Reducing garment mass for end-user comfort: a literature review

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ABSTRACT

There has been some anecdotal evidence to suggest a ~30% reduction in garment mass would be meaningful for end-user comfort. However, evidence of a systematic relationship between mass of a garment and end-user comfort is not available. The aim of this literature review was to explore the relationship between heaviness, comfort perception and garment mass to provide a framework for meaningful development targets. In the field of psychophysics, several models have been proposed to quantify relationships between weight and the perceived response by an individual; Weber's Law, Fechner's Law and Stevens Power Law. These laws identify weight discrimination thresholds and provide an indication of perceived intensity for weight evaluated in the hand, relative to a comparison. This has important application to in-store or sale environments, where consumers evaluate products using their hands. For hand evaluations, meaningful development targets for reductions in garment mass should therefore be made with consideration of these models and in particular Weber's Law. For the evaluation of garment mass during wear, the relationship between heaviness, comfort and mass has only been investigated in two studies, specifically for shoes. Although heaviness, comfort and shoe mass were reported to be unrelated, observations were based upon the mass of five shoes only, limited in range. Currently, there is not sufficient evidence to provide meaningful development targets for garment mass reductions required for end-user comfort during wear. Thus, the relationship between heaviness, comfort and mass requires further evaluation, particularly for apparel.

KEYWORDS

Garment, Mass, Comfort

Introduction

Minimising additional weight of clothing garments in order to maintain human performance is a well-recognised ergonomic principle, particularly for the development of protective and military clothing and to a lesser extent, clothing for sport and recreational activity. Definition of the maximum acceptable weight of clothing products has been attempted in several studies. For example, the maximum weight of an industrial helmet is claimed to be under 300 g (Abeysekera 1992) and a shoe mass less than 440 g per pair has been reported to have no detrimental effect on running economy relative to barefoot (Fuller et al. 2015). However, the perceivable threshold for differences in weight and the hedonic sensory experiences elicited in response to the weight of clothing products has received lesser attention.

There has been some anecdotal evidence within the clothing industry to suggest a ~30% reduction in garment mass would be meaningful for comfort. However, evidence to support a systematic relationship between reduction in garment mass and end user comfort is not available. In the field of psychophysics, several models have been proposed to quantify relationships between weight and the perceived response by an individual; Weber's Law, Fechner's Law and Stevens Power Law.

These models have identified weight discrimination thresholds, indicating the smallest change in weight that a person could sense when the weight of an object remains constant in one hand and is increased or decreased in the other hand and provide an indication of perceived intensity for weight. In the context of clothing, this may be representative of an in-store or sales environment, whereby consumers evaluate products using their hands. However, during wear and in the absence of centrally generated input to the muscle with active lifting, the perception of weight, although still possible, may be considerably different. Thus, cutaneous inputs such as pressure (the amount of force applied per unit area of skin) with fabric-to-skin interactions, may be important stimulus parameters for feelings of lightness/heaviness, tightness/looseness, and for emotional responses of pleasantness or comfort.

The aim of this literature review was to explore the relationship between heaviness, comfort perception and garment mass to provide a framework for meaningful development targets.

Findings

In the field of psychophysics, several laws have been proposed to quantify relationships between mass and the perceived response by an individual; Weber's Law, Fechner's Law and Steven's Power Law (Harper and Stevens 1948; Weber 1996).

Weber's law expresses a general relationship between a quantity or intensity of something and how much more needs to be added/removed for us to be able to tell that something has been added/removed (Weber 1996). For instance, it explains why are we able to tell if three nuts have been taken from a bowl that is nearly empty compared to if the bowl is full. In his study of discrimination thresholds for weight conducted in 1834, Weber blindfolded participants and gave them two weights of equal magnitudes (standard weight) to hold in each hand. He then began to gradually add weight (test weight) to one hand. The participants were asked to compare the weights in both hands and determine which was larger. In doing so, Weber describes a just-noticeable difference (JND); 'the minimum difference in weight that a person can detect 50% of the time' (Weber 1996). Although the JND changes depending on how much mass there is before an increment is added, the ratio of JND to background intensity is constant within a certain range.

