Personal and Social Considerations of Wearable Light Therapy for Seasonal Affective Disorder

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Personal and Social Considerations of Wearable Light Therapy for Seasonal Affective Disorder

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ABSTRACT

We explored the social acceptability and user experience of wearable form factors as a portable option for Bright Light Therapy (BLT). BLT remains the predominant therapy for Seasonal Affective Disorder despite a non-compliance rate of ~70% commonly attributed to the inconvenience of prolonged daily sitting in front of light boxes. To date, attempts to address convenience using wearable/portable light treatment options have been met with limited success for nuanced reasons (i.e., stigma, efficacy, etc.). In an effort to more substantively explore factors related to the wearability, convenience, contextual appropriateness, and social acceptability of on-body light therapy usage, we developed and evaluated six fashion-aligned wearable therapy prototypes leveraging light-emitting materials and low-profile hardware. Our results showed that participants preferred more mainstream and convenient form factors (e.g., glasses, golfer's hat, scarf), were open to wearing their BLT in certain public and private locations, and appreciated device duality and the fashionable potential of treatment (to counter stigma).

CCS Concepts

• Human-centered computing→Accessibility design and evaluation methods • Social and professional topics→People with disabilities

Keywords

Seasonal Affective Disorder; Bright Light Therapy; Wearable Technology; Fashion and Accessories; Social Aspects

1. INTRODUCTION

Autumn/winter Seasonal Affective Disorder (SAD) is a seasonal-based syndrome that results in depression-like symptoms in the fall/winter months due to lack of sunlight exposure [5, 8]. It affects approximately 5% of individuals in the United States alone, with a higher incidence occurring in geographical regions located in the northern hemisphere [8]. Symptoms associated with SAD include depression-like behavior, mood swings, increased appetite and weight gain, decreased desire for social engagement and lethargy [23], - all of which can have a significant impact on one's personal and professional well-being. Common treatment for SAD entails undergoing Bright Light Therapy (BLT) to counteract the effects of minimal sunlight exposure. While BLT encompasses a range of methods, (e.g., vacationing in sunny destinations, taking Vitamin D supplements, and using dawn simulators), one of the most effective and popular daily forms of BLT involves the use of a light box (see Figure 1) to administer artificial, full-spectrum, white light to simulate exposure to natural sunlight. Despite the proven effectiveness of light box treatment over the past 30 years, this method is accompanied by a number of shortcomings. Light boxes can be highly restrictive due to their lack of portability, and they also require a user to sit in a dedicated location for an extended period of time. Users are also required to face the bright light, which has been known to induce a number of side effects including nausea, headaches, and eyestrain [8].

Figure 1. Products used to treat Seasonal Affective Disorder: light box (left), light visor (right) [14].

In an effort to reduce treatment inconvenience and ameliorate some of the negative aspects of light boxes, light visors (see Figure 1) have also been developed and researched [3, 9, 18, 22] as a portable BLT option. A portable BLT device was heavily regarded as a convenient alternative to the light box [18, 22], facilitating on-the-go treatment in a 'set it and forget it' form factor. However, light visor stimulus efficacy has demonstrated mixed results [9, 18, 22] and adoption has been met with limited success, suggesting several other, nuanced reasons: e.g., social acceptability [3], efficacy, comfort, convenience, etc. Even when worn in the home, the extreme brightness and cumbersome visor enclosure has been known to obstruct one's view, negating any 'convenience' achieved through portability. Additionally, a wearable designed to 'move' with a user implies that treatment is no longer confined to the privacy of the home and now holds the potential of being responsible for broadcasting one's disability in public. Thus, stigma remains an extremely critical factor with respect to wearable treatment considerations, as conspicuous assistive device usage is both a personally-sensitive and culturally-charged issue [12, 16, 20]. As a result, designers and healthcare practitioners must remain cognizant of the fact that one's willingness to use therapeutic devices may be subject to numerous factors beyond mere convenience, and that the novelty of wearable assistive devices merits further exploration in order to gain a more cohesive understanding of wearable assistive technology (AT)

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usage patterns. In an effort to better understand these factors as they pertain to wearable light therapy for SAD, we have developed and tested six wearable prototypes to address questions related to user experience properties such as the appearance and feel of the devices, as well as perceived factors such as treatment convenience, compliance, functionality, and device social acceptability. Our objective is to use insights gained from this research to inform a future in-situ evaluation of the social comfort of wearable light therapy.

