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presents

***Scent-Infused Textiles to Enhance
Consumer Experiences***

by

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Scent-Infused Textiles to Enhance Consumer Experiences

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Goal:

Recently, fragrances have become available that can be readily formulated into polymer fibers. This advancement opens a potential for synthetic products with scents ranging from synthetic leatherwear to pine scented curtains. The team will explore the incorporation of scents into polymer fibers, and the psychology of acceptance of synthetic scents in textile goods. The long-term goal of this project is to investigate the addition of scents to textile goods in order to provide an innovative and marketable advancement to the textile industry.

Abstract:

Innovations resulting from technological advancements represent the best strategy for success in the increasingly competitive textile industry. Recently, fragrances have become available that can be readily formulated into polymer fibers. Properly designed textiles containing effective, long-lasting fragrances would provide a significant contribution to the textile industry. The proposed research will investigate new fragrance technologies for use in new and boutique textile technologies. The team will explore the incorporation of scents into polymer fibers, the production of scented fabrics with and without corresponding pigments to modify the response, and the psychology of acceptance of synthetic scents in textile goods. As progress toward this goal, we have identified a supplier for scented-infused fabrics, researched potential odors that can be introduced into textiles, and researched market possibilities for scented textiles.

State of the Art:

The NTC has not previously funded research on scented textiles. There has been research on delivering reactive chemical species or incorporating bioorganisms to reduce smell (C98-A17 Textiles Having the Ability to Deliver Reactive Chemical Species), and M00-MD03

(Development of Bio-Active Fabrics), respectively, but none to date on direct incorporation of fragrance or optimizing fragrance effectiveness.

Consumers in the US and around the world consistently demand scent-based products for the self and the environment, as demonstrated by the \$5 billion in perfume industry sales for 2002 and an increasing market for scented products for the home (air fresheners, scented candles, etc.). The recent emergence of a market for fragrance-infused fabrics for home décor has been well-documented in the popular press (ex., *The Citizen*, April 13th, 2005). This article notes that “home fragrance products brought in \$2.7 billion in sales in 2004. That’s projected to increase to \$3.6 billion in 2006” (http://www.thecitizennews.com/main/archive-050413/re-18_scent.htm).

The burgeoning demand for olfactory stimulation in part reflects the role of odor in influencing emotional state and well-being. Scents can enhance mood, promote optimism, relax or stimulate, aid the recall of personal memories, and facilitate creative thinking (Ehrlichman & Bastone, 1992; Herz, 1998). The introduction of an orange odor into a dentist’s office, for example, reduced anxiety and improved mood in female patients (Lehrner et al., 2000). Odors also play a role in influencing preferences for people, objects, and places across many situations and social interactions (Pierce et al., 2004).

The powerful influence of scent has been shown in consumer settings as well, as the presence of scents can influence shopping behavior and buying decisions. Knasko (1989) found that consumers spent more time in the jewelry section of a department store when it was suffused with a pleasant aroma than when it was unscented. Hirsch & Gay (1991) demonstrated that consumers were more likely to purchase athletic shoes when displayed in a scented room than in an unscented room. Similar findings by Spangenberg et al. (1996), Mitchell et al. (1995), and others confirm the influence of odors on purchasing decisions and consumer behavior, demonstrating further the distinct effects and hedonic value of scents and fragrances in human interactions.

Additionally, the increasing significance of branding for product distinction makes this research important. Marc Gobé (2001) has developed a convincing argument that retailers who connect on an emotional level to the end consumer in terms of lifestyle identification, will increase market share and maintain leadership in their market niche.

Approach:

The approach of the proposed research is to assess the psychophysical properties and marketing possibilities of incorporating fragrance into textile yarns during fiber production using fragrance. Figure 1 illustrates how scented fabrics can be incorporated into a garment.

A goal of the project is to evaluate fragrance-scented fibers that have been woven into yarns. Of critical importance is that the concentrates be specifically formulated to ensure full dispersion of the fragrance uniformly through the fiber, to allow minimization of the additive concentration, to ensure that the fragrance can survive the temperatures of melt extrusion. The primary research question during the initial phases of the research is determining the concentration necessary to assure that specific amounts of fragrance are available from the fiber.

