WHAT IF OUR CLOTHES COULD SHOW HOW FAST WE RUN?
Social Fabric Fitness:
The Design and Evaluation of Wearable E-Textile Displays to Support Group Fitness

Matthew Louis Mauriello
Michael Gubbels
Jon E. Froehlich

CHI 2104
April 30th, 2014
Plethora of Run Trackers

Designed for the individual!
Group Running Benefits

- Adherence to training
- Educational benefits
- Increases enjoyment
- Aids training intensity

Carron et al., 1996; Hanc, 2005; Kolata, 2009; Robbins, 2009; Youngren, 2009 Barder & Knight, 2010
Group Running Benefits

- Adherence to training
- Educational benefits
- Increases enjoyment
- Aids training intensity

Social facilitation theories posits: the presence of others can increase a person’s drive and focus (e.g., Carron, 1996; Strauss, 2002)

Carron et al., 1996; Hanc, 2005; Kolata, 2009; Robbins, 2009; Youngren, 2009 Barder & Knight, 2010
Social Facilitation: A Self-Presentation View

Charles F. Bond, Jr.
Connecticut College

This article offers a self-presentation account of performance in others’ presence. The account attributes social facilitation to the performer’s active regulation of a public image, and it attributes social impairment to embarrassment following loss of public esteem. Individuals lose esteem by making numerous errors on difficult tasks. This self-presentation analysis is tested in a study of context effects in verbal learning. Two tasks are studied: a difficult task that includes a few simple items and an easy task that includes a few complex items. Consistent with the self-presentation analysis (but not with drive theories of social facilitation), the presence of an observer impairs the learning of simple items if those items are embedded within a difficult task. Also, an observer’s presence does not impair the learning of complex items if those items are embedded within an easy task. Questionnaire responses suggest a naturally occurring confound between task difficulty and perceived failure.

The influence of the presence of others on individual behavior, a classic topic in social psychology, was studied extensively in the early 1900s (Dashiell, 1935). Contemporary interest in the topic derives from Zajonc’s proposal (1965) that the presence of others acts as a source of generalized drive (Spence, 1956), and energizes the dominant response tendency to the exclusion of competing responses. Cottrell (1972) amended Zajonc’s theory, contending that the presence of others arouses apprehension over evaluations. He claimed evaluation apprehension as a source of generalized drive.

This article proposes an alternative analysis of behavior in others’ presence. Following Cottrell, the analysis attributes the influence of others’ presence to the potential that presence gives them for evaluation. But Cottrell seemed to ignore the fact that the object of evaluation is the individual’s performance. The contingency of others’ evaluation on the exhibited performance renders any generalized drive interpretation of their influence obtuse. Because a favorable evaluation could be secured or an unfavorable one avoided by competent performance, the nonactive presence of others provides an incentive for exhibition of socially valued behaviors (Goffman, 1979). In addition, the performer’s status as the basis for evaluation gives that performance ongoing psychological significance for the performer. Lacking direct access to another’s evaluation, the individual is left to infer it. The inference derives, in part, from a moment-by-moment retrospective self-evaluation that may influence subsequent behavior.

Erving Goffman elaborates related insights in his self-presentation analysis of social interaction (1959, 1967). Self-presentation theory depicts behavior in others’ presence as attempts to control or reactions to a public self-image. According to Goffman when the individual appears before others, he or she will discover that an idealized self-image has been claimed. This acceptable image (called face) has a normative character. It obligates others to accord the individual the status claimed and obligates the

Presence of others can motivate the individual to project image of competence.

For tasks perceived to be too difficult, however, performance may actually decline as individual becomes self-conscious.
Potential Dichotomy
Increased motivation vs. increased anxiety
SFF Externalizes Performance
Wearables & Sports

Wearables for Sensing

Wearables for Sensing & Visualization
Wearables & Sports

Wearables for Sensing

Wearables for Sensing & Visualization
Wearables & Sports

Wearables for **Sensing**

Wearables for **Sensing & Visualization**
Under Armour E39
Real-time athlete monitoring
Adidas miCoach Elite
Real-time athlete monitoring
Wearables & Sports

Wearables for Sensing

Wearables for Sensing & Visualization
Wearables & Sports

Wearables for Sensing

Wearables for Sensing & Visualization
Reebok Checklight
Co-located sensing & feedback on athlete
SFF: Design and Evaluation Process
SFF: Design and Evaluation Process