2. BACKGROUND

Research dating back to the 1980s has systematically demonstrated the efficacy of BLT in treating SAD-related symptoms [2, 5, 6, 8, 9, 15, 17, 18]. To date, the most common form of treatment has entailed the use of a large, stationary light box to administer full-spectrum, bright white light operating at 10,000 lux [8]. For the most effective results, users are advised to participate in daily treatment sessions between 30-60 minutes and restrict light box usage to only the morning hours [8]. Given that light is required to enter the eye for proper absorption, it is critical for users to stay situated in front of the device while maintaining a fixed distance between 12-18 inches [8]. As a result, light boxes face high abandonment rates [2, 15] due to their constraining nature (e.g., lack of portability, bright light side effects constrained treatment environment), with roughly 69% of light box users acknowledging personal BLT non-compliance due to treatment inconvenience [2].

A number of mobile consumer products have been developed in order to help individuals manage their SAD or other energy related afflictions. However, their effectiveness in treating SAD-related symptoms remains unknown due to lack of published data. The Re-Timer Wearable Light Therapy Glasses[1] were developed for jet lag, SAD, and other common circadian rhythm disorders. This product uses an oversized glasses-like frame (which can fit over most commonly worn glasses) to administer green light upward into the eyes from the bottom portion of the frame). The Valkee Bright Light Headset[2] is an in-ear system that administers light to the brain through headphone style earbuds. This product has been marketed for offsetting many of the common symptoms associated with jet lag. The SunSprite sunlight tracker[3], developed by a Harvard medical team, is a small, solar-powered wearable device that pairs with a smart phone application in order to track sunlight exposure over time. Such a device can be used to help raise awareness of one's daily sunlight exposure so as to better manage one's SAD, however, the SunSprite is a passive device that only measures light and cannot be used to administer artificial light for treatment.

Light visors have been researched as an alternative form of BLT since at least the 1990s [9, 18, 22] and are also available commercially to treat SAD-related symptoms. Numerous studies have been conducted to test light visors operating at a range of intensities (96-6000 lux) [9, 18], treatment durations [18], and light spectra [9, 22], however, light visor efficacy has yielded mixed results. A number of theories have been postulated regarding visor treatment inconsistency, including a placebo effect [22], upper eyelid drop (reducing the amount of light absorbed by the eye) [4], device novelty, lighting angle, or alternative stimulus intensity response [22]. In addition to performance inconsistencies, light visors are also impacted by existing usability challenges (e.g., light intensity, cumbersome form factor, constraining usage scenario) and appear to have a much lower adoption rate and general awareness level than light boxes (none of our participants had ever heard of or seen a light visor prior to our study). While reasons behind minimal adoption remain unknown, research involving light visors suggests many possible issues such as treatment efficacy [9, 18, 22], and context appropriateness [3]. Given the limited research on the social acceptance of light therapy (and the fact that individuals can feel self-conscious when using assistive devices publicly [11, 12, 20]), we are also interested in exploring socially-situated factors that impact overall assistive device adoption and use.

2.1 Assistive Devices, Stigma, and Adoption

To understand how social context can impact overall AT usage, we examine literature on AT and stigma. Parette and Scherer reported social acceptability (often dictated by aesthetics) as being one of the most crucial factors influencing device use by those with developmental disabilities, and that stigma associated with AT can often lead to device abandonment [13] as devices often highlight an individual's disability. O'Kane et al. (2014 & 2015) explored the impact of social factors on healthcare device use and found that context heavily influenced when and how (e.g., carrying vs. hiding one's device) an individual might choose to use their device [11, 12]. The notion of 'boundary work' has also been evidenced in the home as individuals may take distinct actions to separate or integrate health-management practices from daily routine activities [1]. Shinohara and Wobbrock explored the impact of socially-situated norms on assistive device usage and found that individuals valued technology that enabled them to look and perform no differently from others [20]. They put forth the notion of *designing for social acceptance* (paying attention to societal and personal values of device usability and appearance) to reduce feelings of self-consciousness when using AT in public.

2.2 Worn Objects and Social Perceptions

Given that AT is commonly worn or co-located in nature, we look to principles of worn objects, identity, and societal perceptions to inform this work. Clothing and other worn objects are largely an expression of personal and group identity [21]. While stylistic preference allows an individual to project their sense of self, highly conspicuous or socially sensitive objects (such as many of the new wearable technologies on the market) that *deviate* from the norm may call unwanted or negative attention to a user – potentially impacting use[4]. As with respect to assistive devices, their often one-size-fits-all nature and medical appearance may conflict with one's personal aesthetic preference – ultimately threatening device rejection. As such, AT that is worn may benefit from fashion-oriented and emotional design [10] to promote *designing for social acceptance* [20].

