Inside The Crowd

A natural experiment analyzing the effects of crowding on passenger comfort and safety perception at Amsterdam Airport Schiphol

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“To use a psychological metaphor, we tend to think of a
crowd as having one personality. What we usually consider in planning for an event has been the size of the crowd, crowd capacity, crowd movement and/or demographics. Important as these may be, they do not tell us the particular type of crowd for which we must be prepared.” — *Alexander E. Berlonghi*

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Chapter 1: Introduction

In the last century, our society has become a world in motion (Franko Aas, 2007). Globalization is often the term referred to, when describing a variety of economic, cultural and societal developments that have shaped our current civilization (Song et al., 2018). Societies that used to be separated by space and time, have become interconnected by the unfailing motion of flows and increasing human mobility (Rumford, 2006). The simplicity of human movement across the world has led to a normalization of air travel, resulting in practical implications for mobility centers in complex transportation networks.

Alongside globalization, travelling has become more common and an increasing amount of people fly multiple times every year for work or recreation (Statista, 2019). As a consequence, airports become more crowded and are forced to adapt to this growing demand for travelling (Schiphol, 2016). Crowd management, which includes “all measures taken in the normal process of facilitating the movement and enjoyment of people” (Berlonghi, 1995, p. 240), has increased in significance. Even though most crowds are safe, some are dangerous. A mass of people can spark a common understanding about a situation, generating collective behavior and potential massive force effects (Henein & White, 2005; Miller, 2013). Therefore, crowds entail a huge safety risk.

Inadequate crowd management causes injury and death every year (Working With Crowds, 2019). Most often, crowds disasters happen during large organized events (Dirk Helbing & Mukerji, 2012; Nederlandse Omroep Stichting, 2010), but accidents can happen when people gather no matter the reason. Amsterdam Airport Schiphol has recognized this risk and has committed to improve their crowd management techniques (2019a, 2019b).

Many scholars have tried to calculate the risks and associated safety measures for crowd disasters. However, this proves to be a challenging task due to the amount of variables involved. Nevertheless, the field of crowd management has come a long way in identifying walking patterns in both normal and crisis situations, based on mathematical models, simulations and observational studies. Additionally, the subjective experience of crowding and related safety of individuals in crowds has been analyzed. However, until now, these studies have not been able to connect specific experiences to different levels of crowding. Furthermore, research on how individual characteristics influence the perception of crowding remains inconclusive. Therefore, the research question is as follows: how do different levels of crowding affect individual safety perceptions and comfort? This study aims to contribute to the knowledge about crowd management by studying crowd perceptions and to deliver expertise to Schiphol Airport.

Following this introduction, a literature review analyses the current body of knowledge in the field of crowd management. Next, the theoretical framework positions this research project in the existing literature and operationalizes the related concepts. The fourth chapters describes the research method, followed by the presentation and analysis of the results. The thesis ends with a conclusion and discussion of limitations.

Chapter 2: Literature Review

2.1 Pedestrian movements

To understand how crowd disasters can develop it is important to analyze the existing body of literature on crowd dynamics. A crowd is defined as an "agglomeration of many people in the same area at the same time" (Dirk Helbing et al., 2013, pp. 2). In order to comprehend the transition from a crowd moving freely towards a crowd disaster, both studies on pedestrian dynamics under normal circumstances and in critical situations are included in this literature review.

Fluids and particles

In order to study crowds, many scientists have turned to the field of physics. Scholars try to make analogies between crowd dynamics and other movements that can be observed in nature. Henderson was one of the first who saw similarity between the patterns of movement of gas particles, described by Maxwell and Boltzmann, and the movements of pedestrians in a crowd (1971; Meyers, 2011). Gas particles ought to be moving completely at random, which is similar to the collective emergent behavior that results from individuals that interact in a large group. However, when the crowd becomes more dense, the analogy no longer applies and the movements become similar to the characteristics of a fluid (Henderson, 1971). Since Henderson's comparison was based on simplified assumptions, the analogy was in need of improvement.

In reaction to this, Helbing (1992) developed a theory that describes the analogy between ordinary fluids and pedestrians, but in contrast to Henderson it takes into account the intentions and interactions of human beings. The theory states that pedestrians move with an intended velocity and that they change direction to avoid interaction processes. In common terms, a person can walk with a certain speed but finds an object in its path: to prevent collapsing into the object, the person adjusts its direction of movement. This behavior is similar to the movement of the water around a stone in the river and is often referred to as the path of the least effort (Zipf, 1949). Nevertheless, the theory has its limitations. Keith Still addresses multiple situations whereas crowds do not behave like fluids (Still, 2000, pp. 15–17). For example, in contrast to fluids, a crowd moves faster at the sides than in the center (Daamen & Hoogendoorn, 2006). Additionally, fluids always distribute evenly across the space where crowds do not. Still explains these differences by identifying the assumption that individuals can freely move across the available space (Still, 2000, p. 16). This is not always the case, since people can compete for space in certain environments creating constrictions in their movement, like in front of a stage. Thus, there are similarities between crowd dynamics and flows of fluids. However, crowds consist of human beings with a choice of direction and the ability to stop or start at will.

Still also proposes a new theory about the movements of human behavior in crowds, including individual behavioral aspects (2000). He describes the path of the least effort but adds the human factor of deciding on a destination. Where gas particles and fluids are directed by physical forces, a human can choose the objective. Therefore, the path of a pedestrian follows the shortest route, or least effort, to reach the chosen destination (p. 7). In case of a crowd, multiple focal routes cross and become interfered. The addition and interference of focal routes create patterns that provide an explanation for the dynamics of crowds. This differs slightly from patterns seen in particles, since their movement is exclusively determined by force and not linked to a chosen destination.

Pedestrian Traffic

In the same line of reasoning, Fruin proposed in the 1970's the perspective to see pedestrian movements as traffic flows (Fruin, 1971). He observed different levels of freedom to select the desired walking-speed or the ability to adjust the route. The desired speed is the walking velocity of a pedestrian when he or she is not hindered by other pedestrians (Daamen & Hoogendoorn, 2006). Depending on the amount of pedestrians in an area, the individual freedom to follow their path differs and this corresponds with a different Level of Service (Table 1) (Fruin, 1971, pp. 7–8). Additionally, the number of conflicts varies, defined as "any stopping or breaking of normal walking pace due to close confrontation with another pedestrian" (Fruin, 1971, p. 4). Conflicts occur more often in higher Levels of Service. Fruin observed these Levels of Service in different circumstances (Table 2).