After optimizing the incorporation of fragrances, the release behavior of the additives in the fibers will be studied. The release rate is expected to follow Fick's Law for an infinite cylinder:

$$J(r,t) = -\frac{D}{r} \frac{\partial C(r,t)}{\partial r}$$

where C is the concentration of aromatic particles, J is the particle flux and D is the diffusion constant for the materials. The concentration and flux are considered functions of radial position as well as time, allowing non-uniform release of particles from the interior to the exterior.

The diffusion constants will be determined through

empirical study. The fibers will be washed in water, hot soapy water, and dry cleaning solution to determine if the scents are washed away in standard use. The half-life of fragrance release will be measured to determine the expected life of the scent in a textile.

Some concerns with direct incorporation are significant. The fragrance can modify fiber properties, may not be at the surface of the fibers where the fragrance can be most effectively released, and the scenting may become progressively less effective with time. These questions will be addressed in the proposed research. Fibers, ultimately, will be incorporated, in turn, into textiles for studying the psychological implications of scent.

Initial evaluation of the emergent technology will focus on user preferences for fragrance type and stimulus strength, using traditional psychophysical evaluations of hedonics and intensity. Product-scent associations will be measured and judged for congruence or "goodness of fit". The importance of congruence between fragrance and product has been shown previously in odor studies (Fiore et al., 2000; Degel et al., 2001) and indicates how odors can influence the overall perception of products and goods. In this respect, textile products will be paired with scents that are either congruent (ex., a talc scent for baby clothing, a musk scent for eveningwear) or mismatched (ex., a pine scent for baby clothing, a talc scent for eveningwear). The results of these initial studies will be used to guide the creation of scent-based textile goods that will then be evaluated through consumer-based studies of the finished products. The team will study the psychological effects of the use of fragrance-embedded textiles by consumers on mood, well-being, and self-perception.

Concurrently with the experimental work, the team will evaluate consumer acceptance of fragrance-embedded textiles. Consumer willingness and acceptability will be assessed initially

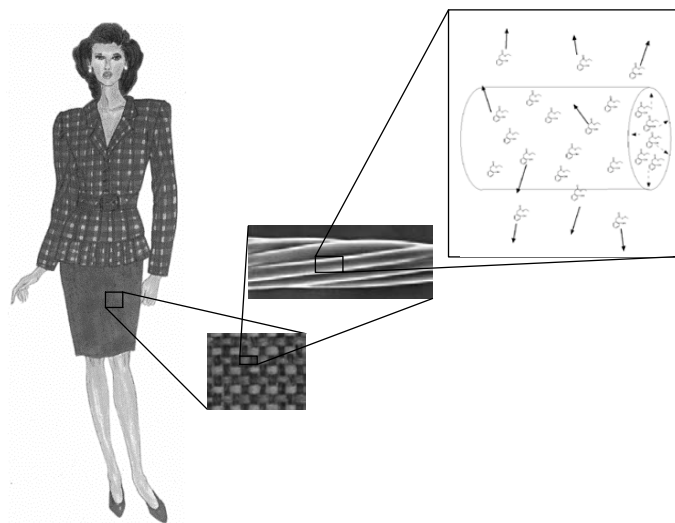


Figure 1. A boutique fabric composed of a woven textile, comprised of multifilament yarn. The individual fibrils are impregnated with fragrance. Fragrance molecules (here, wintergreen) diffuse at a constant rate to the surface of the fiber. The fragrance is released at the surface and diffuses away to provide a controlled-release scent.

through survey scales and focus group methods, and ultimately by consumer-based trial evaluations of finished products. A potential concern with scented textiles is allergic reaction. Since the fragrance is incorporated into the fibers and only small quantities become available at the surface through diffusion, there is never a large quantity of any potential allergen exposed. In addition, fragrances will be chosen to minimize potential reactions. Nevertheless, we will conduct panel studies to verify that allergic reactions, if any, are minimized.

