ECONOMY OF ACTION AND PEDESTRIANS IN THE BUILT ENVIRONMENT

By

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ABSTRACT

One public health approach to increase lifestyle physical activity is increasing choice to climb stairs instead of using the escalator or lift. Nonetheless, pedestrians in the built environment tend to avoid it. Proffitt's economy of action model explained that pedestrian locomotor choices might influenced by perception. The first study (n=870) revisited Shaffer and Flint (2011) by asking participants to estimate the angle of an escalator. At this site, the escalator could be moving upwards, downwards or stationary when the estimates were made. Participants reported an escalator that was moving upwards as less steep than a stationary one or one moving downwards. Use of a moving escalator in Shaffer and Flint (2011) confounded perception of slant with movement. The second study (n=849), conducted in Indonesia, assessed the potential effects of temperature and humidity on a) speed of climbing an outdoor staircase and b) estimates of the angle. Chosen speed is an index of the allocation of resources. As temperature increased, speed of climbing reduced. For perception, both temperature and humidity influenced the explicit estimate of the angle; as climatic variables increased, perceptions became more exaggerated. There were interactions between sex and climate variables consistent with differences in thermoregulation between the sexes. In the third study (n=730) in the UK, participants were timed crossing a level surface on the approach to a choice between stairs and a ramped ascent. Participants who chose the stairs walked faster on the approach to them. Increasing temperature was associated with reduced speed of approach. The fourth study (n=307) followed up the third by auditing those who chose the stairs or the ramp for ascent at the site. Participants subsequently made verbal and visual estimates of the steepness of the stairs. Contrary to predictions, there were no differences in explicit estimates

of angle between those choosing the stairs and those choosing the ramp, nor were there any effect of climate variables. Collectively, these findings suggest that availability energetic resources influence the overestimation of perceived steepness. In addition, natural variation in climate not only affects explicit perceptions but also directly influence both walking and climbing behaviour.

DEDICATION

To my parents, my husband, and my daughter

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List of papers

The following four empirical papers form the basis of this thesis:

Ekawati, F.F., Azmi, I.S.M., White, M.J., & Eves. F.F. Does a moving escalator look less steep than a stationary one? (In preparation to submit).

Ekawati, F.F., White, M.J., & Eves. F.F. Effect of Climatic Conditions on Behaviour and Perceived Steepness. (In preparation to submit)

Ekawati, F.F., White, M.J., & Eves. F.F. Effects of climbing choice, demographics and climate on walking behaviour.

Ekawati, F.F., White, M.J., & Eves. F.F. The relationship between behavioural choice of pedestrians and perception of a staircase on the route.

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1. CHAPTER ONE

INTRODUCTION

1.0 Introduction

1.1 The Problem of Obesity

Obesity, defined as excess amount of adipose tissue, is a crucial public health challenge worldwide (Kelly, Yang, Chen, Reynolds, & He, 2008). According to the World Health Organization (WHO, 2016), the worldwide prevalence of obesity has doubled since 1980. Not only has obesity increased in the industrialized nations, this epidemic also affected developing countries, particularly in urban areas (Caballero, 2005; Malik, Willett, & Hu, 2013).

In the UK, 65% of men and 58% of women aged 16+ were categorized either as overweight (BMI ≥ 25) or obese (BMI ≥ 30) (Health Survey for England, 2014). In addition, the proportions of men and women obese were 24% and 27% respectively. It is estimated that by 2025 the proportion of obese adults will be 47% of males and 36% of females, rising to 60% and 50% respectively in 2050 (Foresight, 2007). Figure 1.1 shows the increasing prevalence of obesity among adults in England. The graph depicts a similar trend of rising prevalence of obesity in recent years for both sexes; however, women are more likely to be at higher risk than men.

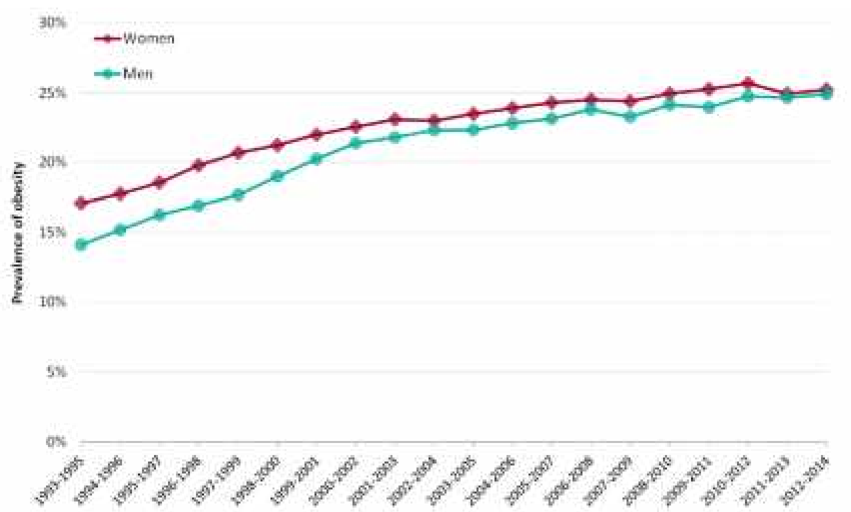

Figure 1.1 Prevalence of men and women among adults classified as obese in England between 1993 and 2014 (Public Health England, 2016).

Obesity is associated with numerous health consequences such as cardiovascular diseases, diabetes, musculoskeletal diseases, and some cancers (WHO, 2016). Besides health problem implications, obesity has also been associated with an increase in health care costs (McCormick & Stone, 2007). For example, the estimated total cost to treat obesity and its consequences was estimated at £991 –1124 million in England 2002 (McCormick & Stone, 2007). Most of the total cost of treating diseases arises from the consequences of obesity rather than obesity itself.

1.2 Environmental Effect on Physical Activity and Weight Status

The current physical environment, which tends to deter physical activity, appears to be the factor that influences the prevalence of obesity (Giles-Corti, Macintyre, Clarkson, Pikora, & Donovan, 2003; Hill, 1998; McCormack et al., 2004). The modern design of the built environment promotes an inactive lifestyle that minimizes the expenditure of energy (e.g. the use of elevators or escalators rather than stairs in workplaces or public access settings). Individuals tend to choose motorised alternatives for their comfort when navigating their surroundings. In addition, the development of technology and transportation progressively diminish physical activity levels in daily life. For example, the availability of television and other screen-based technologies within the home contributes to a young population who have a sedentary lifestyle (Gorely, Marshall, Biddle, & Cameron, 2007). Although the effect of television and video viewing was not problematic among some groups of adolescents during their leisure time, this lifestyle contributed most to the development of a sedentary lifestyle, particularly when they were not at school (Gorely et al., 2007). In addition, Shoham et al., (2015) argued that low levels of physical activity were also influenced by car-ownership among African populations across the different types communities. Similarly, based on travel diary data, 87% of African-Americans chose cars rather than walking (Frank, Andresen, & Schmid, 2004).

Research on the environmental correlates of physical activity has been developed to encourage people to be physically active. This issue has received considerable critical attention from public health researchers. A supportive environment such as the presence of sidewalk/pavement, traffic conditions, and urban design was critically associated with physical activity behaviour (McCormack et al., 2004). Recent reviews have reported that walkability, traffic speed, access or proximity to recreational facilities, residential density, and land-use mix were the strongest correlates between the environmental attribute and physical activity among children (Bauman et al., 2012; Ding, Sallis, Kerr, Lee, & Rosenberg, 2011) whereas, land-use mix and residential density were the most substantial correlates to adolescent behaviour (Bauman et al., 2012; Ding et al., 2011). In addition, residential density, public transport density, and park density were environmental attributes that had independent associations with total physical activity among adults across various countries (Sallis et al., 2016). Furthermore, living in the most active-friendly environment could increase adult physical activity by 68-89 minutes per week (Sallis et al., 2016).

Findings from the Canadian Community Health Survey demonstrated that the area of residence has an association with weight status (Lebel, Pampalon, Hamel, & Thériault, 2009). The authors reported that men who live in rural environments were typically categorised as overweight, whereas many overweight women could be found in deprived areas. In addition, women living in a poor area were heavier than those who live in a wealthy neighbourhood (Matheson, Moineddin, & Glazier, 2008). Based on those findings, it seems that the environment has a salient role in developing prevalence of overweight people. For example, living in a physically inactive environment is generally believed to lead to obesity among individuals who do not control their dietary intake. In addition, an area with greater access to unhealthy food stores (such as takeaway and fast food outlets) had a higher prevalence of people classed as overweight or obese (Giskes, van Lenthe, Avendano-Pabon, & Brug, 2011). In short, environment and lifestyle are inseparable factors in increasing the prevalence of being overweight or obese.

1.3 Lifestyle Physical Activity

The accumulation of physical activity throughout the day within the environment is one public health approach to increasing levels of inactivity in developed countries (Sallis et al., 2006; WHO, 2010). Undoubtedly, regular physical activity could reduce risk of developing many non-communicable diseases (NCDs) including cardiovascular disease, type 2 diabetes mellitus, some cancers, osteoporosis, dementia, Alzheimer’s, and obesity (Reiner, Niermann, Jekauc, & Woll, 2013; Warburton, Nicol, & Bredin, 2006). Despite these benefits, a review reported that participation in physical activity among adults is decreasing globally as a result of modernisation and advances in technology (Ng & Popkin, 2012). Ng & Popkin, (2012) suggest that technological linkages and reduced physical activity are predicted to continue. By 2030, adults in developed countries will only expend 142 METs hours per week in total, which is lower than the public health recommendation (Haskell et al., 2007; Ng & Popkin, 2012).

The public health guidelines advise every adult to accumulate 30 minutes or more of daily moderate-intensity physical activity during the week, or expend 450-750 MET. min per week of a combination of moderate and vigorous-intensity physical activity (Haskell et al., 2007). Brisk walking has the greatest potential for achieving these recommendation in daily life. (Murtagh, Boreham, & Murphy, 2002). Walking is well-known as one of the most accessible forms of active transport that can contribute to a lifestyle that includes physical activity. Using motion sensors such as an accelerometer and pedometers to count the steps of someone walking is likely to be easy and affordable for individuals who are aiming to increase physical activity (Tudor-Locke & Myers, 2001). Therefore, Tudor-Locke & Bassett (2004) proposed four indices that can be used to classify the number of steps in healthy adults: <5000 steps per day = sedentary, 5000 – 7499 steps per day = low active, 7500 – 9999 steps per day = somewhat active, ≥10.000 steps per day = active. Furthermore, individuals who can reach >12.500 steps per day are categorised as highly active. These classifications appear to be used effectively in practice to encourage physical activity.

1.3.1 Walking behaviour

Walking appears to be an ideal introduction that facilitates an active lifestyle for inactive people and offers low risk of injury compared to other types of physical activity (Hootman et al., 2001; Parkkari et al., 2004; Siegel, Brackbill, & Heath, 1995). In recent years, there has been an increasing interest in research on walking behaviour. For example, Tudor-locke & Ham (2008) reported that shopping was associated with the most popular walking behaviour among Americans (31.5%). In addition, only 12.5% and 4.8% of US adults engaged walking for transport and walking for exercise purposes, respectively. Similarly, Kruger, Ham, Berrigan, & Ballard-Barbash (2008) estimated that only 28.2% of US adults walked for transport for approximately 10 minutes. With any kind of walking, furthermore, women have a greater preference to engage in walking compared to men (Tudor-locke & Ham, 2008). Consistently, Pollard & Wagnild (2017) reported that women have a higher prevalence in walking for leisure than men in high-income countries. On the other hand, men were 3.9% more likely to walk for transport compared to women (Kruger et al., 2008).

Walking is a physical activity that is freely available for the majority of the population (Siegel et al., 1995). Both men and women in England were reported as spending more time per day walking than on any other physical activity outside of work (Health Survey for England, 2008). Walking speed is increasingly recognised as a key instrument in epidemiologic studies. Previous findings show that walking speed has an implications for cardiovascular risk factors, economic vitality, climates, and culture (Bemelmans et al., 2012; Levine & Norenzayan, 1999). Concerning cardiovascular health benefit, Bemelmans et al., (2012) reported that the higher walking speed (average speed = 4.66 $km.h^{-1}$) could improve lipid profiles among middle-aged populations. Another outcome in the study of walking speed showed that the countries with a faster pace indicated better economic factors, colder climates, and a more individualistic culture (Levine & Norenzayan, 1999).

As previously mentioned, climatic conditions were associated with walking behaviours such as reducing the speed and its duration (Klenk, Büchele, Rapp, Franke, & Peter, 2012; Levine & Norenzayan, 1999). There was also a decreasing participation in walking due to the high temperature in summer months (Tudor-Locke et al., 2004). In addition, poor weather (e.g. wind, rain, or cold) obviously appeared as a primary barrier to walking activity (Kirby & Inchley, 2012; Sawchuk et al., 2011). Furthermore, changes in temperature were relevant to sex differences. For example, females were less likely to be active than males when the daily temperature increased (Klenk et al., 2012) and males walked faster than females in a cold environment (Rotton, Shats, & Standers, 1990).

Walking behaviour and daily routines are closely associated. However, weather conditions and seasonal differences seem to be the main factors in reducing participation. Generally, individuals prefer to stay indoors or use other types of transportation to reach their destination when facing adverse weather or experiencing inclement winter and peak summer conditions. As a result, the average number of steps per day decreases significantly. For example, Tudor-Locke et al., (2004) reported that the number of steps during the summer was approximately was 200/day more than spring and 900/day more than winter. Insufficient physical activity can be overcome by taking the stairs rather than lifts or escalator within the built environment, because indoor stair climbing can be employed regardless of the weather.

1.4 Stair Climbing and Its Benefits

Stair climbing is an activity that is freely accessible for individuals when navigating their environment. Climbing the stairs has become a lifestyle model for enhancing physical activity that is encouraged. There is an evident opportunity to climb the stairs in public settings such as shopping malls, train stations, workplaces, and privately in homes. Although it is considered as an unattractive activity for some demographic groups (Eves, 2014), stair climbing evidently carries multiple health advantages for most of the population.

Besides being acknowledged as one of the public health recommendations to increase lifestyle physical activity (Sallis et al., 2006; WHO, 2010), regular stair climbing has been associated with abundant health benefits (Meyer et al., 2010). Evidence suggests that regular stair climbing could enhance the cardiovascular fitness of sedentary individuals, improve cholesterol profiles, and improve body composition (Boreham et al., 2005; Boreham, Wallace, & Nevill, 2000; Kennedy, Boreham, Murphy, Young, & Mutrie, 2007; Meyer et al., 2010). In their study, Boreham et al., (2005) found that climbing stairs over 11 minutes per day could increase VO_2Max by 17.1% of in sedentary females; moreover, this duration is sufficient to obtain cardiovascular adaptation. Even with a low volume of stair climbing intervention (6 minutes per day), the improvement in VO_2Max of sedentary workers was increased by approximately 9.4% (Kennedy et al., 2007). Besides the effect on cardiorespiratory fitness, stair climbing interventions with a longer duration could improve body composition and lipid profile. Meyer et al., (2010) found that 12-weeks' stair climbing intervention could reduce 0.7±2.6% of body weight, – 1.5±8.4% of fat mass, 1.7±2.9% of waist circumference, and 3.0±13.5% of LDL cholesterol. In addition, there was a significant improvement in the lower extremity muscle power in older adults who participated 12-weeks' stair climbing exercise (Bean et al., 2002).

Another benefit that can be obtained from climbing stairs is longevity. Having investigated the activities of 17.835 Harvard alumni, Lee & Paffenbarger, (2000) suggested that climbing stairs and other moderate or vigorous activities could reduce mortality rates. The authors concluded that the more energy expenditure, the greater chance of longevity. As previously investigated, in addition, Paffenbarger & Lee, (1996) reported that males who climbed < 20 flights of stairs per week had a lower death risk compared to those who walked < 15 km per week. Furthermore, men who climbed between 20 to 35 flights of stairs per week had a lower rate of stroke than men who climbed less than 10 flights a week (Lee & Paffenbarger, 1998).

1.4.1 Energy Expenditure

Stair climbing is a vigorous lifestyle physical activity requiring more energy per minute than jogging. A previous study has reported that the energy expended when ascending stairs is 9.6 times that of the resting state (Teh & Aziz, 2002); also, this intensity is higher than running 4 mph and cycling (see figure 1.2). More recent studies, furthermore, have investigated two methods of stair climbing in relation to metabolic cost (Gottschall, Aghazarian, & Rohrbach, 2010; Halsey, Watkins, & Duggan, 2012). Evidence suggests that double-step in one ascent has a greater benefit for metabolic energy, which used approximately 9.2 ± 0.1 kcal min^{-1}

(Halsey et al., 2012). This method is a recommended strategy for active individuals to maximise cardiovascular benefits (Gottschall et al., 2010). However, concerning the management of body weight, the authors suggested one step ascent in a single episode of climbing stairs because it would maximise the number of calories burned. Stair climbing provides an invisible method to burn calories. For example, an 80 kg man who climbs a three meter flight of stairs ten times a day would expend approximately 28 kilocalories per day (more than 10.000 kcals per year) (see Olander & Eves, 2011).

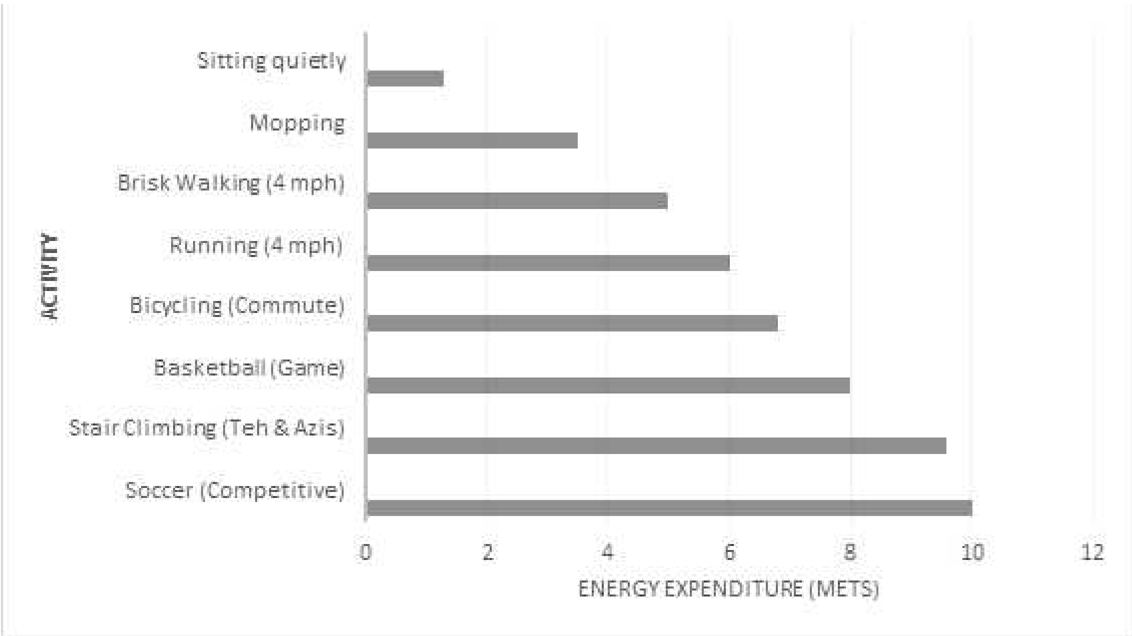

Figure 1.2 Energy expenditure for sports competition, exercise, common type of physical activity and inactivity (Ainsworth et al., 2011; Teh & Aziz, 2002).