These observations seem to be correct although several situations contradict his findings. For example, the marching of soldiers enables movement within a small area per person because their movement is coordinated and directed to the same goal. Additionally, case studies show that crowds with a high density are congested, but not unable to move as Fruin suggests (Still, 2000). Thus, the observations of Fruin seem to be correct until the crowd reaches a high density because people are able to coordinate, or in theoretical terms 'self-organize', and find the ability to move in a congested environment (Still, 2000).

The ability to self-organize is a logical consequence of the principle of the least effort (Still, 2000; Zipf, 1949). The concept is used throughout the whole field of crowd dynamics and refers to “spontaneous organization . . . not induced by initial or boundary conditions, by regulations or constraints" (Dirk Helbing et al., 2013, pp. 2) and implies that “these patterns are not externally planned, prescribed, or organized . . .”(Dirk Helbing et al., 2001, p. 368). It is the result of a heterogeneous flow that adapts to the circumstances until a homogenous flow appears (Hoogendoorn, 2005). To put it more clearly, a heterogeneous flow consists of multiple pedestrians with different desired walking speeds, all choosing a different path and speed that requires the least effort to reach the destination. However, this heterogeneity increases the probability to collide, or to conflict, with other pedestrians and therefore increases the need to bypass. As a consequence, individuals adjust their behavior to the pedestrians in their direct surroundings, leading to the formation of homogeneous groups.

In the same line of reasoning, pedestrians walking in two directions adjust and form lanes by moving aside or create diagonal strips in case of crossing flows (D. Helbing et al., 2000; Dirk Helbing et al., 2000; Hoogendoorn, 2005). Adjusting the route to avoid collision is called the ‘evasive effect’ (J. Lee et al., 2016). The ‘following effect’ describes the adjustment in behavior to follow other pedestrians that move in the same direction (2016, pp. 12–13). Both effects diminish the probability of collision and result in a higher walking velocity (2016, pp. 16–17).

Table 1. *Levels of Service (Fruin J. , 1971)*

	Description	Conflicts
A	The area is sufficient for pedestrians to move freely at their desired pace	Free Flowing
B	The area is sufficient for pedestrians to maintain normal walking speed. Crossing of routes exist and minor conflicts will occur.	Minor Conflicts
C	Pedestrians experience restricted freedom to select individual walking speed or passing opportunities. There is a high probability of conflict.	Some Restrictions to Speed
D	The majority of the pedestrians are restricted in walking speed and bypassing. The density causes momentary stoppages of flow.	Restricted movement for most

E	All pedestrians experience restricted movement. Reverse- and cross-flow paths are extremely difficult.	Restricted movement for all
F	The individual freedom of movement is extremely restricted for all pedestrians. Only shuffling-movement is possible in forward motion. There is frequent unavoidable contact between pedestrians.	Shuffling movement for all

Table 2. *Level of Service Category – Fruin (in (Still, 2000, p. 24))*

Level of Service	Square meters per person related to this Level of Service category					
	A	B	C	D	E	F
Walkways	> 3.25	3.25 to 2.32	2.32 to 1.39	1.39 to .93	.93 to .46	< .46
Queuing Areas	> 1.21	1.21 to 0.93	.93 to 0.65	.65 to .28	.28 to .19	< .19

Self-organization is taken a step further with the explanatory social-force model (Dirk Helbing et al., 2001; Dirk Helbing & Molnár, 1995). This model explains pedestrian behavior as a reaction to a stimulus, in which the reaction depends on personal aims (pp. 4282-4283). In Helbing & Buzna (2013) they elaborate on this model, stating that the organizational aspect of crowds is the result of simple interactions between the individuals, which results in automatic adjustments in behavior. This is demonstrated by the formation of stripes in intersecting flows or the appearance of lanes in crowded areas. (pp. 10-13). Helbing explains this automatic organizational behavior by means of evolutionary game theory, arguing that individuals adjust their strategy after they learned from similar situations they experienced themselves or saw by others. Thus, the social force model assumes that an individual tries to move in a desired direction with a desired speed to arrive at the destination at a certain time. When the individual encounters obstacles or conflicts, it adjusts its strategy by choosing a different path and/or changing its walking velocity.

This model is consistent with the proposed ‘path of least effort’ from Still (2000). Additionally, it is partly in line with the Level of Service model of Fruin (1971). People changing their strategy to reach their destination in time fits with the idea of passing opportunities and adjusting speed. In contrast to the model of Fruin, the social force model incorporates not only the ability to bypass or adjust speed, but also the ability to adjust their walking pattern and strategy completely, resulting in movement even in high density situations.

In case of transportation areas like airports, an additional factor contributes to the self-organization dynamics of pedestrians: the weaving phenomenon. “A traffic phenomenon that more than two pedestrian crowd flows with transfer purpose confluence or shunt continuously in a short distance” (Yao et al., 2012, p. 2). In other words, pedestrians move into the spaces between other pedestrians in a pattern that is similar to woven threads or braids. As a result, stripe and lane formation (Helbing et al., 2013) occur, referred to as ‘cross weaving flow’ and ‘forward- and lateral weaving flow’ in the weaving phenomenon. However, the additional factor in the weaving process is the constraint in space and time. The path of pedestrians in transportation areas is relatively fixed compared to pedestrians on the street or shopping areas. Therefore, their route is more constraint. Second, since the pedestrians are bound by their plane departure, they are limited in time. Projected on the social force model, the desired time to arrive at a destination is particularly inflexible. As a result, collisions happen more frequently. (Yao et al., 2012).

2.2 Crowd movements

The section above provides insight in the current knowledge on pedestrian dynamics in normal and low-density situations. However, any situation can evolve into a high-risk scenario. For example, an emergency can alter the pedestrian movements in one preferred direction, creating higher densities in specific areas. Critical situations are characterized by the emergence of alternative behavioral patterns of the pedestrians. The transition from self-organization to alternative patterns is not yet understood, but it is clear that the density of the crowd plays a significant role. In high density conditions, a crowd no longer follows the movements of fluid but shows similarities with granular matter (Hoogendoorn, 2005; Daanen & Hoogendoorn, 2006).

