context as well as being used for more restoration-based situations. Additional important considerations are determining the appropriateness of these techniques within a particular situation and the cost based on time required.

This research confirmed the lack of current, thorough information on reweaving and reknitting techniques plus a lack of commentary in the textile conservation literature to explain the application of these methods. The high ratings that the reweaving and reknitting treatment samples received in this research compared with the other two more established conservation techniques suggest the need to explore and develop innovative methods in which reweaving and reknitting techniques can be successfully adapted within a textile conservation context.

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Appendix A

Review of Literature

Ethics

The visual image of a textile or costume, whether in terms of design and pattern or of cut and construction, cannot always be separated from the medium. In a woven structure such as a tapestry, the construction and the design are one and the same. No distinction exists between support canvas, medium, and representation as with a painting, for example. For this reason, any missing part of a textile, whether it is large or small, represents a loss of both material and image. This is the basis of a major problem for textile conservators when determining treatment options to repair damaged textiles or costume – how to integrate the two parts of the work (Brooks, et al. 1994; Giannatiempo Lopez 1994; Hutchinson 1990-91; Shore 1993).

Two conflicting opinions that exist when determining treatment options to repair losses in a textile share the same concern – that the style and character of the textile must be preserved. The first opinion (conservation) supports the idea that honesty with respect to the observer and to the artist who originally created the textile must be maintained and that the repairs done must be distinguishable from the original textile. The second opinion (restoration) holds that any repair work done should be as invisible as possible on the condition that all repairs are fully documented by photographs and detailed reports (Lodewijks, Leene 1972, 137-138). Many attempts to clarify this issue have centered on discussions concerning the meaning of conservation and restoration by conservation and museum professionals and what these terms imply in the course of developing treatments for the repair of damaged textiles. Opinion varies from the most conservative to more all- inclusive philosophies.

An American Institute for Conservation roundtable discussion on "Conservatism in Conservation" supports the theory of minimal treatment or intervention based on the belief that the ideal treatment is not yet available. The minimalist approach advises caution when determining treatments, noninvasive procedures, or the ideal option of no treatment except for emergency situations (AIC / Abbey Newsletter 1991). Perkins, Brako, and Mann theorize that textile conservators only recently have "feared the use of restoration techniques" and turned to minimalism as a way of addressing loss, primarily as a reaction to past loss compensation treatments that compromised original artifacts. They conclude that despite technical advances made in compensation materials and discretion in their application that have allowed textile conservators to restore aesthetic integrity to artifacts and still adhere to strict conservation standards, "the minimalist approach to compensation and the place of aesthetic integrity in textile conservation is continually undergoing reassessment" (Perkins, Brako, Mann 1990-91, 13-14).

Textile conservator Harold Mailand encourages the search for "new and better conservation materials, practices and processes" and advocates the "sharing of technologies and information in other areas" (Mailand 1993, 72). Mailand's conservation philosophy strives for a balance between established and innovative techniques, using traditional ways complemented by new methods; he believes that "stabilization can and should be carried out in an unobtrusive and aesthetically pleasing manner" (Mailand 1993, 65).

Carol Bier provides a curatorial interpretation of condition and loss compensation concluding that the condition of any textile is both relative and changing. Treatment options can vary depending for what context or particular end use a textile is being considered. She cites examination for possible acquisition, research value, and presentation as variables that can affect the course of treatment (Bier 1990-91). The Victoria and Albert Museum staff utilize "all practices" – conservation, restoration, minimum intervention, collections management – because "we find all of these practices acceptable and practice them skillfully and intelligently" (Ashley-Smith 1994a,1).

Jonathan Ashley-Smith acknowledges how diversity of professional experience, cultural factors, variety of object types and end uses, among other factors, can impact treatment decisions. To address this issue, the conservation department staff at the Victoria and Albert Museum have compiled an ethics checklist to help conservation staff think in a more consistent way when determining conservation treatments (Ashley-Smith 1994b).

Various professional guidelines have attempted to clarify the meaning of conservation, but deviations exist between them. Mary Brooks provides an extensive discussion of the distinctions between the various national codes (Brooks 1994). No international agreement on the key elements defining the activity of conservation exists. The AIC Guidelines for Practice states that a conservation treatment "should be reversible and should not falsely modify the known aesthetic, conceptual, and physical characteristics of the cultural property, especially by removing or obscuring original material" (AIC 2008, 25). The United Kingdom Institute for Conservation Guidance for Conservation Practice defines conservation treatment as "the means by which the true nature of an object is preserved" (Brooks 1994, 75). *Conservation* –

Restoration: The Options (issued jointly by The Conservation Unit and Historic Scotland) emphasizes in bold type that "conservation and restoration are aspects of the same process." (Brooks, et al. 1994, 109).

Varying approaches to conservation and restoration result from specific cultural and historical perspectives and can differ both within and across cultures. Ceremonial textiles of native and indigenous societies are an important example of this issue. Different cultural requirements are made by the community that originally made and may still use the textiles. The Code of Ethics of the New Zealand Professional Conservators' Group explicitly acknowledges the continuing sacred function of a textile by balancing care for the object with the need for access by the users (Brooks, et al. 1994).

Areas of loss in a textile create aesthetic and structural problems as they can affect the visual, physical, and functional aspects of a textile. An area of loss can dominate a design to the extent that it distorts the original intended visual effect. In some instances, however, the idea of incompleteness may be a culturally defined concept. Some cultures appear more willing to accept a continual recreation of the piece or missing areas than others (Brooks, et al. 1994). In many museums of the world, restoration, rather than conservation, continues to be applied to art objects. In this approach the care of museum collections is considered in terms of restoration of objects that can include their partial or complete reconstruction to improve their appearance (Klein 1997).

Many countries have a long tradition of textile restoration, with treatments often being done by the makers of the textile. The state-run Manufacture des Gobelins of France has always restored its own tapestries in its own workshops. In England, the Vanderbank family tapestry workshop cleaned, repaired and enlarged its own tapestries over several generations (Brooks, et al. 1994). Tapestries in Italian institutions often are treated with full reweaving to respond to the aesthetic and structural needs of a tapestry based on the strong handicraft tradition of Italian textile conservation (Mathisen, Da Zara, 2000).

Other long traditions of restoration as everyday practice also survive. Ecclesiastical textiles, for example, have traditionally been repaired by nuns for religious use (Benford, Marino, Buden 2002). Preference for textile restoration also can result from government presumption and intervention. The former USSR funded total restoration of the damaged interior of the Kuskovo Palace having copies made of original damasks, using the same threads and dyes, at the Novospassky Monastery textile department (Brooks, et al. 1994).

Textile conservation developed out of restoration traditions and techniques. Both approaches are based on hands-on skills to implement treatments. Conservation concepts evolved as an alternative approach to treating historic textiles due to the loss of information resulting from previous restoration approaches and a growing opinion to interfere as little as possible. These developing conservation concepts reflected changing ideas about the key elements of a textile and the role of historic textiles, combined with an awareness of problems with materials used in both conservation and restoration (Brooks, et al. 1994).

Both textile conservation and textile restoration involve intervention, which is the physical modification of the textile with the intention of preserving or enhancing it physically and / or visually. In neither case can the original state of the textile be recreated (Brooks, et al. 1994). Conservation aims to maintain the integrity of the textile physically and visually while removing and adding minimal material. The primary aim of restoration is to make the object more visually appealing and enable it to provide information it contains about materials, design and purpose, more readily. Restoration can be highly interventive, such as the reweaving of a section of tapestry. In terms of physical and potential chemical interaction with historic material, reweaving is far less interventive than supporting brittle silk by stitching or adhesives (Ashley-Smith 1995).

Intervention involves risk of damage, whether that intervention is for improved stability or appearance. What decreases risk of damage are skill and experience. Interventions for appearance (restoration) often can benefit stability (conservation) by reducing the risk of further damage, as with reknitting a damaged knit fabric to restore the original knit pattern and to repair and stabilize damaged knit structures. In contrast, interventions to improve stability, such as stitching an underlay patch to a textile to stabilize an area of warp and weft loss, do not always improve appearance (Ashley-Smith 1995; Brooks, et al. 1994).

Jonathan Ashley-Smith argues that any process that increases the risk of damage is unacceptable. He defines damage as the change in value of an object resulting from an intervention process (Ashley-Smith 1994a). The value of an object is in its providing information, enjoyment, utility or the potential to be useful. An object's value justifies the expenditure of time, energy, and money spent in restoration or conservation treatment and confirms why our culture wishes to preserve objects

Ashley-Smith 1995; Brooks, et al. 1994; Kronkright 1993). Increased stability of an object through conservation increases utility because the object can be used profitably over a longer period of time. Improving an object's appearance through restoration also can increase utility as a greater quantity of enjoyment or understanding will be made available. Values are not intrinsic qualities in the objects themselves, but rather we as individuals or institutions see value in the context of some end use of an object. Thus our perception of what are legitimate or proper end uses for an object controls what values it may have as a resource (Ashley-Smith 1995; Brooks, et al. 1994; Kronkright 1993).

Attributes of value can derive from historic, social, or political contexts; educational or research value; technological interest; aesthetic or financial value (Ashley-Smith 1995; Kronkright 1993). Whether a curator or owner feels that as a result of conservation treatment the modified object will become more aesthetically integrated, become a more honest presentation of the pre-damaged state of work, or be more stable, the history of conservation treatment decisions have created collections that reflect the chronology of changing tastes and judgments of generations of owners (Ashley-Smith 1995; da Silveira 1994; Kronkright 1993).

Dinah Eastop observes that recognizing the roles assigned to textile objects and the effect these roles have on treatment decisions are important steps in understanding why so many different approaches to textile conservation exist. These different roles help to explain regional and institutional diversity in textile conservation (Eastop 1994). Luciana da Silveira recommends four determining factors to be used when considering textile conservation treatment options. The role and condition of an object, in addition to its nature (materials, construction, historical context and evidence), and practical constraints (conservator's experience, availability of resources / time, materials, and display and storage facilities) converge to determine appropriate treatment options (da Silveira 1994).

Michaela Keyserlingk feels that conservators should have a greater awareness of cultural conditioning as a factor in arriving at objective, ethical decisions in determining treatment options for artifacts. No matter how scientific the identification of materials and causes of deterioration may be, the interpretation of this information and opinion of a textile's original state and historical changes are for the most part subjective. Each generation interprets the art of the past in its own terms. A conservator chooses specific treatment options largely because of individual upbringing, experience, conditioning, national preferences, sense of fashion, and individual inclination. Keyserlingk describes this "conservation dilemma" as an inability of conservators to separate themselves from their present time and background. A conservator's connection to the present has differently formed senses, intellect, power of interpretation and treatment choices. No matter how hard a conservator tries to be objective, Keyserlingk believes that "it is impossible not to impose present assumptions on the past" (Keyserlingk 1994, 49).

Keyserlingk says that conservators can approach this issue by developing a better awareness of the subjectivity, shortcomings, and hidden biases of both themselves and various professional codes of ethics, noting that while codes of ethics may provide guidelines that reflect only general aims, "true professionalism in the end rests with us" (Keyserlingk 1994, 49). Mathisen and Da Zara observe that as museum employment becomes more scarce and more conservators enter into private practice, clients requesting more integrative treatments such as reknotting a carpet could cause the profession to evolve and necessitate the need for training in handicraft techniques (Mathisen, Da Zara 2000).

The terms restoration and conservation are not mutually exclusive and have more similarities than differences. Many of the distinctions that have been drawn between restoration and conservation are matters of interpretation rather than definition (Keyserlingk 1994; Perkins, Brako, Mann 1990-91). Restoration and conservation have many meanings and may change with time and vary with context. The critical distinction between these two interlinked approaches lies in the objective of intervention: conservation preserving overall integrity, and restoration recreating the visual effect or function. This important difference in concepts is a primary factor for understanding how and why techniques of loss compensation continue to develop and change within the field of textile conservation (Shore 1993).