3. MOTIVATION AND RELATED WORK

Given the high BLT abandonment rates and minimal research involving the social acceptability of wearable BLT (and light therapy in general) for treating SAD, we chose to explore how wearable prototypes could not only aid treatment, but also address issues of stigma and social acceptance. We first look to the

[1] http://www.sad-lighthire.co.uk/products.php?pid=239
[2] http://usa.valkee.com/humancharger/
[3] https://www.sunsprite.com/

[4] www.wired.com/2013/12/glasshole/

Figure 2. Wearable BLT prototypes: 1.Glasses, 2.Fascinator Hat, 3.Golfer's Hat, 4.Hood, 5.Fiber Optic Scarf, 6.Cowl [15].

predominant available form of wearable light therapy, light visors, to understand many of the existing contextual challenges that may be associated with this device. Overall, light visor designs appear to lack sensitivity toward the societal norms governing self-presentation (or, worn items) (described in [20]). While a visor offers a general purpose solution for mounting lights, mainstream visor (e.g., outdoor activities) usage trends toward a niche market, and the visor conveys a contextual disconnect as visors are predominantly used on sunny days to block light. Their cumbersome form facetor may likely have been dictated by hardware and power constraints, as well as the need for the light to remain in a fixed position while striking the retina. While a visor offers functional performance, these more nuanced, culturally-charged issues may largely impact overall device adoption.

While technological limitations may have been a constraining factor in the past, developments in low profile hardware, light-emitting materials, and novel fabrication techniques permits for the integration of componentry in less commonly explored materials (e.g., textiles) and in a variety of form factors. Since we were developing new forms of on-body technology, we wanted to produce designs that were consistent with current, widely adopted wearable accessories. We also wanted to test more seasonally-aligned (e.g., hats/scarfs versus visors) fashion-oriented designs in order to assess how aesthetics, personal preference, and device duality (i.e., a device that can double as both a regular accessory when not in use and as light therapy when illuminated) could impact overall perceptions of, and willingness to partake in, wearable light therapy.

Recent studies looking at the action spectrum for effective BLT have revealed the efficacy of lower intensity (200 - 400 lux), narrow-band blue LEDs (468 nm) for treating SAD-related symptoms [6, 19]. These findings imply improved conditions for treatment management, as lower intensity light may prove to be less irritating to the eyes, supporting longer treatment durations and potentially reducing the occurrence of upper lid drop - increasing the amount of light that enters the eye. LEDs are also ideal for integration into wearable form factors that are closer to the face as they are small, lightweight, and dissipate minimal heat when configured correctly. With these new research developments and wearability options enabled through low-profile hardware, we are eager to explore novel form factors in wearable BLT and to inform our efforts through user-centered design considerations. Initial efforts for wearable light therapy prototype development are detailed in [15]. In this paper, we present the results of a follow-up, user-centered study of the 6 prototypes. Aside from our previous publication, to our knowledge there has been limited research specifically addressing the personal usage habits, adoption considerations, and social acceptability of BLT for SAD.

4. USER-CENTERED EVALUATION

Six fashion-forward wearable prototypes were developed for lab-based evaluation: glasses, a fascinator hat, a golfer's hat, a hood, a fiber optic scarf, and a cowl [15]. These form factors were informed by prior work and an initial wearable BLT survey [15], and were developed based on preliminary user feedback, existing research, seasonal considerations, physical affordances of the accessory (e.g., proximity to the eyes), and gender and aesthetic considerations. For further information about the prototype development, specifically with respect to explicit design choices, materials and light sources, technical aspects, construction methods, and the initial survey and pilot study data, please refer to prior work [15]. For this paper, we focus on the formal user evaluation of each wearable prototype as we were interested in capturing attitudes toward device appearance, one's willingness to wear light therapy, and the perceived convenience, functionality, and social/contextual appropriateness of device use.

4.1 Light Considerations for Testing

While we were not using our prototypes to conduct clinical trials for SAD, we felt that it was critical to incorporate lights into our wearables to give users the overall experience of wearing light on one's face and upper body. Light sources that met the specifications for the action spectrum (~470 nm) [6, 19] were integrated into each form factor to simulate the experience of having light on the face from multiple vantage points. We adhered to the lamp and lighting standards (IEC 62471:2006, section 4.3.3) [7] regarding spectrum, intensity, and distance to ensure that our prototypes were safe for user testing. An ORB Optronix SP-200 Spectroradiometer[5] was used to take light measurements of each prototype. Measurements (see Figure 3) were taken at the approximate distance and angle of which the prototype's light

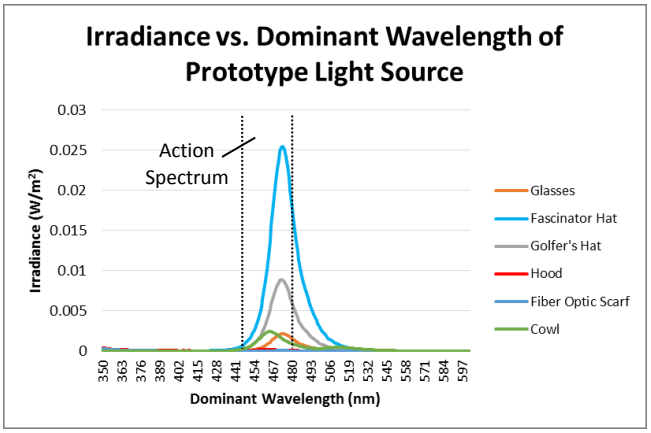

Figure 3. Prototype irradiance and wavelength measurements. The action spectrum (446-477nm) represents the portion of light considered responsible for the beneficial response in humans facing circadian rhythm and affective disorders [19].