Granular matter is the agglomeration of macroscopic, solid particles like rice or sand. The pattern that is seen both in granular matter as well as in high-dense crowds is jamming (D. Helbing et al., 2000). Hereby, the viscosity between individual particles increases when the density increases, causing velocity to slow down or even stop and to form a jammed mass (Dirk Helbing et al., 2013, pp. 17–26). ‘Jamming’ is mostly seen in front of a bottleneck, which is described below, but the characteristic that viscosity increases when the density increases, plays an important role in other patterns as well. Multiple patterns that are seen in critical crowd situations can be distinguished and are described in the following section.

Faster is slower

One of the observed effects is the ‘faster is slower effect’, first noted by Helbing in a pedestrian behavior model (Dirk Helbing et al., 2000). It describes the delay in pedestrian flow due to the occurrence of blockages (Parisi & Dorso, 2005) and increased frictional forces (Parisi & Dorso, 2007) when individuals increase their desired walking velocity in high density crowds. Thus, individuals who want to walk faster experience increased frictional forces, similar to granular matter, and obstacles resulting in a slower walking pace: the faster is slower effect. The social force model can explain this effect; As a consequence of a trigger, individuals adjust their desired arrival time at the desired destination. Next, they adjust their velocity and walking pattern to reach this goal. However, in high density there is limited space to coordinate movement and thus the amount of conflict increases and eventually delays the pedestrian flow. In worst-case scenarios, these processes can cause ‘phantom panic’, due to the increasing physical pressure which results in an increasing desire to leave and reach the desired destination (2013, pp. 19–20).

This theory is supported by recent experiments with granular materials (Gago et al., 2013) and humans (Garcimartín et al., 2014). In the last experiment, students were asked to evacuate a room in two sets. In the first set, they were asked to leave the room as fast as possible but ‘pushing’ or ‘elbowing’ was not allowed. In the second set, these elements were allowed and thus interpersonal viscosity was increased. The results showed that the students evacuated the room faster in the first set than in the second set, proving the ‘faster is slower’-effect. Thus, this effect demonstrates that during specific circumstances the self-organization can become inefficient and result in congestion.

Non-separation

Another observed effect is the lack of lane formation, or ‘non-separation’ (Dirk Helbing et al., 2001). Helbing dedicates this to the increase in fluctuation in extreme conditions (D. Helbing et al., 2000). When pedestrians are in a highly stressful environment, they lose their tendency to follow a specific path and therefore increase their fluctuations of movement through the area. This disintegrates the previously self-organized lanes. Besides the lack of lane formation, the fluctuations can lead to blockage of the flow. (Dirk Helbing et al., 2001, p. 369). The process starts with an increased width of lanes and a decrease in number of lanes

(Meyers, 2011, pp. 702–703). Unfortunately, detailed understanding of the transition from self-organized separation to a non-separation pattern has not yet been established.

Crowd turbulence

Another dynamic that can be observed is the emergence of crowd turbulence. This term is attributed to the process of random, involuntary movement of the crowd. People in the crowd are not able to move individually anymore as the crowd is only capable of mass-motion. Sudden changes in acting forces can cause people to fall or stumble (Dirk Helbing et al., 2013). Inside a crowd, densities can differ. Empirical studies demonstrate that the average density rarely exceeds 6 people per m^2 but that local densities can reach almost double this value (Dirk Helbing, Johansson, & Zein Al-Abideen, 2007). Parts with a lower pedestrian density can move towards pedestrian flows that contain a high density. This can cause shockwaves, also known as stop- and go waves (Dirk Helbing et al., 2006; Virkler & Elayadath, 1994), "a boundary in a pedestrian stream that represents a discontinuity in the flow-density domain" (Sun et al., 2018, p. 2). This pattern was first observed in car traffic, in case free highway traffic arrives at a traffic jam (Lighthill & Whitham, 1955). An empirical study demonstrated that stop- and go waves can transform into crowd turbulence in case the density increases even more (Dirk Helbing et al., 2007). Observation studies of granular movement show stop-and-go waves and clogging, or jamming, effects (Dirk Helbing et al., 2013, pp. 17–26). In human behavior, this is projected in the stopping of an individual until space opens up and the individual moves again (stop-and-go) as well as the eventual clogging of an out-flow if individuals lose their patience and move forward without the opening of space (p. 20) increasing the compression of the crowd. The dynamic of shockwaves is mostly seen in front of bottlenecks.

Bottlenecks

There is no agreement in the literature about the exact definition of a bottleneck. In logistical studies a bottleneck is referred to as a disturbance of traffic as a consequence of a specific physical condition. They cause congestion and queuing upstream of the bottleneck and a free flow downstream (US Department of Transportation, 2016), due to the bound merging of traffic or pedestrian lanes. An example of traffic settings where bottlenecks occur is a situation where a multiple lane highway merges into one lane, resulting in a traffic jam upstream. In crowd studies, bottlenecks can be small doorways or the transition from a room to a hallway. Multiple studies have been devoted to describing the walking patterns across bottlenecks (Dirk Helbing et al., 2006, 2013; Still, 2000; Sun et al., 2018). A detailed literature review about these studies extends beyond the scope of this project. However, bottlenecks only cause congestion or jamming in case of higher densities, since pedestrians can pass bottlenecks freely in lower densities. Therefore, the jamming effect that is seen in granular material can be compared with high density crowds and provides an indication of a turbulent flow instead of free flowing pedestrians (Dirk Helbing et al., 2013). This proves to be of high risk in situations where the inflow is significantly higher than the outflow or if people are ‘panicking’ (Dirk Helbing et al., 2013).

Two types of panic can be distinguished. The first type, acquisitive panic, occurs when people are experiencing a strong desire to reach a certain goal and is often referred to as a ‘craze’. The second, escape panic, describes the same process but presents the desire to move away from a source of (perceived) danger. In both situations people start to become competitive and together with the high density, additional frictional effects occur and the earlier mentioned ‘faster is slower’-effect arises, potentially in combination with jamming (Dirk Helbing et al., 2013). Helbing uses the term ‘panic’ to describe the behavior of a crowd mass in response to a perceived threat (2013). However, panic is a contested term which is addressed later in this literature review.

Empirical studies of crowd dynamics and disasters have observed multiple features that appear in high density circumstances (Dirk Helbing et al., 2000; Dirk Helbing et al., 2007; Kelley, Condry, Dahlke, & Hill, 1965; Still, 2000). These features are summarized in Table 3 (Dirk Helbing et al., 2013) and are consistent with the observed patterns described above.