Review of First Year Progress and Goals:

During the first year of our project, we focused on three goals:

- 1). Identifying a supplier for scented-infused fibers and establishing a working relationship with an existing company to supply fibers for study
- 2) Researching potential odors that can be introduced into textiles, and
- 3) Investigating the market possibilities for scented textiles.

We have successfully achieved these goals.

1). Identifying a supplier for scent-infused fabrics

We have established a strong working relationship with Fiber Innovation Technology of Johnson City, Tennessee. This company is an innovative business focusing on the development of new technology and use for specialty synthetic fibers for applications in both textiles and nonwovens. Their facility in Johnson City focuses on product development and production, and has full capacity to develop and manufacture customized fibers. More information about this company and their capabilities can be found at <http://www.fitfibers.com/>.

In collaboration with Fiber Innovation Technology we obtained the scent-infused yarn to be used in our experimentation. The process by which they introduce scent into the fibers is proprietary and covered by a confidentiality agreement signed by Philadelphia University and Fiber Innovation Technology. Thus, we cannot publish any technical data about yarn content.

We obtained lilac-scented yarn from Fiber Innovation Technology during the summer and are using the yarn to produce fabric swatches of different scent concentrations. These knitted patches will be evaluated for their psychophysical properties and will be assessed for diffusion and odor retention.

2) Researching potential odors that can be introduced into textiles

Scent can be defined as the detection of fragrance molecules. Ideally, a scent incorporated into a fabric will have two primary qualities. First, the odor should have aesthetically pleasing properties to produce a positive response to the introduction of the scent. Second, the scent must be easily detectable so that the product has a discernable novel feature. Research over the

summer focused on identifying odors which possessed the characteristics of being easily detectable and positively pleasing.

A literature review conducted this summer illustrated the difficulty of determining odor preferences among consumers. The complexity of odor perception is well illustrated by the complex relationships surrounding odor preferences or hedonics. Preferences for odors are influenced by a confluence of related factors, including the perceived *intensity* of the odor, *familiarity* with the odor, *associations* arising from previous encounters, *congruence* between fragrance and product, *cultural* differences, and *interindividual* differences.

With these caveats in mind, consistently positive evaluations for U.S. consumers are typically given to odors in fruity, floral, and food categories. Table 1 provides representative odor categories and sample chemical products within each category. Odors with the descriptors contained in the table could be readily incorporated into textiles, depending upon the congruence between fragrance and product.

Table 1. Representative Odor Categories and Exemplars with High Hedonic Ratings

Citrus	<i>Lemon</i> (Citral, Citronellal), <i>Orange</i> (Mandarin Oil, Decyl acetate)
Floral	<i>Carnation</i> (Phenethyl salicylate), <i>Gardenia</i> (Nonyl acetate), <i>Geranium</i> (Citronellol), <i>Lilac</i> (Anisyl acetate), <i>Lily</i> (hydroxycitronellal), <i>Rose</i> (Rose absolute), <i>Violet</i> (Costus Oil, Methyl-2-nonenote)
Fruity	<i>Apple</i> (Benzyl acetate), <i>Apricot</i> (Allyl butyrate), <i>Banana</i> (Amyl acetate), <i>Grape</i> (Isobutyl isobutyrate), <i>Peach</i> (Allyl butyrate), <i>Strawberry</i> (Benzyl benzoate)
Herbaceous	<i>Clove</i> (Eugenyl acetate), <i>Minty</i> (<i>l</i> -carveol, <i>l</i> -Carvone, <i>l</i> -Menthol)
Sweet	<i>Anise</i> (Ethyl acetate, <i>Methyl</i> sorbate), <i>Cinnamon</i> (Cinnamaldehyde), <i>Honey</i> (Allyl phenoxyacetate), <i>Sweet</i> (Acetanisole), <i>Vanilla</i> (Anisyl acetate)

With respect to odor detectability, Figure 2 shows the detection threshold for several common fragrances. Each of these fragrances is readily detectable at relatively low concentrations and consistently rated highly on hedonics. This group of odors represents potentially valuable fragrances for incorporation into scented fabrics.