Building on the work of Weber, Fechner investigated the relationship between the intensity of a stimulus and the perceived (estimated) magnitude (Weber 1996). To derive this relationship, Fechner made two assumptions: (1) the JND is a constant fraction of the stimulus (i.e. Weber's law holds) and (2) the JND is the basic unit of perceived magnitude, so that one JND is perceptually equal to another JND. Mathematically this produced a logarithmic relation between stimulus intensity and sensation, indicating whether a doubling of a stimulus results in a doubling in perception of the stimulus.

In the early 1950's however, Weber-Fechner's log law was modified to a power function by Stevens (Harper and Stevens 1948; Weber 1996). Stevens challenged the assumptions made by Fechner, conducting experiments with human participants to investigate how perception increases with an increase in stimulus intensity. Stevens found that for most senses, the relationship between the intensity of a stimulus and the estimated response magnitude is best described by a power law, which directly converts judgements of a sensation into measurements of sensory magnitude. Using this approach, Stevens identified three types of stimulus response curves. The first is a response compression curve, indicating that as the intensity of a stimulus increases, the perceived response also increases but not as rapidly as the intensity; the exponent is < 1.0. The second is a response expansion curve, indicating that as the intensity of a stimulus increases, the perceived response is more than doubled; the exponent is > 1.0. Finally, a linear stimulus response curve indicates that as the intensity of a stimulus increases, the perceived response increases relative to the intensity; the power of the exponent is 1.0 or close to 1.0. For the perception of weight, Harper and Stevens

(1948) report a power function with an exponent of 1.45. Therefore as the intensity of weight increased, the perceived response more than doubled (Harper and Stevens 1948).

Overall, Weber-Fechner Law and Stevens Power Law provide valuable insight into the perception of weight when evaluated in the hand, relative to a comparison. This has important application to in-store or sale environments, whereby consumers evaluate products using their hands. Meaningful development targets for reductions in garment mass for hand evaluations should therefore be made with consideration of these models. In particular, reductions in garment mass should be made in line with Weber's Law with targets representing the minimum reduction in mass required for an individual to notice 50% of the time. It is currently unknown whether Weber's Law holds true when wearing a garment.

To our knowledge, only two studies have investigated the relationship between heaviness, comfort and mass during wear, specifically for running shoes (Slade et al. 2014; Saxton et al. 2020). Saxton et al. (2020) reported poor correlations between perceived mass and actual mass (1 min evaluation: r = 0.28 and 5 min evaluation: r = 0.33) and between comfort and actual mass (r values not reported). Moreover, a relationship between comfort and perceived mass was not observed (1 min evaluation: r = 0.07 and 5 min evaluation: r = -0.07). Together, these findings suggest shoe comfort and mass to be unrelated. However, it is important to note that observations were based upon the mass of five shoes, limited in range (Saxton et al. 2020). This consequently resulted in all shoes being rated between four and six on the visual analogue scale for heaviness (0 not heavy at all to 10 most heavy imaginable) and comfort (0 not comfortable at all to 10 most comfortable). The ratings provided therefore suggest that all shoes were identified as neither heavy nor light and comfortable. A greater range in actual mass may be required to pertain the true relationship between perceptions of mass, perceptions of comfort and actual mass. Moreover, it is unclear how these findings might apply to mass perception and discrimination of apparel.

Finally, although there has been some anecdotal evidence within the clothing industry to suggest a ~30% reduction in garment mass would be meaningful for end-user comfort, the outcome of this literature review provides no external evidence to support such a metric. The relationship between heaviness, comfort and mass therefore requires further evaluation.

Conclusions

Where comparisons between garments are being made with hand evaluations (in-store point of purchase, or point of first contact), reductions in the mass of garments should be made in line with Weber's Law. These targets represent the minimum reduction in mass required for an individual to notice 50% of the time. Although it is currently unknown whether Weber's Law holds true when wearing a garment, according to Stevens Power Law, as the intensity of weight increases, the perceived response is more than doubled (Harper and Stevens 1948). Thus, reductions to garment mass could translate to meaningful and perceivable benefits during wear. Unfortunately, the results from this literature review indicate no evidence of a systematic relationship between comfort and mass during wear. The reduction in garment mass required for meaningful end-user comfort is therefore unknown and requires further investigation. This is fundamental to the development of garment mass reduction targets relevant to end-user comfort.

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