Table 3. *Features typically seen in crowds at extreme densities (Dirk Helbing et al., 2013).*

	Behavioral features in extreme densities
1.	Blind actionism
2.	Attempt to move faster than normal
3.	Pushing and physical interaction
4.	Uncoordinated movement in bottlenecks
5.	Development of jams, intermittent flows and clogging
6.	Increase in experienced physical pressure
7.	Sudden change in acting forces, potentially causing people to fall
8.	Fallen or injured people form obstacles for escaping people
9.	Herding behavior
10.	Lack of usage of alternative exits

Altogether, the existing literature has come a long way in understanding crowd dynamics in different situations. Under normal conditions, pedestrian movement can be explained by the social force model, resulting in self-organization (Dirk Helbing & Molnár, 1995). This is characterized as a free flow dynamic. Crowds at risk are observed to behave differently, mainly due to a high density of people. This results in a lack of self-organization and additional dynamics like clogging and shockwaves (Dirk Helbing et al., 2000; Still, 2000). In 2016, similar findings were combined in a framework in order to understand and diminish risks of crowd disasters (Wieringa et al., 2016). The framework consists of a flowchart of four layers of development. The first layer describes free flow of crowd with efficient self-organization. The second layer states an instable flow in which the self-organization became in-efficient. Next is crowd turbulence with accounts for pre-disaster phenomena and the last layer is the development of a crowd disaster. All layers are subdivided into different processes that characterize the flow, like pushing or herding. (Wieringa et al., 2016).

The framework is meant for events in public areas but since the development of crowd disasters follows the same steps in all contexts, it is applicable in a wide variety of settings. The flowchart that is presented in the framework corresponds with the findings from the literature review and earlier crowd disaster studies (Dirk Helbing et al., 2013; Dirk Helbing et al., 2007). Interesting to note is that they included the level of stress in the different layers in the framework as 'low', 'high' and 'max'. However, this is not based on scientific research and lacks detail on the experience of individuals in the crowd during the different layers. (Wieringa et al., 2016). The perception of the identified dynamical patterns in crowds, such as turbulence and non-separation, can affect the perceptions of safety and comfort of people moving in the crowd. Therefore, this must be accounted for when studying the perception of safety in crowding. The next session elaborates on the factors influencing perception.

2.3 Patterns in perception

In general, the perception of individuals in crowds has not been extensively researched. However, it is connected to the umbrella of research into emotions and feelings, including the feeling of safety. Often, safety is defined as the inverse of risk but others argue that such a definition is insufficient, since risk is a vague concept itself and does not include all dimensions of safety (Möller et al., 2006). First, Möller argues the difference between absolute safety and relative safety. Absolute safety describes that risk can be completely eliminated, which is similar to the argument that safety is a binary value: something can be either ‘safe’ or ‘unsafe’ (Brown & Green, 1980). On the contrary, relative safety claims that risk can only be reduced to a certain level (Möller et al., 2006), as a continuous variable, for example: cycling with a helmet is safer than without. (Brown & Green, 1980). From this perspective, it is useful to distinguish between risk and a hazard. A hazard is “Anything with the potential to cause injury or ill health, for example chemical substances, dangerous moving machinery, or threats of violence from others” (Health and Safety Authority, 2016, p. 3). In contrast, risk is a value of probability and describes the chance that a hazard will cause harm (Health and Safety Authority, 2016). Therefore, safety measures, like a helmet, decrease risk.

A comparison to the economic theory of maximizing utility provides more insight into the value of safety: an individual always attempts to maximize utility and to choose one state as preference above another state, judged on the perceived value of both states. Therefore, utility is a personal construct. From this perspective, maximizing safety can be seen as a type of maximizing utility. An experiment supported this comparison, asking respondents to indicate their level of satisfaction with different levels of safety (Brown & Green, 1980) and similar methods have been used regularly since then (Cheah et al., 2012; Mearns et al., 1998; Morral et al., 2015a, 2015b). Psychological research has shown that the satisfaction with different levels of safety is related to the degree of controllability (Möller et al., 2006) for example: individuals perceive flying as less safe than driving, due to the low degree of control by the passenger (Slovic, 1987). This perception does not necessarily correspond with the objective safety; it only makes the person feel safer.

Altogether, it is possible to sum up two conclusions. First, subjective safety, or the perception of safety, is a perception determined by many different (environmental) factors. Second, subjective safety is not necessarily equal to objective safety.

Behaviour in the crowd: Competition or cooperation?

Building on that, one important element in the perception of safety is generalized belief: individuals share a common understanding about a situation, an object or ideology. The understandings are “simplistic and emotion-provoking explanations of ambiguous situations created by structural strain” (Miller, 2013, p. 8). A generalized belief can cause a transformation from individual behavior to collective behavior, where control over the action is given to others instead of the self (Coleman & Coleman, 1994; Le Bon, 1896), often referred to as mass psychology (Dirk Helbing et al., 2013; Miller, 2013). The result is conformity (Schmöcker, 2013) and the imitation of the behavior of others (Dirk Helbing et al., 2013), a process which is also known as ‘herding behavior’.

Multiple theories exist about the psychological processes that underlie conformity and collective behavior, ranging from the intrinsic desire to compare one's self to others, to the contagiousness of behavior. (2013, pp. 3–8). An example of a generalized belief that results in collective behavior is the understanding that something is a potent threat, leading to a mass flight response (Miller, 2013). Simulations show that neither herding behavior nor individualistic behavior leads to efficient evacuation, since herding leads to congestion and individualism implies that all pedestrians need to find the exit on their own (Dirk Helbing et al., 2000). Thus, one hypothesis is that an optimal evacuation procedure requires a mixture of herding and individualistic behavior. However, this has yet to be tested. Other possibilities might require types of behavior that have not been identified yet.

Collective behavior is often studied in connection with the emergence of panic, starting with the work of LaPierre (in Quarantelli, 2001). LaPierre described panic as dysfunctional escape behavior. Since then, the main discussion in this subfield evolves around the nature of panic. One of the first sociologists studying this subject conceptualized 'panic' into four elements: a) hope to escape through dwindling resources; b) contagious behavior; c) aggressive concern about one's own safety; and d) irrational, illogical responses" (Keating in Rita F. Fahy, 2009, p. 4). Publications from the early 20th century argue that the overwhelming emotion of those in panic mode, can evoke the same reaction in others and can therefore be labeled as contagious (Quarantelli, 2001). Empirical studies from the same time period support these claims (Cantril, Gaudet, & Herzog, 1940). Thus, the field of sociology was dominated by the belief that panic was irrational and competitive behavior.