[5] http://www.orboptronix.com/product_sp-200.html

source would sit with respect to a user's eyes: the glasses (22 mm in front of eyes), the fascinator hat (20 mm in front of eyes and 40 mm above eyes), golfer's hat (32 mm above eyes), the hood (120 mm at farthest point and wrapped around head), the fiber optic scarf (130 mm angled below eyes), and the cowl (240 mm angled below eyes). The light intensity differed for each prototype, allowing us to capture personal preferences regarding whether or not the light was too bright (i.e., potentially impacting whether users may choose to wear it) or whether the light was too dim, causing users to question the efficacy of the prototype.

4.2 Participants

Ten individuals (4 female) were recruited from the Pacific Northwest. This geographical region was chosen due to the higher incidence of SAD. Participant age was distributed as such: 18-25(1), 26-30(1), 31-35(2), 36-40(3), 41-45(2), 46-50(1). One participant was clinically diagnosed with SAD and all participants reported having used a light box to treat their SAD-related symptoms. Eligibility criteria for this study entailed a minimum of 2 consecutive years of SAD-related symptom expression as well as the use of a light box to treat one's SAD-related symptoms. Few individuals with classic SAD symptoms are clinically diagnosed due to the fact that diagnosis requires rigorous testing under the supervision of a psychiatrist. Those with a clinical diagnosis of SAD often display extremely severe symptoms. Due to these conditions, clinical diagnosis of SAD is representative of only a small subset of the greater SAD population, which is already a small percentage of the general population. While we were only able to include 1 clinically diagnosed individual in our study, the remaining 9 participants collectively reported symptom duration of 3 – 20 years and *all* participants reported using a light box at some point in time to treat their SAD-related symptoms. Experience with using a light box was a critical criterion for participant inclusion for two predominant reasons:

1) It established a baseline for symptom severity (i.e., symptoms were so severe that participants expressed self-actionable behavior by purchasing a light box and engaging in routine BLT treatment sessions).

2) This encompassed a population sample familiar with current bright light therapy technology, thereby making them more qualified to express existing positive and negative aspects associated with light box treatment and also making them ideal candidates by which to evaluate our next generation wearable prototypes.

4.3 Method

The study took place in lighting-controlled testing rooms with A/V recording equipment. A survey was administered to capture demographic and SAD-related data (e.g., SAD duration, treatment methods, etc.). Participants were then instructed to complete the Personal Inventory for Depression and SAD Self-Assessment (PIDS-SA) [24] questionnaire (sections 2-4) prior to beginning the study.

4.3.1 User Study

Six prototypes were evaluated for this study. Participants were first introduced to the prototype on the mannequin for an overall impression of the wearable in both illuminated and unilluminated states. Next, the participants donned the wearable (unilluminated then illuminated). Help was given if the electronics needed additional handling (two prototypes needed to be plugged into a wall outlet, however, could operate untethered with the proper circuit design). Participants were instructed to use the mirror for an overall impression of the prototype when worn and to talk aloud, commenting both on the appearance and personal comfort. If participants wanted more time with the wearable they were encouraged to explore the device further. Evaluation of the prototypes entailed participants speaking aloud and answering paper-based surveys for each prototype. The surveys consisted of 27, 7-point Likert Scale and open response questions. A Philips goLite BLU[6] energy light box and a picture of a light visor (representative of existing products) were also in the testing room for each participant to refer to throughout the session. Participants repeated this testing procedure for each prototype, with a final questionnaire administered at the end. The prototype presentation order was counterbalanced across participants based on a Latin Square Design.

5. RESULTS

Overall, participants were receptive to the idea of wearable BLT to address convenience and compliance implications when treating SAD-symptoms. All participants scored 6 or above on Part 2 of the PIDS-SA questionnaire, indicating that they are likely to have mild to clinically significant SAD symptoms that present with seasonal changes.