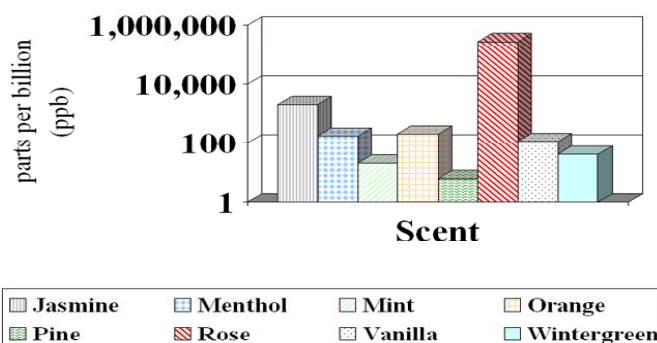


Figure 2. Detection threshold of common fragrances (Leffingwell)

3) Investigating the market possibilities for scented textiles

Market Overview

The United States apparel industry is worth \$173 billion dollars. Of this market value, approximately 2% of the industry is currently selling product that applies some technological method of infusing apparel fabrics with an essential oil fragrance. The technological method most widely used is the encapsulation method, where microencapsulated essential oils are applied to a fabric in the finishing stage. The purpose of this research has been to explore an alternative to the encapsulation method, namely the benefits of infusing fragrances at the filament stage during extrusion processes.

Market Situational Analysis

Fashion retailers' interest in fragrance infused fabrics dates back to the 1960's when Kanebo, a Japanese consumer products company, manufactured women's scented tights. In fact, hosiery and intimate apparel have been the more widely explored product categories to apply scent infused fabric technology. More recently, international companies such as Woolmark have formed joint ventures with the International Fragrances and Flavors association to delve into R&D initiatives with mills around the world. Woolmark calls its use of microencapsulation Sensory Perception Technology™ fabrics. Woolmark is applying this technology to hosiery, lingerie, underwear, socks, outdoor clothing, carpeting and other interior textiles.

In 2005, the Invista Company, owner of fiber brands such as LYCRA®, TACTEL® and SUPPLEX®, launched the LYCRA®Body Care Collection. The Body Care Collection includes moisturizing and fragrance features in the yarns to enhance the wearer's sense of well being in the intimate apparel category. The micro-beads which are built into the fibers release their contents when the elastane content fabrics are stretched during wear. The Olga clothing brand, launched a collection utilizing LYCRA®Body Care Collection in April 2005.

The Nike clothing brand has also explored encapsulation methods to a limited extent. Associates have estimated that fragrance infused fabric technology, such as the one seen in the Nike Precool System running shirt, is less than 5% of their total buy.

Product Categories

The product categories that have incorporated scent infused fabrics include: hosiery, lingerie, athletic apparel, denim, sheets, bedding, curtains and carpet.

Market Challenges: Barriers to Entry

As stated earlier, the encapsulation method is the more widely used technological means of enhancing fabrics with fragrance. However, this method has proven costly and challenging on the retail level. First, the cost of encapsulated fragrances ranges from \$10 to \$50 per pound. After that initial raw material cost, the cost of shipping is hazarded by the fact that often, the

capsules are crushed during shipping. Second, at the retail level, the fabrics/garments are left unwrapped and exposed on the selling floor so that consumers may handle the product and determine personal affinity for the scent. The challenge here has been that if three separate scented prototypes are being modeled for handling, the incompatibility of scents has made the product difficult to sell.

The above stated challenges give further support to explore fragrant fabrics infused at the filament stage, and justify the approach adopted in the current project. Direct infusion of scents at the filament stage avoids these technological difficulties and enables the manufacture of scent-infused products to be done significantly less expensively than through the use of encapsulated fragrances.

Market Opportunities

In many ways, the failures of fragrant fabrics using the encapsulation method serve as lessons in what to avoid in marketing fabrics infused with fragrance at the filament stage. Since the filament infusion method does not contain capsules, the problem of prematurely crushed capsules is eliminated. The growth of the athletic apparel product category and the extension of intimate apparel into everyday wearing “bodywear” offer new opportunities for applying this technology.