1.4.2 Determinants of Stair Avoidance

When ascending the stairs, individuals require more energy than walking on the level. Consequently, the presence of motorised alternatives in public access settings such as escalators or lifts becomes more attractive to pedestrians. Observing pedestrian behaviour in shopping malls, Eves, (2014) found that more than 90% of them avoid the stairs by choosing an adjacent escalator. In other words, stair avoidance is a pedestrian's preferred behaviour in the majority of settings. A number of potential factors influence stair avoidance when an alternative is available.

1.4.2.1 Demographic Factors

Demographic factors such as sex, age, and weight status influenced the choice of behaviour among pedestrians in public access setting (Adams et al., 2006; Eves, 2014). Women, the elderly, and those categorised as overweight were more likely to avoid the stairs than their comparison groups (Eves, 2014). These outcomes are relevant to an account of energy minimisation. Climbing the staircase requires leg strength to support the whole-body weight so that the leading leg can be placed to the next tread up the stairs. Women have lower leg strength than men, yet have a greater proportion of their body weight as fat (McCardle, Katch, & Katch, 2007). Consequently, they have lower climbing resources than men of the same weight because they are carrying the extra 'dead' weight when reaching the top of the stairs (see Eves, 2014). Similarly, the quality of leg strength decreases with age (Lindle et al., 1997); thus, elderly people will use relatively more energy resources to ascend the stairs than younger individuals. As with sex, between-group comparisons suggest that physiological differences between the old and young affect the explicit awareness of geographical slant (see later). Although Proffitt and colleagues did not formally test the effect of weight status but instead of the additional weight of backpack on slant perceptions, Eves and co-workers found that weight status could influence the perceived steepness of the staircase and further the choice behaviour. For example, when ascending the stairs individuals will carry their own body weight against gravity. Accordingly, overweight pedestrians expend more energy than those with healthy weight, which explains why they tend to avoid the stairs than their counterparts.

1.4.2.2 Presence of Bags

As mentioned before, pedestrians carrying extra weight in the form of body fat, or those carrying heavy backpacks are likely to avoid stairs. Pedestrians carrying bags during their journey influences the use of stairs in both shopping malls and public access settings. For example, a study conducted in an airport by Adams et al., (2006) demonstrated that both males and females with luggage tended to avoid stairs more than those with no luggage. More recently, a review conducted by Eves, (2014) found that pedestrians carrying large bags were more likely to avoid the stairs than unencumbered individuals. In addition, a specific study in workplaces, showed that stair avoidance also occurred more frequently in individuals who were carrying extra weight in the form of heavy backpacks (Eves, Webb, & Mutrie, 2006).

1.4.2.3 Place and Time

Place and time are also considered as a determinant of pedestrian behavioural choice. When navigating the built environment, individuals will be faced with a choice between stairs and escalators or elevators as a part of their journey. In general, the choice of stairs and escalators occurs in public access settings. Meanwhile, in workplaces, the choice of ascent is usually between the stairs and elevators. Concerning stair choice behaviour in these two environments, journey time is a salient factor that should be considered (Eves, Lewis, & Griffin, 2008; Kerr, Eves, & Carroll, 2001). Taking the stairs became the first option for pedestrians who were going to exit quickly from the train station, as access to the escalators was blocked.

This situation commonly occurs during the morning rush hour and at the peak of pedestrian traffic volume (Eves, Olander, Nicoll, Puig-Ribera, & Griffin, 2009). However, time pressure is less likely to affect a pedestrian's choice of behaviour in shopping centres (Eves & Webb, 2006), since access to the escalator and waiting for an elevator are less of a problem due to the more even spacing of traffic in time. In a shopping centre, individuals are not in a rush. Thus, they are more likely avoid the stairs by choosing motorised alternatives to save their energy than pedestrians leaving a station. The number pedestrians who took the stairs in shopping centres was 5.5% (Eves & Webb, 2006), while in train stations, the rates of pedestrian taking the stairs were 19.2% (Eves et al., 2009). As will be outlined later, these low levels of stair usage among pedestrians may be influenced by their perception of the inclination of the stairs (Eves, Thorpe, Lewis, & Taylor-Covill, 2014). Furthermore, perceived steepness of a slope may be an environmental signal that pedestrians can use to manage their resources (Eves et al., 2014).

1.4.2.4 Climates

Previous studies have suggested that climatic conditions affected pedestrians' behaviour in Hong Kong (Eves et al., 2008; Eves & Masters, 2006). Although the effect was not related directly to stair climbing, the authors reported that temperature and humidity influenced walking up a slanted travelator, i.e. climbing behaviour. Eves and colleagues found that decreasing number of walking up travelator among non-Asian population was associated with high levels of humidity. Furthermore, demographic characteristics of sex were relevant to the effects of changes in climatic conditions. In contrast to the consistent outcome in stair climbing studies that women tend to avoid stairs more than men (Eves, 2014), in this case men were more likely avoid walking up the travelator than women (see Eves et al., 2008). Climate is relevant to sex differences in the process of heat dissipation. The surface area per unit mass of men is less than that of women (McCardle et al., 2007). As a result, men are less able to radiate heat from their skin than women thus making them more dependent on evaporative heat loss. In summary, climatic conditions seem to be a barrier to physical activity, as being physically active in a humid environment will increase the feelings of discomfort caused by sweating.

1.4.2.5 Social Reinforcement

Stair avoidance in a public setting can be influenced by social reinforcement factors such as kind of dress, social group, and speed (Adams et al., 2006). Clothing type was a significant predictor of stair avoidance. Men who dressed informally were more likely avoid stairs than those who dressed formally, whereas women avoid stairs when dressed formally. In addition, both men and women travelling in a group selected the stairs less frequently than single travellers. Concerning the effect of walking speed on choice of stairs in an airport, Adams et al., (2006) suggested that travellers who walked slower were less inclined to use stairs than those who walked faster.

1.4.3 Stairs interventions

It has been suggested that stair climbing activity could improve health and longevity. Therefore, a number of researchers have conducted interventions to encourage stair-use and to investigate the effect of those interventions. A number of stair-use interventions have successfully encouraged stair climbing behaviour within the built environment. Evidence suggests that point-of-decision prompts are more effective for increasing stair use compared to stairwell enhancements (Soler et al., 2010). Concerning the effectiveness, Bellicha et al.,

(2015) reported that the effects of interventions on stair climbing behaviour were greater in public access settings compared with the effect in workplaces (see Eves & Webb, 2006; Eves, 2008, 2010). Bellicha et al., (2015) argued that different responses to stair climbing interventions were influenced by both motivational and directional signs. For example, the combination of motivational and directional signs is more effective for increasing stair climbing behaviour in workplaces than using motivational signs only. Although a systematic review showed the effectiveness of interventions, Eves & Masters, (2006) argued that the result of interventions cannot be applied universally. For example, there were no effects of any stair use interventions in Hong Kong that had previously succeeded in western countries.

1.5 Geographical Slant Perception

Geographical slant perception is defined as the apparent slope of a surface in the environment relative to the ground plane. This visual perception does not rely on the viewpoint, where the magnitude of the pitch is determined from the ground to the frontal plane. For example, when an individual faces the hills or stairs, their perceived angle is equivalent to the slope. The perception of geographical slant is useful for guiding locomotion in the environment, since geographical slant has an immediate connection to action (Gibson & Cornsweet, 1952). For an individual, 30° is the maximum angle of hill that can be walked up, and it is too steep for people to walk down (Proffitt, Bhalla, Gossweiler, & Midgett, 1995). Moreover, Proffitt et al., (1995) seminal study revealed that individuals overestimate the apparent slant of a hill.

A further explanation of the relationship between slant perception and actions is provided by Proffitt and colleagues in their study focusing on economy of action. They argued that the apparent steepness of slant is a challenge to locomotion, which will also change depending on the availability of energy resource (Proffitt, 2006). However, some researchers still disagree about this outcome. An alternative account concerning the effects of resources on perception has been proposed by Durgin and colleagues. They argued that explicit estimates could be influenced by demand characteristics instead of resources (Durgin et al., 2009; Durgin, Klein, Spiegel, Strawser, & Williams, 2012). Further explanation of slant perceptions studies is discussed below.

1.5.1 Early study

In an early publication on slant perception, Gibson & Cornsweet, (1952) contrasted optical slant with the geographical slant. They revealed that an optical slant is defined as an inclination of surface angles to the line of sight, whereas geographical slant is defined relative to the surface of the earth. In the next decade, Kammann, (1967) investigated the perception of slopes of a hill. He argued that explicit reports of geographical slant were overestimated in both sexes; furthermore, females did so more than males. One of the most esteemed research programme of studies in geographical slant perceptions was begun by Proffitt and colleagues in the mid-1990s. In the first extensive research of geographical slant, (Proffitt et al., 1995) investigated 300 students' perception of the inclination angle of nine hills (2°, 4°, 5°, 6°, 10°, 21°, 31°, 33°, and 34°) around the University of Virginia.

To measure the perception of hill slant, Proffitt and colleagues proposed three different measures, namely verbal, visual, and haptic, which eventually became the standard forms of measurement used in geographical slant perception studies. For verbal measure, participants reported the slope of the hills in degrees relative to the horizontal. The visual measure was obtained by matching the angle of the slope in cross section with an adjustable segment of a disk. For the third measure, termed haptic, participants used the palm of their hand to adjust a flat surface so that it paralleled the slope of the hills. The device developed by Proffitt to provide the haptic measure was termed a ‘palm-board’ (figure 1.3).

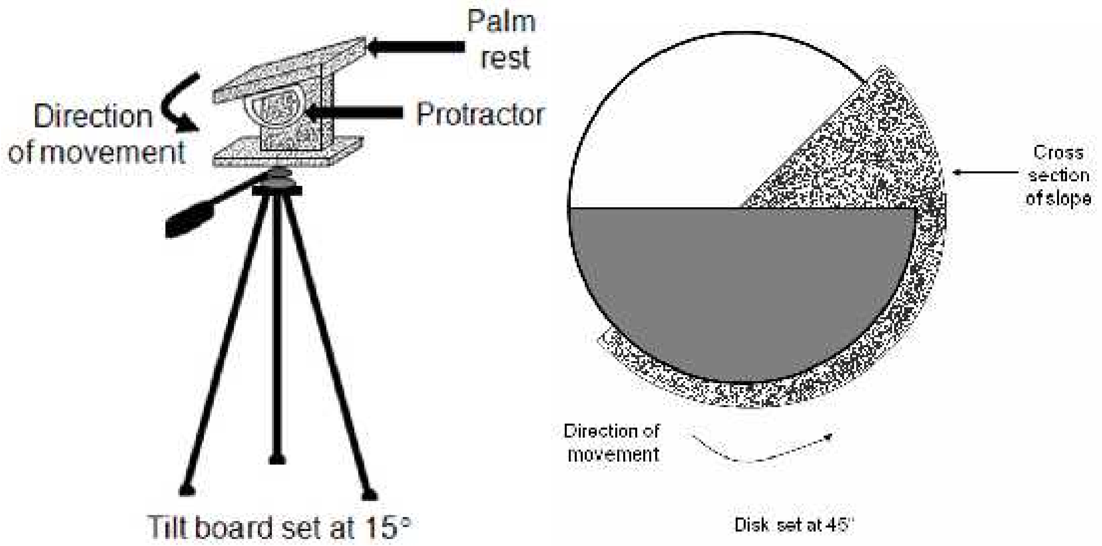

Figure 1.3 The adjustable palm board (left) and the adjustable disk (right) used by Proffitt et al., (1995).

In their first study, Proffitt and colleagues investigated the perception of hill slants viewed from the base and those viewed from the top and further compared the results of them. The evidence showed that there was a difference in response between explicit measures (verbal and visual) and an action measure (haptic). For the hills viewed from the base, verbal and visual measures revealed the exaggerated perception of the slope, with a 5° hill reported to be about 20° and a 10° hill reported to be 30°. Conversely, perceptions were more accurate when participants used the adjustable palm board to provide the haptic measure of slant. Large overestimations also occurred when participants verbally and visually reported the inclination of the hills from the top, but once again there was no effect on haptic measures. When the results of judgments and point of view interacted, the response of the participants was different for various hills. The angle of the smallest slopes appeared the same when viewed from the base and from the top of the hills. On the other hand, for the 31°, 33°, and 34° of hills, participants judged the hills to be steeper than their real appearance, and they were steeper when viewed from the top. These results imply that the geographical slant perceptions are influenced by individuals' potential behaviour when planning locomotion in the environment. For example, standing on the top of a 30° hill is dangerous, and it is too steep for people walking down the hill without any risk of slipping or falling. Thus, people will judge the hill to be steeper from the top than from the base. In addition, the hills looked steeper when an individual's availability of energy resources was depleted. Fatigued participants' estimates were further exaggerated for the hills (Proffitt et al., 1995).

Supporting a previous study, Bhalla & Proffitt, (1999) suggested that conscious awareness of geographical slant is influenced by individual's physiological potential. Individuals with less physiological potential for climbing - such as physically fatigued individuals, the elderly, those carrying a heavy backpack, and those with declining health - gave more exaggerated estimates of steep hills than their comparable groups.

Proffitt and colleagues (1995) argued that different responses to explicit awareness and visually guided action are based on the differing goals and the systems that supported these goals. Conscious awareness of geographical slant shows exaggerations as any changes in explicit visual awareness allow individuals to plan their locomotor activities without having to explicitly assess their resources (Proffitt, 2006). Visually guided actions do not show overestimations in apparent slant as they are associated with the dorsal stream and the control of interactions with the surface; accurate perception of the surface is required to interact with it (though see Eves, 2015 for a different viewpoint about haptic estimates). With respect to the slanted surface that would be traversed, explicit awareness informs a long-term action plan in an environment and is associated with the acceptable rate of energy expenditure that would be consistent with the available resources (Proffitt & Linkenauger, 2013). When individual faced a hill or a staircase, its apparent steepness informs conscious decisions about how to ascend them. In contrast, the visually guided action is related to an immediate action and unaffected by physiological potential (Proffitt & Linkenauger, 2013).

1.5.2 Embodiment perception

When observing the environment, visual experience influences the opportunities for action. This condition is referred to as embodied perception. For example, the steepness of hills became more exaggerated when individuals were fatigued by previous vigorous physical activity (Proffitt, 2006). In the context of the perception of distance, in addition, the apparent distance looked greater for people carrying a heavy backpack (Proffitt et al., 2003). These examples reveal that explicit awareness is relevant to the energetic cost of locomotion. Being tired or carrying a heavy bag would require more strength to climb the hill and walk a certain distance. Thus, individuals might slow their speed when climbing and walking as a consequence of depleted energy resources to better match those available.

In addition, fear has an association with explicit measures (Stefanucci, Proffitt, Clore, & Parekh, 2008). The authors reported that when they estimated the slope of a 7° hill from the top, individuals who stood on the immobilised skateboard and felt fearful verbally and visually judged the slope steeper than those who stood on the box and reported being unafraid. Proffitt, (2006) argued that they are afraid of falling into a potentially dangerous circumstance, which is an additional cost that influences perceived steepness. His previous study in geographical slant perception supported this contention. As for looking up, participants made three different measures of geographical slant from the top of several hills at the university. (Proffitt et al., 1995). For explicit measures, the hills that were steeper than 25° looked greater than the shallow ones. As reported previously, the maximum angle of a hill that can be climbed is 30°, and it would cause falls or turn into an unstoppable run when individuals attempted to descend a 30° grassy hill. Compared to climbing, the act of falling cannot be attributed to energetic cost, rather it is more energetically efficient.

1.5.3 Stair perception and its study

Stairs are man-made hills within the built environment. Therefore, people overestimate the inclination of stairs as with hills in explicit awareness (Eves et al., 2014). In general, the perception of the steepness of hills and stairs verbally and visually exaggerates, with a 10˚ hill reported to be about 30˚ and a 23˚ staircase reported to be 45˚ (Eves et al., 2014; Proffitt et al., 1995). The link between the two is more obvious when the effect of demographic differences in geographical slant perception is involved. In addition, the behavioural tendency of a pedestrian approaching a stair climbing choice point makes clear the prediction that the slant influences choice. Observing pedestrians behaviour in a public access setting, Eves, (2014) suggested that Proffitt's resource based model may be relevant to the choice of stair climbing or an adjacent escalator.

1.5.3.1 Demographic influences

Explicit reports of geographical slant in studies of both the hills and stairs differ between demographic groups. On average, demographic groups with fewer resources for climbing such as women, the old and those who are overweight provided explicit estimates of slant that were more exaggerated than their comparable groups. The following section will explain why sex, age, and weight status can influence explicit measures.

1.5.3.1.1 Sex

Several studies have reported that females are physiologically weaker than males (Clarke, 1986; McCardle et al., 2007). As a consequence, females use more of their available energy resources than males when they are given any kind of climbing task. In line with Proffitt's resource model, explicit perceptions of the slope are influenced by an individual's available resources. Proffitt and colleagues found that there was a significant difference in explicit estimates between the sexes. Consistent with Proffitt's linkage of the perception of steepness to resources, females provided higher verbal and visual estimates of stairs than males (Eves et al., 2014; Taylor-Covill & Eves, 2013, 2014, 2016). Unlike haptic reports in the studies of hills, women have also provided somewhat higher haptic estimates of stairs than male participants in one study (Taylor-Covill & Eves, 2013a), though the effects did not survive Bonferroni adjustment for multiple comparisons. Generally, there were no differences between men and women in haptic estimates (Eves et al., 2014; Taylor-Covill & Eves, 2014, 2016).

1.5.3.1.2 Age

The evidence suggests that muscle strength declines with age (Lindle et al., 1997), which means that older people require a greater proportion of their available resources to physically interact with the environment, for example, when they are climbing stairs. Consistent with declining resources, age differences affect perceived geographical slant in explicit awareness. Bhalla & Proffitt, (1999) reported that older participants provided more exaggerated estimates of steep hills (25° and over) than younger participants. Furthermore, (Eves et al., 2014) showed that increasing age was associated with steeper estimates for verbal and visual measures, with Taylor-Covill & Eves (2016) confirming effects of age in a laboratory study.