5.1 Quantitative Data

We wondered whether openness to use portable or wearable BLT was correlated with self-reported (PIDS-SA) aspects of SAD (in particular, noticeable seasonal changes in behavior (Part 2) and noticeable light response symptoms (Part 4)). Our findings reveal that seasonal behavior changes had a significant correlation with openness to use portable and/or wearable BLT (r=.80), while light-based symptoms had a lower, though still positive, correlation with openness (r=.25). We ran an overall, 6-way, (for 6 prototypes) repeated measures analysis of variance (RM-ANOVA) across all of the satisfaction questions (Likert scales 1-7, 27 total questions per prototype). We did this because all of the data was related and some of the prototypes were somewhat similar to one another. A borderline significant effect of prototype was observed, $F(5,15)=2.6$, $p=.07$. The fascinator hat was rated significantly lower in satisfaction than the other prototypes. Pairwise comparisons showed that only the fascinator hat and the glasses

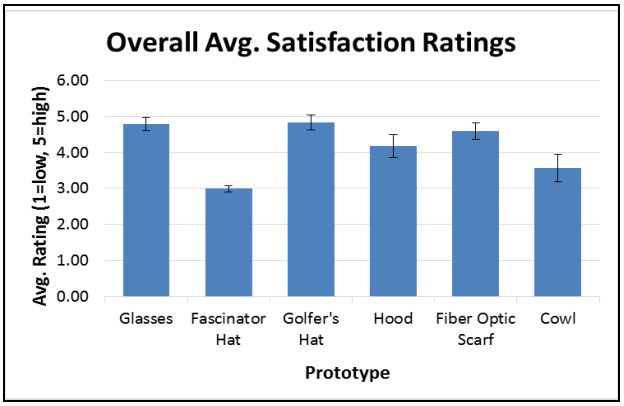

Figure 4. Average satisfaction ratings for the 6 prototypes.

[6] http://www.usa.philips.com/c-p/HF3332_60/golite-blu-energy-light

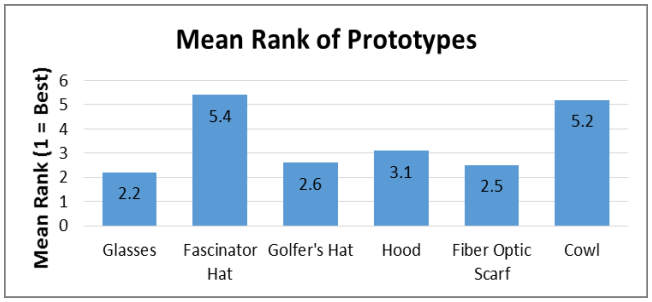

Figure 5. Average rank (Most Preferred = 1) for prototypes.

were significantly different from each other at the p=.05 level, with Bonferroni corrections. Figure 4 summarizes the overall average satisfaction ratings for the 6 prototypes. Next, we looked at how users stack ranked the 6 prototypes (from most to least preferred) with respect to one another (see Figure 5). The glasses were consistently the top rated item, followed by the fiber optic scarf, the golfer's hat, the hood, the cowl, and the fascinator hat. A non-parametric test showed this ranking difference to be statistically significant at p<.001. Reasons for preference for the top ranked items included convenience, unobtrusiveness, ability to be worn inside, outside, or any time of day, discretion, and not having to go against one's normal style and aesthetic.

5.1.1 Social and Contextual Appropriateness

We evaluated each prototype on a number of different 'appropriateness' dimensions in order to better ascertain those parameters in which individuals were most and least willing to use their wearable light therapy. We were particularly interested in the nuanced cross-section between a device that can provide treatment and how the image of AT influences one's willingness to use their device. Based on prior research [13, 16, 20] and anecdotal evidence we predicated our research objectives largely on the fact that societal perceptions, stigma, and therapy convenience will likely impact one's willingness to wear or use AT.

Thus, one way to address this issue is to create a device that looks like less of an assistive device and more like a mainstream item, or, even a desirable fashion piece. We sought to explore this concept by using representative wearable accessories to double as an assistive device. In doing so, we wanted to better understand if the less a device looks like a form of treatment the more an individual would be willing to wear it. We asked participants to rate their attitudes toward the devices in a number of scenarios. Table 1 outlines these dimensions and the participants' average response scores. Additionally, given that wearable and assistive devices may be sensitive to contextual [12] and cultural parameters, we polled users on the physical locations that they would potentially use such wearable forms of BLT (see Figure 6). The glasses, fiber optic scarf, and golfer's hat received higher ratings across the board in both public and private locations. It appeared that the context of public use was a greater determining factor regarding one's potential willingness to wear BLT in public. Meetings and other public venues, such as restaurants or malls, were not as highly rated, perhaps because this is when business or social interaction takes place. However, public commute, one's office, and the street were still highly rated as a likely place that one would wear their BLT device.