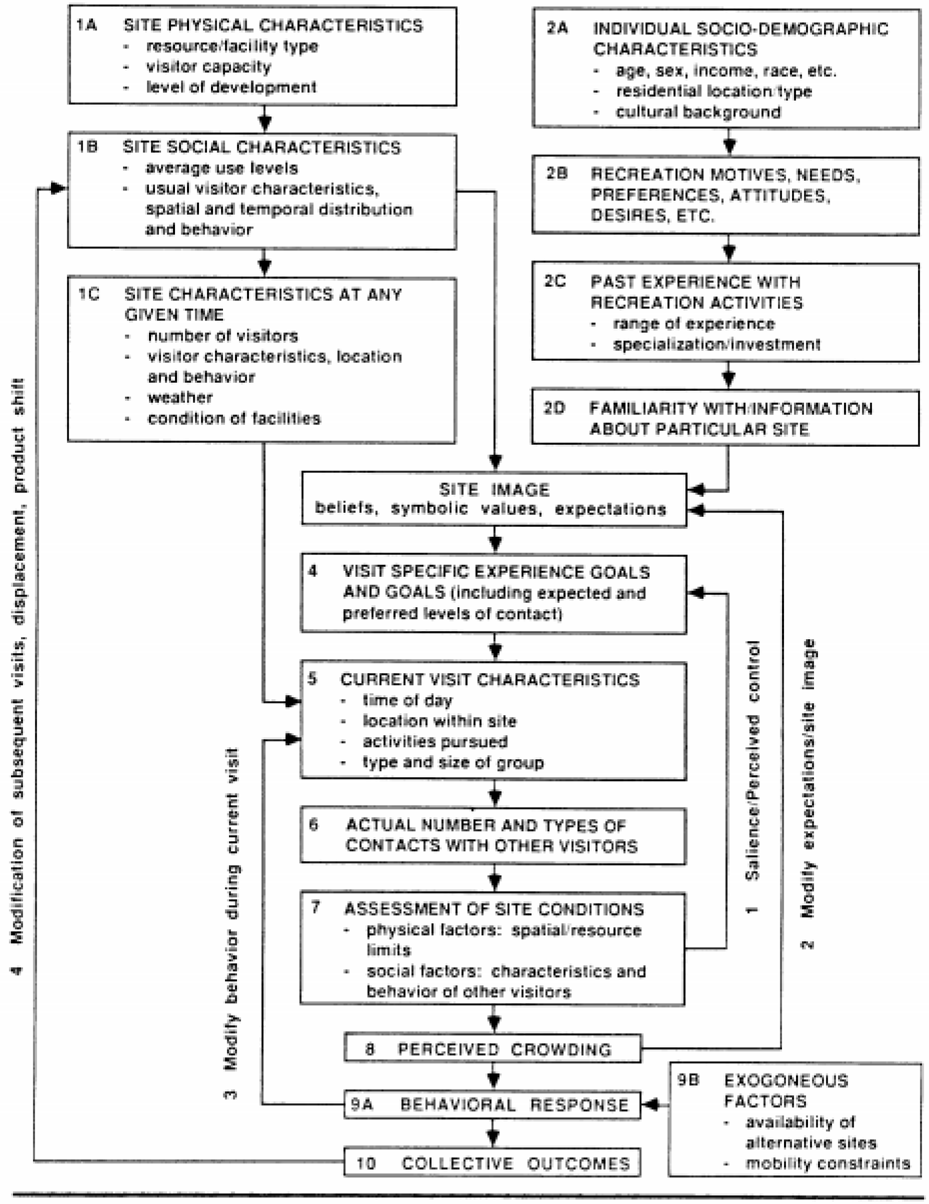
In the second half of the 20th century, this belief started to shift. The empirical studies of Cantril, Gaudet & Herzog are now heavily criticized on their methods (1940) and recent studies contradict them with observations that cannot be explained by unregulated competition (Cocking et al., 2009; Johnson, 1987) or irrationality (Rosengren in Quarantelli, 2001; Rita F. Fahy, 2009). Instead, they argue, an emergency situation can create the feeling of a common identity which results in cooperative behavior rather than competitive (Cocking et al., 2009; Johnson, 1987). Additionally, when seen from the perspective of the actor, behavior in emergency situations is logical and rational (Quarantelli, 2001). Recent empirical studies demonstrate a lack of response from spectators, rejecting the contagious element, and argue that mainly media platforms create a frame of mass panic (Rosengren in Quarantelli, 2001).

To sum up, panic is no longer seen as irrational but is understood as rational behavior that is often combined with cooperative elements instead of competition. Additionally, panic is not contagious but it can be attributed to a generalized belief that a situation or an object is a threat that leads to collective behavior.

Perception of safety

Two publications from the early nineties are key for how we understand perception of safety within crowds. In 1989, Westover elaborated on the experience of crowding by demonstrating the influence of visitors expectations of the site, on their perception (1989). Additionally, the perception can change over time due to the adjustment of those expectations (1989, p. 260). Westover illustrated the relationship between the environment, the perception and the adjustment of behavior into a model, shown in Figure 1. The importance of environmental factors and personal motivations has been supported by case studies of neighborhoods (Naceur, 2013; Odufuwa et al., 2019) and shopping centers (Ceccato & Tcacencu, 2017). Additionally, a study about perceived safety inside an airport shows that the satisfaction with safety is determined by environmental factors, like cleanliness and overall maintenance, as well as the travel experience (Ceccato & Masci, 2017). This is similar to the 'broken windows'-theory from the field of criminology (Kelling & Wilson, 1982). This theory states that disorderly conditions and untended behavior in a specific environment create the idea of 'not caring' and abandonment, which induces more vandalism and crime. The study of Ceccato & Masci demonstrates that the environment does not only influence the probability of crime but also the perception of probability of crime and therefore the perception of safety (2017).

Figure 1. General Model of Recreational Crowding (Westover, 1989, p. 261)



In 2018, Alkhadim et al. developed a model to study subjective safety in crowds, derived from a theory of Fruin from 1993 (2018, p. 30). Fruin described four key risk factors that influence objective crowd safety, or ‘crowd disaster’ (Alkhadim et al., 2018). The first risk factor Fruin mentioned is ‘force’. Crowds can contain forces up to 4500 N as a result of people pushing and leaning. Due to these forces, individuals become unable to expand their lungs and die of suffocation, or compressive asphyxiation. The second element is ‘information’, which includes all sights and sounds that affect the perception of the crowd. Information can cause certain reactions or behavior. Additionally, the capacity of the spaces determines the degree of crowding. Therefore, the third element is ‘space’. Finally yet importantly, the timeframe in which densities occur plays a role in the development of a crowd disaster. The duration of the incident and the flow rate for example, are important factors and make up the fourth element ‘time’. Together, these elements are referred to as ‘FIST’. (Fruin, 1993).