Current trends in developing treatment options emphasize the importance of the individuality of each object. Routine methods are replaced by methods suitable for each specific situation (Ashley-Smith 1994b; Brooks, et al. 1994). Lena Engquist Sandstedt applies the concept of situational ethics to textile conservation in determining treatment options for objects. Situational ethics stress the prevailing circumstances at the point when the ethical decision must be made. No general rules exist as every situation is relative. Sandstedt feels that conservation ethics should be understood in the sense of situational ethics where each conservation decision made involves an analysis of each problem that will decide on a course of treatment, rather than a "hard and fast" set of conservation methods (Sandstedt 1994, 70).

Many treatments now lie somewhere in between conservation and restoration. In some situations restoration is a part of a conservation treatment. Brooks et al. discuss the "synergistic use" of the two techniques where a modified restoration technique is integrated within a conservation-based intervention. The intent is to inform, not deceive. They describe this approach as "ethical conservation" and recommend the appropriateness of this technique particularly when the visual imagery of the textile is a key factor (Brooks, et al. 1994, 110). Jonathan Ashley-Smith concludes that a major part of ethical treatment is to continually ask questions about "what you're doing, decide how far to go, and when to stop" (Ashley-Smith 1994a, 9).

A flexible and effective variety of textile treatments is possible when elements of both conservation and restoration can be combined. Restoration techniques used appropriately within a conservation context have an important role to play in the preservation, understanding, and enjoyment of textiles (Brooks, et al. 1994).

Reweaving

Reweaving as a method of repairing losses in a damaged textile has a history as old as that of hand-woven textiles and is found in most cultures throughout the world (Shore 1993). Reweaving evolved to a highly developed specialty by the Middle Ages when the art of "invisible reweaving" repaired valuable and highly prized textiles of artistic and historic value belonging to the Church and nobility (Benford, Marino 2002, 6).

Weaving artisans of the sixteenth century could repair a woven textile so that the repair was invisible to the untrained eye. Medieval and Renaissance tapestry expert Thomas P. Campbell, Associate Curator of European Sculpture and Decorative Arts at the Metropolitan Museum of Art in New York City, concludes that "invisible reweaving" was done so well in medieval times that it could go undetected for years (Benford, Marino 2002, 1). Reweaving repairs done to the Shroud of Turin in the sixteenth century, for example, only recently were identified after C-14 carbon dating was attempted a second time since 1988 to confirm the age of the textile. The second C-14 testing determined that analysis of a spliced thread from the reweaving repair confirmed one half of a thread dated to the sixteenth century and the other thread half was from the third century. Dr. Campbell refers to the sixteenth-century weavers as "magicians" in assessing their ability to invisibly reweave repairs to a woven textile such as the Shroud of Turin (Benford, Marino 2002, 4).

The term "reweaving" often is used interchangeably with the term "darning" in a wide variety of publications. The processes actually are quite different from each other. Reweaving is the technique of repairing a damaged fabric by weaving in original or new yarns to replicate yarns, weave structure, and pattern of the original fabric (Fabricon 1993; Loptaka 2003; NCA 2002; Saunders 1958). An early USDA farmer's booklet on household mending describes reweaving as "nothing more than a darn done carefully with matched yarn, so that it reproduces the original almost exactly" (Scott, Morrison 1946, 14). The *Good Housekeeping Needlecraft Encyclopedia* defines darning as "weaving on a small scale. It is essentially a practical application of running stitches" (Carroll 1947, 431). A dress-making textbook from the early nineteenth century describes basic darning used in "the repairing of a tear or hole by the weaving of a thread back and forth" (Woman's Institute 1926, 152).

For this research, reweaving is actual weaving of replacement warp and weft yarns to replicate original weave structure; the ends in a reweaving are woven in to the fabric, and not stitched in as with darning. Darning is working one continuous yarn back and forth across a damaged area using small stitches. With real reweaving, each row is worked and rewoven with separate yarns. "Reweaving is a refined art and should not be confused with mending, darning, or patching" (Lopatka 2003, 2).

An early nineteenth-century household sewing guide provides instruction on the basic darning technique to repair damaged stockings and table linens, and also to reinforce new stockings (A Lady 1838). A needlework directory from the latter nineteenth century further distinguishes between common web darning, cashmere twill darning, and damask darning. In web darning replacement warp and weft threads are stitched into the damaged fabric crossing at right angles to create a "plain web" or "network" (Caulfeld, Saward 1885, 142). This dictionary defines cashmere darning: "the method for replacing the web of any twilled material, such as Cashmere, is to employ the ravellings of the cloth itself" to replicate the weave structure of a twilled fabric (Caulfeld, Saward 1885, 142). This actually seems to be reweaving. Damask darning is recommended in the repair of damask fabrics, requiring the use of a needle and "flourishing thread" (Caulfeld, Saward 1885, 143). Period illustrations of these techniques confirm the use of one continuous yarn that is worked back and forth across a damaged area as with contemporary darning methods (Caulfeld, Saward 1885, 143).

Twentieth-century trade literature defines two distinct methods of reweaving. The choice of method is dependent on the size and condition of the damaged area and fabric to be worked on. The French weave, also known as the "invisible weave," uses individual replacement yarns that replicate original warp and weft yarns of the damaged textile (NCA 2002, 1). The replacement yarns are woven into the original fabric by hand to replicate original weave structure. The new fabric created closes the loss, and the repair is virtually indistinguishable from the surrounding fabric. The technique of side-weaving is used for larger tears and when French weaving is not practical. With this technique, the weaver cuts a patch of matching fabric and places it over the damaged area, matching the fabric weave and pattern. The edges of the patch are frayed and then woven into the fabric so that the edges of the repair are invisible to the eye (Fabricon 1993b; Loptaka 2003; NCA 2002; Saunders 1958). Commercial reweaving methods are used widely in the repair of expensive apparel, household textiles, and upholstery.

The majority of tapestry and rug dealers from the early to mid 1900s preferred reweaving as the "only acceptable" technique for repairing valuable textiles, feeling that the presence of patches on the back "proclaimed that the textile had been repaired" (Finch 1987, 71). This was an important consideration, especially in the 1950s, when conservation ethics were in the early stages of development, and it was a customary practice to completely remove damaged materials and replace them with reweaving (Finch 1987). The preference for reweaving is specifically indicated in a letter written in 1950 by Beshir Galleries in New York to George Hewitt Meyers, founder of The Textile Museum:

> After considerable inquiry and investigation I have come to the conclusion that it is not going to be very satisfactory to undertake to put your large Chinese rug in condition by patching. It is impossible, because of the unique character of your rug, to find old pieces for patching that are of anything like the same thickness and appearance. Also the painting and retouching involved would be very uneven and disfigured. Even such a patchwork job would cost between $700. and $800. and the rug would not come out attractively saleable.
>
> I would recommend that, despite the somewhat greater cost, the rug be repaired by reweaving. This would put it in excellent condition, make it uniform, and minimize any appearance of repair. I have had experts examine the rug and they agree with me about this. The very best work would not cost more than $1600. to $2000. Since the rug is so valuable, the investment in a proper repair job by reweaving would be more than absorbed in the sale price. It would be saleable in a way which, patched up, would never be. (Wolf, Swetzoff 1990-1991, 46-47)

Reweaving to repair losses in handwoven textiles continues to be the preferred method for most restorers. The process is so well identified that some specialists spend their entire careers reweaving losses in valuable rugs, carpets, blankets and tapestries (Benford, Marino 2002). Textile conservators generally prefer not to use reweaving as a general loss compensation technique, and when reweaving repairs are found in historic textiles, they usually are viewed as part of a textile's history and are not changed or removed (Shore 1993).

Reweaving has long been considered a valid conservation technique when treating historical tapestries and carpets, however. Reweaving of these types of objects by reweaving has such a long history that the practice is justified by its strongly held tradition. Although controversy sometimes arises over the use of reweaving, the practice is well defended by conservators for use on tapestries and carpets because it maintains weave structure and restores structural integrity (Derelian 1987; Shore 1993).

Nobuko Kajitani discusses the use of a combined approach of traditional and more recently accepted restoration/conservation methods in the repair of tapestries that include reweaving and sewing down loose warps and wefts onto a full or local backing support fabric. Reweaving is applied to areas where enough traces of the original yarn remain to indicate design and the warps and wefts are strong enough to support the reweaving repair. Both methods often are used on the same tapestry where causes of deterioration may vary from one area to another (Kajitani 1987).

R. Bruce Hutchinson supports the use of reweaving in tapestry conservation as the most appropriate method in the repair of well-defined losses of silk and dark brown or black wool outlining of design elements (Hutchinson 1987). Loretta Dolcini discusses the use of reweaving as a preventive treatment approach in dealing with the gradual deterioration of tapestries. This “patient remediation” of “small problems” is intended for the long term upkeep and preservation of tapestries (Dolcini 1987, 86). The approach requires time and skill, but Dolcini is confident that the initial larger expense of reweaving will result in more structurally and aesthetically sound repairs over the long term (Dolcini 1987).

Textile conservator Yvan Maes defends the use of reweaving techniques in the repair of a tapestry where substantial losses in the silk had destroyed the visual composition of the tapestry, believing that "no classical method of conservation could have solved this aesthetic problem" (Maes 1987, 107). Maes also indicates disappointment with "patchwork" (patching); his experience confirms that differences in the weave structures of the tapestry and patching fabric create problems that sometimes appear only after a lapse of time (Maes 1987, 109). In contrast, tapestries restored in his workshop using reweaving more than thirty years ago do not show any problems (Maes 1987).

Reweaving is textile conservator Stan Derelian's preferred method of tapestry repair because he feels it is the only way to restore a tapestry to an acceptable level of structural integrity. Plain cloth patches stretch differently from a tapestry, and the stress is transferred to the surrounding margins. With time and handling, they have a tendency to pull loose, actually making a hole larger. Derelian's experience has been that "most people, even some with strong academic credentials, are surprisingly ignorant of the importance of structure to both monetary and display value" (Derelian 1987, 4).

The conservation reweaving technique involves the replication of weave pattern in areas of loss. Structural integration is achieved by overlapping old and new yarn ends. Materials are chosen to match original fiber content and existing color as closely as possible. The result can be aesthetically impressive and the textile significantly strengthened as a result (Derelian 1987; Shore 1993; Benford, Marino 2002).

Mailand feels that the concern for the aesthetic integration of original and new is an important issue that must be weighed against the need to use minimally interventive techniques that are potentially removable, if not entirely reversible. He observes that concern for the structural stabilization of textiles has taken precedence over visual compensation and aesthetic reintegration in determining choice of technique for filling voids and has led to very neutral fills, such as plain fabric backings. Mailand argues that a fill that meets both criteria of structural stabilization and aesthetic integration is possible and feels that textile conservators need to take a more progressive approach toward this particular problem (Mailand 1990-1991).

Perkins, Brako, and Mann discuss the collaborative decision-making process between textile conservators and a rug restorer in determining ethical treatments for six important Oriental rugs from the collection of the St. Louis Art Museum in preparation for exhibition. The goal of the project was to stabilize and aesthetically improve disfiguring losses and old repairs on all six rugs. They developed procedures that combined reweaving and reknotting, techniques traditionally used by rug restorers to achieve aesthetic compensation, while adhering to established conservation philosophy and guidelines. Analysis of the old repairs confirmed that treatments inconsistent with original rug construction can cause disfigurement and distortion on the rug surface and internal structure. They chose reweaving for larger areas of loss to provide more stabilization than patching, without loss or damage to original materials. The conservators successfully combined and utilized a variety of restoration and conservation techniques and skills previously used only exclusively by either professional rug restorers or textile conservators. The combination of the restoration and conservation approaches used in this particular project provided alternative treatments that allowed for the visual improvement of a pile rug using traditional rug restoration techniques within the limits of conservation ethics (Perkins, Brako, Mann 1990-1991).