- Ideation & Lo-Fi Proto.
- Parallel Prototyping: 3 Designs
- Refine Final Design
- Informal Pilot Studies
- Final Pilots
- Field Study of 10 Running Groups
- 2 Race Studies
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DESIGN GOALS

- Comfort
- Robustness
- Display Content
- User Experience
SFF: SYSTEM OVERVIEW

RunKeeper

- Time: 52:43
- AVG MIN/MI: 8:31
- Calories: 469
- Distance: 4.5 miles
- Current Pace: 9:37

Heart Rate: 132
60-70% (Weight Control)
SFF: SYSTEM OVERVIEW

Android Smartphone with RunKeeper

Wirelessly transmits run data to wearable display

Wearable Prototype

Battery
SFF: System Overview

- Android Smartphone with RunKeeper
- Wirelessly transmits run data to wearable display
- Battery
- Wearable Prototype

Diagram shows a person running with a smartphone on their arm and a wearable prototype on their back, both connected by wireless signals.
Designing the Visual Content
Glanceable & Easy-to-understand

- cals. burned
- time

SFF

1:21:41

1343

10:09

8:05

320

90

240

132

80

MILES

DISTANCE

CALORIES

AVG MINS/MI
SFF: PRIMARY VISUALIZATIONS
SFF: PRIMARY VISUALIZATIONS

TIME: 52:43

CURRENT PACE: 9:37

DISTANCE: 4.5 MILES

PAUSE

09:37

PACE/MI

DURATION: 52:43

469 CALORIES

8:31 AVG MIN/MI

GOOD

SFF: PRIMARY VISUALIZATIONS
Although RunKeeper tracks a single user, these measures are shared across the running group as they run together.
SFF: Primary Visualizations

- **Pace/MI**: 09:37
- **Duration**: 52:43
- **Distance**: 4.5 mi
- **Heart Rate**: 132 bpm
Comfort
Low-Fidelity Prototypes
SFF: Design and Evaluation Process

- Ideation & Lo-Fi Proto.
- Parallel Prototyping: 3 Designs
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Steps:
- Informal Pilot Studies
- Final Pilots
SFF: Design and Evaluation Process

1. Ideation & Lo-Fi Proto.
   - Parallel Prototyping
     - 3 Designs
   - Informal Pilot Studies
2. Refine Final Design
3. Field Study of 10 Running Groups
4. 2 Race Studies
   - Final Pilots
3 PROTOTYPE DESIGNS
Prototype #1
Custom LED Matrix Display

Prototype #2
Electronic Ink Display

Prototype #3
Erogear LED Matrix Display
Prototype #1
Custom LED Matrix Display

Prototype #2
Electronic Ink Display

Prototype #3
Erogear LED Matrix Display
Prototype #1
Three prototyping dimensions

Prototyping **Technology**

Prototyping **Visualization**

Prototyping **Materials**
Prototype #1
Three prototyping dimensions

Prototyping Technology

Prototyping Visualization

Prototyping Materials
Prototype #1
Three prototyping dimensions
Prototype #1
Single Letter Display Test
Prototype #1
Scrolling Display
Prototype #1
Three prototyping dimensions

1. Select MCU Platform
2. Prototype Circuit Designs
3. Build Software
4. Layout PCB
5. Manufacture PCB
6. Test Final PCB & Software
Prototype #1
Three prototyping dimensions

Prototyping **Technology**

1. Select MCU Platform
2. Prototype Circuit Designs

Prototyping **Visualization**

3. Build Software
4. Layout PCB

Prototyping **Materials**

5. Manufacture PCB
6. Test Final PCB & Software
Prototype #1
Prepare PCB Schematic
Prototype #1
Manufactured Flexible PCB

Flexible PCB
24 x 6 Matrix
Green or Blue LEDs

Manufactured at PCBUniverse.com and pick-and-place performed by Tristate Electronics
Prototype #1
Flexible PCB
Prototype #1
Prototype Evolution
Flexible PCB
Prototype #1
Three prototyping dimensions

Prototyping Technology
1. Select MCU Platform
2. Prototype Circuit Designs

Prototyping Visualization
3. Build Software
4. Layout PCB

Prototyping Materials
5. Manufacture PCB
6. Test Final PCB & Software
Prototype #1