In 2018, the FIST elements were adjusted to ‘perceived force’, ‘perceived poor information’, ‘perceived insufficient space’ and ‘perceived real time management’(Alkhadim et al., 2018). Related to the scope of this study is the connection between perceived insufficient space and perceived safety. Alkhadim revealed that individuals feel more safe in higher levels of crowdedness (Alkhadim et al., 2018). However, the study was performed on pilgrims during Hajj. Earlier findings revealed that social identification within a crowd leads to strong cohesion and positive feelings, which is considered to be high among religious crowds (Alnabulsi & Drury, 2014; Kim et al., 2016). Thus, the question still remains how perceived insufficient space is connected to perceived safety. Additionally, this relation appears to be influenced by different factors, like social identification. Therefore, the next section is dedicated to the existing theory about the influence of different factors on the relationship between perceived insufficient space and perceived security.

Influential factors

The relationship between perception and behavior is influenced by a variety of factors. Alkhadim mentioned four different categories of potentially influencing factors that originate from the individual: physical, physiological, psychological and personal (2018). These categories leave out motives and environmental factors, as for example the characteristics of a location. In this review, the factors are divided in three categories: personal factors, situational factors and environmental factors.

Personal factors

The current body of literature about individual characteristics and their influence on the perception of safety under the circumstance of crowding is minimal. However, these factors have been researched in other contexts and provide insight in potential effects. In order to analyze the influence of different factors, it is necessary to differentiate between effect on the perceived insufficient space and the effect on perceived safety.

Perceived insufficient space has often been researched in the context of perception of crowding. Studies support the idea that different age groups experience crowding differently (Jin & Pearce, 2011; Jurado et al., 2013; Rasoolimanesh et al., 2016). Jin & Pearce demonstrated that people between 18 and 24 years old are most concerned about crowding, compared to other age groups (2011). More specific, 18-24 year olds expressed a lower tolerance of crowding levels and more concerns about crowding in relation to the environment. However, individuals above the age of 40 prove to be more sensitive to crowding and thus assess a situation more early as crowded than younger people (Jurado et al., 2013). Thus, age can be of influence on the perception of insufficient space.

Additionally, the effect of gender has been studied with mixed results. The perception of crowding among tourists in China showed no differences in gender (Jin & Pearce, 2011) while the study of tourists in Malaysia determined a significant effect of gender on the same dependent variable: perception of crowding (Rasoolimanesh et al., 2016). Another study from 2017 supported the claim that man and women do not perceive crowding differently (Hoskam, 2017). Thus, the potential influence of the factor gender remains inconclusive.

The third factor that has been studied is nationality. Multiple studies have demonstrated that different nationalities experience crowding in a different matter (Jin & Pearce, 2011; Neuts & Nijkamp, 2012; Rasoolimanesh et al., 2016). For one, Jin & Pearce found that domestic visitors are more sensitive to crowding than foreign tourists (2011). Second, Asians seem less susceptible to crowding than other nationalities. Additionally, an experiment from the late seventies examined the role of interpersonal distance preference and its influence on stress related to crowding (Aiello et al., 1977) and this relation is supported by the outcome of experiments in 1991 and 2019 (Engelniederhammer et al., 2019; Sinha & Sinha, 1991). Building on that, the preference of interpersonal distance varies across cultures (Beaulieu, 2004; Lomranz, 1976). As culture is highly related to nationality, it is possible to argue that nationality can influence perceived insufficient space both directly as well as indirectly, via the factor ‘culture’. The exact effect of individual cultures on this relation remains yet to be studied.

A fourth element that has been studied is the factor of experience. For this study, this can be sub-divided into travel experience and familiarity with crowded areas. Jin & Pearce argued that people with a lot of travel experience, more than 10 trips in 5 years, are less worried about crowding than other visitors (2011), which is supported by Hoskam (2017). For familiarity, Neuts & Nijkamp demonstrated that individuals with more experience in crowded situations are less likely to assess a situation as crowded (2012). Hoskam found that people that live in more densly populated areas, perceive less crowding due to the fact that they are often exposed to similar situations (2017). Thus, the expected relation is that higher level of experience in crowded situation leads to lower perceived insufficient space.

Another factor is education, again with mixed results. Rasoolimanesh used a questionnaire with a Likert scale with 1 stating ‘not at all crowded’ and 4 ‘extremely crowded' to measure the perception of crowding (2016). He found that higher educated individuals perceive less crowding. However, these results are inconsistent with the conclusions from an earlier study in 2013; Jurado concluded that highly educated tourists are more sensitive to crowding than individuals with lower levels of education (2013). Additionally, it is possible that a correlation exists between high education and travel experience, influencing the results of the studies mentioned above. Therefore, no conclusion can be drawn about the effect of education. All mentioned personal factors with the expected effects are summarized in Table 4.

Table 4. *Individual characteristics and their expected effect on perceived insufficient space*

Factor	Expected effect
Age	Lower tolerance of crowding between the age of 18-24 Higher perceived insufficient space >40 years of age
Gender	Inconclusive
Nationality	Perceived insufficient space varies across different nationalities
Travel experience	More experience with traveling decreases perceived insufficient space
Familiarity	More experience in crowding decreases perceived insufficient space
Education	Inconclusive

The variable of perceived safety is more difficult to pin point. First, safety perception does not have one supported definition and is often used interchangeably with subjective safety and perception of risks. Additionally, being or feeling 'safe' can be seen along many dimensions, depending on the risk that is studied. However, some characteristics of individuals can be identified to be of influence to the perception of safety in its most general form.

The effect of gender has been studied most often, however with mixed results. In a study of perceived risk of victimization while out after dark, females reported lower levels of perception of safety than men (McGrath & Chananie-Hill, 2011). Lower perceptions of safety among women is supported by other studies (Hoskam, 2017). However, a study about safety in schools did not support these differences (Adams & Mrug, 2019). Additionally, some studies show effects of age, nationality, being the ethnic minority, status and experience (Adams & Mrug, 2019; BATRA, 2008; Cummings et al., 2013; McGrath & Chananie-Hill, 2011). Altogether, these studies support the idea that perceived safety is a personal construct and is influenced by a variety of individual characteristics.