1.5.3.1.3 Weight status

In previous studies, the effects of body weight on slant perception were not directly investigated, despite the influence of additional weight in a backpack. The influence of body weight on geographical slant perception was tested formally by Eves et al., (2014) in a staircase study. In that study, weight had a positive relationship with the verbal measure and, surprisingly, also the haptic estimate. In line with economy of action, Eves and colleagues (2014) reported that heavier individuals provided a steeper estimate of a stair slant than their comparators. Individuals with more weight will have more work to climb the stairs against gravity. Accordingly, overweight individuals expend more energy than those with healthy weight, which explains why they tend to overestimate the stairs in comparison with their counterparts. Nonetheless, the study used self-reported weight. In a follow-up, Taylor-Covill & Eves (2016) objectively measured weight and using DXA scans, separated body mass into fat mass that must be carried up the stairs, i.e. 'dead' weight, and fat-free mass that must do the carrying, e.g. muscles, bones and the cardiovascular system. Taylor-Covill & Eves (2016) found that body mass index (BMI) has a relationship with the perceived steepness of the stairs, overweight individuals verbally exaggerate stair angle more than those who healthy weight. Furthermore, the authors reported that changes in the dead weight of fat mass influenced explicit estimates, when the amount of fat mass reduced the slope of the stairs looks shallower. Whereas for fat-free mass, there was no relationship in any perceptual measure. Unlike the components of fat-free mass that function as resources to climb the stairs, the dead weight of body fat has no contribution to climbing activity. It is a biological backpack that be carried by individuals. Accordingly, Taylor-Covill & Eves (2016) confirmed that body weight in the form of fat rather than fat-free mass influence perceived steepness of the staircase in explicit awareness.

1.5.3.2 Energetic influences

The economy of action model stated that availability of resources affects perceptions of slant, and potentially, subsequent actions. For example, the perception of the stairs is influenced by the amount of energy required to ascend, and the act of climbing depended on the amount of available metabolic energy. In previous studies, several factors influencing the perception of slant have been investigated. Generally, there are significant changes of perceived slant in explicit awareness, but not haptic measures. Those factors will be reviewed below.

1.5.3.2.1 Fatigue

The effects of fatigue on slant perceptions are clearly apparent in studies of both hills and stairs. Consistent with Proffitt's linkage of the perception of steepness to resources, explicit perceptions are influenced by depletion of energy resources. In previous studies, Proffitt and colleagues reported that physically-fatigued individuals provided a greater explicit estimates of slant perceptions of hills than their comparison groups. Verbal and visual estimates of the slant increased after an exhausting run around the campus (Bhalla & Proffitt, 1999; Proffitt et al., 1995). For haptic estimates, their perceptions remained unaffected. In line with these studies of hills, Taylor-Covill & Eves, (2013) investigated the effects of the depletion of physical resources on perceptions of staircase slant in a laboratory setting. The authors reported that fatigued participants' estimates were further exaggerated in explicit reports. Once again, haptic judgments were unaffected by any change in resources.

1.5.3.2.2 Blood Glucose

Glucose is a simple soluble carbohydrate that is used by the body to supply resources to the muscles. Oxidative processes based on glucose are the primary source of energy for physical activity. Recently, investigators have examined the effects of the availability blood glucose and geographical slant perceptions. Schnall, Zadra, & Proffitt, (2010) investigated the effects of a sugary drink that boosts blood glucose levels on the perception of hill slant in fasted participants. Participants who consumed the sugary drink estimated a hill's slant to be less than their comparators who received a drink with low calorie sweetener in two separate studies. More recently, Taylor-Covill & Eves, (2014) examined individuals' stair perceptions based on energetic resources available in foodstuffs which they chose both before and after the perceptual judgments of stair slant. Participants unknowingly were allocated to two experimental groups based on choice of high vs. low energy density foodstuffs to reduce the potential effect of demand. This study revealed that verbal and visual judgments of stair slant were overestimated by participants who choose higher energy foodstuffs than their comparison group in two separate studies. Both Schnall et al (2010) and Taylor-Covill & Eves (2014) provide data that supported a resource-based model of slant perception in which energy depletion affects exaggeration of explicit estimates, but not haptic measures.

1.5.3.2.3 Additional weight

A previous study in geographical slant perception has suggested that added weight in a backpack increased the perception of a hill's slant (Bhalla & Proffitt, 1999). In that study, encumbered participants made three estimates of 5° and 31° hill slant. Results showed that the increases in overestimation for backpack studies were similar to the results for the fatigue experiment. In line with the studies of hills, exaggeration of stair slant occurred when participants were encumbered with extra body weight (Eves et al., 2014; Taylor-Covill & Eves, 2016). Furthermore, Taylor-Covill & Eves (2016) reported that the dead weight of fat mass that is always attached to the body (biological backpack) has an association with the exaggerated verbal and visual estimates, meanwhile there was no association in the haptic measure.

1.5.3.3 Potential External Influences

Little is known about the potential external factors such as climate conditions and the surface of properties that may affect these perceptual judgments.

1.5.3.3.1 Climate Effects

There has been a rapid development in research on demographic influences related to geographical slant perception. Generally, demographics of sex, age, and weight status have a greater effect on the slant perception of hills and stairs in explicit awareness (Bhalla & Proffitt, 1999; Proffitt et al., 1995; Taylor-Covill & Eves, 2013). To date, there is no information about the effect of climatic conditions on geographical slant perceptions, despite clear effects on behaviour and resources for climbing. For example, high levels of humidity and temperature were associated with the reduction of walking up the travelator among pedestrians in Hong Kong (Eves, Masters, & McManus, 2008; Eves, Masters, et al., 2008; Eves & Masters, 2006). Eves and colleagues sequentially investigated the effects of stair use interventions on physical activity behaviour among Asian and non-Asian pedestrians in Hong Kong. Generally, the results showed that there was no change in stair climbing behaviour across the studies. Importantly, the authors argued that climatic variables, especially humidity, was one of the biggest issues influencing pedestrian behaviour in Hong Kong. The climate in Hong Kong is subtropical: the temperature and humidity are typically above 30° and 80%, respectively. Consequently, stair climbing became an uncomfortable activity in these environmental conditions. The increased needs to reduce heat because of elevated temperature and humidity would increase blood flow to the skin at the expense of the availability of supply for the working muscles. Consequently, the resources required in a climbing activity would be decreased by this redistribution of blood. Based on Proffitt's model, reduction in available climbing resources will affect individuals' slant perception. Therefore, the climatic conditions could have an association with the exaggerated angular perception of the stairs; the higher the temperature and the humidity, the steeper the perceived slopes in explicit awareness.

1.5.3.3.2 Properties of the Surface

In the development of geographical slant perception studies, the experimenters use three different slant surfaces in their investigation (i.e. hills, stairs, and escalators). Proffitt and colleagues utilised hills as stimuli in their experiment. They concluded that the apparent hill slants were overestimated in explicit awareness and became further exaggerated when an individual's available energy resources were depleted, due to being encumbered by a heavy backpack and fatigue. In contrast, the haptic measures were unaffected by any kind of manipulations. Supporting these arguments, Eves and colleagues presented evidence that overestimation in geographical slant perceptions also occurred when pedestrians judged the inclination of stairs in the built environment. Similar to Proffitt's work, they also investigated any potential factors influencing the judgments. Stairs, man-made hills in the built environment, were also verbally and visually overestimated as with hills. In addition, the estimation was more exaggerated when the participants were carrying a bag, encumbered by added weight in the form of body fat, and fatigued due to an exhausting run (Eves et al., 2014; Taylor-Covill & Eves, 2013, 2016).

1.5.4 Alternative explanations of geographical slant perception research

Proffitt's economy of action account for slant perception is not free from critical debate. Durgin et al., (2009) have argued that explicit estimates in a backpack experiment conducted by Bhalla & Proffitt were influenced by experimental demand characteristics. Durgin and colleagues suggested that participants gave higher explicit estimates of geographical slant as they knew the intention of the backpack manipulation. Replicating the backpack experiment, Durgin et al., (2009) one key group of participants were told that the backpack contained physiological monitoring equipment. Durgin and colleagues reported that when participants finally believed that the backpack was not the primary manipulation, i.e. they had an explanation as to why they were wearing the backpack, the judgments of slant were the same in both groups encumbered and non-encumbered. In contrast, those given no explanation for the presence of the backpack, exaggerated the slope more than the unencumbered. The authors argued that the exaggeration in explicit estimates in Bhalla & Proffitt's experiment was not the effect of the additional weight of a backpack, but was an experimental demand in which participants who were asked to carry a heavy backpack without any explanation while estimating the angle of the slope, reported it as steeper to comply with their lay explation for the presence of the additional weight.

Although Schnall, Zadra, & Proffitt, (2010) have presented strong evidence that explicit perception of geographical slant was affected by physiological resources, Durgin and colleagues again provided further alternative explanation related to effects of experimental demand. Manipulating the beliefs and blood sugar levels, Durgin et al., (2012) suggested that perceptions about the content and purpose of the drink mediated the effect of glucose manipulation, lower estimates of slant given by participants due to demand characteristics of the situation in an experiment. Supporting these results, Shaffer, McManama, Swank, & Durgin, (2013) suggested that participants who were reported as more susceptible to experimental demand characteristics were more likely to reduce their estimations of geographical slant after the manipulation of blood sugar.

Also arguing against an effect of resources on slant perceptions, Shaffer & Flint, (2011) investigated the perception of the slant of a moving escalator. They reasoned that an escalator moving upwards should increase an individuals' physiological potential and, hence, reduce the estimation of slant relative to stairs. The experimenters compared the participants' perception of the slope of an escalator in a shopping mall and a set of stairs on a University campus. The study showed that with verbal reports, participants also overestimated the actual slope of the escalator, and this overestimation was similar in magnitude to the overestimation for the staircase in their study. While Shaffer & Flint, (2011) argued that geographical slant perceptions were not influenced by physiological costs of the presented physical activity, the study confounded sampling with stimulus location and is uninterpretable (see Eves et al., 2014).

1.6 Purposes of the Current Thesis

1) Investigate the perception of escalators as a potential determinant of choice (chapter 2).

   Previous studies have reported the consistent success of interventions in public access settings such as train stations (Nocon, Müller-Riemenschneider, Nitzschke, & Willich, 2010). However, little is known about the perceptual determinants of choice between stairs and escalators (but see Eves et al., 2014). A recent report suggested that the steepness of escalators is exaggerated to the same extent as stairs in explicit awareness (Shaffer & Flint, 2011). To date, there is no information about the potential effects on perception of a moving slope relative to a stationary one. Therefore, the aim of this study was to investigate the perception of escalators as a potential determinant of choice. Investigating the verbal and haptic estimates in pedestrians, this study took advantage of an escalator that could be both stationary and move in either direction.

2) Investigate potential effects of temperature and humidity on the natural behaviour of stair climbing, as well as the associated perception of the stairs (chapter 3).

   Accumulating activity during daily life is a public health approach designed to counter high levels of inactivity. Nonetheless, climate is a potential barrier to walking. To date, there is no information about the effect of climatic conditions on the perceived steepness of stairs, despite the evident effects on behaviour and resources for climbing. For that reason, the first aim of this study was to obtain information about a pedestrian's natural climbing behaviour in different climatic conditions. In this study, participants' speed of climbing was covertly measured using a stopwatch. Chosen speed of climbing represents an individual’s use of resources. The second aim of the third chapter of this thesis was to test whether differences in climate were associated with verbal and haptic estimates of the steepness of stairs that would be climbed subsequently.

3) Investigate the behaviour of pedestrians approaching a choice-point between stairs and a ramp at an exit from a university campus towards the local station (chapter 4).

Pedestrians when approaching the choice-point between stairs and other options that may use different energy resources to complete their journey make a choice between the options. Studies show that only 5.5% and 19.2% pedestrians take the stairs in shopping centres and train stations, respectively (Eves et al., 2009; Eves & Webb, 2006). In the fourth chapter of this thesis, the study set out to investigate the walking behaviour of pedestrians approaching the point of choice between the stairs and a ramp towards the local station at a university. The walking speed of pedestrians was used to estimate their use of resources; a faster speed would require more resources. The walking speed was recorded covertly using a stopwatch when the participant crossed distance level section of ground between two short staircases before approaching the choice-point. Furthermore, a pedestrian’s choice was coded, whether they subsequently climbed the staircase or chose the ramp. In addition, the effect of temperature and humidity on the speed of walking was also investigated.

4) Investigate the factors that deter individuals from making choices between stairs and a ramp at an exit from the university campus towards the nearest train station (chapter 5).

While chapter four focused on the relationship between available resources and behavioural choices, chapter five was designed to ascertain if individual choices were related to the perception of the stairs. A previous study has reported that there was an association between the exaggeration of perceived steepness and climbing choice (Eves et al., 2014). Using a quasi-experimental design, this study looked at the choices of individual pedestrians in the university setting, where individuals could avoid the stairs or climb them. Participants reported two explicit judgements of slant in a counterbalanced order; furthermore, their actual choice of behaviour was recorded without them being aware. The study set out to test whether explicit estimates of steepness of the stairs were related to behavioural choice. As the temperature and humidity had an impact on perceived steepness in Indonesia (see Chapter 3), and individuals' walking speed approaching the experimental site in the companion study, in the study in this chapter tested whether differences in climate were associated with explicit perceptual judgments of the steepness of stairs at the site.

1.7 References

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2. CHAPTER TWO

DOES A MOVING ESCALATOR LOOK LESS STEEP THAN A STATIONARY ONE?

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2.0 Does a moving escalator look less steep than a stationary one?

2.1 Abstract

Perception of the steepness of stairs is exaggerated in explicit awareness. Overestimation of perceived steepness in consciousness allows individuals to manage their physiological resources for climbing. Pedestrians who avoid stairs by choosing the escalator report them as steeper than those who climb them. This paper investigates the perception of escalators as a potential determinant of choice. Participants estimated the slant angle of a 4.5 m escalator (33.1°) that could be stationary and move in either direction, i.e. up or down, at Millennium Point in Birmingham, UK. The final sample (n = 870) was stratified for the frequency of each sex within experimental conditions to n = 145. Results reveal significant differences between measures (verbal and haptic) and the sexes. As with stairs, verbal estimates greatly exaggerated the actual slant of the escalator. In addition, it appeared less steep when it was moving upwards, and females estimated the escalator as steeper than males. For the haptic estimate, there was no effect of escalator movement, nor any significant effect of the demographic variables. Our results suggest that an escalator that moves upwards might be attractive to a pedestrian, as the perceptual stimulus would indicate a minimization of resources required to get to the top. As a result, it may look less steep than a stationary one in consciousness.

2.2 Introduction

Accumulation of physical activity within the environment as part of daily life is one public health approach to inactivity in the population (Sallis et al., 2006). Perception of the environment may be important to this goal (Bauman et al., 2012). Increased choice to climb stairs rather than use the lift or escalator is one public health initiative to increase lifestyle physical activity (Bellicha et al., 2015; Eves & Webb, 2006; Soler et al, 2010). Despite consistent success with interventions in public access setting such as train stations (Nocon, Müller-Reiemenschneider, Nitzschke, & Willich, 2010), little is known about the determinants of choice between stairs and escalators. This paper investigates the perception of escalators as a potential determinant of choice.

Perception of the steepness of hills and stairs, termed geographical slant perception, is grossly exaggerated in explicit awareness (Bhalla & Proffitt, 1999; Eves, Thorpe, Lewis & Taylor-Covill, 2014; Proffitt, Bhalla, Gossweiler & Midgett, 1995). Proffitt (2006) argued that the explicit perception was linked to expenditure of energy during locomotion. Exaggerated perception of steepness in consciousness allows pedestrians to manage their locomotor resources. Proffitt and co-workers proposed three different measures to assess the perception of slant. Observers reported the slope of the hill in degrees (verbal) and matched the angle of the slope in cross-section with an adjustable segment of a disk (visual). In general, verbal and visual estimates exaggerate the slope, with a 10° hill reported to be about 30° and a 23° staircase reported to be 45° (Eves et al., 2014; Proffitt et al., 1995). In contrast, when participants use the palm of their hand to adjust a flat surface so that it parallels the slope, referred to as a haptic measure, perceptions are more accurate (Eves, 2015; Proffitt et al., 1995; Taylor-Covill & Eves, 2013a).

Consistent with Proffitt's linkage of the perception of steepness to resources, explicit perception become more exaggerated when an individual's available energy resources are depleted. Fatigued participant's estimates are further exaggerated for hills and stairs (Proffitt et al., 1995; Taylor-Covill & Eves, 2013b). In these studies, haptic judgments were unaffected by any change in resources. Similarly, estimates of slant were increased when participants were encumbered with an additional load in a backpack (Bhalla & Proffitt, 1999) or extra body weight in the form of fat (Eves et al., 2014; Taylor-Covill & Eves, 2015). In addition, older participants give more exaggerated estimates of steep hills and stairs than younger participants (Bhalla & Proffitt, 1999; Eves et al., 2014). Once again, haptic estimates were relatively immune to the effect of resources. One further resource-related effect on explicit perception is important. Consistently, females exaggerate the steepness of hills and stairs more than males (Eves et al., 2014; Proffitt et al., 1995; Taylor-Covill & Eves, 2013b, 2014, 2015). On average, women have a greater percentage of their body weight as fat yet have lower leg strength than males (see Eves, 2014). The net result is that climbing requires a greater proportion of the resources of woman than a man of the same weight and fitness. From a design viewpoint, this ubiquitous difference between the sexes in perception means that samples stratified for sex are a key feature of sampling, even when haptic estimates are collected (e.g. Taylor-Covill & Eves, 2013a); differences between the sexes in haptic estimates have been reported (Profitt et al., 1995).

Exaggeration of perceived steepness is said to allow individuals to manage their physiological resources for walking and climbing (Eves et al., 2014; Proffitt, 2006). Pedestrian behaviour in the built environment supports this contention. In public access contexts such as shopping centres, demographic groups with reduced resources for climbing, e.g. women, older individuals and those carrying large bags or excess body weight, are more likely to avoid the stairs by choosing an adjacent escalator than their comparison groups (Eves, 2014). Thus, demographic differences in perception are mirrored by behaviour when presented with a choice between stairs and an adjacent escalator (Eves, 2014). Perceived steepness of a slope appears to be an environmental signal that pedestrians use to manage their resources (Eves et al., 2014).