Three prototyping dimensions

1. **Prototyping Technology**
   - Select MCU Platform

2. **Prototyping Visualization**
   - Prototype Circuit Designs

3. **Prototyping Materials**
   - Build Software

4. Manufacture PCB

5. Test Final PCB & Software

6. Layout PCB
Prototype #1
Three prototyping dimensions

Prototyping **Technology**

Prototyping **Visualization**

Prototyping **Materials**
Prototype #1
Three prototyping dimensions

Prototyping Technology

Prototyping Visualization

Prototyping Materials
2 x Arduino Pro Minis

Cotton Diffusion Layer

2 x LED Matrices on Flexible PCB

Velcro Perimeter

Pleather Enclosure

2 x 3.7V (2000 mAh) LiPoly Batteries
SFF: THREE PROTOTYPES

Prototype #1

As a comparison:
iPhone 4S = 140 g

* With enclosure
Prototype #1
Custom LED Matrix Display

Prototype #2
Electronic Ink Display

Prototype #3
Erogear LED Matrix Display
Prototype #2
Three steps

Find **Manufacturer**
Prototyping **Software**
Prototyping **Materials**
YOU'RE LOOKING AT THE WORLD'S 1ST PRODUCTION-READY PLASTIC DISPLAY
DISTANCE 10.4 miles
Prototype #2
Final e-Ink Prototype

Plastic Logic Flexible e-Ink Display 4.7” (320 x 240)

Nylon Enclosure

DISTANCE 10.4 miles

4 x 1.5V (2000 mAh) AA Batteries

32-bit BeagleBone (AM335x 720MHz ARM)

Plastic Logic Display Controller (HummingBird)
SFF: Three Prototypes

<table>
<thead>
<tr>
<th></th>
<th>Prototype #1</th>
<th>Prototype #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display Weight</td>
<td>66.9 g</td>
<td>25.4 g</td>
</tr>
<tr>
<td>Total Weight</td>
<td>152.9 g</td>
<td>411.7 g</td>
</tr>
<tr>
<td>Pixels</td>
<td>24 x 12</td>
<td>320 x 240</td>
</tr>
<tr>
<td>Refresh Rate</td>
<td>5 Hz</td>
<td>1.1 Hz</td>
</tr>
<tr>
<td>Dimensions*</td>
<td>21.3 x 12.2 cm</td>
<td>18.4 x 14 cm</td>
</tr>
<tr>
<td>Display Thickness*</td>
<td>13.5 mm</td>
<td>4.9 mm</td>
</tr>
</tbody>
</table>

* With enclosure
Prototype #3
Early Erogear Visualizations
Prototype #3
Extremely Flexible/Lightweight
Prototype #3
Final Erogear Prototype

- 2 x 32-bit MCU; 16-bit LED Matrix Driver; Bluetooth Modem
- 2 x 32x8 Erogear LED Matrices
- 2 x 3.7V (2200 mAh) Li-Ion Batteries
### SFF: Three Prototypes

<table>
<thead>
<tr>
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<th>Prototype #3</th>
</tr>
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<tr>
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* With enclosure
SFF: Design and Evaluation Process

1. Ideation & Lo-Fi Proto.
2. Parallel Prototyping: 3 Designs
3. Informal Pilot Studies
4. Refine Final Design
5. Field Study of 10 Running Groups
6. 2 Race Studies
7. Final Pilots
SFF: **Design and Evaluation Process**

- **Ideation & Lo-Fi Proto.**
- **Parallel Prototyping**
  - 3 Designs
- **Refine Final Design**
- **Field Study of 10 Running Groups**
- **2 Race Studies**

**Informal Pilot Studies**

**Final Pilots**
Informal Pilot Studies

- Evaluate Comfort
- Examine Viewability
- Investigate Robustness
- Gain qualitative reactions

Prototype #3
Pilot Studies

In-situ observation
Data Collection
In-situ observation
Data Collection
Pre- and Post-Surveys
Viewability
Examining Diffusion Layers
Viewability
Prototype #1 & #2
Viewability
Prototype #1 & #2
Viewability
Prototype #3: Lighting Conditions
SFF: Design and Evaluation Process

- Ideation & Lo-Fi Proto.
- Parallel Prototyping: 3 Designs
- Refine Final Design
- Field Study of 10 Running Groups
- 2 Race Studies
- Informal Pilot Studies
SFF: DESIGN AND EVALUATION PROCESS

- Ideation & Lo-Fi Proto.
- Parallel Prototyping 3 Designs
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Prototype #3
Eogear LED Matrix Display
SFF: PRIMARY VISUALIZATIONS