Sarah Wolf and Julia Swetzoff discuss the development of a "passive fill" technique for the repair of an Oriental carpet based on the successful repair of a tapestry using the same method (Wolf, Swetzoff 1990-1991). With this technique, a new design insert matching the original pattern is woven separately, attached to a fabric underlay patch, and then stitched to the loss area with hand stitches. The method is called "passive fill" because the patch is only attached to the rug between warps and wefts rather than through the entire structure. The passive fill technique was judged to be successful since it met project goals of visual and aesthetic continuity, respect for original materials, structural soundness, and reversibility (Wolf, Swetzoff 1990-1991).

Rug restorer Marla Mallett describes the changing preferences of rug collectors when determining treatment options for the repair of antique kilim rugs and other weavings. Only ten years ago, nearly all old pile rugs considered collectible were routinely restored to satisfy a clientele demanding mint condition. Today, many of the same collectors are less concerned about condition, placing more value on age and aesthetics. "The tide is turning, with less drastic methods of conservation more frequently favored" (Mallett 2004, 1). Mallett also adds that with early tribal flatweaves becoming increasingly scarce, some pieces now on the market display extensive restoration "looking belabored, tired, and clumsy. We only can wish that beautiful weavings botched by inept hands had not been touched" (Mallett 2004, 1).

Mallett does feel that late nineteenth or early twentieth-century rugs to be used on the floor require reweaving or stabilization of weak or torn areas to prevent further damage. Mallet says that textiles from earlier than the late nineteenth century to be mounted present different issues, and questions "why should we attempt to make textile art look new?" recommending that collectors wanting unblemished pieces "are better advised to purchase new production" (Mallett 2004, 1). However, reweaving was the treatment of choice for the majority of early kilim weavings featured on Mallett's website receiving treatment in her studio.

Ashley-Smith questions why people should consider highly skilled intervention in the treatment of objects being "wrong, dirty or shameful" rather than "merely more expensive than other alternatives" (Ashley-Smith 1994a, 5). He feels that highly skilled intervention can increase an object's utility in terms of "increased flow of information" (aesthetics) and increased stability. "Intelligent and skilled intervention is bound to be a good value for the money" (Ashley-Smith 1994a, 5).

Winfried Heiber, a paintings conservator from Dresden, Germany, specializes in a reweaving technique that he has refined over the past twenty years to repair tears in paintings canvases. The basic technique actually rebuilds the original weave structure of the damaged canvas with replacement threads that are comparable in diameter and structure to the original canvas threads. The essential aim of this technique is to restore a damaged canvas support by reweaving the original weave structure to rebuild strength, tension, independent movement of threads, compliance, and surface, thereby ensuring long-term behavior and aging characteristics compatible with the original, undamaged material (Heiber 2003).

Heiber feels that this method, known as the "thread-by-thread tear repair method" is superior to other more traditional methods of paintings canvas repair (relining, patching, infills) because the technique is minimally invasive compared with other repair methods, since the treatment focuses only on the specific area of damage rather than the entire painting. Heiber also notes that this feature of the technique allows for the preservation of aesthetic and historic aspects of a painting, which can affect its market value and are important concerns to collectors (Heiber 2003).

Heiber notes that "Conservation ethics teach us that economic aspects and time pressure should not compromise the choice of the most appropriate treatment" (Heiber 2003, 46). He believes that the thread-by-thread tear repair method, in spite of the sometimes time consuming nature of the process, is actually a more economical treatment over the long term, as it poses the least risk to paintings compared with the other repair methods. It is sometimes the only possible treatment option for certain types of ruptures or for paintings that cannot be taken off stretcher frames and require more specialized repair techniques of high quality. "One can do thread-by-thread tear repair and not go broke; it is both excellent conservation and cost effective" (Merze-Le, Tallent 22, 2000).

Robert Proctor, a paintings conservator in private practice from Dallas, Texas, has developed his own modification of the thread-by-thread tear repair method of reweaving damaged paintings canvases. Proctor feels that traditional methods of paintings canvas repair – relining and patching the reverse of a canvas – have their limitations and can cause problems over the long term. Linings are too invasive, and patches can result in a patch or tear "coming forward" over time. His theory behind his preference for the reweaving technique is to return the painting to a state as close to the pre-torn configuration as possible. Proctor agrees with Heiber that reweaving a damaged paintings canvas using the tear repair method takes more care and time, but is a minimally interventive technique that focuses on isolating the treatment to the area of damage. He notes that even in instances where the complete reweaving of a tear may be impractical, aspects of the technique can be incorporated into other tear repair techniques (Proctor 1994, 2002).

All of the conservation case studies reviewed for this research discussed the use of reweaving for flat textiles. To my knowledge no conservation case studies have been published to date on the use of reweaving in the treatment of costume or three-dimensional textile objects.

Hutchinson quotes two lines from the Koran that compare the use of reweaving versus other methods of repair which, when read together, seem to suggest how textile conservators might approach their work in the maintenance of a positive attitude of "spiritual and physical integrity" when determining textile loss compensation treatments:

> "The potter who patches a cracked vessel and represents it as sound does evil"

and

> "Painting is a deception, desecration; it is not repair. To repair is to re-weave." (Hutchinson 1990-1991, 11)

Reknitting

The basic concept of reknitting involves taking hidden yarns from an original knit fabric, or reproducing yarns to match those of an original knit fabric as closely as possible, and knitting them into a damaged area. For a reknitting repair to be truly non visible much care must be taken to match the original yarn and knit structure of the damaged knit fabric (NCA 2002).

Despite the lengthy history of knit textiles and costume, very little published information in English on reknitting techniques is available. An early nineteenth-century sewing guide recommends basic darning techniques for the repair of holes, runs, and worn areas in knit fabrics and hosiery (A Lady 1838). Caulfeild and Saward provide more detailed instruction in the repair of knit fabrics outlining techniques that attempt to replicate stockinet knit structures including a ladder repair technique using a crochet hook to pick up dropped stitches to repair runs, basic grafting in which a knit patch is inserted into a damaged knit fabric, and a technique called "Swiss darning," which replicates individual stitches of a damaged knit fabric using a darning needle and yarn (Caulfeild, Saward 1885).

An early twentieth-century domestic arts and sciences manual outlines techniques for the repair of stockinet knit fabrics. "Stockinet grafting" is recommended for the repair of tears by grafting the edges of a tear together with loop stitches to imitate the damaged knit fabric's original structure (Woman's Institute of Domestic Arts and Sciences 1926). "Stockinet patch" is used for larger knit damages and involves inserting a knit patch into a damaged knit area and grafting the edges of the patch with those of the original knit fabric (Woman's Institute of Domestic Arts and Sciences 1926). Stocking runs are repaired with the basic ladder repair technique using a crochet hook to pick up dropped stitches and securing the top of the ladder repair with hand stitches (Woman's Institute of Domestic Arts and Sciences 1926).

Household consumer publications from the mid-twentieth century describe simple techniques for mending stockinet knits. Basic grafting is the recommended repair technique for tears. Stockinet web darning is used for larger holes where a foundation of vertical threads is formed to secure the loops at the edges of a damaged area. A separate yarn then is worked in horizontal rows over the thread foundation to duplicate the original stockinet stitch patterning (Carroll 1947; Scott 1946). A USDA Farmer's Bulletin on mending describes an unusual variation to the stockinet web darning technique, the "blanket-stitch method," in which horizontal rows of blanket stitches are worked over a foundation of horizontal threads to secure the damaged area. The author comments that the blanket stitch technique "is easier to do than the knit stitch, but it shows more and has no give" advising that this technique "should be used only where the garment will not be stretched in use" (Scott 1946, 15).

The *Good Housekeeping Needlecraft Encyclopedia* provides instruction for the repair of runs in stockinet knit using a crochet hook to pick up loose stitches and securing loose ends with hand stitching (Carroll 1947). A variation of a knit patch technique also is described in which the loose loop ends at the lower edge of a damaged knit area are picked up with knitting needles, and a patch then is knitted matching the gauge and design of the knit fabric to fit the hole. The top and sides of the knit patch are joined to the sides of the hole using "a back and forth weaving stitch" (Carroll 1947, 438-439).

Two consumer publications specializing in textiles from the late twentieth century provide basic instruction for stockinet knit repair. *Threads Magazine* describes the basic technique for repairing runs in stockinet knit that is the same as the earlier techniques described (Hebert 1993). *Piecework Magazine* illustrates a simple grafting method to repair tears that is also similar to early techniques (*Piecework Magazine,* May/June 1997, 6).

Trade literature contains more thorough information on reknitting techniques. Virginia Saunders presents detailed photographs and illustrations outlining procedures for repair of "snags," runs in stockinet knit, stockinet grafting for tears, web darning of holes in stockinet, and a different method of repairing larger holes in stockinet in which two long darning needles are used as the foundation anchors for the loose loops at the edge of a damaged area instead of rows of yarns as with web darning methods previously described. The replacement knit stitches are worked over one needle and into the loops of the preceding row. The second needle secures the next row to be reknit, and the two needles alternate moving up each row until the entire damaged area is reknit (Saunders 1958). Although this book has helpful photographs and illustrations, the written instructions are vague overall.

The Fabricon Company provides the most comprehensive, clearly written, and well illustrated instruction, as well as including the largest variety of reknitting techniques for a wide range of knit structures. Techniques are outlined and illustrated for repair of "snags," runs in stockinet knit, grafting and tapered grafting, and web darning. Additional techniques for the repair of purl, rib, and garter stitch knits;

jersey; bonded knits; double knits; and patterned knits also are included (Fabricon, n.d.).

No U.S. textile conservation literature is as detailed as the trade literature which provides specific instruction on reknitting techniques. Three textile conservation case studies describe the treatment of knit apparel. Marie Wulfcrona-Dagel discusses the conservation of eighteenth-century Swedish knit apparel from the collection of the Nordiska Museet in Sweden. Knit losses were stabilized by sewing thin dyed woolen woven tabby underlay patches to the knit structures with a fine silk thread (Wulfcrona-Dagel 1980). Edward Maeder describes the restoration of a sixteenth-century Swiss mercenary soldier's costume in which he repaired a knit loss in a wool beret with dyed-to-match wool that was knitted into a small square, placed under the hole, and stitched into place with fine silk thread also dyed the same color (Maeder 1980). Brooks, Clark, Eastop, and Petschek discuss the treatment of an early nineteenth century machine-knitted silk shawl. Because the client wished to wear the shawl occasionally, the damaged knit pattern was restored by removing disfiguring darning repairs and reforming the original knit pattern manually with a needle, using a combination of remaining original unraveled threads and visually compatible cotton thread (Brooks, et al.1994).