While it has been argued that the steepness of escalators is exaggerated to the same extent as stairs in explicit awareness (Shaffer & Flint, 2011), the solitary study on escalator perception compared a moving escalator in a shopping mall with stationary stairs on a university campus. Inevitably, location and demographics of the sample would be confounded (see Eves et al., 2014). Additionally, to date, there is no information about the potential effects of a moving slope relative to a stationary one on perception. An escalator that moves upwards might be attractive to a pedestrian, as the perceptual stimulus would indicate a minimization of the resources used to complete the ascent. As a result, a moving escalator may look less steep than a stationary one in consciousness. This study took advantage of an escalator that could be both stationary and move in either direction. Verbal and haptic estimates of escalator steepness tested the effects of motion on escalator perception in the built environment.

2.3 Methods

2.3.1 Site

The study was conducted at Millennium Point, a museum and educational complex with two escalators, two lifts, and a single set of stairs, remote from the escalators on the ground floor in Birmingham, UK. One escalator that was positioned on its own was stationary unless the beam of infra-red sensors was broken so that the escalator would go up or down, depending on the direction of travel of the pedestrian using it. The height of the climb was 4.5m while the slope of the escalator was 33.1˚. The stairs positioned some 25m from the foot of the escalator involved 30 steps with a climb of 4.5m and an overall slope of 21.9˚

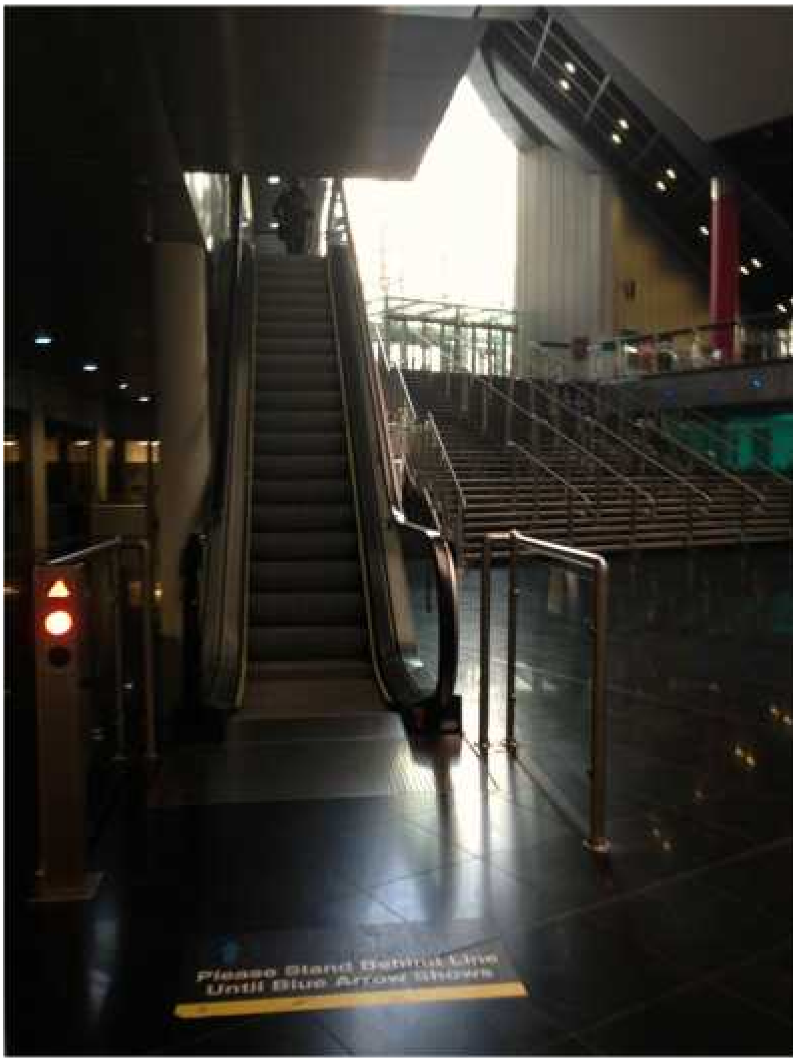

Figure 2.1 A photo of the environment used in the current study from the point at which participants made judgements of escalator.

2.3.2 Participants

We aimed to recruit 300 participants in each escalator condition. A sample, stratified for sex, was collected to avoid confounding of the quasi-experimental main effects of sex with escalator condition. Participants were asked if they would volunteer for a study on perception and physical activity when they approached the base of the escalator. After they agreed, they made perceptual judgements. Sixty five participants were excluded - 17 with a verbal estimate of 90° or more, 48 who thought all staircases were 45° - and the final sample of 870 participants was stratified for the frequency of each sex within experimental conditions to n = 145.

2.3.3 Measures and Procedures

Two estimates of slant, namely verbal and haptic, were provided by all participants positioned 3.6m from the base of the escalator in a counterbalanced order. For the verbal measure, participants were instructed to look directly at the escalator and then estimated the angle of inclination in degrees with respect to the horizontal, having been told 0° was horizontal and 90° vertical. For the haptic measure, participants used a Palm-Controlled Inclinometer (PCI; see Taylor-Covill & Eves, (2013a) for more details). Participants used the palm of their hand to adjust a flat plate within the PCI till it paralleled the slope of the escalator. If participants gave a verbal estimate of 45°, they were asked after the PCI estimate why they gave this verbal estimate. Any participants stating that all stairs were 45°, a common belief, were excluded as their estimate of the angle was not based on perception. Following these judgements, participant's sex was coded from appearance and they self-reported their age, height and weight. Two further questions were asked of participants. They were directed to look at the stairs to the next floor and asked, '*How hard do you think you would have to work to climb the stairs?*' on an 11 point scale with verbal anchors of '*no effort at all*' at 0, '*somewhat out of breath*' at 5 and '*very out of breath*' at 10. Finally, participants rated '*How confident are you that you could walk quickly for 20 minutes without stopping?*' on an 11 point scale with verbal anchors of '*not at all confident*' at 0, '*somewhat confident*' at 5 and '*completely confident*' at 10.

2.3.4 Analysis

Analyses employed repeated measures ANOVA with the between subject factors of Sex (male, female) and Condition (up, stationary, down) and the within subject factor of Measure (Verbal, Haptic). In follow-up analyses, multiple regressions were used to predict each perceptual measure with the potential predictor variables of direction of movement, sex, age, Body Mass Index (BMI), effort to climb the stairs and self-efficacy for walking. The moving escalator conditions were dummy coded to test the potential effects of direction of travel relative to a stationary escalator. Four participants who were multi-variate outliers in the regression analyses were excluded leaving a final sample of 866 participants.

2.4 Results

A repeated measures ANOVA with sex and condition as between-subject factors and measure as the within subject factor revealed significant differences between measures ($F_{1, 864} = 1560.54$, $p < .001$) and the sexes ($F_{1, 864} = 18.83$, $p < .001$), with an interaction between the two ($F_{1, 864} = 6.63$, $p = .01$). While females estimated greater verbal angels than males (Females = 54.2°, *SE* = 0.70; Males = 50.2°, *SE* = 0.63), there were no significant differences between the sexes for the haptic measure (Females = 31.0°, *SE* = 0.50; Males = 29.8°, *SE* = 0.45).

Table 2.1 contains the standardized coefficients and summarizes the results of analyses with multiple regressions that include all measured demographics. The potential predictors of estimates of steepness were direction of movement of the escalator, sex, age, BMI, effort and self-efficacy. For the verbal estimates, the escalator appeared less steep when it was moving upwards (*m*= 50.8°, *SE*= 0.83°) relative to stationary but there was no effect of it moving down (down, *m*= 52.9°, *SE*= 0.80°; stationary, *m*= 53.2°, *SE*= 0.83°). In addition, females verbally estimated the escalator as steeper (m= 54.2°, SE= 0.66°) than males (m= 50.2°, SE= 0.66°). Unlike verbal estimates with a staircase, there were no effects of age or BMI on the verbal estimate of the steepness of the escalator. For the haptic estimate, there was no effect of escalator movement (up, *m*= 30.6°, *SE*= 0.60°; stationary, *m*= 30.7°, *SE*= 0.57°; down, *m*= 29.8°, *SE*= 0.59°), nor any significant effect of the demographic variables. In addition, there were no effects of reported effort for stair climbing or self-efficacy for walking quickly on either measure.

Table 2.1 Standardized coefficients for the effects of movement direction and demographic variables on estimates of escalator slant.

Variable	**Verbal**	**Haptic**
Up<Not	-.080*	-.004
Down<Not	-.012	-.040
Females>Males	.144***	.059
Age (years)	-.044	.049
BMI, mean centred	.015	.008
Effort	.023	.011
Self -efficacy	.002	.002
Adjusted R^2	.022	.000
F (7, 858)	3.76***	1.03

Note. *p < .05 **p < .01 ***p < .001

Table 2.2 summarises the results of multiple regression analysis for reported effort to climb the stairs. For this analysis, sex, BMI and self-efficacy were significant contributors to the model. In keeping with the absence of any contribution of effort to estimates of the steepness of the escalator, there was no contribution of the verbal estimate of escalator steepness to reported effort to climb stairs.

Table 2.2 Standardized coefficients for the effects of demographic variables on estimates of effort to climb stairs.

Variable	**Effort**
Females>Males	.167***
Age (years)	-.011
BMI, mean centred	.065*
Self -efficacy	-.222***
Verbal	.027
Adjusted R^2	.090
F (7, 858)	18.03***

Note. *p < .05 **p < .01 ***p < .001

2.5 Discussion

In summary, an escalator moving away from the participants was associated with a reduction in explicit estimates of steepness whereas one moving towards them did not differ from the stationary escalator. As down escalators would only be ascended in exceptional circumstances, it is possible that they are not perceived as a slope to be climbed by cognitive processes linked to locomotion. As with stairs, females exaggerated verbal estimates of escalator slant more than males. Haptic estimates were more accurate and there were no effects of escalator movement or demographics on the hand-based measure.

Consistent with Shaffer & Flint (2011), verbal estimates for the escalator were exaggerated. The overestimation of 17.7° for a slope of 33.1° closely matches what appears to be a 17.1° overestimation of a 30° escalator moving upwards in the earlier study. Stratified sampling for sex, and subsequent multi-variate control for demographics that can influence perception, produced estimates that replicated Shaffer & Flint (2011). The apparent slope of escalators, like stairs and hills, are exaggerated in explicit awareness. Sex influenced this perception, as it does for stairs, confirming concerns about the possible effects of biased sampling in the earlier study (see Eves et al., 2014). What is clear here is that Shaffer and Flint's design in which stationary stairs were compared with a moving escalator was sub-optimal. When a stationary climb was compared with a moving one of the same dimensions, movement influenced perception.

Differences in topography can compound errors in sampling. The typical height of each step on an escalator is 20 cm, somewhat higher than the 14 – 18 cm set for public access stairs by building regulations (Roys, 2001). One must assume similar stair dimensions for Shaffer & Flint though no information on the actual dimensions is available (Shaffer personal communication, 2013). Increased height for an escalator step minimizes the spatial footprint for the escalator in the building but this increase may also influence perception. In a seminal study, Warren (1984) investigated the step height that minimized the energetic cost of climbing. Optimal heights for energetic cost in the range 19.6 – 24.2 cm were echoed by perceptual choice of the 'most comfortable' height for climbing, 18.9 – 22.9 cm. The typical height of an escalator step is closer to the optimal height for energetic minima than regulation heights for stairs. As a result, escalator steps may look more 'optimal' that stair steps and this locomotor cognition could reduce explicit estimates of slope. To answer Shaffer & Flint's (2011) question may require a 'constructive' replication in which stairs with the same step height and depth of the comparison escalator are used.

While there were no effects of the demographics of age or BMI that have been reported for stairs (Eves et al., 2014; Taylor-Covill & Eves, 2015), it is possible that the reduced cost of escalator use relative to stair climbing diminishes potential effects of resources. Unpublished observations reveal that only 5.0% of pedestrians using an ascending escalator choose to walk up it without any intervention (Eves & Hoppé, unpublished; *n* = 8,194); riding on the escalator that minimizes energetic cost appears to be the default behaviour to get to the top. As a result, perception of escalators may not be associated with climbing behaviour in the way that stairs must be. Consistent with this suggestion of reduced effects of resources for escalator perception, only modest amounts of variance of escalator steepness, 2.2%, were accounted for by study variables relative to stairs, e.g. 14.7% in Eves et al., (2014.). In contrast, sex, BMI and self-efficacy for walking briskly were associated with estimates of the effort to climb stairs of the same height, accounting for 9% of the variance.

Providing escalators in the public access sites such as train stations and airports facilitates the movement of pedestrians. In a train station, the escalator transported pedestrians at 1.6 times the rate of the stairs (Eves, Lewis & Griffin, 2008). In addition, escalators provide a more comfortable ascent for passengers who may experience walking difficulties and/or be encumbered by large bags when travelling or shopping. These conveniences come at an economic cost. A constantly running escalator of fixed speed is used only 38.3% of the time in business hours (Oaks, Thomas, Chao & Rommes, 2008). As a result, 61.7% of electricity costs are wasted. Oaks and colleagues estimated that there was a 17,500 kWh electricity waste every year in a shopping mall in the US, equivalent to $1,000 for each continuously running escalator. Two alternative modes of operation for escalators are to provide intermittent movement. Escalators can operate in shut-down mode when not required, only moving when a photo-electric beam is broken like the escalator investigated here. The second alternative is for escalators to slow down when not required by a pedestrian. For example, a slow-down escalator can reduce speed to 0.16 $ft.s^{-1}$ when not in use. Data from Washington Metropolitan Area Transit Authority reported potential electrical energy saving of approximately $1,800 per year for each slow-down escalator for ascent and $1,600 for each slow-down escalator for descent

(US General Services Administration, 2006). In addition, intermittent escalators have reduced maintenance costs compared to conventional ones, estimated at $924 per year (US General Services Administration, 2006). If the reduction in perceived steepness occasioned by an escalator moving upwards translates into great use relative to stairs, the result here suggests one can add a health cost to the economic ones for continuously moving escalators.

It appears that escalators move continuously because of *potential* costs of litigation should a pedestrian have an accident. Typically, the beam for intermittent escalators is placed a few feet in front of the moving treads. As a result any pedestrian is detected by the sensor 'and acceleration to full speed will be accomplished before he or she steps onto the unit' (p. 29, US General Services Administration, 2006). Further, 'Studies has shown that acceleration/ deceleration rates of 1.0 ft/sec^2 are completely comfortable and safe'. (p 75, US General Services Administration, 2006). Nonetheless, the industry expert panel in the US decided against recommending intermittent escalator formats. The panel concluded that 'even if there were energy and economic savings and no discernible decrease in escalator safety, the potential for substantial liability costs in the present litigious climate will likely preclude the adoption and use of intermittent escalators in the United States' (p. 20, US General Services Administration, 2006). This recommendation occurred despite the absence of any evidence of reported problems caused by changes in movement in the data provided in the appendices. For example, the director of building services from the TELUS Convention Centre reported that 'The escalators have not raised any concerns or resulted in any injuries due to the operational characteristics' (p. 34, US General Services Administration, 2006).

Finally, a number of limitations need to be considered. Inevitably, the study recruited a convenience sample of pedestrians using the site and it is impossible to know whether the result would generalise. In addition, the escalator had a single speed and it is unknown whether differences in speed would be associated with differences in perception. Finally, participants did not complete an angle knowledge test in which they were asked to reproduce a 30 angle (see Taylor-Covill & Eves, 2015). Such a test screens participants for estimates which are not based on accurate knowledge of the meaning of angles in degrees. As a result, some verbal estimates may have been unreliable.

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3. CHAPTER THREE

EFFECT OF CLIMATIC CONDITIONS ON BEHAVIOUR AND PERCEIVED STEEPNESS

Febriani F. Ekawati, Michael J. White & Frank F. Eves.

3.0 Effect of Climatic Conditions on Behaviour and Perceived Steepness

3.1 Abstract

Increased activity as part of daily life is one public health initiative to counter high levels of inactivity at a population level. Nonetheless, climate can influence walking for transport. This study investigated potential effects of temperature and humidity on the natural behaviour of stair climbing, as well as the associated perception of the stairs. Participants (402 males and 423 females) were timed covertly climbing a 3.93 m staircase (20.4°) at a university in Indonesia to provide a measure of behaviour. In addition, they made two perceptual estimates of the steepness of the stairs. Results revealed significant effects of temperature and sex on climbing speed. Speed of climbing stairs was reduced as temperature increased and women climbed the stairs slower than men. For perception of the stairs, both temperature and humidity influenced the explicit estimate of the angle of the stairs; as climatic variables increased, perceptions became more exaggerated. In addition, sex and age were associated with exaggeration in the explicit estimate. Females and older participants reported the stairs as steeper than their comparison groups. The data suggest that climatic conditions may act as a barrier to expending resources climbing stairs as part of lifestyle physical activity.

3.2 Introduction

Accumulation of physical activity during daily life is one public health approach to increasing levels of inactivity in the developed world (Sallis et al., 2006). Increased choice to climb stairs rather than use the lift or escalator is one public health initiative to increase lifestyle physical activity (Bellicha et al., 2015; Eves & Webb, 2006; Soler et al., 2010). Nonetheless, these interventions are not universally successful. Stair climbing interventions in Hong Kong had minimal effects on lifestyle physical activity at a population level (Eves & Masters, 2006;

Eves, Masters, McManus, Leung, Wong & White, 2008). Instead, climate appeared as a barrier to any increases in activity.

Climatic conditions influence physical activity in different countries (Tucker & Gilliland, 2007) and across the seasons in the same country (Matthews et al., 2001; C. Tudor-Locke et al., 2004). While the inclement winter months are obviously a barrier to physical activity, there is also a drop in activity in the peak summer months (Matthews et al., 2001; C. Tudor-Locke et al., 2004). Previous studies have reported that attributes such as temperature and humidity are associated with walking behaviours, specifically reducing the speed of walking (Levine & Norenzayan, 1999) and its duration (Klenk et al., 2012).

Elevated levels of temperature and humidity can affect pedestrian's choice of behaviour in public access settings. In Hong Kong, choice to walk up a sloping travelator was moderated by climate (Eves & Masters, 2006; Eves et al.,, 2008). As temperature and humidity increased, walking was reduced. Increased needs for heat loss as the climatic conditions became less suitable for activity will increase blood flow to the skin. As a result, the resources for climbing are reduced by this redistribution of blood at the expense of the supply availability for exercising muscle. In addition, the demographic characteristics of the pedestrians, i.e. their sex, were relevant to the effects of changes of temperature and humidity. Men were more likely avoid walking up the travelator than women as the climatic conditions became less suitable for physical activity (Eves et al., 2008). This result contrasted with the consistent outcome in stair climbing studies that women tend to avoid stairs more than men, consistent with differences in available climbing resources (Eves, 2014). Physical activity such as walking and climbing stairs will always generate heat in the body that need to be eliminated. Climate is relevant to sex differences in the process of heat dissipation. The surface of area per unit mass of women is greater than that of men (McCardle et al., 2007). As a result, women are better able to radiate heat from their skin than men who rely more on evaporative heat loss. As a result, sweating as a means of heat loss is more important in men than it is in women. Air saturated with moisture, as it is when humidity is high, is a major barrier to sweating providing an explanation for the greater effects of humidity in men than women on walking up the travelator (Eves et al., 2008).