- TIME: 52:43
- SPEED: 8:31
- DISTANCE: 4.5 mi
- AVG MIN/MILE: 469
- HEARTRATE: 132
- DURATION: 52:43
- DISTANCE: 4.5 mi
- HEARTRATE: 132 bpm
SFF: Final Visualizations

![Visualizations of a mobile app and a t-shirt with digital displays showing various metrics such as time, distance, pace, and calories.](image-url)
Group set target pace

Last 9 mins of the run
Running faster than set pace
Still faster than set pace but slowing down
SFF: **Shared Goal Visualization**

Now running **slower** than set pace
Final Prototype
Shared Goal Visualization
**SFF: Design and Evaluation Process**

1. **Ideation & Lo-Fi Proto.**
2. **Parallel Prototyping**
   - 3 Designs
3. **Informal Pilot Studies**
4. **Refine Final Design**
5. **Field Study of 10 Running Groups**
6. **2 Race Studies**
7. **Final Pilots**
SFF: Design and Evaluation Process

- Ideation & Lo-Fi Proto.
- Parallel Prototyping 3 Designs
- Refine Final Design
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- Informal Pilot Studies
- Final Pilots
- 2 Race Studies
Running Groups Needed to Help Evaluate New Wearable Running Technology

Do you run? Do you run in groups? We need your help! In our study, we are looking for existing groups of runners (3 or more) to assist us as volunteers in a research project exploring e-textile athletic jerseys.

Specifically, we have designed and constructed prototype athletic jerseys that communicate running information such as pace, duration, and distance via a live, wearable display. As a participant, your role is to help us better understand how these jerseys impact your sense of the run activity and the runners around you.

For the study, we will ask you to first complete a short demographic and pre-activity survey. Then, you will perform a short running activity of 20 – 35 minutes (depending on your preference) with the group. One (or two) people in the running group will be wearing our e-textile jersey along with a provided mobile phone and arm strap. After completing the run, you will be asked to fill out a short survey about your experience. The entire session should last approximately 60 minutes.

Participants will be reimbursed $20 per hour for their time. Study sessions will be conducted on the University of Maryland, College Park campus or, in some cases, at a specific physical location of your choice. All participants must be 18 years of age or older and be an active runner. Apart from that restriction, we encourage people of all genders and ethnicities to participate. If you are interested in participating, please email Matthew Maukello (mattm@cs.umd.edu) the following information:

- How often you run (e.g., once a week, three times a week)
- How often you run in a group and the typical group size
- How you currently track your runs (e.g., Nike+, Runkeeper, paper + pen)

Feel free to take a look at our research lab's website to find out more about our research program: http://www.cs.umd.edu/hcil. Please also feel free to redistribute this posting.

Sincerely,

~Matthew Maukello, MS
Department of Computer Science
University of Maryland
A.V. Williams Building, 4122
College Park, MD 20742

http://www.cs.umd.edu/~mattm/
Twitter @mattm401
SFF: STUDY PROCEDURE

Overview

SFF

Pre-Study Questionnaire
SFF: Study Procedure

- SFF Overview
- Pre-Study Questionnaire
- SFF Run (30-60 minutes)
SFF: Study Procedure

- SFF Overview
- Pre-Study Questionnaire
- SFF Run (30-60 minutes)
- Post-Study Questionnaire
SFF: Study Procedure

- SFF Overview
- Pre-Study Questionnaire
- SFF Run (30-60 minutes)
- Post-Study Questionnaire
- Post-Study Interviews
FIELD STUDY PARTICIPANTS
10 GROUPS; 52 INDIVIDUALS (35 FEMALE)

Avg Group Size: 5
Avg Age: 40.7
Avg Target Pace: 10:14
Avg Distance: 3.5 mi
We analyzed the Likert scale survey data to uncover trends and use the interview and open-form data to provide context.
SFF: Field Study Results

- Comfort
- Display Content
- Awareness
- Motivation
- User Experience
- Cohesiveness
- Self-Consciousness
- Other Technology
SFF: Field Study Results

- Comfort
- Display Content
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- Self-Consciousness
- Other Technology
FIELD STUDY RESULTS

COMFORT; WEARERS (N=19)

7-Point Likert Scale
Higher is more comfortable
**FIELD STUDY RESULTS**

**Comfort; Wearers (N=19)**

![Bar Chart]

- **7-Point Likert Scale**
- **Bar Height:** 5.5

![Battery Image]

- **Battery**
FIELD STUDY RESULTS

Comfort; Wearers (N=19)

Battery: 5.5
Display: 5.2

7-Point Likert Scale
“I thought [the system] would be uncomfortable; it turned out to be unnoticed.”