Goals for the Next Year

Our goals for the next year are to provide psychophysical assessments of scent-infused fabrics and to explore consumer response to the incorporation of synthetic fragrances in textile goods.

Psychophysical Assessment

We are currently preparing fabric swatches of different scent concentrations using the yarns provided by Fiber Innovation Technology. These knitted patches will be evaluated experimentally for their psychophysical properties and will be assessed for diffusion and odor retention. To accomplish this goal, we have defined five factor levels, which are determined by the percentage of content of the scented yarn in the patches (Table 2). Content will range from 0 to 100% scented yarns.

Table 2. Design Factors for Experimental Study

Factor A % scented yarn	Factor B (Male)	Factor B (Female)	Factor C (soccer)	Factor C (baseball)
0%	+	-	+	-
25%	+	-	+	-
50%	+	-	+	-
75%	+	-	+	-
100%	+	-	+	-

The experimentation phase will be conducted during Fall 05 and Spring 06, and will be focused mainly on two aspects: 1. to determine the significance of the response to scented textile products, and 2. to test the resistance of the scented fabric to laundry products.

The response to scented textile products will be analyzed with the collaboration of the University Athletic department. We will attach these knitted patches onto t-shirts to be worn by test participants for sensory evaluations (see Figure 3). The scented t-shirt with the patches at each factor level will be worn by our student athletes (male and female) during their training sessions and their response will be analyzed using experimental design (Table 2). This statistical technique will allow us to determine at which factor the response is significant and if the interaction of another factors such as gender, and sport activities have a significant effect in the response to scented textile products.

Simultaneously, the resistance to washing of the infused scent will be tested in the Grundy Laboratory located at the Philadelphia University Research Center. Specifically, we will determine the effects of repeated washings on the olfactory qualities of the fabric and determine the limits of washing so that the scented textile continues to maintain a significant effect in the response of the users.

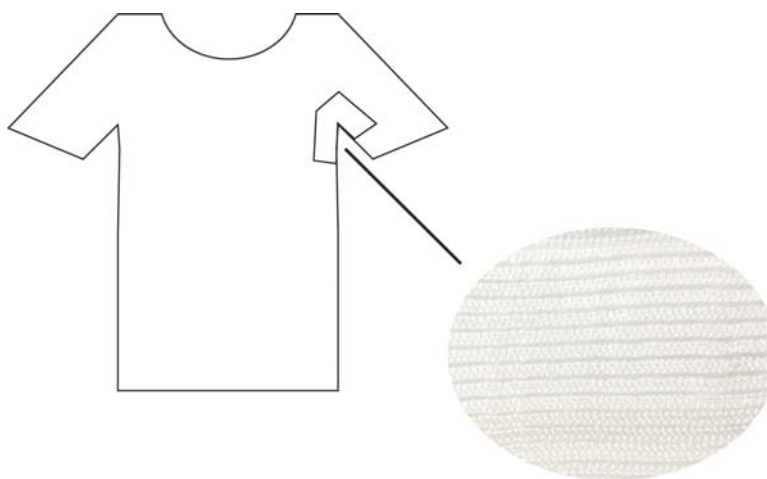


Figure 3. Scented Swatch Incorporated Into a T-Shirt for Sensory Evaluation

Consumer Market Evaluations

Continued studies of the scope of the market for fragrance-embedded textile products will focus on consumer evaluations of garments infused with fragrance to establish user preferences for fragrance type and stimulus strength. We will also establish sensory panels to provide psychophysical evaluations of the hedonics and odor strength of our different test patches. Psychophysical ratings will be done through the use of standardized labeled magnitude scales for measuring olfactory perceptual responses (Green et al., 1996). From these studies, valuable information concerning acceptability, allergic reactions, and consumer preference for various fragrances will be collected.

Project Website: <http://www.ntcresearch.org/projectapp/?project=F05-PH03>

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