Walking on the slanted surfaces such as stairs or a sloping travelator requires more energy than walking on the level. Energy expenditure for ascending the stairs is 9.6 times that of the resting state (Teh & Aziz, 2002). Stair climbing is as a vigorous, lifestyle physical activity requiring more energy per minute than jogging. Proffitt (2006) argued that the available energy resources affect individual perception of the environment. When resources are depleted, individuals' perception of distance and steepness of a climb becomes more exaggerated. Proffitt reasoned that this change in perception reflects an economy of action. Individuals with reduced resources may choose a slower pace to walk to allow them to complete the journey (Proffitt, 2006) or avoid climbing stairs when alternative methods of ascent are available (Eves, 2014; Eves et al., 2014).

To measure slope or stair perception, participants provide three different estimates (Bhalla & Proffitt, 1999; Eves et al, 2014; Proffitt, Bhalla, Gossweiler, & Midgett, 1995). Individuals report verbally the angle of the slope in degrees relative to the horizontal (verbal measure) and use an adjustable segment of a disk to match the angle of the slope in cross section (visual measure). These explicit verbal and visual measures exhibit exaggerated perception of slope, with a 23° staircase reported to be around 45° and a 5° hill reported to be 20° (Eves et al., 2014; Proffitt et al., 1995). In addition, demographic groups with less resources for climbing - such as the elderly, those carrying a heavy backpack or extra body weight, and physical fatigued individuals - provide explicit estimates of slant that are more exaggerated than their comparison groups (Bhalla & Proffitt, 1999; Eves et al., 2014; Proffitt et al., 1995; Taylor-

Covill & Eves, 2013a; Taylor-Covill & Eves, 2015). For example, females consistently estimate slopes as steeper than males (Eves et al., 2014; Proffitt et al., 1995; Taylor-Covill & Eves, 2013a, 2014, 2015). On average, females have a greater proportion of their body weight as fat yet have lower leg strength than males (McCardle, Katch & Katch, 2007). Consequently, they have less climbing resources than males of the same weight because of the extra 'dead' weight they must carry up the stairs (see Eves, 2014). In contrast to the exaggeration of slope with the verbal and visual measures, haptic estimates are more accurate. To provide a haptic measure, participants use the palm of their hand to adjust a flat surface to match the slant of the staircase (Taylor-Covill & Eves, 2013b, 2013c; Eves, 2015). Stairs avoidance as a behavioural choice by pedestrians is associated with perception of steepness (Eves et al., 2014). Pedestrians who avoided stairs by riding the escalator reported the slant of the stairs as steeper than their comparison group. This effect occurred even when potential effects of demographic grouping on perception was controlled by stratified sampling and statistical adjustment.

To date, there is no information about the effect of climatic conditions on perceived steepness of stairs, despite clear effects on behaviour and resources for climbing. This study measured the speed of ascent of stairs covertly to obtain information about the natural behaviour of pedestrians climbing in different climatic conditions. We predicted reduced speed of climbing as climatic conditions became less suitable for physical activity (Levine & Norenzayan, 1999). Secondly, we set out to test whether differences in climate (temperature, humidity) were associated with differential estimates of the steepness of stairs that would be climbed. We predicted that less suitable climate would be associated with exaggerated angular perception of the stairs for the verbal measure but that there would be no effect on the haptic measure. In addition, we predicted greater effects of climate variables in men than women consistent with effects reported in Hong Kong (Eves et al., 2008).

3.3 Methods

3.3.1 Participants

Eight hundred fifty one stair users at the Universitas Sebelas Maret were recruited for the study over 25 different days from 21st August to 30th September 2016. They were asked if they would volunteer for a study on perception and physical activity. Once they agreed to be interviewed, they were asked about their estimates of the steepness of the stairs.

3.3.2 Stimuli

One set of connecting stairs between buildings in the Medical School, Universitas Sebelas Maret, Surakarta, Indonesia was employed for the study. Slightly different from staircases in the UK in general, this stair started with three different sizes of tread depth, followed by twenty relatively uniform steps including two half-landing surfaces (3.93 m high, number of steps = 20; overall angle = 20.4°, angle of each section = 22.3° - 24.2°). The stairs had open sides but were shielded from the sun above the heads of climbers. Therefore, air temperature and humidity could still affect pedestrians.

Figure 3.1 A photograph of a staircase used in the current study (left) and the photograph of a participant making a haptic estimate in the field (right).

3.3.3 Measures and Procedure

Participants faced directly at the stairs, standing 3 m away from the base. They were then made two perceptual judgements, namely verbal and haptic, in a counterbalanced order of the 20-step section of the staircase. For the verbal measure, participants were instructed to look directly at the stairs and then estimated the angle of inclination in degrees with respect to the horizontal, having been told 0° was horizontal and 90° vertical. For the haptic measure, participants used a Palm-Controlled Inclinometer [PCI; see Taylor-Covill & Eves, (2013b) for more details]. Participants used the palm of their hand to adjust a flat plate within the PCI until it paralleled the slope of the stairs. Following these judgements, participant's sex was coded from appearance and they self-reported their age, height and weight. Finally, as the participants climbed to the top of the stairs, the experimenter measured their climbing time covertly using a stopwatch. Climbing was timed from when the leading leg was placed on the first step until both feet were placed on the top step. Weather data every hour, starting from 8:00 until 18:00 for that measurement day was obtained from Adi Soemarmo - Surakarta weather station. For each measurement day, air temperature (˚C) and air humidity (%) were recorded. During the study period of August to September 2015, temperature and humidity ranges were 24.8˚-35.2˚C and 47-76% respectively. Data collection started in the morning around 8:20 and finished early evening around 17:00.

3.3.4 Statistical Analysis

Participants were excluded if they thought all staircases were 45˚ (n =13), ran when climbing the stairs (n = 3) and paused while climbing the stairs to speak on the phone (n = 2). In addition, preliminary inspection with box-plots excluded two outliers on the verbal measure and four for the haptic measure. The final sample included (n = 825) divided into two groups of men (n =402) and women (n =423). Multiple regressions were used to test the effect of temperature and humidity independent of effects of time of day (hour), sex, age and BMI. Unsurprisingly, temperature and humidity were highly correlated (Pearson's r = -0.79, $p<.001$); as the day warmed, humidity dropped. To counter this multi-collinearity between the two variables, humidity was used to predict temperature in the data set, and the residuals saved for inclusion in the analyses. The net outcome was a measure of temperature that was independent of humidity. There were differences between the sexes in BMI and the climatic variables (all $p<.001$), with a suggestion of a difference in age. Therefore, all variables were mean-centred within each sex to avoid confounding of the main effect of sex with the other variables. Multiple regressions were used to test the effect of climate and demographic variables on a) climbing time ($m.s^{-1}$) and b) the verbal and haptic measures of perceived steepness.

3.4 Results

3.4.1 Effect of climate on behaviour

The average climbing speed was 0.286 m.s^{-1} (*SE* = 0.001). For the climate variables, the average temperature was 30.2° C (*SE* = 0.09; range 25° C – 35° C) and the average humidity was 62.7% (*SE* = 0.25; range 47% – 76%).

Table 3.1 summarizes the results of multiple regression analyses for the speed of climbing the stairs (m.s^{-1}). There were significant effects of sex and temperature on climbing speed, with a significant regression equation, $F_{6, 818} = 10.06$, $p < .001$, that explained 6.2% of the variance. Both predictors were negatively associated with climbing speed. Women climbed the stairs slower than men, and when the temperature went up, individuals slowed their speed. As can be seen from the table, there were no significant effects of age, BMI, humidity and time of day.

Table 3.1 Summary of the effects of demographic and climate variables on speed of stair climbing (m.s-1).

Variable	**Standardized coefficients**	**95% Cis**
Females<Males	-.227***	-.294, -.161
Age (years), mean centred	.034	-.035, .103
BMI, mean centred	-.035	-.103, .032
Temperature, residual mean centred	-.127**	-.211, -.042
Humidity, mean centred	.048	-.058, .153
Time of day (hour)	.042	.157, -.074,
Adjusted R^2	.062	
***F* (6, 818)**	10.06***	

Note. *p < .05 **p < .01 ***p < .001

Figures 3.2 and 3.3 below summarize the effects of the climate variables on speed of climbing. The figures depict the values for one *SD* above and below the mean to allow comparison with the effects of climate on perception. Follow-up analyses that tested for potential interactions between sex and the climate variables revealed no interaction between sex and temperature (β = 0.009, p = .850), despite the appearance of the figure, nor any interaction with humidity (β = 0.024, p = .612). Clearly visible in both figures is the faster climbing speed of men relative to women.

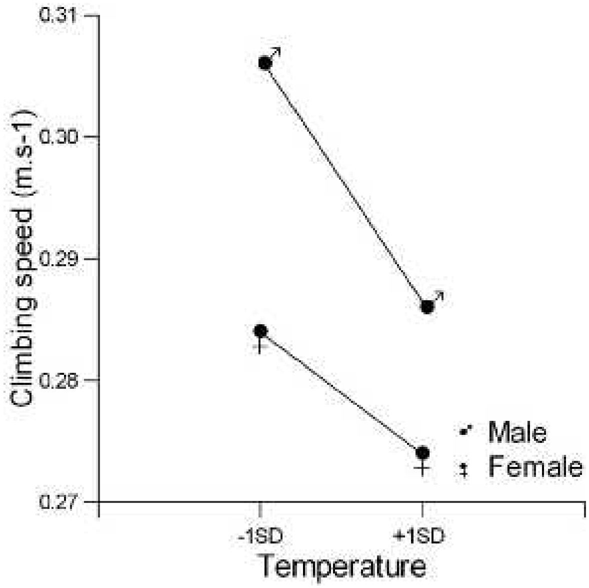

Figure 3.2 Effects of temperature on climbing speed.

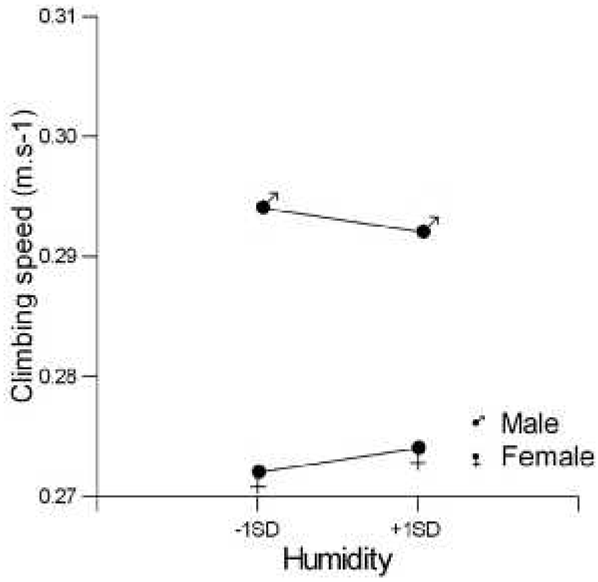

Figure 3.3 Effects of humidity on climbing speed.

3.4.2 Effect of climate on perception of slope

A preliminary multivariate repeated measure analysis of variance with sex as the between-subject factor and measure as the within subject factor revealed a main effect of sex ($F_{1, 823} = 9.77$, $p = .002$), a main effect of measure ($F_{1, 823} = 1{,}483.3$, $p < .001$), and an interaction between the two ($F_{1, 823} = 12.20$, $p = .001$). While females estimated greater verbal angles than males (Females = 39.1°, *SE* = 0.42; Males = 36.3°, *SE* = 0.43) there were no differences between the sexes for the haptic measure (Females = 23.3°, *SE* = 0.40; Males = 23.2°, *SE* = 0.41).

Table 3.2 contains the standardized coefficients and summarizes the results of multiple regression analysis that included demographic factors and climatic variables for the verbal measure. Inclusion of the potential interactions of climate variables with sex revealed no interaction with humidity ($\beta = 0.009$, $p = .852$) and this term was dropped from the final model summarised in the table.

Table 3.2 Summary of the effects of demographic and climate variables on verbal estimates of stair slope in degrees.

Variable	Standardized coefficients	95% Cis
Females>Males	.163***	.096, .230
Age, mean centred	.116**	.046, .185
BMI, mean centred	.017	-.051, .085
Temperature, residual mean centred	.118*	.009, .227
Humidity, mean centred	.131*	.025, .236
Sex x temperature interaction	-.105*	-.201, -.009
Time of day (hour)	.080	-.037, .195
Adjusted R^2	.049	
***F* (7, 817)**	7.084***	

Note. *p < .05 **p < .01 ***p < .001

As with climbing speed, there were effects of sex in that females estimated the stairs as steeper than males. In addition, older participants estimated the stairs as steeper, consistent with previous research (Eves et al., 2014). For the effects of climate variables, there was an effect of humidity such that greater humidity was associated with steeper estimates. Further, the effect of temperature interacted with sex of the participant.

Figures 3.4 and 3.5 below summarize the effects of the climate variables on verbal estimates of slope. Once again, the figures depict the values for one *SD* above and below the mean.

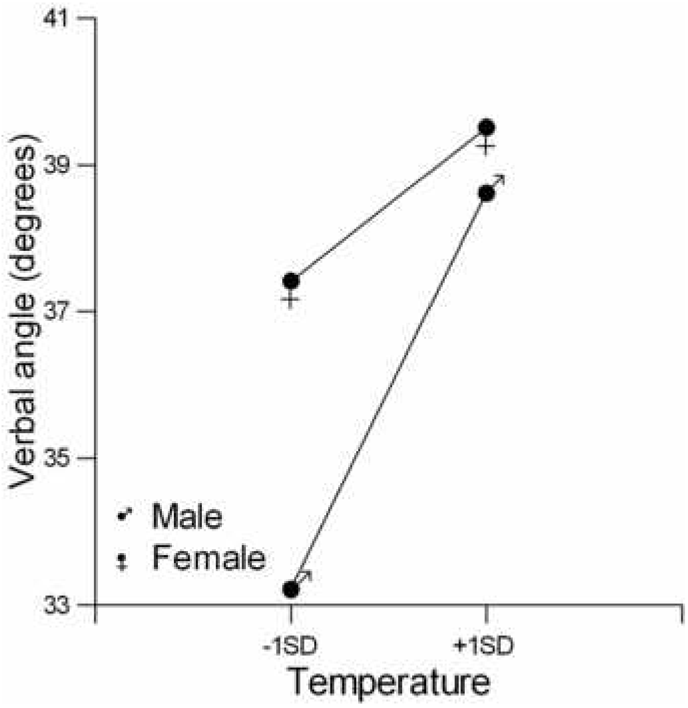

Figure 3.4 Effects of temperature on estimated verbal angle.

As can be seen from Figure 3.4, there were greater effect of temperature on males than females. Follow-up regressions for each sex separately revealed significant effects of temperature in males (β = .142, p = .005) but not in females (β = .031, p = .536). Inspection of Figure 4 below reveals no evidence of an equivalent interaction with sex for humidity. Participants subjected to higher levels of humidity provided steeper estimates of slope in both sexes.

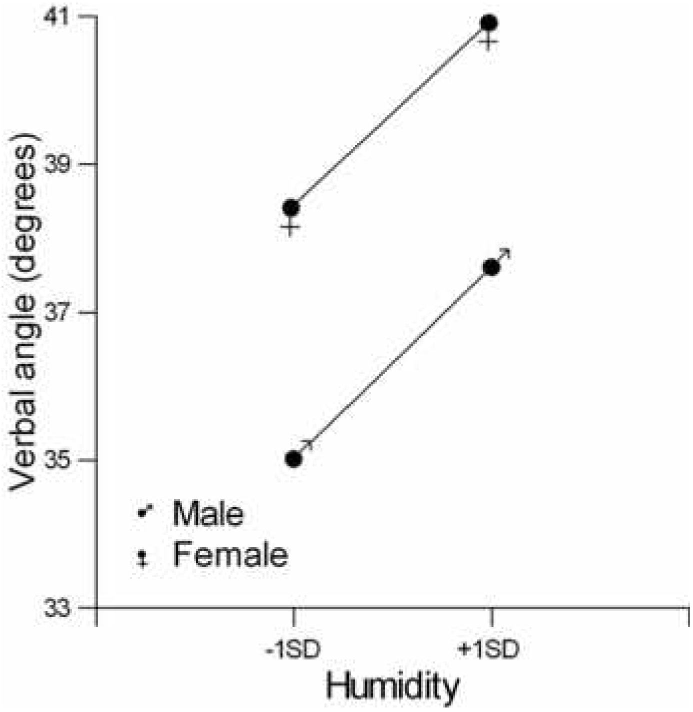

Figure 3.5 Effects of humidity on estimated verbal angle.

For the haptic measure, a non-significant basic model, $F_{6, 818} = 1.596$, $p = .145$, explained no meaningful variance (0.4%) and is not presented.

3.5 Discussion

In summary, speed of climbing stairs was reduced as temperature increased, consistent with data for walking on the level (Levine & Norenzayan, 1999). In addition, women climbed slower than men. For perception of the stairs, both temperature and humidity influenced the verbal estimate; as climatic variables increased, perceptions became more exaggerated. In addition, the demographic predictors of behavioural potential of sex and age were associated with exaggeration in the verbal estimate. Consistent with previous studies, verbal estimates of the angle were greater in females and older participants than their comparison groups (Eves et al., 2014). In contrast to previous research, there was no effect of self-reported weight on perception (Eves et al., 2014). It may occur because of a self-report bias in weight. Women tended to underreport their weight while men overestimated their height (Gunnare, Silliman, & Morris, 2013; Kuczmarski, Kuczmarski, & Najjar, 2001; Merrill & Richardson, 2009; Mozumdar & Liguori, 2011; Villanueva et al., 2001). There were no effects of climatic or demographic variables on haptic estimates.

In the previous study on the effects of climate variables on climbing, the range for humidity was 28-93% (Eves et al., 2008). Here, the range of 47-76% was more restricted. Humidity, which would disadvantage heat loss by sweating, would only be an issue at higher levels of humidity when air saturated with moisture would become a major barrier to sweating. Inspection of Figure 1 in Eves et al 2008, suggests considerable variability in behaviour within the humidity range measured here. Follow-up analyses were performed on the original Hong Kong data set, restricting it to the range of humidity available for Indonesia (see supplemental material 1 for the full analyses). Within this restricted range, there were no effects of humidity on walking up the travelator in either men (Odds ratio [OR] = 1.015, 95% confidence interval (CI) = 0.994, 1.036, p =.173) or women (OR = 1.015, 95% CI = 0.997, 1.029, p =.121). The absence of effects of humidity on behaviour in the original data is consistent with the absence of effects on climbing speed for the Indonesian sample. For temperature in Hong Kong, however, increased temperature reduced walking in men (OR = 0.849, 95% CI = 0.806, 894, p <. 001) but there was no effect in women (OR = 1.006, 95% CI = 0.968, 1.046, p =.750). For Indonesia, increases in temperature reduced climbing speed for both sexes, with no comparable interaction of temperature with sex for behaviour. The greater sample size of the Hong Kong data set (n = 58,603 vs. n = 825), and hence the greater power to address the question, may explain the discrepancy between the two data sets.