-G5P2-W
**FIELD STUDY RESULTS**

**Comfort; Wearers (N=19)**

- **Battery**: 5.5
- **Display**: 5.2

7-Point Likert Scale


**Field Study Results**

**Comfort; Wearers (N=19)**

<table>
<thead>
<tr>
<th>Device</th>
<th>7-Point Likert Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery</td>
<td>5.5</td>
</tr>
<tr>
<td>Display</td>
<td>5.2</td>
</tr>
<tr>
<td>Heart Monitor</td>
<td>5.1</td>
</tr>
<tr>
<td>Armband</td>
<td>4</td>
</tr>
</tbody>
</table>

Higher is better
“Armband is heavy; other [equipment] was fine...”

-G2P1-W
SFF: Field Study Results

- Comfort
- Display Content
- Awareness
- Motivation
- User Experience
- Cohesiveness
- Self-Consciousness
- Other Technology
### Field Study Results

Display Content; All (N=52)

<table>
<thead>
<tr>
<th>Rank Order List</th>
<th>Average Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pace</td>
<td>1.5</td>
</tr>
<tr>
<td>Distance</td>
<td>2.2</td>
</tr>
<tr>
<td>Duration</td>
<td>3.1</td>
</tr>
<tr>
<td>Visualization</td>
<td>3.9</td>
</tr>
<tr>
<td>Heart Rate</td>
<td>4.3</td>
</tr>
</tbody>
</table>
SFF: Field Study Results

- Comfort
- Display Content
- Awareness
- Motivation
- User Experience
- Cohesiveness
- Self-Consciousness
- Other Technology
“It made me more aware of our pacing and kept me more focused on the run.”

-G2P2-W
SFF: Field Study Results

- Comfort
- Display Content
- Awareness
- Motivation
- User Experience
- Cohesiveness
- Self-Consciousness
- Other Technology
FIELD STUDY RESULTS

Motivation; All (N=52)

“Made me feel like I was pushing my efforts, which is good.”

“Motivated me to go faster than the pace displayed.”

-G7P8

-G7P7
**SFF: Field Study Results**

- Comfort
- Display Content
- Awareness
- Motivation
- User Experience
- Cohesiveness
- Self-Consciousness
- Other Technology
“Yes, I expected to feel more conspicuous; didn’t really mind it.”

-G2P2-W
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- Final Pilots
### Race Study Participants

4 Individuals (1 Female)

<table>
<thead>
<tr>
<th>ID</th>
<th>Age</th>
<th>Gender</th>
<th>Race</th>
<th>Target</th>
<th>Pace</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>34</td>
<td>M</td>
<td>County 8K</td>
<td></td>
<td>6:15</td>
<td>County 8K</td>
</tr>
<tr>
<td>R1</td>
<td>33</td>
<td>F</td>
<td>County 8K</td>
<td></td>
<td>8:20</td>
<td>County 8K</td>
</tr>
<tr>
<td>R2</td>
<td>26</td>
<td>M</td>
<td>Labor Day 10K</td>
<td></td>
<td>7:45</td>
<td>Labor Day 10K</td>
</tr>
<tr>
<td>R2</td>
<td>18</td>
<td>M</td>
<td>Labor Day 10K</td>
<td></td>
<td>8:30</td>
<td>Labor Day 10K</td>
</tr>
</tbody>
</table>

Male, 34
Target Pace: 6:10
County 8K

Female, 33
Target Pace: 8:20
County 8K

Male, 26
Target Pace: 7:45
Labor Day 10K

Male, 18
Target Pace: 8:30
Labor Day 10K
Race Deployment

Competitive Interactions
Gold Medal
“It made me run faster because my performance was on display.”

-R2P1-W
Limitations
Limitations

Novelty

Observational Bias
Future Work
Encouragement

GOOD Job!

Keep Going!
Future Work
Social Media Integration
Future Work

Cross Domains
Summary

This work contributes to two rapidly growing areas: personal informatics and wearable technology.

Through parallel prototyping, iterative design, and exploratory studies we demonstrate the potential to motivate group fitness performance with wearable technology.
Our Research Team:

Matt Mauriello  
@mattm401

Michael Gubbels  
@mokogobo

Jon Froehlich  
@jonfroehlich

Thanks to our collaborators:  
RunKeeper and Erogear

Thanks to Nokia for funding