Situational factors

Literature demonstrates that besides individual characteristics, aspects about the situation influence perception as well. This category can be subdivided into the individual level and the trip level. On an individual level, multiple studies show that the emotional state of individuals influence their perception of safety and their behavior (J. Y. S. Lee et al., 2001). Also the use of stimulants such as alcohol or drugs, can influence the perception of safety. On the trip level, studies have identified two types of pedestrians (Iliadi, 2016). The first type has a predetermined goal, which is determined by decision style of the individual or the purpose of the trip. The second type behaves intuitively, without the urgent desire to reach a certain destination. It is suggested that the first type experience crowding more negatively. Besides pedestrian type, studies about groups show that the size of the group influences behavior and environmental perception (Hoskam, 2017; Zuurbier, 2019). As mentioned earlier, the factor of social identification with a group of people has a large effect on how crowding is perceived (Alnabulsi & Drury, 2014; Kim et al., 2016; Novelli et al., 2013). This is the case at, for example, religious gatherings or large cultural events.

Environmental factors

Many characteristics of the environment influence perception and emotion. The architecture of the location (Kendrick & Haslam, 2010), lighting (Ariffin & Zahari, 2013; Boyce et al., 2000; Hagen, 2011) sound and noise (Bruner, 1990; Cameron et al., 2003; Li, 2019), weather (Andrade et al., 2010; Li, 2019), all effect the perception of safety, comfort levels and perception of crowding. The lack of lighting causes lower perceptions of safety, although the exact preferences depend on the situation. Music can improve the atmosphere and increase safety perceptions but noise can inspire fear and influence the perception of crowding. The weather mainly influences the comfort levels. Bad weather causes a negative mood in crowds.

Chapter 3: Theoretical Framework and Operationalization of Variables

The literature review identified several relevant theories to address the main research question: how do different levels of crowding affect individual safety perceptions and comfort? The first important theory explains the relation between the density of moving individuals and patterns of movement (Dirk Helbing & Molnár, 1995; Henderson, 1971; Still, 2000). Moving individuals have specific dynamics that are seen in crowds with low densities, causing people to be able to self-organize their movements (Dirk Helbing et al., 2013; Dirk Helbing & Molnár, 1995). These low densities cause a free flow of pedestrians (Fruin, 1971).

The second category involves crowds with higher densities. Higher densities create patterns other than self-organization and free flow (D. Helbing et al., 2000; Dirk Helbing et al., 2001; Parisi & Dorso, 2007) but similar to granular matter. The resemblance between this element and crowd dynamics lays within the increased viscosity between individual particles in higher densities (Dirk Helbing et al., 2013, pp. 17–26). Due to this increased viscosity, multiple patterns occur such as 'the faster is slower effect' and 'non-seperation' (Parisi & Dorso, 2007). Additionally, these patterns are associated with an increased risk of crowd disaster (Still, 2000; Wieringa et al., 2016). The distinction between patterns in low densities (normal) and higher densities (risk) are stated in Table 5.

Besides patterns related to risk in crowd dynamics, there are also relevant theories about the perception of these risks (Brown & Green, 1980; Möller et al., 2006). First, the perception of safety is determined by many different environmental factors. Second, subjective safety is not necessarily equal to objective safety. Additionally, this perception can be influenced by a generalized belief leading to collective behavior which is highly relevant in the context of crowds (Coleman & Coleman, 1994). My literature review links the patterns in different densities to the perception of safety by analyzing the perception of insufficient space. This perception is influenced by different individual factors like age, gender, nationality, travel experience and goal orientation (Jin & Pearce, 2011; Jurado et al., 2013; Rasoolimanesh et al., 2016).

To sum up, the identified patterns in high-density crowds contribute to the recognition of risk in crowds. However, even though these patterns can be recognized, it remains unclear how an individual in different levels of crowding experiences them. This research aims to contribute to the field of crowd dynamics and safety by bridging this gap. To do so, it uses a questionnaire within the setting of a field experiment.

Table 5. *Characteristics of crowd dynamics in normal and risk situations*

	Crowd dynamics	
	Normal	Risk
Physical dimension	Lane formation Stripe formation Free flow	Lack of lane formation Lack of separation Faster is slower effect Crowd turbulence Shockwaves Clogging Increased physical interaction
Psychological dimension	Individualism	Blind actionism, collective behavior Increase in experienced physical pressure

3.1 Operationalization

Level of crowding

In order to find a suitable method to gain insight in how different levels of crowding affect individual safety perceptions and comfort, the related concepts need to be defined and operationalized. As stated in the first paragraph of the literature review, a crowd is defined as an “agglomeration of many people in the same area at the same time” (Dirk Helbing et al., 2013, pp. 2). The independent variable ‘levels of crowding’ is thus understood as a variance in the number of people that has agglomerated, expressed as the number of people in a certain area. During the data collection, the different levels of crowding are defined by use of the maximum capacity based on evacuation time (BRIS, 2012). This process is described in more detail in chapter 4. Thus, the objective level of crowding can be determined. However, as discussed in the literature review, previous research has indicated that the perception of crowding is not necessarily directly linked to the actual crowding levels (Alkhadim et al., 2018; Zuurbier, 2019). Individuals experience crowding differently. Therefore, both objective crowding as well as the perception of crowding are included as independent variables in this study.

Zuurbier suggests that the factors that influence perception of crowding can be divided into 5 categories: Safety, Comfort, Ambiance, (objective) Crowdedness and Attractiveness (2019). Alkhadim used four different dimensions but those can all be subdivided into the categories of Zuurbier (2019). Thus, ambiance and attractiveness are included as variables, besides safety and comfort that are discussed in more detail below.

Perception of safety

Perception of safety varies between individuals and will be measured as a continuous variable. One situation or environment can feel more or less safe to an individual than another situation or environmental setting. Moreover, safety can be measured along different dimensions. This is indicated by previous research about perceived safety that showed that, when asked about safety in general, people often automatically refer to social safety (Zuurbier, 2019). Alkahadim successfully used the following indicators to measure perceived safety related to crowding: 'Perceived risk of Fatalities', 'Perceived risk of Damaged facilities', 'Perceived Risk of falls, Slips and Trips' and 'Perceived Risk of Trampling or Stampede' (2018). As this research focuses on risk for the individuals and due to the limited survey space, the 'perceived risk of damaged facilities' is left out as an indicator. The included indicators measure perceived safety for the risk of physical harm due to crowding. However, as mentioned before, perceived safety largely depends on the state of mind (Möller et al., 2006). Therefore, it was deemed necessary to add another indicator of perceived safety: comfort.