For perception, Proffitt (2006) argues that explicit perception of slope, exemplified by verbal estimates, allows participants to choose a climbing speed that matches their available resources. In addition, explicit estimates of slope have been linked to avoidance of climbing behaviour when an alternative method of ascent is available (Eves et al., 2014). There was greater explicit exaggeration of slope in individuals who avoided climbing by choosing the escalator. In this study, higher levels of climate variables that act as a potential barrier to lifestyle physical activity were associated with enhanced exaggeration of the explicit perceptual signal that can deter behaviour. It is noteworthy that both temperature and humidity influenced perception whereas only temperature influenced climbing behaviour. One might expect that changes in any environmental cue that can influence choice would be observed earlier than actual changes in behaviour; time to complete the journey, as well as resources, influence the chosen speed. Concerning temperature, there were greater effects on perception in men than women, echoing the follow-up analyses of the effects of temperature on behaviour in Hong Kong. Such an effect would be consistent with effects on perception of a cue that *could* influence behaviour.

An alternative explanation concerning the effects of resources on perception has been proposed by Durgin and colleagues. While they have argued, quite correctly, that explicit estimates could be influenced by demand characteristics in an experiment (Durgin et al., 2009, 2012), the caveat is unlikely to be relevant here. Participants were not involved in any experiment (c.f. Taylor-Covill & Eves, 2015). Instead, we tested the potential effects of natural variation in climate on perception. The pattern of effects on verbal estimates such that there were greater effects of temperature in males than females but no differential effects of humidity would render demand an unlikely explanation of the data. Effects of demand that varied differentially by separate climate variables would be implausible.

3.6 Acknowledgements

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3.7 References

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Supplemental material 1

Table 1. Effects of the demographic and contextual variables on walking up the travelator in male and female pedestrians on the Mid-Levels escalator system within the humidity range 47-76%.

Men (n = 28,834)

Variable	Odds ratio	95% CI
Young>old	3.358***	2.016, 5.593
11–13:00 > 17–19:00	0.932	0.705, 1.233
Pedestrian traffic (continuous)	0.998***	0.998, 0.999
Temperature (continuous)	0.849***	0.806, 0.894
Humidity (continuous)	1.015	0.994, 1.036

Note. *p < .05 **p < .01 ***p < .001

Women (n = 29,769)

Variable	Odds ratio	95% CI
Young>old	4.530***	2.485, 8.256
11–13:00 > 17–19:00	1.566***	1.263, 1.941
Pedestrian traffic (continuous)	0.998***	0.998, 0.999
Temperature (continuous)	1.006	0.968, 1.046
Humidity (continuous)	1.013	0.997, 1.029

Note. *p < .05 **p < .01 ***p < .001

4. CHAPTER FOUR

EFFECT OF CLIMBING CHOICE, DEMOGRAPHICS AND CLIMATE ON WALKING BEHAVIOUR

Febriani F. Ekawati, Michael J. White & Frank F. Eves.

4.0 Effects of climbing choice, demographics and climate on walking behaviour

4.1 Abstract

Walking is acknowledged as a current public health recommendation to increase lifestyle physical activity. Although walking for transport has an association with health benefits, it is frequently avoided when there is a mechanised alternative and when climate or the individuals' available resources are unfavourable. Using chosen walking speed to estimate the use of resources by pedestrians, this quasi-experimental study investigated 730 pedestrians' behaviour when approaching a choice-point between a short stair and a ramp at an exit from university campus towards the local station on six separate days. Results revealed that individuals who climbed the stairs walked faster than those who chose the ramp. In addition, females and those who were overweight walked slower than their comparator groups. In this study, temperature was associated with walking behaviour; as temperature increased, the walking speed of pedestrians became slower. When choosing the speed of walking, the purpose of the walking itself is important. In this study, time minimization to arrive more quickly at the train station is a plausible alternative explanation for effects of resource allocation on walking speed.

4.2 Introduction

Current public health approaches to target inactivity focus on the accumulation of physical activity during daily life (Sallis et al., 2006; WHO, 2010). Walking is a physical activity that has a low risk of injury, is popular, and freely available to most of the population (Hootman et al., 2001; Siegel et al., 1995). In the Health Survey for England (2008), both men and women report spending more time per day walking than on any other physical activity outside of work. Furthermore, regular walking has been found to reduce cardiovascular risk factors and have beneficial effects on individual's general health and vitality (Bemelmans et al., 2012; Blacklock, Rhodes, & Brown, 2007). There is also evidence that walking for transport has been associated with a reduction of cardiovascular disease, especially among commuting women (Hamer & Chida, 2008). Although walking for transport is strongly associated with better health outcomes (Hanson & Jones, 2015; Murphy, Nevill, Murtagh, & Holder, 2007; Murtagh et al., 2015; Park et al., 2014), many individuals do not perform this activity as part of daily life when there is a mechanised alternative. For example, Frank, Andresen, & Schmid, (2004) estimated that only 13% of African-Americans and 6% of white Americans walked for transport in travel diary data; most chose cars for the journey. Similarly, Cervero & Duncan, (2003) reported that only 34.3% walked for trips of under one mile, with the majority choosing cars for these short journeys. Walking for transport that would benefit health is avoided frequently.

Walking speed is one parameters of the intensity of the behaviour. The public health guidelines recommend that adults should accumulate 30 minutes or more of daily moderate-intensity physical activity (Bull et al., 2010; Haskell et al., 2007) that is equivalent to brisk walking, i.e. 3 - 4 mph or 1.34 - 1.79 $m.s^{-1}$. However, studies from the US and Australia reported that the duration of walking for transport in the adult population who performed the behaviour was 20 – 28 mins per day, with only 6% of adults meeting public health guidelines (Kruger et al., 2008; C. Tudor-Locke, Bittman, Merom, & Bauman, 2005). In addition, males may be more likely to engage in walking for transport than females (Cervero & Duncan, 2003; Frank et al., 2004; Kruger et al., 2008; Whitfield, Paul, & Wendel, 2015), with some evidence of differences by ethnicity in these possible gender differences. In contrast, some researchers have reported that women were slightly more likely to walk for leisure than men, 9.5% vs. 8.7% (Kruger et al., 2008). Nonetheless, on average, only 9% of adults engage in 30 mins or more per day of walking for leisure (Kruger et al., 2008). The intensity of walking for leisure, on the other hand, can meet the current physical activity recommendations. The average speed of walking for recreational reasons was estimated at 1.56 ± 0.17 $m.s^{-1}$ (Murtagh et al., 2002). Nonetheless, a meta-analysis reported that women walked at 1.24 $m.s^{-1}$ – 1.39 $m.s^{-1}$,a speed that was slower than that chosen by men, 1.34 $m.s^{-1}$ – 1.43 $m.s^{-1}$ (Bohannon & Williams Andrews, 2011).

When the cost of active transport is higher, i.e. climbing stairs at three times the cost of level walking (Teh & Aziz, 2002), only 7.5% choose to walk up the stairs (Eves, 2014). Avoidance of stairs when a mechanised alternative is available is very frequent. In addition, demographic subgroups with reduced resources for climbing, e.g. women, overweight pedestrians and those carrying large bags, are more likely to avoid it by choosing the escalator (Eves, 2014). In modern cities, sloped ramps are an alternative to stairs that allow equal access for wheelchair users who cannot negotiate a staircase. Data from two separate sites where a sloped ramp was the alternative revealed that ramps were more frequently chosen (Eves, submitted). Ascent using a ramp allows a more gradual use of resources for the climb than a staircase. Further, demographic groups that are more likely to avoid stairs by taking the escalator - women, overweight pedestrians and those carrying large bags - were also more likely to choose the ramp to ascend than their comparison groups (Eves, submitted).

Weather conditions and seasonality deter physical activity behaviour of all populations (Matthews et al., 2001; Tucker & Gilliland, 2007; C. Tudor-Locke et al., 2004). Studies specific to young children and adolescents have suggested that both low and high temperatures represented a barrier to physical activity (Bélanger, Gray-Donald, O'loughlin, Paradis, & Hanley, 2009; Edwards et al., 2015). Previous studies have reported that temperature and humidity have a direct impact on walking speed (Levine & Norenzayan, 1999; Rotton et al., 1990), the rates of walking (De Montigny, Ling, & Zacharias, 2012) and its duration (Klenk et al., 2012). In addition, climatic conditions were relevant to sex differences for the effects of temperature and humidity. Females reduced their walking duration more than males when the daily temperature went up (Klenk et al., 2012) and men walked faster than women in a cool environment (Rotton et al., 1990).

This quasi-experimental study investigated the behaviour of pedestrians approaching a choice-point between stairs and a ramp at an exit from a university campus towards the local station. A short flight of stairs on the direct route to the station was the alternative to a slope that allowed avoidance of stair climbing. Previous observations revealed that the majority chose the ramp [65.2% (95% CI = 63.0, 67.3), n = 2,529; Eves submitted]. This study used chosen walking speed to estimate the use of resources by pedestrians; a faster speed would require more resources. We predicted that resources chosen would reflect those available. If avoidance of the stairs is related to available resources, then those choosing the ramp would walk slower on the approach to the choice-point. Additionally, we predicted that demographic subgroups with reduced resources would also walk slower than their comparators. Finally, we predicted that at higher temperatures, individuals would slow their walking speed.

4.3 Methods

4.3.1 The site

On the route to University station, pedestrians cross a distance of 10.2m on level ground 20m before they reach a short staircase (1.02 m high, number of steps = 7). Figure 4.1 depicts this level surface. The ↑ in the figure indicates the level ground over which the participants' walking speed was timed.

Figure 4.1 A photograph of the study location taken from the first floor of Computer Science building at the University of Birmingham showing the level ground (↑) and a short staircases (X).

Figure 4.2 The short staircase and the alternative ramp for ascent on the route to the station.

The direct route over the staircase to the station, 42.6m, was shorter than the more circuitous route via the ramp, 46.1m. The ↑ in the figure indicates the pavement that leads to the station entrance and beyond it.

4.3.2 Participants

On six separate days between 17th July and13th October 2016, the walking speed of 730 male and female pedestrians crossing level ground was recorded. These individuals were going to or past the station from the University square. Observations were made between 14:00 and 17:00. Only pedestrians walking alone were timed to control for potential effects of social interaction on the speed of walking and subsequent choice.

4.3.3 Measures and Procedures

The walking speed was recorded covertly using a stopwatch when the participant crossed the distance between the two short staircases. The speed was timed from when the leading foot was placed on the top of the first staircase until one of the feet was placed on the first step of the second staircase. The observer coded whether the pedestrian subsequently climbed the staircase or chose the ramp. In addition, weight status was coded from appearance using separate silhouettes for men and women as to whether the pedestrian was overweight (BMI > 25). As previous observations revealed that few pedestrians carried large bags, presence of any bag was coded as well as the pedestrian's sex. Double coding revealed excellent Kappas for weight status ($\kappa = 0.79$), presence of bags ($\kappa = 1.00$) and sex ($\kappa = 1.00$). Weather data every hour, starting from 12:00 until 18:00 for that measurement day was obtained from Winterbourne – University of Birmingham weather station. During data collection periods, the ranges of temperature and humidity were 10° - 32°C and 41 - 91% respectively.

4.3.4 Statistical Analysis

Seven participants were excluded from the analyses due to incomplete data. There was a strong negative correlation between temperature and humidity ($r = -.874$, $p < .001$); as the temperature went up, humidity went down. To counter this multi-collinearity between the two variables, the temperature was used to predict humidity in the data set, and the residuals saved for inclusion in the analyses. The net outcome was a measure of humidity that could not be explained by temperature. Multiple regression analyses were used to investigate the influence of the six independent variables on the participants' walking speed.

4.4 Results

The average walking speed was 1.075 $m.s^{-1}$ (*SE* = 0.004). For the climate variables, the average temperature was 19.7° C (*SE* = 0.26; range 10° C – 32° C) and the average humidity was 59.6% (*SE* = 0.25; range 41% – 91%). In these observations, 64.8% of pedestrians chose the slope, consistent with previous observations (Eves, submitted). The sample was composed of 49.3% women, 16.2% overweight pedestrians and 41.8% carrying bags.

Table 4.1 contains the standardized coefficients and summarized the results of multiple regression analyses for walking speed ($m.s^{-1}$). There were significant effects of choice, sex, weight status, temperature and humidity on walking speed, with a significant regression equation, $F_{7,\ 713} = 21.91$, $p < .001$ accounting for 16.9% of the variance. In these data, there were no effects of the presence of the bag or any interaction between presence of a bag and choices on the speed of walking.

Table 4.1 Standardized coefficients (95% CIs) for the effects on speed of walking (m.s-1).

Variable	Standardized coefficients	95% Cis
Choice (Stair > Slope)	-.074*	-.143, -.005
Gender (M > F)	-.247***	-.316, -.178
Healthy weight > Overweight	-.236***	-.303, -.168
Bag/ no bag	-.056	-.126, .013
Bag by choice interaction	-.046	-.499, .093
Temperature, mean centred	-.093**	-.161, -.025
Humidity residual, mean centred	.101**	.032, .169
Adjusted R^2	.169	
F (7, 713)	21.91***	

Note. *p < .05 **p < .01 ***p < .001

Pedestrians who chose the stairs walked faster than those who avoided them (stairs M = 1.105 $m.s^{-1}$, 95% CI = 1.089, 1.120 vs. slope M = 1.063 $m.s^{-1}$, 95% CI = 1.053, 1.074). The data confirm that males walked faster than females (males M = 1.109 $m.s^{-1}$, 95% CI = 1.097, 1.120 vs. females M = 1.041 $m.s^{-1}$, 95% CI = 1.029, 1.054) and healthy weight individuals walked faster than those who were overweight (healthy weight M = 1.090 $m.s^{-1}$, 95% CI = 1.081, 1.099 vs. overweight M = 1.000 $m.s^{-1}$, 95% CI = 0.981, 1.020). In addition, at higher temperatures, individuals slowed their walking speed. Paradoxically, pedestrians walked faster at higher humidity. In these data, carrying a bag did not significantly slow the speed of walking (bag M = 1.066, 95% CI = 1.053, 1.079 vs. no bag M = 1.082, 95% CI = 1.070, 1.094).

4.5 Discussion

This study set out to investigate the walking behaviour of pedestrians approaching the point of choice between stairs and a ramp towards the local station at a university setting. In summary, the speed of walking was related to the choice of pedestrians when leaving the university campus. Individuals who chose the stairs on the route to the station walked faster than those who avoided them. In addition, women and overweight walked slower than their comparison groups. Consistent with Levine and Norenzayan (1990), increasing temperature was associated with reducing the walking speed of pedestrians.

Concerning the public health recommendations, the intensity of walking that meets the requirement is 3-4 mph or 1.34 - 1.79 $m.s^{-1}$ for most healthy adults. In this study, the average walking speed was 1.075 $m.s^{-1}$ which is lower than the recommendations. This finding is in agreement with Kruger et al., (2008) and Tudor-Locke et al., (2005) findings which showed that walking for transport did not meet the cut-point of public health recommendations. Given that preferred walking speed that minimizes the energy costs of walking is about 1.3 $m.s^{-1}$, this result is surprising (Hreljac, 1993). One possible explanation concerns the site itself. To reach the flat section of ground over which individuals were timed, pedestrians had to climb a height of about four metres from the university main square. It is possible that pedestrians have slowed their speed of walking prior to reaching the measurement site.

When approaching the choice-point, pedestrians chose whether to take the stairs or avoid them. We found that individuals who avoided the stairs walked slower than those who climbed them. In addition, women and the overweight walked slower than their comparison groups. Taking the stairs requires more energy than walking on the level. Teh & Aziz (2002) estimated that energy expenditure for climbing the stairs was 9.6 times that of the resting state. Demographic groups with reduced resources may slow their pace to preserve resources, just as they are more likely to avoid the stairs when an alternative method of ascent is available (Eves, 2014; Dennis R. Proffitt, 2006). It is possible that the effects of demographics also reflects differences in available resources to complete their journey, consistent with differences in method of ascent. An alternative explanation for choosing the stairs is time minimization in some pedestrians. The distance of the pathway over the staircase to the station was shorter than the circuitous route via the ramp. Pedestrians who were in a rush to catch the train would choose the shorter way to get the station. The time pressure for a specific journey is a reasonable alternative explanation for this difference in speed based on choice (see Eves, Lewis, & Griffin, 2008). One aspect not addressed in this study was pedestrians' perception of the stairs when they were approaching the choice-point. It has been reported that the apparent steepness of the stairs in consciousness may have affected the behavioural choice of pedestrians in a public access setting (Eves et al., 2014). Interviewing pedestrians about the perceived steepness of the stairs and auditing the pedestrians' choice behavior at this site might clarify the issue.

Therefore, we conducted a companion study (chapter 5) to test the effect of choice behaviour and perceived steepness of the stairs when an alternative ramp is available.

Physical environment attributes such as temperature and humidity contribute to reducing walking speed and its duration as they increase (Klenk et al., 2012; Levine & Norenzayan, 1999). Consistent with the previous studies, as temperature increased, individuals slowed their walking speed. The need to minimize the cost of mobility in a hot and humid environment reduces the speed of walking, as resources, i.e. the supply of oxygenated blood, is required to supply the skin for cooling as well as support for exercising muscle (McCardle et al., 2007). In contrast to previous research, however, pedestrians walked faster at higher humidity, a paradoxical finding that is inconsistent with the underlying physiology. Despite the relatively large sample size, only six separate days of monitoring were employed. As a result, between day differences in both climate variables may have been confounded with any within day differences between them. Computing residuals to separate the two variables may have been unable to disentangle between and within day effects. The increased speed with increased humidity is physiologically implausible and likely to reflect limitations in the data set.

Proffitt (2006) argued that there are three factors influencing individuals in choosing walking speed, i.e. the purpose of walking, anticipated duration, and anticipated energetic cost. In this study, the purpose of many people walking in the observed location will be going to the nearest train station. It is possible that some of those who walked faster and then climbed the stairs were affected by time pressure due to the train schedule. As a result, they accelerated the pace of walking to minimize time reaching the destination. In conclusion, the preference of pedestrians' walking speed on the route to University station might be related to time minimization rather than resource matters. In this location, chosen walking speed may not solely reflect available resources.