Appendix B

Treatment Samples Summary

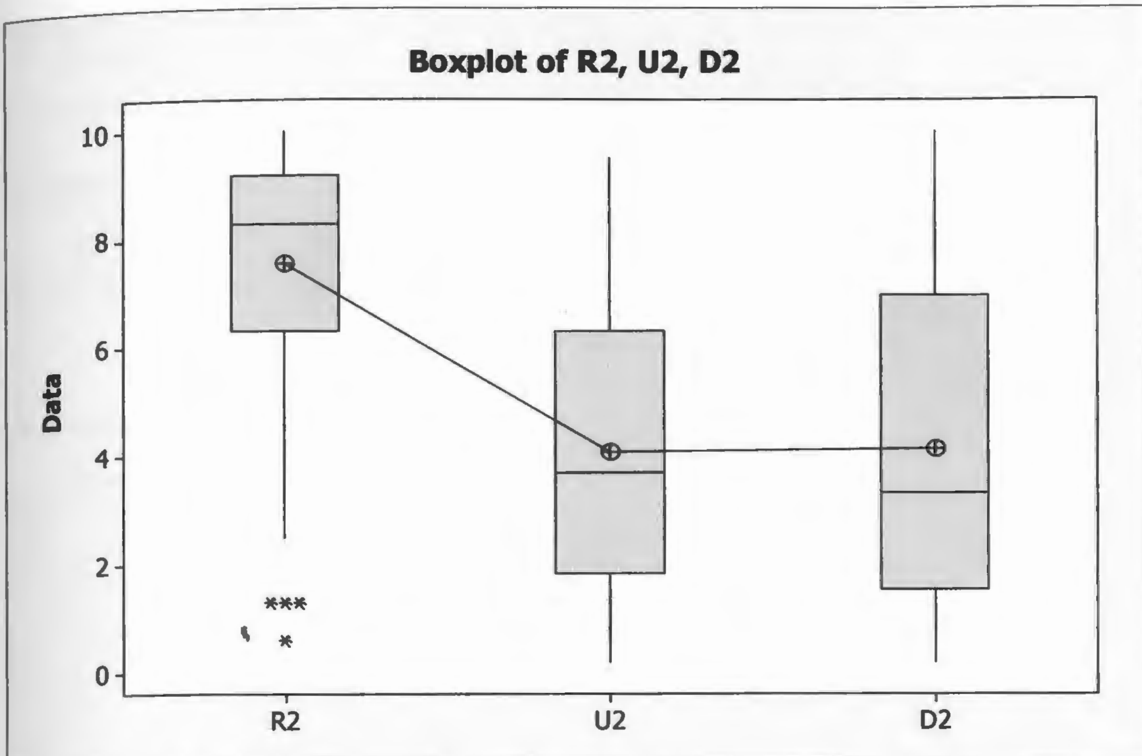
Sample Number	Sample Fabric Description	Repair Technique Used
1.	Plain weave / high thread count	Adhesive-coated backing
2.	Patterned knit	Underlay attached with hand stitches
3.	Double knit	Knit grafting
4.	Patterned knit	Knit grafting
5.	Double knit	Underlay attached with hand stitches
6.	Stockinet knit	Underlay attached with hand stitches
7.	Patterned weave	Underlay attached with hand stitches
8.	Twill weave	Adhesive-coated backing
9.	Plain weave / low thread count	French reweaving
10.	Plain weave / low thread count	Underlay attached with hand stitches
11.	Plain weave / high thread count	Underlay attached with hand stitches
12.	Patterned knit	Adhesive-coated backing
13.	Patterned weave	Adhesive-coated backing
14.	Plain weave / high thread count	French reweaving
15.	Twill weave	Underlay attached with hand stitches
16.	Stockinet knit	Adhesive-coated backing
17.	Patterned weave	Side weaving
18.	Twill weave	French reweaving
19.	Double knit	Adhesive-coated backing

Sample Number	Sample Fabric Description	Repair Technique Used
20.	Stockinet knit	Reknitting
21.	Plain weave / low thread count	Adhesive-coated backing

Appendix C

Statistical Analysis: Woven Fabrics

Effect of Three Treatments on Structural Integrity of Woven Fabrics



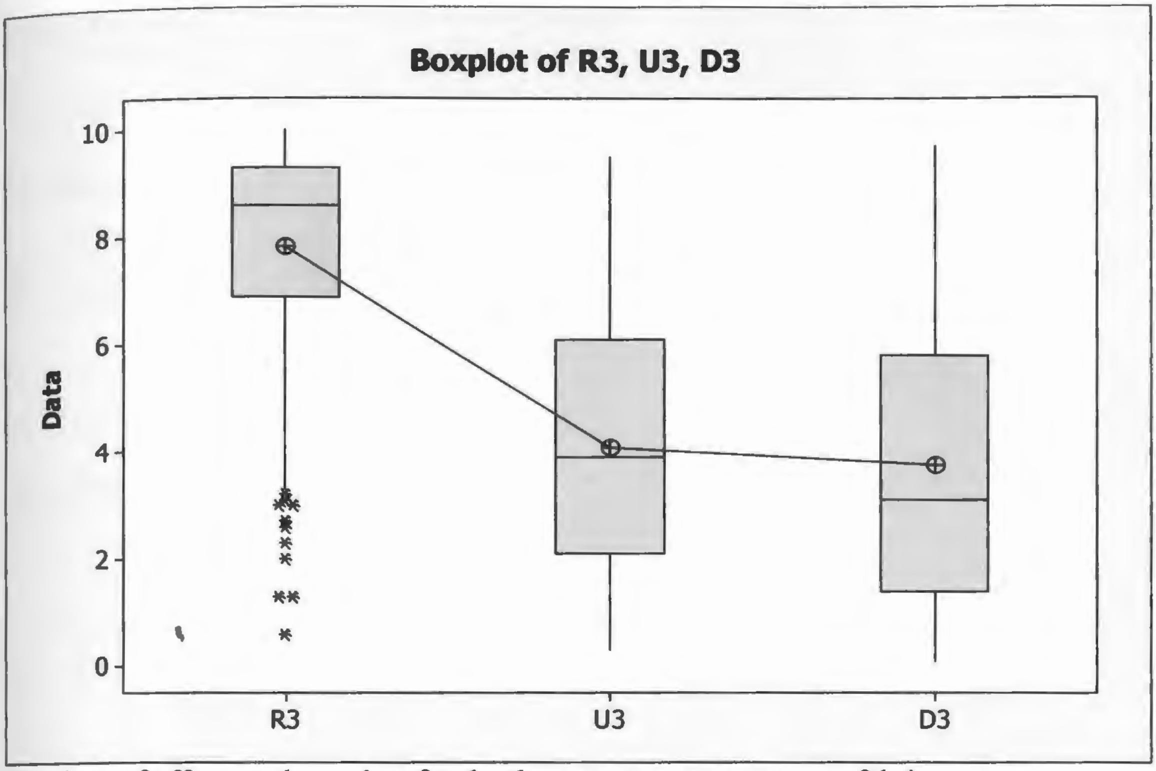
Displays of structural integrity data for the three treatments on woven fabrics

One-way ANOVA: R2, U2, D2

```
Source   DF       SS      MS       F      P
Factor    2  1572.60  786.30  120.92  0.000
Error   585  3803.96    6.50
Total   587  5376.56

S = 2.550   R-Sq = 29.25%   R-Sq(adj) = 29.01%


                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level    N   Mean  StDev  ---------+---------+---------+---------+
R2     196  7.567  2.202                               (--*--)
U2     196  4.071  2.540  (--*--)
D2     196  4.124  2.865  (--*--)
                          ---------+---------+---------+---------+
                                 4.8       6.0       7.2       8.4

Pooled StDev = 2.550
```

```
Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons

Individual confidence level = 98.04%


R2 subtracted from:

      Lower  Center   Upper  ----+---------+---------+---------+-----
U2  -4.098  -3.495  -2.893  (----*----)
D2  -4.045  -3.442  -2.839  (----*----)
                            ----+---------+---------+---------+-----
                              -3.6      -2.4      -1.2       0.0


U2 subtracted from:

      Lower  Center  Upper  ----+---------+---------+---------+-----
D2  -0.550   0.053  0.656                            (----*----)
                           ----+---------+---------+---------+-----
                             -3.6      -2.4      -1.2       0.0
```

Effect of Three Treatments on Drape of Woven Fabrics



Displays of effect on drape data for the three treatments on woven fabrics

One-way ANOVA: R3, U3, D3

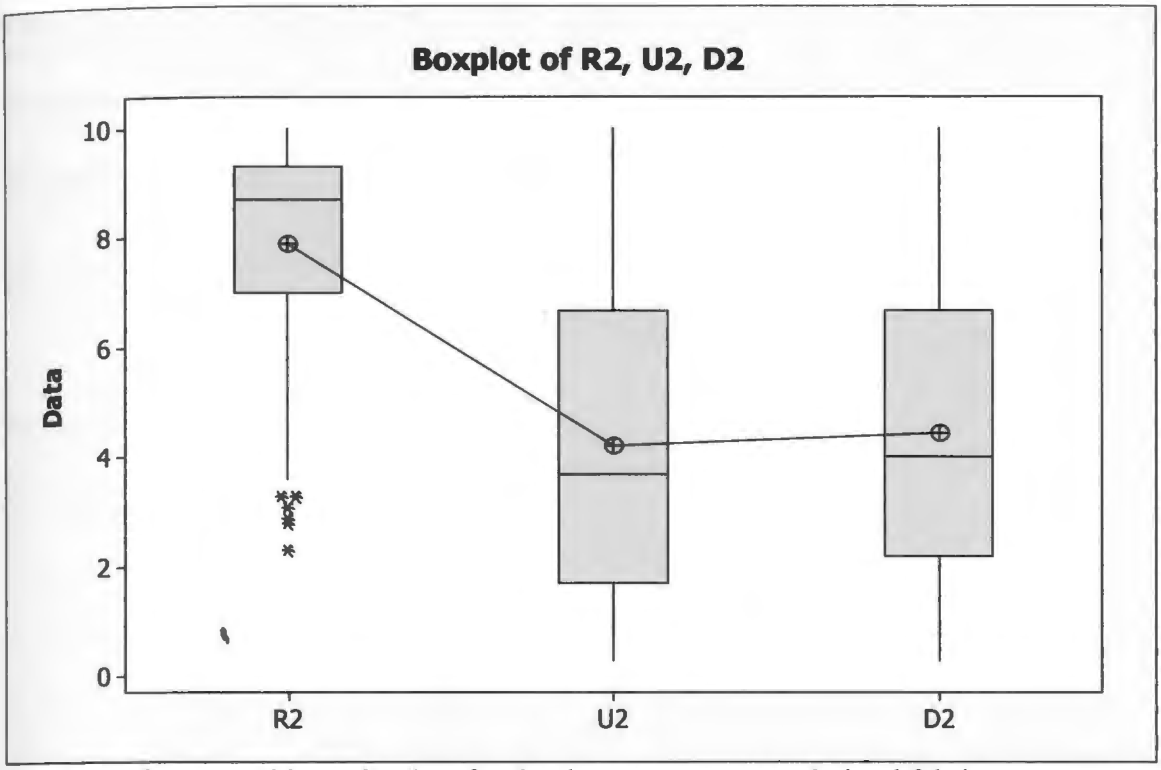
```
Source   DF       SS       MS       F      P
Factor    2  2036.92  1018.46  165.10  0.000
Error   585  3608.74     6.17
Total   587  5645.66

S = 2.484   R-Sq = 36.08%   R-Sq(adj) = 35.86%


                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level    N   Mean  StDev  -------+---------+---------+---------+--
R3     196  7.839  2.044                             (-*--)
U3     196  4.070  2.542    (-*-)
D3     196  3.734  2.805  (-*-)
                          -------+---------+---------+---------+--
                               4.5       6.0       7.5       9.0

Pooled StDev = 2.484
```

```
Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons

Individual confidence level = 98.04%


R3 subtracted from:

     Lower  Center   Upper    -+---------+---------+---------+--------
U3  -4.357  -3.769  -3.182      (---*---)
D3  -4.693  -4.106  -3.518    (---*---)
                              -+---------+---------+---------+--------
                             -4.5      -3.0      -1.5       0.0


U3 subtracted from:

     Lower  Center  Upper    -+---------+---------+---------+--------
D3  -0.923  -0.336  0.251                             (---*---)
                             -+---------+---------+---------+--------
                            -4.5      -3.0      -1.5       0.0
```

Appendix D

Statistical Analysis: Knitted Fabrics

Effect of Three Treatments on Structural Integrity of Knitted Fabrics



Displays of structural integrity data for the three treatments on knitted fabrics