Finally, we looked at two of the most important satisfaction questions that we asked our participants: how do these prototypes

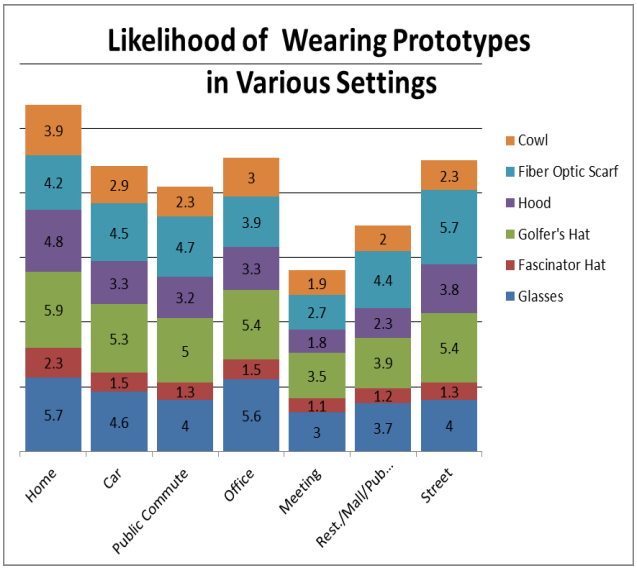

Figure 6. Likelihood of participants wearing prototypes in different locations (7-point Likert scale, 7=Most Likely).

rate on usefulness and convenience, in particular against the light box or the light visor (see Figure 7). We framed the terms 'useful' and 'convenient' as which device users felt would be the most effective at treating SAD, and which device was considered the most conducive for individuals to integrate into their lives and use, respectively. As such, an item that might be deemed useful was not necessarily convenient (e.g., light box) and vice versa. We were particularly interested in those items that received high ratings for *both* 'usefulness' and 'convenience' and found that the hood, the fiber optic scarf, the glasses, and the golfer's hat met this criteria. Two separate one-way ANOVAs examined these questions and significant results were found for both. For usefulness, a significant effect of prototype was found, $F(7, 56) = 4.2$, $p=.001$. Again, the glasses were the highest rated for usefulness. No further significant effects emerged in post-hoc tests

Table 1. Average ratings of attitudes toward wearable BLT (7-point Likert Scale, 1 = Strongly Disagree, 7 = Strongly Agree).

	Wearable BLT Prototype					
Societal Perception Questions	Glasses	Fascinator Hat	Golfer's Hat	Hood	Fiber Optic Scarf	Cowl
I would wear this item w/o the lights	4.3	1.3	5.1	3.6	4.4	2
When emitting light, I found the item to be socially awkward	4.4	4.1	4.1	2.5	2.9	4.4
I find the item to be aesthetically pleasing	3.5	3.8	5.2	4.7	6	2.6
I would wear this item in public	4	1.4	5.9	3.8	5.9	1.8
The item looks like a regular item that I would wear	4.9	1.5	5.6	3.6	5.4	1.8
Without the lights on you can't tell that it's a form of therapy	6.3	5.8	6.1	6.3	6.7	5.4
The item is fashionable	4.15	5.2	4.7	4.8	6.1	2.7

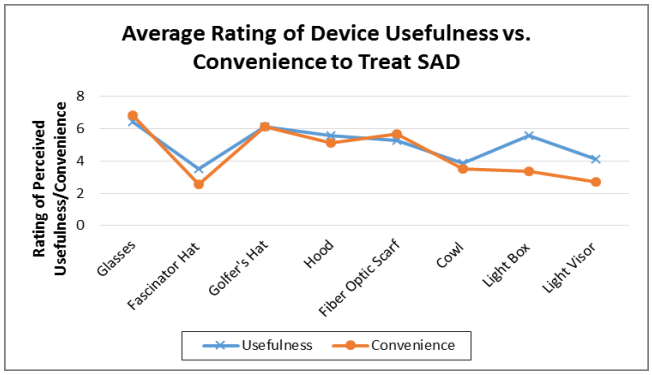

Figure 7. Average rating of device usefulness vs convenience in treating SAD (7-point Likert Scale, 7 = Strongly Agree).

with Bonferroni corrections. For the convenience question, a significant effect of prototype was also found, $F(7,63)=14.5$, $P<.001$. Post-hoc analyses with Bonferroni corrections only showed significant differences between the glasses and light box/light visors at the .05 level, with the glasses rated as significantly more convenient.

5.2 Qualitative Data

Participant commentary and questionnaire data revealed positive yet complex attitudes toward the wearable BLT prototypes. Users did resonate with the flexibility of portable treatment as providing a practical solution for the inconvenience of light boxes. In fact, one user recounted their current practice of holding their small light box in front of them as they ran around the house doing chores and exercising on a treadmill. We illuminate participant feedback with respect to 5 distinct themes that emerged from the data: 1) personal preference and aesthetics, 2) device duality, 3) light source concerns and preferences, 4) form factor functionality, and 5) stigma and contextual considerations. We note that at times there were overlapping themes that emerged from user statements, illustrating the multifaceted considerations inherent in wearables research.