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5. CHAPTER FIVE

THE RELATIONSHIP BETWEEN BEHAVIOURAL CHOICE OF PEDESTRIANS AND PERCEPTION OF A STAIRCASE ON THE ROUTE

Febriani F. Ekawati, Michael J. White & Frank F. Eves.

5.0 The relationship between behavioural choice of pedestrians and perception of a staircase on the route.

5.1 Abstract

Research into stairs and escalators reveals that females, the elderly and individuals carrying large bags or excess body weight are more likely to avoid stairs than their comparison groups. Exaggerated perceived steepness of the stairs in these subgroups may contribute to this avoidance. Overestimation of perceived steepness in consciousness allows individuals to manage their energy resources for climbing. Individuals with reduced climbing resources may report more exaggerated steepness of stairs. This quasi-experimental cohort study examined perceptual judgments that might deter individuals from making the choice between a short flight of stairs and a sloped ramp at an exit from a university campus towards the nearest train station. A purposive sample of 307 pedestrians were watched covertly when approaching the choice point and the direction of their route, i.e. stairs or the ramp, noted. Furthermore, they made two perceptual estimates of the steepness of the stairs and their actual behavioural choice was noted after the perceptual judgments. Results revealed significant effects of sex and age on slant perceptions. Unlike a previous study, there was no association between exaggeration of perceived steepness and climbing choice. Effects of delay due to an interview of five minutes, and any associated detour, might influence pedestrians' actual behaviour rather than any potential effect of resources.

5.2 Introduction

Physical inactivity is increasingly recognised as a worldwide public health concern (WHO, 2010). Accumulating activity during daily life, e.g. taking the stairs instead of escalator, is the current public health approach to this problem (Sallis et al., 2006; WHO, 2010). Research into stairs and escalators found that pedestrians with reduced resources are more likely to avoid stairs by choosing an escalator due to exaggerated perceived steepness of the stairs (Eves, 2014; Eves et al., 2014). This paper investigates the factors that might deter individuals from making the choice of stairs rather than a sloped ramp at an exit from a university campus towards the nearest train station.

The apparent steepness of hills and stairs is exaggerated in explicit awareness (Bhalla & Proffitt, 1999; Eves et al., 2014; Proffitt, Bhalla, Gossweiler, & Midgett, 1995). In a seminal paper, Proffitt et al., (1995) revealed that participants typically reported a 5° hill to be about 20° and a 10° hill to be about 30°. More recently, Eves et al., (2014) found that a 23° staircase was reported to be around 45°. To assess the perception of slant, Proffitt and colleagues proposed three different measures. Individuals report the angle of the slope in degrees relative to the horizontal (verbal) and match the angle of the slope in cross section by using an adjustable segment of a disk (visual). For the haptic measures, participants use the palm of their hand to adjust a flat surface to match the slope of the hill (Proffitt et al., 1995). Consistently, exaggeration of the steepness occurred when the verbal reports and visual matching were employed to estimate the slant (Eves et al., 2014; Proffitt et al., 1995). In contrast, when participants use their unseen hand to adjust a flat surface so that it parallels the slope, responses were more accurate (Eves, 2015; Proffitt et al., 1995; Taylor-Covill & Eves, 2013a, 2013b).

A number of researchers have reported that exaggeration of perceived steepness is influenced by an individual's available energy resources. The steepness of hills and stairs became more exaggerated when individuals were fatigued by prior vigorous physical activity (Proffitt et al., 1995; Taylor-Covill & Eves, 2013a). Similarly, perceptions of slant were elevated when participants were burdened with a heavy backpack or excess body weight in the form of fat (Bhalla & Proffitt, 1999; Taylor-Covill & Eves, 2016). In addition, women and older participants give more exaggerated estimates of slant for steep hills and stairs than their comparison groups (Bhalla & Proffitt, 1999; Eves et al., 2014; Proffitt et al., 1995; Taylor-Covill & Eves, 2013a). Proffitt, (2006) suggests that exaggeration of perceived steepness in consciousness allows individuals to manage their energy resources for locomotor planning such as walking and climbing without having to explicitly inspect resource availability.

This quasi-experimental cohort study looked at the choice individual pedestrians made at a university site at which individuals could avoid a staircase by choosing a ramp or opt to climb the stairs. A companion observational study revealed that 64.8% avoided the stairs by choosing the ramp at this university site (see chapter 4). A previous quasi-experimental study by Eves et al., (2014) suggested that resources influenced perceived steepness and pedestrian's behaviour in a station and a shopping mall respectively. This study set out to test if individual choices would be related to perception of the stairs when the alternative was a ramp rather than the alternative of an escalator in the shopping mall study (Eves et al., 2014). We predicted that individuals choosing the ramp instead of the stairs would exaggerate stair steepness more than those who chose to climb the stairs. As temperature and humidity have been related to perceived steepness in Indonesia (see chapter 3) and walking speed on the approach to this site in the companion study, we predicted effects on perception such that higher temperature and humidity would be associated with greater exaggeration of the steepness of the stairs. Only verbal and visual estimates of steepness were obtained as it is only these measures that reveal exaggerated estimates of stair slope (Eves, 2015).

5.3 Methods

5.3.1 Participants

Pedestrians (N = 307) were recruited while going to or past the station from the University square at the University of Birmingham. Participants were excluded from all the analyses if they had missing data (n=15), believed that all the staircases were 45 degrees (n = 3), failed the test of angle knowledge (n = 28), or gave an angle estimate as vertical or greater (n = 5).

5.3.2 Setting and Stimuli

On the route to University station, pedestrians made perceptual judgements for a 1.02 m high staircase (number of steps = 7, overall angle = 17.9º) by a statue of Faraday on the Edgbaston campus at the University of Birmingham. At this site, a short flight of stairs can be avoided by choosing a ramp to make the climb on the way to the station. The direct route over the staircase to the station, 42.6m, was shorter than the more circuitous route via the ramp, 46.1m.

5.3.3 Measures and Procedures

An observer noted the pedestrian’s approaching the choice point and the direction of their route, i.e. stairs or the ramp, unbeknownst to the pedestrian. Following this, the observer asked individuals if they would volunteer for a study on perception of the environment. Purposive sampling was used in that the observer alternated between those appearing to choose the ramp and those appearing to choose the stairs; the direct route over the stairs require passing on the left-hand side of a tree whereas the ramp was on the right hand side of the tree. Participants willing to be interviewed were directed to stand 3 m away from the base of the staircase and then reported two explicit judgements of slant (verbal and visual) in a counterbalanced order. For the verbal measure, they were instructed to look directly ahead at the set of stairs and then reported the angle of inclination in degrees with respect to the horizontal, having been told 0° was horizontal and 90° vertical. For the visual measure, participants were handed a disk with an adjustable segment and asked to adjust the moveable, blue section to represent the apparent slope of the stairs in cross section (see Taylor-Covill & Eves, 2013a for details of the disk). If participants verbally reported the stairs as 45°, they were asked why they gave this estimate. Participants were excluded if they said they thought all staircases were 45˚.

To assess the validity of participants' perceptual judgements, a test of angle knowledge was performed. After providing perceptual judgement of the stairs, participants were instructed to turn away from the stairs and given the same disk used for visual estimates and asked to produce a 30° angle. Participant's sex was coded from appearance and they self-reported their age, height and weight. Finally, the observer noted the actual behavioural choice made by the pedestrians after the perceptual judgements; 216 chose the stairs whereas 91 chose the slope. This actual choice was used in the analysis. Hourly weather data corresponding to the measurement day, starting from 12:00 until 16:00 was obtained from Winterbourne – University of Birmingham weather station. During data collection period on 22 separate days from June to November 2016, the ranges of temperature and humidity were 7° - 27°C and 39 – 75% respectively, with averages of 15.9° and 61.9%. As in previous studies, temperature and humidity were correlated though less strongly than in previous studies (Pearson's r = -0.43, p < .001); as the day warmed, humidity dropped. To counter this multi-collinearity, humidity was used to predict temperature and the residuals saved for inclusion in the analyses. This resulted in a measure of temperature that was independent of humidity.

5.3.4 Statistical Analysis

Multiple linear regressions were used to predict each perceptual measure with the potential predictor variables of behavioural choice or intention of choice, sex, age, Body Mass Index (BMI), temperature and humidity. There were differences between the sexes in BMI. Therefore, BMI was mean-centred within each sex to avoid confounding of the main effect of sex with weight-related differences. In any follow-up analyses, t-tests were used to assess the means for the sexes and behavioural choices.

5.4 Results

In the final data set, 182 individuals chose the stairs whereas 74 chose the ramp after the perceptual estimates. The sample was, on average, 22.7 years old (*SE* = 0.36) with a healthy BMI (*M* = 22.7, *SE* = 0.24) representing a predominantly student sample that contained 137 males and 119 females. The averages for temperature and humidity were 15.9°C (*SE* = 0.30) and 61.9% (*SE* = 0.39) respectively. More women chose the ramp than men (37.5% vs. 21.2%; Chi Square (1) = 8.59, p=.003) following the perceptual measures.

Table 5.1 contains the standardized coefficients and summarizes the results of multiple regression analysis that included demographic factors and climatic variables for the verbal and visual measures. As can be seen from the table, sex and age have significant effects on slant perceptions. Female estimated greater verbal and visual angles than males (Verbal: females = 43.8° *SE* = 1.4, males = 37.5° *SE* = 1.1; Visual: females = 38.6° *SE* = 1.6, males = 34.1° *SE* = 1.2), though the effect for the visual angle only approached significance in this data set. In addition, the data contain an unexpected effect in that older participants estimated the stairs as less steep than their younger comparators for the visual measure, though there were no significant effects of age for the verbal estimate. In these data, there were no effects of behavioural choice, climatic conditions, or BMI on either estimate of the steepness of the stairs.

Table 5.1 Standardized coefficients for the effects of the choice, demographic variables and climatic conditions on estimates of stair slant.

Variable	**Verbal**	**Visual**
Behavioural choice	-.015	.086
Male < Female	.224***	.115†
Age	-.092	-.174**
BMI, Mean Centred	.032	.077
Temperature residual	-.039	.035
Humidity	.060	.061
Adjusted R^2	.043	.038
F (6, 249)	2.91**	2.83*

Note. † p<.10 *p < .05 **p < .01 ***p < .001

In a subset of the sample (n = 168), data were available about the choice of route prior to making perceptual estimates. Table 5.2 summarizes the results of multiple regression analyses for verbal and visual measures. As can be seen from the table, only sex has a significant effect on verbal estimate.

Table 5.2 Standardized coefficients for the effects of intention of choice, demographic variables and climatic conditions on estimates of stair slant.

Variable	Verbal	Visual
Intention of choice	.044	.053
Male < Female	.247**	.161†
Age	-.084	-.126
BMI, Mean Centred	-.005	.010
Temperature residual	-.052	.001
Humidity	-.097	-.051
Adjusted R^2	.060	.024
***F* (6, 161)**	2.776*	1.688*

Note. † $p<.10$ *$p < .05$ **$p < .01$ ***$p < .001$

5.5 Discussion

The present study was designed to test whether individual choices were related to explicit estimates of the angle of the stairs. In summary, this study did not detect any evidence for a relationship between perceived steepness of the stairs and pedestrians' choice behaviour. In addition, when the intention of choice was involved in the analyses, the result remained the same. The demographic predictor of the behavioural potential of sex was associated with exaggeration in the verbal measure but only approached significance for the visual measure. Nonetheless, females verbally and visually overestimated the angle of the stairs more than males. This results is consistent with the earlier studies of stair perception (Eves et al., 2014; Taylor-Covill & Eves, 2013a, 2014, 2016). In contrast to earlier findings, visual estimates of the angle were lower in older participants than their younger counterparts (c.f. Eves et al., 2014;

Taylor-Covill & Eves, 2016). There was no effect of self-reported weight or climatic conditions on perception.

Proffitt (2006) argued that individuals' availability of energy resources influence explicit perception of the slope. Hills and stairs appear steeper for those with reduced physiological potential for climbing such as women, fatigued pedestrians and the overweight (Bhalla & Proffitt, 1999; Eves et al., 2014; Proffitt et al., 1995; Taylor-Covill & Eves, 2013a, 2014, 2016). The effects of sex here would be consistent with such a suggestion whereas the absence of effects of BMI would not. The latter may reflect the healthy weight nature of the studied population. Unlike the data from Indonesia, (see chapter 3), there were no effects of temperature or climate on explicit estimates. In this UK data set, however, the average temperature, 15.9^{o} C was much lower than that recoded in Indonesia 30.2^{o} C. Temperature, and the accompanying humidity, will only become a barrier to physical activity at temperatures at 25^{o} C or above, a level that occurred for only 10 participants, i.e. 3.9% of the sample. While older participants have also been associated with more exaggerated estimates of steep hills and stairs (Bhalla & Proffitt, 1999; Eves et al., 2014), the converse was found for the visual matching estimate. The staircase here at 17.9° was less steep than tests of potential effects of age in previous studies. Perhaps more importantly, it presented a climb of 1.02m. It is possible that this modest height of climb accounts for the discrepancy from previous research. Taken together, the data here do not indicate a consistent effect of potential resource differences for the modest expenditure required by a 1.02m climb.

In this quasi-experimental study, there was no association between exaggeration of perceived steepness and climbing choice. This result differs from a previous study that reported there was an overestimation of stair angle in individuals who avoided climbing by choosing the escalator (Eves et al., 2014). One possible explanation for non-significant effects of choice is that analyses used the actual behavior of the pedestrians not their initial intentions; although purposive sampling was employed, 70% of the sample actually climbed the stairs. It is possible that some of those who intended to use the slope subsequently used the stairs that were in front of them after they had provided perceptual estimates. This would inflate the estimates of stair slope relative to a sample truly stratified for initial choice. As a result, effects due to time minimization instead of any effects of resources could occur. The distance of the route over the staircase was 3.5m shorter than the circuitous route via the ramp. Perhaps more importantly, choice of the ramp after positioning near the stairs would require a further detour to join the originally intended route. After being interviewed for about five minutes, participants might choose the shorter way to complete their journey despite having originally been walking in the direction of the ramp. In conclusion, these data do not indicate any effects of explicit perception were related to behavioural choice.

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6. CHAPTER SIX

GENERAL DISCUSSION

6.0 General Discussion

This thesis aimed to determine the extent to which the perception of geographical slant was related to the use of resources when pedestrians could climb stairs at potential points-of-choice. Proffitt's economy of action model explained that perception might influence pedestrian locomotor choices. In this research, therefore, demographic differences and physical variables such as climatic conditions in the perception of slant were tested to confirm the model. In addition, both the speed of climbing stairs and speed of walking when approaching the choice points were measured in order to obtain information about the pedestrian's natural climbing behaviour and to estimate the use of resources in walking behaviour.

6.1 Key findings

6.1.1 Perception and resources

In summary, the studies presented in this thesis show some, but not all, of the potential effects of resources on the explicit awareness of geographical slant perception. While Shaffer & Flint, (2011) argued that the estimation of an escalator's slant is exaggerated to the same extent as stairs in explicit awareness, the first study (chapter 2) of this thesis provided different information about the potential effects on perception of moving relative to a stationary slopes. Participants estimated the geographical slant of an escalator that could be either stationary or move in both directions. In this study, verbal and haptic estimates of an escalator's steepness tested the effects of motion on the perception of an escalator. The results showed that the escalator appeared less steep when it was moving away from the participants relative to stationary, whereas one moving towards them did not differ from the stationary escalator. An escalator moving upwards might be attractive to pedestrians, as the perceptual stimulus would indicate a minimization of the resources employed to complete the ascent. As a result, an escalator moving up may look less steep than a stationary one. Meanwhile, climbing escalators that move downwards is an uncommon behaviour; it is possible that descending escalators are not perceived as a slope to be climbed by cognitive processes linked to locomotion. This fact that verbal estimates were influenced by the motion but there was no effect on haptic measures of slant would be consistent with Proffitt's model.

Overall, the estimates of escalator slant in this study were comparable to the overestimates report by Shaffer & Flint (2011); this similarity strengthens the ability to compare the two studies; moving escalators are a problematic stimulus. In Shaffer and Flint's experiment, the design of the study was sub-optimal as they compared a stationary stair with a moving escalator. A further problem may have been the dimensions of each of the stimuli. When a stationary escalator was compared with a moving one, which has the same dimensions, the perception of slant was different due to the influence of the movement. In addition, the different topography between the stairs and the escalator used by Shaffer and Flint in their study needs to be questioned, as the height of each step between the two may influence perception. Warren, (1984) reported that 19.6 – 24.2 cm was the range of optimal heights for energetic cost. The typical height of each step on an escalator is 20 cm, somewhat higher than the dimensions of the stairs in public access (Roys, 2001). Accordingly, the dimensions of an escalator are closer to the optimal height for energetic minima than the regulation height for stairs. As a result, dimensions may influence perception of the slope of escalators and stairs, independently of the actual slope.

6.1.2 Perception, behaviour, and climate

In the second study (chapter 3), the effects of climatic conditions on the perception of the geographical slant and stair climbing behaviour were investigated. For the perception of stairs, participants made two perceptual judgements of the 20-step section of the staircase, namely verbal and haptic, in a counterbalanced order. Further, differences in climate (temperature, humidity) were tested to collect information that would indicate whether these differences were associated with differential estimates of the steepness of stairs to be climbed. The result of this study demonstrated that both temperature and humidity influenced the verbal estimate; as climatic variables increased, perceptions became more exaggerated. In contrast to study two, study four (chapter 5) revealed that climatic conditions had no effects on the estimate of the steepness of the stairs. The greater sample size in the second study (n = 825 vs. n = 268) may make some contribution to the discrepancy of the result between the two studies. Estimated slant in explicit awareness is a multivariate question with many different contributors and large sample sizes will better uncover small effects (Eves et al., 2014).

The study also investigated the speed of ascent of stairs covertly to obtain information about the natural behaviour of pedestrians climbing in different climatic conditions. The findings of the current study were consistent with the study of walking on level ground (Levine & Norenzayan, 1999); the speed of climbing stairs was reduced as temperature increased. Climbing behaviour was relatively unaffected by humidity. The effect of humidity as a variable would be a problem when it is at a high level coupled with high temperatures; when air is saturated with moisture it becomes a primary barrier to heat loss by sweating. In this study, however, the range of humidity on the measurement day was not very high. This condition might explain why humidity has no effect on climbing behaviour. Study three (chapter 4) investigated the effects of climatic conditions on the walking behaviour of pedestrians at an exit from a university campus towards the local station. Consistent with the previous studies, as temperature increased individuals slowed their walking speed (Levine & Norenzayan, 1999). In contrast to the finding in the second study (chapter 3) which reported there was no effect of humidity on speed of climbing, paradoxically, pedestrians walked faster at higher humidity. This result is inconsistent with the physiological explanations. In humid condition, the resources for climbing, i.e. oxygenated blood will be used not only to supply the skin for cooling, but also to support muscle work (McCardle et al., 2007). Accordingly, individuals' walking speed in a humid environment should slow. It seems likely that the data set was poorly conditioned to address the question.