One-way ANOVA: R2, U2, D2

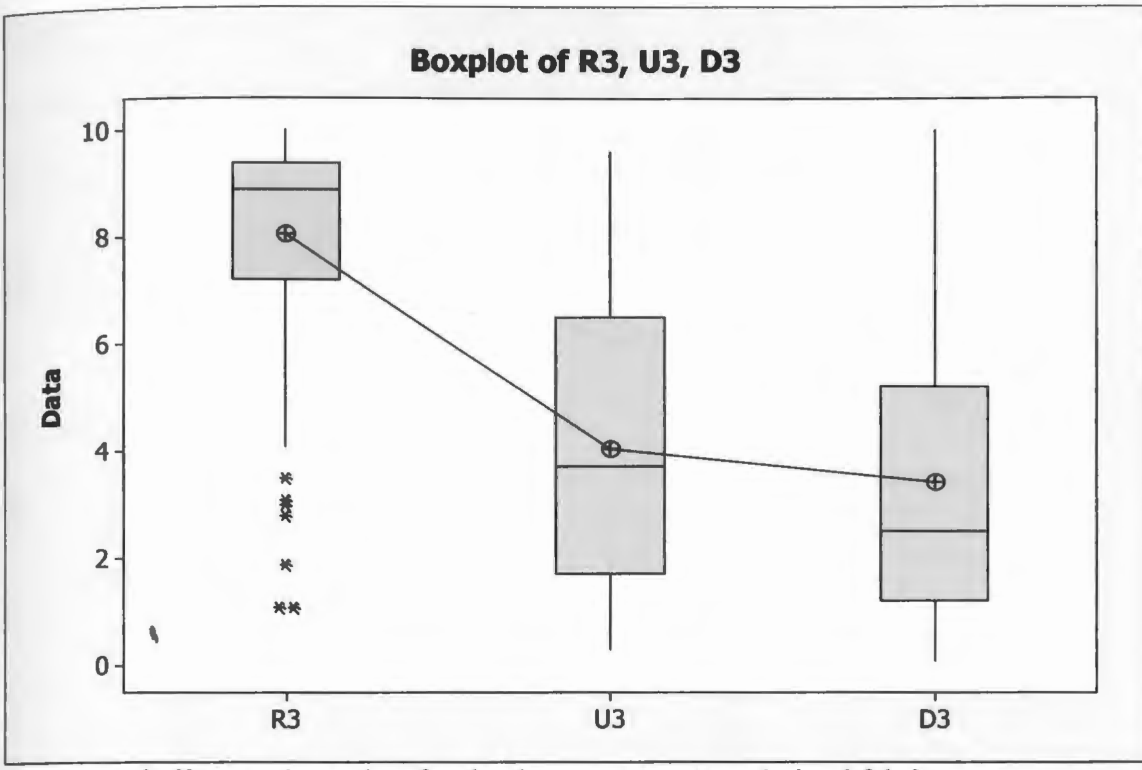
Source	DF	SS	MS	F	P
Factor	2	1254.15	627.07	95.52	0.000
Error	438	2875.53	6.57		
Total	440	4129.68			

S = 2.562   R-Sq = 30.37%   R-Sq(adj) = 30.05%

```
                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level    N   Mean  StDev  --------+---------+---------+---------+-
R2     147  7.910  1.965                              (---*--)
U2     147  4.222  2.780  (--*---)
D2     147  4.453  2.847    (--*---)
                          --------+---------+---------+---------+-
                                4.8       6.0       7.2       8.4

Pooled StDev = 2.562
```

```
Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons

Individual confidence level = 98.03%


R2 subtracted from:

     Lower  Center   Upper  ---------+---------+---------+---------+
U2  -4.387  -3.687  -2.988  (---*----)
D2  -4.156  -3.456  -2.757   (----*----)
                            ---------+---------+---------+---------+
                                  -3.0      -1.5       0.0       1.5


U2 subtracted from:

     Lower  Center  Upper  ---------+---------+---------+---------+
D2  -0.469   0.231  0.930                           (----*---)
                           ---------+---------+---------+---------+
                                 -3.0      -1.5       0.0       1.5
```

Effect of Three Treatments on Drape of Knitted Fabrics



Displays of effect on drape data for the three treatments on knitted fabrics

One-way ANOVA: R3, U3, D3

```
Source   DF       SS      MS       F      P
Factor    2  1874.19  937.10  152.97  0.000
Error   438  2683.23    6.13
Total   440  4557.43

S = 2.475   R-Sq = 41.12%   R-Sq(adj) = 40.86%


                           Individual 95% CIs For Mean Based on Pooled StDev
Level    N   Mean  StDev   +---------+---------+---------+---------
R3     147  8.067  1.934                                (--*-)
U3     147  4.039  2.738        (--*--)
D3     147  3.416  2.672   (--*-)
                           +---------+---------+---------+---------
                          3.0       4.5       6.0       7.5

Pooled StDev = 2.475
```

```
Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons

Individual confidence level = 98.03%


R3 subtracted from:

     Lower  Center   Upper  -------+---------+---------+---------+--
U3  -4.704  -4.029  -3.353     (---*--)
D3  -5.327  -4.651  -3.975  (---*--)
                            -------+---------+---------+---------+--
                                -4.0      -2.0       0.0       2.0


U3 subtracted from:

     Lower  Center  Upper  -------+---------+---------+---------+--
D3  -1.298  -0.622  0.053                      (--*--)
                           -------+---------+---------+---------+--
                               -4.0      -2.0       0.0       2.0
```

Appendix E

Statistical Data

Appendix E
Statistical Data

Key:		
A	Appearance	1-21 Treatment Samples
B	Structural Integrity	
C	Effect on Drape	

	A	B	C		A	B	C		A	B	C
1	0.8	1.1	1.7	2	0.4	0.8	0.7	3	4.1	3.9	7.2
1	0.7	1.0	3.9	2	0.5	0.6	1.9	3	9.3	9.4	9.5
1	3.3	3.3	0.5	2	1.1	8.6	2.4	3	9.0	9.0	9.0
1	1.3	8.4	5.3	2	6.3	6.3	2.4	3	9.8	7.9	9.3
1	5.5	7.3	4.7	2	6.4	7.0	9.0	3	6.5	5.2	7.4
1	4.2	4.8	4.9	2	2.6	3.8	1.3	3	8.6	6.4	3.1
1	1.5	7.2	7.4	2	1.7	9.6	1.8	3	9.4	9.3	9.2
1	7.3	7.7	8.2	2	1.3	2.5	2.0	3	9.4	9.5	9.5
1	1.8	3.1	6.5	2	2.2	2.7	1.1	3	6.4	4.9	6.0
1	3.0	1.3	2.2	2	2.2	4.4	3.7	3	8.3	9.1	9.1
1	4.4	7.4	7.4	2	2.2	8.5	2.2	3	10.0	8.6	8.5
1	1.9	0.4	7.3	2	4.6	9.4	9.3	3	9.3	9.2	9.2
1	1.1	5.5	1.1	2	1.4	6.4	7.1	3	9.1	7.3	8.9
1	0.6	0.6	0.7	2	0.6	0.6	9.1	3	5.4	4.6	7.4
1	7.8	2.1	0.7	2	1.1	8.1	8.3	3	8.8	8.7	8.6
1	3.3	1.8	0.7	2	4.8	6.1	4.8	3	6.5	2.9	5.3
1	7.3	7.8	8.4	2	4.7	5.2	5.8	3	6.3	6.2	5.7
1	1.1	2.9	1.6	2	0.7	0.6	0.5	3	5.3	4.0	5.3
1	4.0	3.0	4.0	2	2.9	3.2	1.7	3	7.1	6.3	8.4
1	1.7	3.8	5.8	2	1.4	2.1	2.1	3	4.6	3.3	1.1
1	2.1	2.0	4.3	2	0.7	0.8	4.3	3	7.2	7.2	7.3
1	1.5	2.4	1.4	2	0.8	0.8	0.8	3	6.0	4.9	5.9
1	1.4	1.9	1.7	2	1.7	2.3	2.0	3	8.4	7.2	8.0
1	0.9	0.9	1.0	2	0.9	0.8	0.9	3	7.3	7.4	6.0
1	3.6	8.6	8.6	2	0.4	1.2	0.4	3	9.7	9.3	9.5
1	8.0	5.4	2.0	2	1.7	5.4	8.6	3	9.0	9.3	9.4
1	1.6	1.6	2.5	2	0.9	1.6	1.1	3	3.2	3.6	3.5
1	2.4	4.5	3.8	2	2.2	2.5	2.2	3	4.7	4.8	4.9
1	1.0	2.2	8.8	2	1.6	1.8	2.6	3	3.7	3.7	3.0
1	0.6	2.4	8.3	2	1.7	1.9	4.0	3	8.0	7.7	7.2
1	0.7	2.0	8.2	2	1.4	1.4	5.0	3	8.4	7.8	8.5
1	3.5	4.0	4.0	2	1.3	1.9	1.0	3	9.0	8.0	7.9
1	1.7	0.7	2.6	2	0.6	0.4	0.5	3	6.9	6.4	6.3
1	2.8	8.0	8.7	2	0.7	8.0	5.9	3	8.2	9.1	9.1
1	4.0	0.6	1.0	2	0.5	1.9	5.5	3	9.5	7.7	8.9
1	1.4	2.1	3.7	2	0.8	1.9	2.4	3	6.3	7.6	8.7
1	4.7	2.3	4.8	2	1.3	7.4	2.9	3	8.6	8.3	7.5
1	5.4	6.4	0.2	2	0.2	4.7	5.9	3	9.4	9.7	9.7
1	5.0	7.5	7.1	2	5.9	8.2	7.5	3	7.0	8.3	6.3
1	8.4	10.0	9.2	2	0.3	10.0	4.6	3	10.0	10.0	10.0
1	4.1	7.0	9.5	2	0.0	1.0	1.1	3	8.1	9.4	2.8
1	3.8	7.9	4.8	2	1.2	3.7	1.3	3	8.2	9.2	9.3
1	0.7	2.4	1.7	2	2.2	2.7	1.1	3	7.2	7.8	7.2
1	3.5	2.0	6.2	2	1.5	3.0	1.7	3	6.6	5.1	6.8
1	3.2	8.2	5.7	2	1.8	6.2	3.9	3	7.1	8.9	8.8
1	0.8	2.0	3.2	2	0.7	5.4	2.5	3	7.8	7.9	6.4
1	3.0	8.8	8.1	2	8.9	2.2	4.9	3	5.1	5.1	8.3
1	0.2	2.0	5.7	2	0.4	1.0	5.7	3	7.4	6.5	7.7
1	8.5	7.5	9.2	2	6.3	6.4	5.8	3	8.3	8.3	9.1