5.2.1 Personal Preference and Aesthetics

Commentary regarding the physical appearance of the device often reflected both objective and subjective attitudes. Feedback describing the wearables encompassed: *'high fashion', 'elegant and fun', 'runway ready', 'cool', 'awesome', 'stylish', 'modest', 'sci-fi', 'vintage' and 'futuristic'*. However, despite many positive descriptors, users often included the caveats:

> *"[F.O Scarf] Not for me, per se, but it would be a convenient solution." – P10, M*
>
> *"[Hood] If this was a more standard hoody, my likelihood of use would be much higher." – P5, M*
>
> *"[Glasses] If they were my normal glasses it would take zero effort to get light." – P1, F*

Thus, while there was a strong appreciation for aesthetically aligned wearable form factors, personal stylistic preferences emerged (*e.g., "not a scarf person" – P10, Male*) as a critical factor as to whether or not a user would want to adopt and use such forms of wearable BLT. As a result, many users indicated that they would wear such a treatment method if the light were integrated into their existing glasses, their preferred hat, or their favorite hoodie.

5.2.2 Device Duality

Participant feedback also acknowledged the dual purpose nature of the prototypes, as many of the form factors aligned with the seasonal period. Given the increased likelihood that a user might already be wearing a hoodie, a hat, or a scarf during the winter months, it made sense to capitalize on these form factors as a BLT delivery system:

> *"[Hood] I liked it. Dual purpose (esp in the winter when I would need more light therapy anyways)."- P2, F*
>
> *"[Glasses]…work well if one wears glasses already." –P3, M*
>
> *"[G. Hat] Very portable…Unassuming when off." – P9, M*
>
> *"[G. Hat] "Comfortable, more likely to wear hats in winter anyway." –P7, F*
>
> *"[F.O. Scarf] I wear scarves anyways so its dual purpose (again, esp in the winter)." –P2, F*

5.2.3 Light Source Concerns and Preferences

Users were routinely concerned with the appearance of the light on their face and devised scenarios to mitigate this:

> *"[Glasses] Would they work as sunglasses? Possible mitigation for public stigma." –P5, M*
>
> *"[G. Hat] Light coming from the middle looks strange (like a spotlight on my forehead).Would be better if spread across"–P2, F*
>
> *"[G. Hat] Would prefer the light to come from the sides. Light from the top casts unflattering shadows." –P2, F*

Participants were not only concerned with the appearance of light on their face, but noted whether or not they thought the light from a particular device may be obtrusive or even if the light was too dim to be perceived as effective:

> *"[Glasses] I like that you don't really notice the light." -P3, M*
>
> *"[G. Hat] Unsure if strong SAD light emitted would be bothersome when coming in the center." –P7, F*
>
> *"[F.O. Scarf] Not sure how easy it'd be to get it into effective position. Lots of wasted light." –P5, M*

One participant indicated that due to the prevalence of SAD in that particular geographical region there may be a general societal acceptance of light-emitting clothing designed in the pursuit of SAD treatment. For wearables that were exceptionally captivating, users were less conscious about wearing the light as they thought that it added to the aesthetic quality of the wearable:

> *"[F.O. Scarf] Loved overall feel/easy to use/ loved t[he] blue cobalt color of the light." – P6, F*

5.2.4 Form Factor Functionality

Participants commented on both positive and negative factors regarding the physical characteristics of the device. There were reservations regarding those wearables oriented toward outdoor use (e.g., the hood or the hat) and how this might impact therapy indoors. For this reason, users appeared to favor the flexibility of usage scenarios offered by the glasses: *"So convenient", "Easy, portable, can continue daily tasks with them",* "*Inconspicuous",* and *"No bulk".*

Participants found more problems with the fascinator hat: *"blinds my good eye"* and the cowl *"very bulky hard to see over"* but did like other functional characteristics of the cowl: *"light weight, warm"* and *"I like that it can be static, where once it is set it can be forgotten about".* Two users liked the versatility of the fiber optic scarf: *"easy to wear [a] variety of ways".* Attitudes toward the hood appeared to be split. Five users thought the hood was too billowy or bulky. Despite this, the majority of users were receptive to the idea of a 'light hood' and 6 users liked being 'surrounded' by light. When asked to provide the reasons behind their top stack ranked prototype, responses continually cycled between convenience, discretion, and aesthetics. Reasons for the lowest ranked item included functional shortcomings and sensitivity to the fashion style.

There were concerns expressed about how easily certain wearables stayed on as the fiber optic scarf tended to shift around. Maintaining the appropriate angle of the light entering the eyes was noted, and certain wearables (the golfer's hat, glasses, and cowl) did a better job of this than others. There were also general concerns about the washability and safety of the electronics getting wet in the rain. Finally, we polled participants for other desired portable/convenient BLT form factors. Suggestions included a(n) umbrella, tie, fedora, ring, watch, helmet, computer monitor frame, hood of a Gortex jacket, headphones, and contacts.