Figure 6.1 below depicts the climate variables in the three studies plotted on the same range for the x-axes across the studies. Consideration of the ranges of temperature and humidity across the three studies may explain the discrepancies between them. As can be seen in the UK, there was a wider ranges of temperature and humidity than that in Indonesia. More importantly, the average temperature in the UK was considerably lower than that recorded in Indonesia. It is almost certain that if the explicit estimate is affected, it would only occur at high level of climate variables. Therefore, the effect of temperature could be found only in Indonesia study. However, the range of humidity in Indonesia was more restricted, with a range of percentages was 47-76%. It is likely that the absence of effects of humidity on behaviour in Indonesia is a result of this condition.

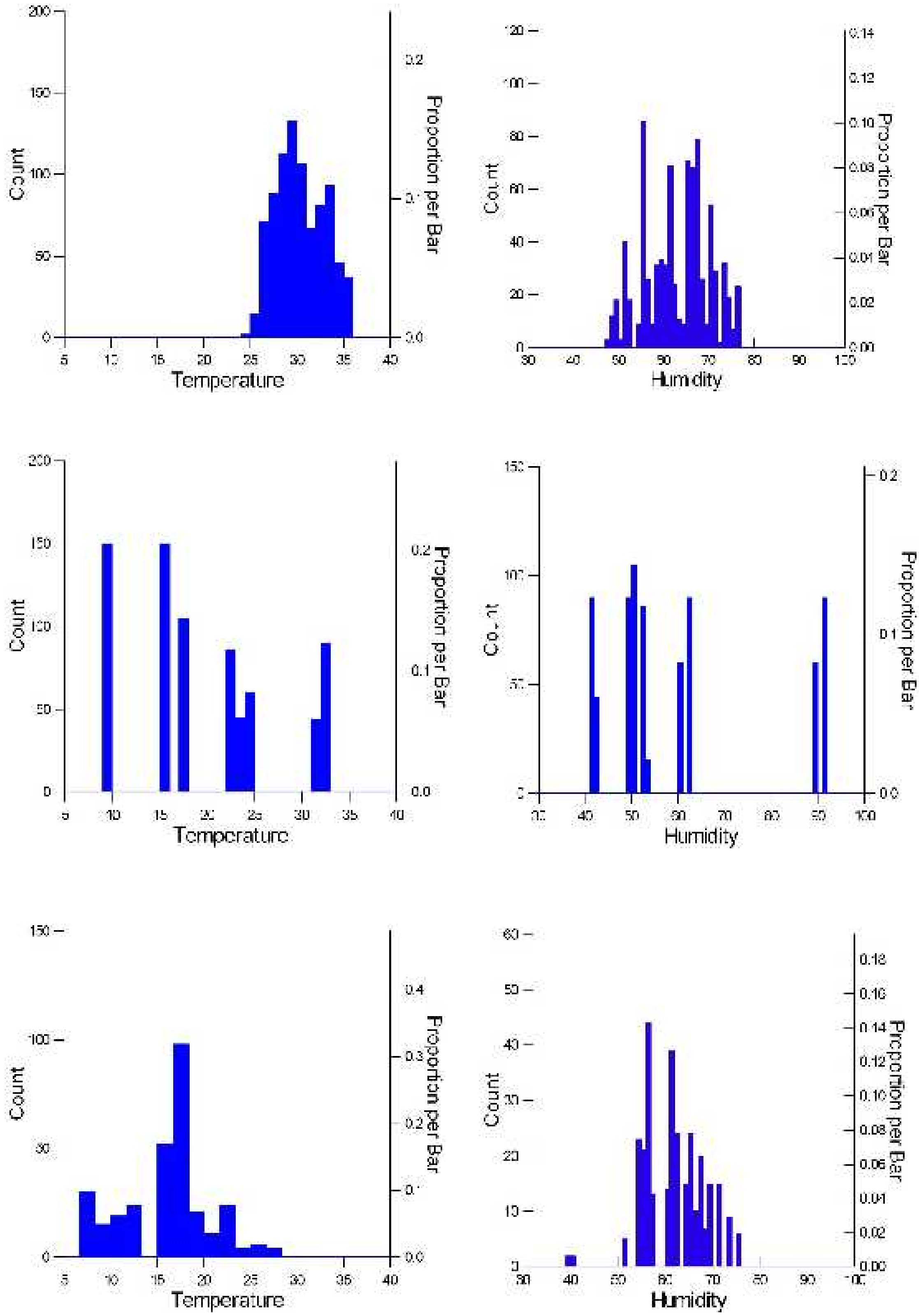

Figure 6.1 Temperature and humidity during an experiment. Upper charts are climate variables during study two conducted in Indonesia. Middle and lower charts are climate variables during study three and four conducted in the UK.

6.1.3 Perception, resources, and behaviour

In chapters four and five, two quasi-experimental studies investigated the behaviour of pedestrians approaching a choice-point between the stairs and a ramp at a university site. These two separate field studies investigated the link between the pedestrians' choice of behaviour and their perception of geographical slant.

Chapter four investigated the use of resources that would be reflected in pedestrians' choice of behaviour. Using walking speed as a variable to estimate the use of resources by pedestrians, this study predicted that a faster speed would require more resources. If stair avoidance is related to available resources, then pedestrians choosing the ramp would walk slower on the approach to the choice-point. The results of this study demonstrated that the speed of walking was clearly related to the choice of pedestrians when leaving the university to reach the nearest train station; individuals who chose the stairs walked faster than those who avoided them. One of factors that can influence individuals in choosing their walking speed may be the purpose of walking itself (Proffitt, 2006). The purpose for the majority people walking in the observed location was to reach the nearest train station. It is possible that time pressure due to the train schedule made some people accelerate their speed *and* choose the shortest path (climb the stairs) to reach the destination. Therefore, the result of this study suggests that the time minimization needed to arrive at the train station provides a plausible alternative explanation to resource issues for differences in walking speed. In observational studies, pedestrian traffic volume has major effects on choice between stairs and an adjacent escalator in stations and shopping malls (Eves et al., 2008; Webb, Eves, & Kerr, 2011). As traffic increases, more pedestrians choose the stairs. Time pressure to leave the station during the rush hour means that any bias to minimize locomotor costs by choosing the escalator is overridden and the stairs become saturated such that 45% of those leaving the train climb them

(Eves et al., 2008). Choosing a site where the possible destination is unlikely to be associated with time pressure would be a better quasi-experimental design to answer this question.

In chapter five, the study investigated the choice of individual pedestrians—whether they avoided the stairs or climbed them. A previous study had reported that resources influenced perceived steepness and pedestrians' behaviour in a shopping mall (Eves et al., 2014). Therefore, this study set out to test whether these individual choices were related to perception of the stairs. Contrary to expectations, this study did not find a significant relationship between perceived steepness of the stairs and pedestrians' behaviour. This result differs from the previous study in which individuals who avoided stair climbing by opting for the escalator subsequently exaggerated the angle of the stairs they had avoided more than those who chose to climb (Eves et al., 2014). Once again, time pressure might be provide an explanation for non-significant effects of choice instead of any effects of resources. Although purposive sampling was employed to interview equal numbers of stair and slope users, 70% of participants climbed the stairs after the interview. It seems that their actual behavior was not their initial intention for some of these pedestrians. After being interviewed for about five minutes, participants might choose the shorter way to reach their destination despite having originally been walking in the direction of the ramp. Although separate analysis of the initial intention for route, prior to making perceptual judgements has been performed for a subset of the data, there was no relationship between perceptual measures and their intended route. Failure to record the original choice for all participants before perceptual estimates rather than the choice after the interview severely limits the conclusions that can be drawn from this study.

6.1.4 Demographics

Across four studies, participant demographics were included in all analyses. Consistent with previous studies, sex was associated with exaggeration in the verbal and visual estimates (Eves et al., 2014; Taylor-Covill & Eves, 2013a, 2014, 2016). Females verbally and visually overestimated the angle of the escalators and stairs more than males. Concerning the reported effort to climb a staircase remote from the escalator in study 1, sex was also associated with estimates of individuals' effort to climb the stairs; females reported more effort than males. There were no effects of demographic variable of sex on haptic estimates throughout the studies in this thesis. The different perceptual estimates between males and females in explicit awareness is relevant to Proffitt's resource model. Proffitt, (2006) suggested that the overestimation of perceived steepness allows individuals to manage their energy resources for planning locomotion efficiency such as walking and climbing. As females have less physiological resources for climbing than males, they would require a higher proportion of their available energy resources than men when given any kind of locomotor challenge. Not only in slant perception, differences by sex were also evident in their choice of behaviour. In the second and third studies, the speed of both climbing stairs and walking on the level was related to sex differences; men climbed and walked faster than women.

The effects of age on perception were not as consistent as effect of sex across three perception studies presented in this thesis. In study one, there were no effects of age on the verbal estimate of the steepness of the escalator. As noted earlier, it is possible that the reduced cost of escalator use diminishes the potential effects of resources when estimating its steepness. Riding on the escalator appears to be the default behaviour to reach the top. As a result, the perception of escalators may not be associated with climbing behaviour in the way that stairs must be. Consistent with previous studies, the results of study two and four demonstrated the association between the demographic predictors of behavioural potential of age and exaggeration in explicit estimates (Eves et al., 2014; Taylor-Covill & Eves, 2016). In contrast to earlier findings, in study four, only the visual estimate of the angle was significantly greater in older participants than their comparators, though the direction of effect for the verbal estimate was consistent with previous reports. Once again, haptic judgments were unaffected by any differences in ages. For the effect of body mass in studies 1, 2 and 4, there was no association between self-reported weight and perceptions. In contrast, BMI was associated with estimates of the effort to climb stairs in study 1, with increasing estimates of effort for increasing weight. Additionally, those coded as overweight walked slower than their healthy weight comparators in study 3. As noted in the introduction, BMI is a variable that summarises both the dead weight of fat mass that must be carried up the stairs and the muscles, bones, cardiovascular and respiratory systems that provide the force for the climbing (Eves et al., 2014; Taylor-Covill & Eves, 2016). BMI is an imperfect variable for tests of effects on perception, particularly so if self-reported with the resultant error that is entailed. Objective measurement of weight in the field would be preferable to reduce contributions of variability from self-report.

6.2 Strengths and limitations

6.2.1 Research design

Quasi-experimental designs were employed in all the studies in this thesis. The participants were recruited in the field during naturally occurring pedestrian behaviour as part of their daily lives. With the exception of studies 2 and 3, between-group designs were used. Unlike most previous studies in the field of geographical slant (e.g. Bhalla & Proffitt, 1999; Proffitt, et al., 1995), pedestrians were interrupted while on a journey that included the stimuli for which estimates were obtained. While Proffitt and colleagues used the hills as stimuli in their studies, in these experiments here participants judged the slant of stairs and escalator within a built environment to collect data concerning potential determinant of choice behaviour related to resources. As a result, perception related to actual behaviour was measured. Similarly, in chapter 4, the walking speed of pedestrians was recorded covertly using a stopwatch and then their choice of behaviour was coded, i.e. whether they subsequently climbed the staircase or chose the ramp. In addition, in the third study weight status was coded from appearance using separate silhouettes for men and women as to whether the pedestrian was overweight (BMI > 25) to optimise coding of this demographic.

6.2.2 Measurements

Standardized estimates of slants were provided by all participants in a counterbalanced order. For the verbal measure, participants were instructed to look directly at the stairs and escalators and then to estimate the angle of inclination in degrees with respect to the horizontal, having been told 0° was horizontal and 90° vertical. For the visual measure, participants were handed a disk with an adjustable segment and asked to adjust the black section, which represented the apparent slope of the stairs and the escalators in cross-section. These measures are equivalent to those employed by Proffitt and co-worker allowing meaningful comparison between the two series of studies. For the haptic measure, participants used a Palm-Controlled Inclinometer [PCI; see (Taylor-Covill & Eves, 2013b)], a measure that has been shown to be more accurate than a palm-board for the relatively steep slopes that are characteristic of stairs. Using the same equipment for a visual measure, testing the knowledge of the angle was performed only in study four, where the visual judgement was involved. The absence of the angle knowledge test in study one and two is considered a potential limitation of the results for verbal estimates; without tests of angle knowledge, it is impossible to exclude data from participants that may have been unreliable due to limited knowledge of actual angles. As a result, increased variance would occur in the models. For both climbing and walking speed, the data were collected using a stopwatch covertly; there can be no effects for demand characteristics when a participant does not know they are being measured. Finally, hourly weather data corresponding to the day of measurement were obtained from Winterbourne, University of Birmingham weather station and Adi Soemarmo, Surakarta Indonesia weather station from professional measurement. Nonetheless, there may have been local variations in climate at the testing sites that were near, but not exactly at the same location as the weather stations.

6.2.3 Sample size

Large sample sizes have been presented in every study in this thesis. For example, chapters two and three involved 870 and 825 participants respectively for geographical slant perception. These sample sizes are larger than any previously presented in this experimental field. Using large sample sizes in quasi-experimental designs across studies in this thesis was necessary if potential random processes related to uncontrollable participant demographics were to be assessed. Given the ubiquitous effects of sex in previous studies, and throughout this thesis, stratified sampling of equal numbers of men and women occurred throughout. Any variables that could co-occur with sex, e.g. BMI, were mean-centred within each sex to avoid confounding sex differences with other variables. Concerning factors that influence explicit reports and behavioural choices, a multivariate statistical analysis is required to reduce potential bias and determine unique quasi-experimental effects for each demographic factor. Therefore, large sample sizes were required to support such an analysis. As presented in study one, for example, multiple regressions were used to predict each perceptual measure with the potential independent predictor variables of direction of movement, sex, age, BMI, as well as the self-reported estimates of effort for climbing and self-efficacy for brisk walking.

6.2.4 Generalisation of findings

Over the past decade, there has been a debate on the effects of resources on perception, which was originally presented by Proffitt and colleagues. Recently, perception studies have shown that demand characteristics in an experiment influenced explicit estimates (Durgin et al., 2009, 2012). Durgin and colleagues were dubious about the generalizability of the effects of resources on everyday perceptions of the natural environment. Supporting Proffitt's model, however, Taylor-Covill & Eves, (2014, 2016) suggested that changes in estimated steepness are influenced by the availability of individual resources and being encumbered by a biological backpack.

By employing a quasi-experimental design in the field, this thesis generally confirmed Proffitt's economy of action model. In the studies here, participants were tested individually and behaviour measured covertly; effect of experimental demand would provide an unlikely explanation for any effects that were found. Chapters two and three in this thesis suggest that the effects of resources on everyday perception generalise to the built environment, and further to locomotor behaviour. Additional evidence that Proffitt's model can be generalised is provided in study 2 of this thesis. Without interviewing participants, the potential effects of demographics and natural variation in climate on behaviour and perception were tested. The evidence suggests that higher levels of climate variables that act as a potential barrier to being physically active were associated with increased exaggeration of the explicit perceptual signal that can deter behaviour. Intriguingly in this study, both temperature and humidity influenced perception, whereas only temperature influenced climbing behaviour. This suggests that the changes in environmental cues that may affect behaviour could be observed first in perception and subsequently on behaviour. It is possible that choosing the speed required to climb the stairs, individuals may implicitly 'consider' their resources based on explicitly perceived angle. As Proffitt (2006) pointed out, perception may allow pedestrians to function without having to actively think about their resources.

Chapters four and five were planned as complementary part of a study that investigated the behaviour of pedestrians approaching a choice-point between stairs and a ramp, a novel choice in the literature, and tested if these individual choices were related to perception of the stairs. Although the result revealed that there was no significant relationship between perceived steepness of the stairs and pedestrians' choice behaviour, an explanation concerning resources indicated that Proffitt's model was relevant to this study. Individuals who chose the stairs walked faster than those who avoided them. This effect, coupled with consistent effects of demographics related to climbing resources, would extend Proffitt's model to actual locomotor behaviour. Consistent with Eves, (2014) and Proffitt, (2006), demographic groups with reduced resources (women and overweight) slowed their pace and avoided the stairs when an alternative method was available. Once again, the potential demographic predictors of reduced resources (females and older) overestimated the angle of the stairs more than their comparators. This results is consistent with the earlier studies of the perception of stairs (Eves et al., 2014; Taylor-Covill & Eves, 2013a, 2014, 2016).

6.3 Future directions

Chapter two showed that an escalator moving away from the participants was associated with a reduction in explicit estimates of steepness, whereas one moving towards them did not differ from the stationary escalator. My results suggest that an upwardly moving escalator might be interesting to a pedestrian, as the perceptual stimulus would indicate a minimization of the resources needed when getting to the top. As a result, it may look less steep than a stationary one. However, more research on this topic needs to be undertaken before the association between resources and perceived steepness of escalators is more clearly understood. In this study, the escalator had a single speed and it is unknown whether differences in speed would be associated with differences in perception. Further studies, which compare the potential effects of different speeds of escalators might be informative. Pedestrians making a journey often seek to minimize the time required and variation in speed would provide clues to the rate of ascent. The logistics of such a study should not be underestimated.

Especially in chapter three, the study was conducted in Indonesia, a tropical country, which was recently categorised (correctly) as the least physically active country in the world (Althoff et al., 2017). Evidence suggested that climatic conditions influenced both the perceived steepness of stairs, and climbing behaviour of Indonesians. In addition, previous studies have reported that cultural context and changes in any environmental cue (climatic conditions) can be barriers to lifestyle physical activity (Frank F. Eves et al., 2008; Frank F. Eves & Masters, 2006; Puig-Ribera & Eves, 2010). In future investigations, therefore, it might be possible to compare geographical slant perceptions and both walking and climbing behaviour between Indonesian and non-Indonesian visitors at a site where tourists are more plentiful.

6.4 Conclusion and implication

This thesis aimed to determine to what extent embodied perceptions could explain pedestrians' choices of behaviour within the built environment. Chapters two, three, and five supported the original model of the economy of action account and confirmed the generalisation of the model to the built environment, including in a non-English speaking population.

Chapters three and four provided evidence that natural variation in climate not only affect explicit perceptions but also directly influences walking and climbing behaviour among pedestrians. This thesis also confirmed the consistent effect of the demographic factor of sex on geographical slant perception and behavioural choices. In summary, these findings suggest that, in general, the economy of action model of perceived geographical slant provides a parsimonious explanation that there may be a tendency to avoid stair climbing when alternatives with lower energy cost or rate of energy expenditure are available. This information, therefore, might be used to develop stair climbing interventions aimed at public health concerns such as obesity and other problems caused by physical inactivity. Any factors that influence the perception of stairs may help to design interventions to increase stair climbing within the built environment.

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