	A	B	C		A	B	C		A	B	C
4	9.2	9.2	9.2	**5**	0.9	0.9	1.0	**6**	0.5	0.6	0.7
4	10.0	10.0	10.0	**5**	1.0	0.4	0.6	**6**	0.5	0.5	0.3
4	9.4	9.3	9.3	**5**	4.3	9.2	6.0	**6**	0.6	9.0	7.0
4	10.0	9.8	9.9	**5**	9.5	7.8	7.2	**6**	8.6	8.7	7.4
4	6.7	7.7	9.0	**5**	3.9	7.1	8.0	**6**	2.9	4.1	7.4
4	9.6	9.2	9.3	**5**	3.8	2.7	4.9	**6**	2.3	4.2	6.5
4	9.4	9.5	9.4	**5**	0.3	5.4	2.6	**6**	0.4	8.0	2.5
4	9.3	9.3	9.4	**5**	2.4	6.7	6.8	**6**	2.0	7.0	7.2
4	9.0	9.1	9.1	**5**	2.3	2.8	1.7	**6**	2.8	3.6	1.8
4	10.0	9.4	10.0	**5**	3.4	6.9	5.4	**6**	2.6	2.9	2.4
4	9.9	9.2	9.1	**5**	4.6	7.4	6.3	**6**	2.1	5.6	4.7
4	9.3	9.3	9.5	**5**	4.8	7.8	5.2	**6**	0.6	8.0	9.0
4	7.5	4.6	6.2	**5**	7.2	5.8	8.0	**6**	3.2	4.8	7.0
4	7.3	6.6	4.9	**5**	0.6	7.7	0.9	**6**	0.7	6.4	2.5
4	10.0	10.0	10.0	**5**	7.1	0.9	1.1	**6**	0.4	0.8	0.7
4	9.6	9.5	9.5	**5**	1.7	0.8	0.4	**6**	1.2	2.2	1.2
4	7.8	7.8	7.0	**5**	4.8	5.7	6.0	**6**	6.8	6.7	6.5
4	9.2	9.5	9.8	**5**	0.7	3.3	1.0	**6**	0.4	4.2	1.6
4	9.2	9.2	9.2	**5**	2.3	2.9	5.4	**6**	2.1	2.4	2.0
4	7.2	8.3	8.1	**5**	2.1	3.0	1.7	**6**	1.2	1.0	1.8
4	10.0	10.0	10.0	**5**	1.5	2.1	2.0	**6**	0.9	1.7	1.9
4	9.1	9.1	9.2	**5**	1.5	0.7	1.7	**6**	1.5	0.7	1.5
4	8.6	8.9	8.7	**5**	1.7	2.5	2.2	**6**	1.4	2.1	1.8
4	10.0	10.0	10.0	**5**	0.9	0.8	0.8	**6**	0.8	0.9	0.9
4	10.0	9.9	9.7	**5**	2.1	5.4	0.9	**6**	1.3	7.5	6.5
4	10.0	10.0	10.0	**5**	8.3	8.7	7.7	**6**	2.4	5.6	5.7
4	7.9	7.9	8.0	**5**	1.0	3.1	2.5	**6**	1.3	3.1	2.6
4	8.3	7.8	8.7	**5**	6.0	5.7	6.5	**6**	2.2	2.8	2.4
4	8.8	8.8	8.9	**5**	7.4	5.3	7.2	**6**	7.4	6.9	7.5
4	8.9	8.9	8.9	**5**	6.5	5.2	8.0	**6**	6.5	5.9	6.3
4	8.9	8.9	8.9	**5**	6.9	3.1	6.3	**6**	6.9	4.3	4.3
4	9.2	9.2	9.5	**5**	6.1	6.3	6.3	**6**	1.6	1.7	1.5
4	9.3	9.3	9.3	**5**	2.7	0.9	1.2	**6**	1.2	0.7	0.8
4	9.8	9.6	9.6	**5**	4.5	9.1	7.5	**6**	0.3	9.0	8.2
4	9.6	9.5	9.5	**5**	3.5	5.7	5.9	**6**	0.7	5.0	6.6
4	8.2	8.4	9.1	**5**	1.2	3.6	4.2	**6**	1.6	2.7	4.3
4	9.7	9.7	9.7	**5**	3.0	8.1	3.8	**6**	2.0	6.2	4.4
4	10.0	9.9	10.0	**5**	6.2	4.9	4.6	**6**	0.2	4.2	5.1
4	9.8	9.3	9.5	**5**	5.6	7.8	7.0	**6**	3.2	7.5	7.0
4	10.0	10.0	10.0	**5**	4.6	6.0	8.0	**6**	0.5	7.2	4.4
4	10.0	10.0	10.0	**5**	0.6	1.5	9.2	**6**	0.5	1.0	8.7
4	9.4	9.4	9.4	**5**	4.7	3.5	3.1	**6**	0.9	2.7	4.2
4	9.8	9.8	9.9	**5**	1.1	1.0	0.4	**6**	0.2	0.7	0.9
4	9.1	9.2	9.4	**5**	2.2	1.6	2.5	**6**	1.9	1.5	1.7
4	9.1	9.2	9.2	**5**	2.4	7.3	4.3	**6**	1.0	2.8	2.2
4	9.3	8.8	7.0	**5**	0.7	2.8	2.8	**6**	0.5	4.0	1.9
4	8.8	2.3	8.1	**5**	5.2	5.3	8.2	**6**	3.2	7.5	9.1
4	10.0	10.0	10.0	**5**	0.8	0.8	0.8	**6**	0.8	0.3	2.9
4	9.8	9.6	9.7	**5**	7.1	8.1	9.6	**6**	7.3	8.7	9.5

	A	B	C		A	B	C		A	B	C
7	0.3	0.4	0.4	8	0.4	0.4	0.4	9	9.5	9.6	9.6
7	0.3	0.4	0.6	8	0.4	0.5	0.6	9	10.0	10.0	10.0
7	0.5	9.0	7.8	8	0.9	7.9	0.9	9	9.4	9.4	9.5
7	5.7	7.2	5.3	8	3.4	6.1	8.5	9	9.9	9.9	9.9
7	6.0	7.0	8.7	8	6.9	9.4	4.0	9	5.8	7.5	8.0
7	0.8	4.6	0.4	8	0.3	7.3	7.4	9	7.2	9.3	9.4
7	0.9	1.6	3.4	8	0.8	9.3	9.2	9	9.1	9.2	9.2
7	0.5	7.7	6.1	8	1.2	7.3	1.7	9	9.6	9.6	9.5
7	2.0	2.9	3.5	8	2.1	3.2	2.7	9	9.8	9.6	9.4
7	2.9	2.9	3.2	8	1.8	3.8	3.3	9	10.0	9.0	9.8
7	1.5	3.0	4.3	8	1.2	3.0	4.4	9	9.5	8.6	8.6
7	0.6	9.2	9.3	8	0.7	0.8	4.7	9	9.4	9.4	9.4
7	2.7	5.3	7.5	8	2.6	2.7	2.9	9	4.6	6.0	6.8
7	1.8	4.1	3.0	8	2.1	3.6	2.4	9	9.3	9.5	9.4
7	1.0	0.9	0.9	8	6.7	1.3	1.0	9	9.8	9.8	9.7
7	0.9	2.7	2.6	8	1.0	3.9	1.6	9	10.0	10.0	10.0
7	6.8	6.8	7.4	8	7.2	7.4	7.4	9	6.5	5.8	6.9
7	0.3	3.5	0.3	8	0.5	3.3	0.7	9	9.6	9.6	9.6
7	2.0	2.8	3.9	8	1.4	2.2	4.0	9	9.1	9.2	9.5
7	2.1	1.6	3.1	8	1.8	1.4	2.5	9	8.5	9.7	9.7
7	1.2	1.1	1.1	8	1.8	1.8	1.8	9	7.5	7.5	7.5
7	0.9	1.2	0.7	8	0.7	1.5	0.6	9	9.5	9.4	9.4
7	1.1	1.7	2.1	8	1.5	2.1	2.2	9	8.6	8.2	8.2
7	0.9	0.9	0.8	8	0.7	0.7	0.7	9	0.7	0.6	0.6
7	0.6	8.8	8.1	8	0.3	6.9	9.3	9	10.0	10.0	10.0
7	7.5	9.0	9.0	8	2.0	8.8	1.2	9	10.0	10.0	10.0
7	1.2	1.6	2.5	8	1.4	2.1	2.0	9	8.4	8.5	8.6
7	2.0	1.8	1.9	8	5.6	5.2	6.3	9	8.6	8.7	8.8
7	1.2	4.3	6.1	8	0.7	5.5	7.8	9	10.0	10.0	10.0
7	2.5	1.8	2.3	8	4.9	5.8	5.7	9	8.9	8.9	9.0
7	1.9	1.0	2.0	8	2.5	4.6	7.0	9	8.5	8.6	8.7
7	0.9	0.8	0.8	8	0.6	0.9	0.5	9	9.3	9.2	9.5
7	0.8	0.7	1.0	8	0.8	1.2	0.7	9	9.4	9.4	9.4
7	0.7	8.7	9.5	8	0.7	9.3	9.3	9	9.3	9.3	9.3
7	3.1	5.9	5.0	8	0.8	1.6	0.8	9	9.7	9.6	9.6
7	1.5	2.7	5.2	8	1.1	2.1	1.9	9	7.8	8.0	8.5
7	1.0	6.4	5.3	8	1.0	8.1	8.1	9	9.3	9.3	9.2
7	0.1	4.6	4.8	8	0.1	4.7	0.1	9	10.0	10.0	10.0
7	3.1	6.9	6.8	8	5.4	7.6	8.3	9	9.8	8.0	7.1
7	0.3	1.9	4.8	8	0.2	4.4	4.4	9	10.0	10.0	10.0
7	0.0	1.4	8.8	8	0.0	1.4	9.7	9	10.0	10.0	10.0
7	1.1	3.5	5.5	8	1.4	4.0	1.5	9	10.0	10.0	10.0
7	3.0	2.1	2.8	8	0.5	5.9	5.8	9	10.0	9.9	9.9
7	1.6	2.7	2.1	8	0.5	1.5	1.7	9	9.6	9.1	9.5
7	0.8	1.3	1.1	8	0.7	3.4	1.7	9	9.5	9.5	9.4
7	0.9	4.3	4.4	8	1.1	4.0	4.0	9	8.8	8.7	8.7
7	2.2	7.5	6.2	8	3.8	7.7	7.0	9	5.1	5.1	7.7
7	0.2	0.2	2.6	8	0.4	0.8	0.9	9	10.0	10.0	10.0
7	7.5	6.6	9.4	8	7.3	8.4	9.4	9	9.7	9.6	9.7

	A	B	C		A	B	C		A	B	C
10	0.6	0.6	0.7	**11**	0.5	0.5	0.7	**12**	0.6	0.6	0.6
10	0.6	0.7	1.4	**11**	1.9	0.3	3.0	**12**	0.4	0.4	1.4
10	3.9	8.6	7.7	**11**	6.8	9.0	7.8	**12**	3.5	4.0	0.3
10	4.1	6.9	3.7	**11**	4.7	6.3	3.2	**12**	7.8	9.4	4.0
10	7.1	5.4	7.9	**11**	6.0	7.3	8.8	**12**	8.0	7.0	7.3
10	3.2	4.5	4.5	**11**	4.8	2.5	2.6	**12**	2.4	3.1	4.7
10	0.6	7.6	5.2	**11**	4.5	7.7	6.6	**12**	3.3	9.3	1.5
10	1.3	1.9	2.1	**11**	4.4	4.9	0.7	**12**	1.2	8.1	0.5
10	4.8	3.7	3.0	**11**	6.4	4.5	3.1	**12**	1.8	1.8	1.7
10	5.8	2.7	3.8	**11**	6.2	3.6	4.9	**12**	5.2	10.0	6.5
10	2.4	3.7	4.8	**11**	5.8	6.1	6.2	**12**	3.6	8.0	1.3
10	0.7	7.6	5.4	**11**	3.2	0.8	4.8	**12**	7.8	1.3	2.9
10	8.5	8.4	8.4	**11**	4.9	6.5	7.8	**12**	3.5	5.8	8.9
10	2.7	3.8	7.2	**11**	1.4	4.0	5.1	**12**	1.2	2.3	3.3
10	7.3	0.9	1.2	**11**	9.3	4.6	2.2	**12**	3.1	0.9	0.7
10	0.9	2.9	1.1	**11**	6.5	5.3	4.6	**12**	3.3	3.7	4.6
10	6.2	6.8	6.4	**11**	5.4	5.7	4.7	**12**	5.4	5.0	4.9
10	0.4	3.6	3.5	**11**	4.4	2.7	2.7	**12**	0.3	0.5	0.5
10	5.3	4.0	4.7	**11**	6.2	6.6	8.9	**12**	3.8	4.3	5.2
10	2.1	2.9	2.1	**11**	1.8	4.2	3.3	**12**	3.2	4.3	4.8
10	0.9	1.0	1.2	**11**	1.8	2.3	2.0	**12**	1.1	1.1	0.6
10	4.5	3.3	4.5	**11**	2.6	3.5	2.4	**12**	2.5	3.7	2.5
10	3.1	2.1	1.3	**11**	2.4	1.8	2.4	**12**	1.1	2.0	2.3
10	0.6	0.6	0.7	**11**	0.7	0.7	0.7	**12**	0.7	0.6	0.7
10	1.2	8.4	2.1	**11**	3.4	5.8	1.3	**12**	3.3	7.8	0.7
10	4.5	5.4	5.2	**11**	6.4	6.5	6.3	**12**	8.5	8.2	0.7
10	1.1	1.7	1.4	**11**	2.6	2.7	4.0	**12**	2.2	2.2	0.7
10	3.5	4.0	3.5	**11**	4.5	5.3	4.7	**12**	4.0	3.5	3.0
10	1.2	3.2	4.0	**11**	2.0	3.5	3.9	**12**	1.5	2.5	3.0
10	2.6	3.8	4.9	**11**	7.6	5.8	6.6	**12**	6.3	2.7	4.2
10	2.2	4.1	5.2	**11**	7.2	4.5	6.1	**12**	6.0	4.8	6.1
10	1.1	1.6	1.6	**11**	2.8	2.5	2.6	**12**	2.7	2.9	1.0
10	4.3	1.9	3.1	**11**	5.6	3.3	1.1	**12**	2.9	2.2	2.1
10	1.0	6.3	5.0	**11**	5.2	7.7	2.4	**12**	5.2	9.1	8.4
10	1.6	4.6	4.5	**11**	4.8	3.8	3.8	**12**	4.0	5.4	0.7
10	1.6	4.0	8.1	**11**	1.8	4.8	7.7	**12**	1.4	3.7	2.9
10	4.4	7.5	5.9	**11**	4.3	6.3	4.0	**12**	2.7	9.2	4.3
10	3.3	4.5	4.5	**11**	4.3	4.3	4.3	**12**	0.7	2.1	0.1
10	6.0	7.0	6.3	**11**	6.0	6.3	4.1	**12**	5.1	5.8	6.8
10	0.2	7.3	7.4	**11**	3.4	5.9	7.2	**12**	4.6	8.1	10.0
10	3.8	2.0	3.8	**11**	6.8	6.8	2.6	**12**	1.6	9.3	9.1
10	2.3	3.4	5.6	**11**	2.8	2.9	3.0	**12**	2.3	2.3	1.3
10	2.8	2.1	5.0	**11**	4.5	1.7	1.1	**12**	1.4	4.8	7.7
10	2.7	1.9	2.0	**11**	2.8	2.5	2.8	**12**	2.2	2.0	3.3
10	1.5	9.5	3.2	**11**	3.4	6.7	5.0	**12**	2.4	2.4	2.5
10	1.9	4.0	4.0	**11**	4.3	6.3	6.4	**12**	0.9	5.5	2.3
10	5.3	5.3	2.1	**11**	2.1	5.9	2.7	**12**	7.7	2.4	1.3
10	0.7	0.4	2.3	**11**	0.5	0.5	0.4	**12**	0.4	2.2	2.2
10	9.5	9.5	9.5	**11**	9.3	9.3	9.3	**12**	9.3	9.3	8.2