5.2.5 Stigma, Adoption, & Contextual Considerations

Discretion of worn BLT was a reoccurring theme for users. While much of the user feedback revolved around usage and appearance concerns of wearable BLT, there was also direct mention of users' appreciation for BLT designs that de-emphasized the assistive nature of the device:

> *"[F.O. Scarf] Not very heavy, cool shade of blue. New look and feel. Doesn't scream therapy."-P9, M*
>
> *"[Fascinator Hat] I like that it has value as a fashionable piece outside of being therapy."-P3, M*
>
> *"[G. Hat] Looks like the light visor but a lot less obvious" –P4, M*
>
> *"[F.O. Scarf] Looks kind of like a normal scarf." –P4, M*

However, there was still concern regarding the light making users feel self-conscious (especially in public), and when it came to public use of any given prototype it was ultimately dependent on the user's preference and comfort level:

> *"[G. Hat] I like it. Not sure I'd wear it out, but would definitely wear at home." –P5, M*
>
> *"[G. Hat] comfortable. Could wear in public." –P8, M*

6. DISCUSSION

The combination of lower intensity blue light to treat SAD mixed with new low-profile hardware and fabrication techniques grants us the opportunity to explore the unrealized potential of wearable BLT. As the conceptual notion of wearing a BLT visor in winter falls short, we designed most of our wearables to align with form factors that one would already expect to see in the winter season. We were surprised by the number of independent comments from participants that recognized and appreciated this fact, highlighting the importance of designing for the intended context of use. Moreover, the powerful role that fashion and aesthetics played for the stack ranked items demonstrates the complex relationship between personal style and one's willingness to wear items.

The fact that treatment is most effective in the morning can be challenging as this is when one needs to ready themselves for the day. Creating a wearable BLT option can address this issue by permitting treatment to move around the house (or on one's commute) with the user, reducing light box inconvenience and potentially increasing compliance. However, for this to happen, the wearable must be unobtrusive, easy to wear, socially acceptable, and should be designed so as not to interfere with currently worn items (e.g., glasses, purses, hats), unless, the BLT wearable can be worn in lieu of one's standard accessories.

While users had mixed feelings towards wearing light in public, there was an overall willingness to try new, convenient forms of light therapy. Interestingly, the high correlation between self-reported SAD severity (PIDS-SA part 2) and users' openness to using portable or wearable BLT suggests users' desire for new SAD treatment options. We were interested in one user's comment that wearing light therapy publicly may be more socially acceptable in areas with a higher incidence and general understanding of SAD. However, sensitivity toward public BLT use was still expressed, suggesting that wearable BLT be designed with built in flexibility so that it can be worn at the discretion of the user (on or off and in home or in public). While we were interested in the holistic design and benefits of the wearable prototypes, a positive takeaway was the fact that some users wanted to wear the light therapy due to the mere aesthetics of the device. Many users commented on the beauty of the fiber optic scarf and wanted to display the light further as opposed to masking it. Additionally, one user commented that while the fascinator hat did not align with their aesthetic preference, they liked that the wearable showcased how therapy can be beautiful. Given the feedback on having the technology integrated into their favorite garment, it's highly likely that certain wearables (e.g., the hoodie or the golfer's hat) would have received much higher ratings if users could have retrofitted personal items with the light. For the design of future wearable BLT systems, we suggest offering high levels of product customization or hardware that can be retrofitted to one's preferred wearable accessory.

Finally, it is important to note that this was strictly a user-centered exploration of form factor, wearable light therapy design, and initial social acceptability concerns for SAD. We recognize the limitation of assessing social acceptability in a controlled environment. We see the results of this study as providing insight into how to refine the prototypes for future in-situ research settings. Future work entails using the results of this study to narrow down those wearables, in this instance, the glasses, golfer's hat, and fiber optic scarf, to study at greater length in one's daily environment for acceptability purposes. Of particular interest is testing these items in venues listed in Figure 6 to

compare results. Additionally, longitudinal clinical testing still needs to be conducted to ascertain the efficacy and usage patterns of such wearable forms of BLT in the wild.

7. CONCLUSION

Wearable forms of light therapy have the ability to introduce new treatment scenarios for Seasonal Affective Disorder, potentially increasing therapy compliance. This is made possible by the development of novel, low-profile, light emitting sources that permit ease of integration into existing textiles. From our user study, we were able to gather insight into the types of wearables that users preferred (glasses, golfer's hat, fiber optic scarf), as well as those features deemed to be advantageous (convenience, aesthetics, customization, and stigma minimization). Such feedback can serve to inform the design of future therapeutic forms of wearable technologies.

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