	A	B	C		A	B	C		A	B	C
13	0.7	0.7	0.8	**14**	7.0	7.6	7.7	**15**	0.4	0.5	0.5
13	0.3	0.4	1.1	**14**	9.7	9.2	9.3	**15**	0.5	0.5	0.5
13	0.6	6.7	0.7	**14**	9.3	9.3	9.4	**15**	0.6	9.3	7.0
13	4.1	8.8	3.1	**14**	8.6	7.0	7.0	**15**	3.1	6.4	5.5
13	7.1	9.0	5.8	**14**	6.5	7.5	9.3	**15**	6.5	6.0	7.7
13	1.5	2.6	1.6	**14**	8.7	3.3	5.8	**15**	0.8	6.5	6.5
13	1.5	5.5	5.5	**14**	8.2	9.5	9.3	**15**	0.5	6.1	5.2
13	0.8	4.6	4.1	**14**	9.3	6.3	9.0	**15**	0.9	5.8	6.3
13	1.1	0.9	1.2	**14**	9.1	8.8	8.9	**15**	1.9	2.0	4.7
13	2.3	8.1	3.8	**14**	10.0	8.9	9.6	**15**	1.0	4.9	1.6
13	1.6	8.0	1.6	**14**	8.1	2.6	6.3	**15**	0.9	4.3	4.5
13	0.8	0.7	4.7	**14**	9.2	9.3	9.3	**15**	0.5	7.1	8.1
13	9.0	8.9	7.1	**14**	8.0	8.1	8.5	**15**	1.2	1.4	1.6
13	1.2	3.0	2.5	**14**	7.2	4.5	2.7	**15**	1.4	3.0	2.1
13	0.8	0.7	0.6	**14**	10.0	10.0	10.0	**15**	0.4	0.5	0.4
13	2.4	2.0	1.4	**14**	9.6	9.6	9.6	**15**	1.4	0.7	0.6
13	6.1	5.9	5.8	**14**	3.4	3.3	3.2	**15**	5.6	5.4	5.1
13	0.7	1.7	0.7	**14**	9.5	9.4	9.4	**15**	0.4	0.4	1.2
13	4.1	3.6	3.3	**14**	8.8	7.8	9.3	**15**	2.7	3.3	4.6
13	2.8	1.2	5.4	**14**	6.7	7.7	4.9	**15**	2.4	2.9	2.1
13	0.5	0.9	0.4	**14**	7.7	8.1	8.4	**15**	0.9	1.3	0.9
13	2.1	1.3	2.0	**14**	7.3	7.3	7.3	**15**	2.2	1.7	2.3
13	0.7	1.2	1.7	**14**	8.3	7.7	7.3	**15**	1.2	1.7	1.4
13	0.6	0.5	0.5	**14**	3.8	3.8	3.6	**15**	0.4	0.4	0.4
13	2.4	4.9	1.7	**14**	9.8	9.5	7.0	**15**	0.5	3.5	7.2
13	4.7	6.8	1.8	**14**	9.0	7.2	7.4	**15**	0.8	7.9	7.7
13	0.9	0.9	0.9	**14**	3.6	3.6	3.0	**15**	1.2	1.5	1.3
13	3.6	3.2	2.2	**14**	7.4	6.9	8.3	**15**	2.3	1.3	0.8
13	0.8	1.8	2.8	**14**	10.0	10.0	10.0	**15**	1.5	2.3	2.5
13	3.2	2.4	2.8	**14**	7.5	8.0	8.1	**15**	2.8	3.4	2.4
13	3.2	2.2	3.3	**14**	7.8	7.8	7.9	**15**	1.6	2.5	1.7
13	0.4	0.8	0.5	**14**	6.6	6.3	6.8	**15**	2.8	3.0	0.7
13	1.2	1.2	0.8	**14**	7.8	7.8	7.0	**15**	1.1	1.3	1.3
13	1.2	9.0	7.8	**14**	9.1	9.0	8.2	**15**	1.9	8.4	7.8
13	0.5	2.9	0.6	**14**	8.2	8.2	9.2	**15**	1.1	2.4	2.4
13	1.2	2.5	1.7	**14**	6.0	6.7	8.1	**15**	0.8	3.0	4.2
13	2.4	8.9	6.3	**14**	7.7	8.4	7.7	**15**	3.6	5.9	4.9
13	0.1	0.2	0.2	**14**	9.6	9.1	9.4	**15**	0.1	1.7	0.7
13	4.2	5.6	6.2	**14**	6.5	6.1	5.8	**15**	3.0	8.1	7.9
13	0.3	9.3	9.3	**14**	8.9	9.2	9.2	**15**	0.4	7.4	7.4
13	0.0	6.1	9.3	**14**	10.0	9.5	9.0	**15**	0.0	3.5	4.6
13	1.1	3.5	1.1	**14**	8.1	9.0	7.2	**15**	0.5	2.5	5.0
13	0.7	6.2	8.3	**14**	9.6	7.8	8.4	**15**	0.4	4.1	7.0
13	0.7	3.9	3.4	**14**	8.2	8.4	8.5	**15**	1.1	1.5	0.5
13	0.8	1.8	1.8	**14**	6.0	6.2	6.2	**15**	1.3	4.8	2.5
13	0.8	7.6	5.1	**14**	7.6	7.6	7.1	**15**	1.1	5.9	6.1
13	3.9	6.5	2.0	**14**	2.6	5.3	7.8	**15**	4.3	7.1	8.6
13	0.2	0.3	4.1	**14**	3.7	1.3	1.3	**15**	0.5	0.6	3.5
13	8.5	6.7	8.3	**14**	7.3	7.4	8.5	**15**	7.8	6.7	8.5

	A	B	C		A	B	C		A	B	C
16	0.6	0.7	0.8	**17**	9.4	9.6	9.6	**18**	9.4	9.5	9.4
16	0.4	0.4	0.4	**17**	9.6	9.1	8.9	**18**	8.6	8.4	8.6
16	0.5	0.3	0.4	**17**	7.6	8.9	9.3	**18**	8.5	9.2	9.5
16	7.3	6.1	2.8	**17**	8.3	6.9	6.9	**18**	8.2	8.3	9.8
16	6.6	8.2	8.7	**17**	7.2	6.7	9.1	**18**	6.7	8.3	9.2
16	1.1	6.0	6.1	**17**	7.3	4.9	6.0	**18**	8.6	4.7	4.3
16	0.6	0.7	0.7	**17**	9.4	9.4	4.4	**18**	9.3	9.3	9.2
16	1.3	7.5	1.2	**17**	9.1	2.5	6.0	**18**	8.5	5.8	7.2
16	1.9	3.3	3.4	**17**	6.0	5.1	6.8	**18**	6.2	6.9	5.7
16	1.0	7.1	2.8	**17**	9.6	9.0	9.5	**18**	8.9	8.8	8.9
16	1.1	9.1	1.4	**17**	7.8	3.2	2.3	**18**	7.7	2.8	4.6
16	0.7	0.7	6.3	**17**	9.3	9.2	9.1	**18**	7.7	7.6	6.1
16	4.2	3.2	2.4	**17**	9.0	9.0	9.1	**18**	6.4	6.6	6.7
16	0.8	0.6	1.8	**17**	9.0	1.3	9.1	**18**	3.2	3.2	4.9
16	7.9	4.3	0.9	**17**	10.0	10.0	10.0	**18**	9.9	10.0	10.0
16	1.0	1.7	0.6	**17**	9.5	8.3	8.9	**18**	8.2	7.4	7.5
16	6.0	5.9	5.5	**17**	2.9	2.5	3.1	**18**	6.8	6.9	6.9
16	0.5	4.0	0.6	**17**	9.3	9.2	8.9	**18**	8.1	8.9	8.9
16	3.8	4.3	9.1	**17**	6.8	7.1	8.1	**18**	7.2	7.4	8.9
16	1.9	1.3	2.0	**17**	1.9	4.4	6.9	**18**	7.0	4.3	5.8
16	0.9	0.7	0.6	**17**	7.6	8.0	8.2	**18**	5.5	5.8	5.6
16	3.3	5.7	3.3	**17**	7.1	6.7	7.1	**18**	7.2	6.6	7.2
16	0.7	1.7	1.3	**17**	7.3	6.2	8.2	**18**	7.4	7.9	5.6
16	0.3	0.3	0.3	**17**	5.0	5.0	3.3	**18**	3.1	1.3	1.3
16	2.3	5.6	0.7	**17**	9.2	8.8	8.4	**18**	7.5	8.4	9.3
16	1.1	2.7	4.5	**17**	9.5	9.4	9.3	**18**	8.6	8.7	8.7
16	1.3	1.4	1.5	**17**	4.0	3.6	5.4	**18**	2.8	3.2	4.6
16	3.8	2.9	1.8	**17**	8.2	5.9	7.1	**18**	7.2	5.3	7.0
16	1.3	2.2	2.2	**17**	9.1	9.1	9.1	**18**	9.2	9.2	9.2
16	3.9	4.2	5.8	**17**	8.7	9.2	9.3	**18**	7.8	8.3	7.8
16	6.6	4.6	4.6	**17**	7.3	7.3	7.3	**18**	8.9	8.9	8.9
16	2.2	3.3	1.0	**17**	8.7	9.2	8.7	**18**	7.5	7.5	6.4
16	0.8	8.2	3.8	**17**	9.1	5.5	5.1	**18**	9.1	3.3	2.6
16	2.7	9.1	9.0	**17**	9.3	9.2	9.3	**18**	7.8	9.2	9.2
16	0.7	2.1	0.7	**17**	9.4	7.1	7.6	**18**	9.5	8.8	9.4
16	0.9	1.5	2.4	**17**	6.2	8.4	8.7	**18**	6.1	6.1	7.3
16	2.1	9.3	5.3	**17**	7.7	8.4	6.8	**18**	7.6	7.5	8.9
16	0.1	4.7	0.4	**17**	6.8	8.0	7.6	**18**	7.6	8.3	7.4
16	4.1	8.0	6.6	**17**	8.4	7.6	5.6	**18**	6.9	8.8	6.3
16	0.3	10.0	0.1	**17**	9.4	9.5	9.4	**18**	10.0	9.9	9.9
16	0.4	0.4	9.5	**17**	10.0	8.4	8.6	**18**	8.9	5.2	5.8
16	1.8	2.6	1.0	**17**	10.0	10.0	8.9	**18**	10.0	9.0	9.0
16	1.3	5.1	7.8	**17**	8.0	8.1	6.1	**18**	9.9	8.7	7.7
16	1.3	1.2	1.8	**17**	4.5	3.1	5.7	**18**	5.0	4.7	8.6
16	0.5	2.2	0.5	**17**	6.5	4.4	5.2	**18**	7.3	5.2	2.0
16	1.0	7.6	4.5	**17**	8.4	4.3	8.2	**18**	8.9	6.7	6.8
16	4.7	4.9	2.1	**17**	3.9	5.7	9.1	**18**	4.8	6.5	8.9
16	1.1	4.1	4.0	**17**	2.8	2.9	3.0	**18**	0.8	4.3	3.3
16	8.7	6.9	7.9	**17**	7.7	5.5	8.6	**18**	6.8	6.0	8.4

	A	B	C		A	B	C		A	B	C
19	1.6	1.6	1.8	**20**	9.4	9.4	9.5	**21**	1.2	1.3	1.3
19	1.4	0.7	0.7	**20**	9.4	9.4	9.2	**21**	1.1	1.0	1.7
19	6.0	6.2	0.4	**20**	7.4	9.1	9.2	**21**	1.9	3.5	0.4
19	8.3	8.2	2.3	**20**	8.4	7.2	4.6	**21**	3.4	7.9	3.3
19	8.7	9.2	7.2	**20**	2.7	4.0	7.3	**21**	5.8	7.9	6.0
19	2.3	2.3	2.5	**20**	5.2	3.7	4.1	**21**	1.3	1.4	1.5
19	5.0	8.6	1.6	**20**	9.3	7.0	7.0	**21**	3.6	2.2	3.6
19	6.9	7.1	0.7	**20**	7.2	5.7	6.8	**21**	0.6	1.5	0.5
19	1.6	2.3	2.2	**20**	6.9	7.0	6.1	**21**	0.7	2.6	3.1
19	2.6	9.5	4.5	**20**	10.0	8.8	9.4	**21**	3.7	8.1	6.3
19	2.6	8.7	1.2	**20**	6.7	3.1	6.2	**21**	1.7	8.8	1.2
19	8.5	5.1	7.7	**20**	9.3	9.4	9.4	**21**	0.9	0.5	0.5
19	7.2	7.0	7.0	**20**	9.1	9.0	9.0	**21**	7.2	6.5	7.3
19	1.7	3.0	1.2	**20**	1.7	3.3	1.1	**21**	0.8	1.3	0.6
19	9.0	1.4	1.3	**20**	9.9	10.0	10.0	**21**	6.9	1.0	3.3
19	1.5	4.6	4.6	**20**	8.6	8.5	8.5	**21**	1.9	2.5	1.9
19	6.7	6.4	6.8	**20**	2.3	2.8	1.9	**21**	3.9	5.5	6.2
19	0.6	0.7	1.8	**20**	9.3	9.7	9.7	**21**	0.9	1.6	0.6
19	5.2	4.5	6.4	**20**	8.1	8.6	9.0	**21**	2.3	3.2	3.0
19	2.4	3.4	2.8	**20**	6.1	5.4	6.3	**21**	2.3	2.8	3.8
19	1.4	1.5	1.5	**20**	5.3	5.6	5.7	**21**	0.9	1.0	0.9
19	4.1	6.4	4.0	**20**	9.0	9.0	9.0	**21**	3.9	5.2	3.7
19	3.6	5.1	4.3	**20**	8.5	7.9	7.3	**21**	1.5	0.9	2.5
19	0.5	0.4	0.5	**20**	8.4	8.3	7.6	**21**	0.3	0.4	0.5
19	6.1	2.3	1.2	**20**	9.7	9.6	9.8	**21**	2.5	7.6	1.0
19	5.3	6.7	3.7	**20**	7.8	8.5	7.5	**21**	5.0	4.7	1.4
19	2.5	3.2	1.3	**20**	7.7	7.0	8.3	**21**	1.8	1.5	1.7
19	6.7	5.7	7.6	**20**	7.5	7.5	8.3	**21**	7.5	6.4	1.4
19	4.5	4.0	4.7	**20**	10.0	10.0	10.0	**21**	2.7	3.0	3.0
19	3.6	2.9	5.5	**20**	8.1	8.1	8.4	**21**	2.7	1.8	2.3
19	4.7	4.1	4.8	**20**	8.7	8.7	8.7	**21**	2.4	1.4	2.3
19	1.9	2.9	2.2	**20**	8.2	8.0	9.3	**21**	0.5	0.5	3.1
19	3.4	6.6	5.3	**20**	8.6	6.2	7.3	**21**	2.6	6.3	5.6
19	5.4	8.9	8.9	**20**	9.3	9.2	9.2	**21**	0.9	8.8	8.8
19	5.0	3.9	4.9	**20**	8.8	8.9	9.0	**21**	1.4	7.6	2.3
19	1.3	1.9	3.6	**20**	7.2	6.6	7.0	**21**	0.4	3.1	3.5
19	5.2	9.2	7.7	**20**	8.0	8.9	8.9	**21**	3.0	8.0	5.1
19	6.4	4.1	4.1	**20**	8.7	8.7	8.7	**21**	2.8	5.7	4.8
19	5.5	7.9	5.4	**20**	8.6	7.9	6.3	**21**	2.8	5.7	4.5
19	3.7	10.0	0.1	**20**	9.2	7.5	7.5	**21**	4.4	9.2	0.4
19	1.1	0.3	8.7	**20**	8.5	8.6	4.7	**21**	0.0	4.6	9.4
19	3.9	3.6	0.8	**20**	10.0	10.0	10.0	**21**	2.6	3.4	0.6
19	4.8	6.7	5.2	**20**	9.8	9.9	9.8	**21**	2.4	7.4	6.7
19	3.2	3.1	2.6	**20**	8.0	8.8	6.4	**21**	0.9	0.7	3.8
19	6.7	6.7	6.7	**20**	8.7	8.7	8.8	**21**	3.2	2.2	3.2
19	1.6	3.9	4.0	**20**	7.1	6.3	7.3	**21**	1.2	7.8	3.3
19	6.6	6.7	1.5	**20**	5.0	5.3	8.7	**21**	3.4	8.2	0.8
19	2.2	2.2	2.3	**20**	1.5	4.4	4.4	**21**	2.3	3.9	4.0
19	8.7	7.0	7.2	**20**	6.2	5.7	8.2	**21**	8.5	7.6	7.7

Appendix F

Textile Repair Evaluation Form

TEXTILE REPAIR EVALUATION

For each of the textile samples listed below, evaluate each repaired textile sample considering:
A) visual appearance; B) structural integrity; and C) effect of each repair on drape.

Rate each of the 21 samples using a rating scale of 0 to 10 with 0 being "undesirable" and 10 "best." Place one vertical mark on each of the three horizontal rating scale lines for each of the 21 samples to indicate your ratings for the qualities noted in A, B, and C above. Please feel free to add any additional comments in the Comments section.

Thank you for your participation!

Sample 1

A 0 ______________________________ 10

B 0 ______________________________ 10

C 0 ______________________________ 10

Sample 2

A 0 ______________________________ 10

B 0 ______________________________ 10

C 0 ______________________________ 10

Sample 3

A 0 ______________________________ 10

B 0 ______________________________ 10

C 0 ______________________________ 10

Sample 4

A 0 ______________________________ 10

B 0 ______________________________ 10

C 0 ______________________________ 10

Sample 5

A 0 ______________________________ 10

B 0 ______________________________ 10

C 0 ______________________________ 10

Sample 6

A 0 ______________________________ 10

B 0 ______________________________ 10

C 0 ______________________________ 10

Sample 7

A 0 ________________________________ 10

B 0 ________________________________ 10

C 0 ________________________________ 10

Sample 8

A 0 ________________________________ 10

B 0 ________________________________ 10

C 0 ________________________________ 10

Sample 9

A 0 ________________________________ 10

B 0 ________________________________ 10

C 0 ________________________________ 10

Sample 10

A 0 ________________________________ 10

B 0 ________________________________ 10

C 0 ________________________________ 10

Sample 11

A 0 ________________________________ 10

B 0 ________________________________ 10

C 0 ________________________________ 10

Sample 12

A 0 ________________________________ 10

B 0 ________________________________ 10

C 0 ________________________________ 10

Sample 13

A 0 ________________________________ 10

B 0 ________________________________ 10

C 0 ________________________________ 10

Sample 14

A 0 ________________________________ 10

B 0 ________________________________ 10

C 0 ________________________________ 10

TEXTILE REPAIR EVALUATION

Sample 15

A 0 ____________________ 10

B 0 ____________________ 10

C 0 ____________________ 10

Sample 16

A 0 ____________________ 10

B 0 ____________________ 10

C 0 ____________________ 10

Sample 17

A 0 ____________________ 10

B 0 ____________________ 10

C 0 ____________________ 10

Sample 18

A 0 ____________________ 10

B 0 ____________________ 10

C 0 ____________________ 10

Sample 19

A 0 ____________________ 10

B 0 ____________________ 10

C 0 ____________________ 10

Sample 20

A 0 ____________________ 10

B 0 ____________________ 10

C 0 ____________________ 10

Sample 21

A 0 ____________________ 10

B 0 ____________________ 10

C 0 ____________________ 10

Comments:

Appendix G

Evaluation Panel Comments

Appearance

"Couldn't tell if some holes were fixed or not."

"The reweaving, re-threading, and re-looping are the most aesthetically pleasing of all repair techniques."

"Color (hue and value) differences in some samples could have been better, especially value – more than hue."

"Visually the ones with black underlays were distracting. Some of the repairs were imperceptible and I think they were most successful visually and in hand."*

"With the multi-colored knit stripe, only the reknit sample was visually acceptable. Solid color fabrics, both knit and woven that used a similar color backing are acceptable visually."

"The reweaving and reknitting jobs look best, but I wonder how costly and time-consuming the work is . . . ?**

"The repair is too obvious." (Sample 2)

Structural Integrity

"The structural stability was hard to evaluate, plus a knowledge of conservation practice can bias one's opinion. Impressive, though."

"Could not judge repair's effect on structural integrity by just looking at it."

Drape
*(see comment under Appearance)

"It may be easier to compare drape if a non-treated fabric is included as a reference."

"Extra layer makes sample stiff." (Sample 1)

"Woven to repair a knit – different drape (Sample 6)

Other

**Issue of time and cost (see comment under Appearance)

"A demonstrated "555" (e.g.) would have made this a lot easier."

"Excellent on all counts." (Sample 3)
"Perfect." (Sample 4)

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Minitab® Release 14.11.1 for Windows.

Sandra C. Aho
April 2008

<u>Thesis Photographs</u>
(Word format)

1. Thesis Photos
2. Thesis Photos.2