Earlier research identifies two relevant dimensions of comfort: physical and psychological (Pearson, 2009). The first describes a physical sensation where 'comfort' is designated as positive whereas other elements are negative sensations. Psychological comfort indicates the emotional well-being and positive mental state of an individual (Williams et al., 2017), often referred to as the level of stress. Therefore, in my study comfort is measured in both the physical dimension as well as the psychological dimension.

Physical comfort as a dimension of perception of safety can be affected by the patterns identified in crowd dynamics, as described in last paragraph of section 2.2. The patterns are shown in table 3. All identified patterns relate to increased physical contact or the avoidance of it. Therefore, physical comfort accounts for these patterns by using two measurement indicators. First, the level of physical comfort is determined by the need to adjust a chosen path either in speed or direction. As Fruin discovered in his research in the 1970's, increasing levels of crowding decrease the free flow and therefore create the necessity to adjust the original path (1971). This provides information about possible emergence of the faster-is-slower effect, separation and lane formation. The second indicator of the level of physical comfort is the experienced physical contact and related violation of personal space. Higher levels of crowding will, naturally, cause more physical contact between individuals. The physical contact increases with higher levels of crowding and results in the emergence of crowd turbulence, clogging, shockwaves and physical pressure.

Psychological comfort has been successfully measured with various scales in the last decade. These scales are designed to function in a specific situation in an optimal way. For this study, it is difficult to choose one of these existing scales. First, most of them are very extensive and would take too long if included in a survey for this study. Second, psychological comfort in relation to crowding specifically has been measured using only one or two of the questions from these extensive scales. Even though most questionnaires are too long, limiting the measure of psychological comfort to only one or two indicators would offer a very limited insight into the level of comfort that individuals experience. Therefore, this study uses a self-created scale adjusted to this specific setting, both in length as well as in content. It is based on the existing scale PEECE: "Patient Evaluation of Emotional Comfort Experienced" (Williams et al., 2017). This scale, containing twelve items, has been used successfully to study the emotional comfort of patients during hospitalization. All items on the PEECE questionnaire used 'I feel …' with five possible responses ranging from 'not at all' to 'extremely'. The scale was adjusted[1], leaving a six question scale to measure psychological comfort[2].

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[1] The question-items 'Calm', 'At Ease', 'Content', 'In Control' and 'Informed' were included. Several questions in the PEECE scale were specifically designed to indicate the quality of care takers and were therefore removed ('Thankful', 'Valued', 'Cared for'), others were related to recovery from illness ('Energized') or less related to emotional well-being in crowds ('Smiling', 'Relaxed'). The last factor in the PEECE scale ('Safe') was omitted since it is already a part of the study.

[2] One type of psychological state is the 'generalized belief', as explained in the literature review. This state can lead to the emergence of herding- or collective behavior and a potential mass flight response. However, previous research has shown that individuals are most often unaware of collective behavior (Kelley et al., 1965). Thus, a survey is not suitable to test this perception. Therefore, this dimension is excluded from this study.

3.2 Hypotheses

The literature review reveals multiple hypotheses of relations between variables. This section states all hypothesis that are studied in this research.

General hypotheses

1. Higher levels of crowding decrease the perception of safety
2. Higher levels of crowding decrease physical comfort
3. Higher levels of crowding decrease psychological comfort

Social demographic hypotheses

1. Older people feel less safe and comfortable in higher levels of crowding than younger people
2. Women feel less safe in all levels of crowding than men
3. Domestic visitors are more sensitive to crowding than people with other origins
4. People with more travel experience feel more safe and comfortable in higher levels of crowding than people with less experience
5. People in larger groups are less comfortable with higher levels of crowding.

Chapter 4: Method

The following chapter elaborates on the research method. This study is interested in the effect of different levels of density of crowd on the comfort and safety perception of individuals. In order to investigate the effect of the level of crowding on the well-being of individuals, I conducted a natural field experiment. This method offers the possibility to measure the dependent variable, perceptions of safety and emotions, at naturally occurring variety in levels of the independent variable, the density of crowd. I conducted the field experiment by using natural occurring variety in density at an airport.

The Flow Measurement System provides precise estimates of the independent variable, the density, and allows me to know the level of crowding for each individual's location. I used a survey to measure the dependent variables with a carefully constructed questionnaire. I repeated the study in different spaces at the Schiphol airport. More details about the selection of locations, the measurement of the independent and dependent variables, the sampling technique and the administration of the questionnaire are provided in this chapter. Finally, I discuss the pilot that I ran to pre-test the set-up of the study and its implications for the final design.

4.1 Area Selection

Amsterdam Airport Schiphol is a network of different areas with a variety of functions. Connected to these functions are variations in accessibility. For example, a departure hall is accessible for everyone. People come here to say goodbye to friends or family, who will check-in for their flight. Areas behind the security check are not accessible for non-travelers but this compartment has different layers of accessibility as well. In sum, the areas at the airport differ in demographic profile depending on its accessibility and functionality. This research studies three areas: 'Departure Hall 2', 'Lounge 4' and 'C-Pier'.

The choice which areas to include is based on functionality, expert judgment and crowding data. One criterion was that all areas must vary in functionality and therefore accessibility. An area with a lounge function creates a different atmosphere than an area where people have to wait or be checked by security. Analyzing a variety of functions creates the opportunity to compare and increases insight in operational processes concerned with crowding at the airport. Another criterion was the added value of insight in crowding in an area, based on judgment from safety experts. They assessed the chosen areas as most valuable for the operation. The last criterion is the crowding of the area. To be able to study different levels of crowding, it is necessary that the area often entails these levels. The chosen areas are all selected because of their variety in levels of crowding, including both quiet moments as well as crowded periods.

Based on these criteria, the chosen areas of study are the ‘C-Pier’, the ‘Departure Hall 2’ and ‘Lounge 4’. The characteristics of the areas are displayed in Table 6. In the following section, all areas are described into further detail.

Table 6. *Functionality, Accessibility and Operation of the Three Studied Areas*

Area	Functionality	Accessibility	Operation
Departure Hall 2	Check-in counters	Open access	Departure
C-Pier	Connection between lounge area and gates	Travelers, staff	Arrival, Transfer and Departure
Lounge 4	Relax and shop before take-off	Travelers, staff	Departure

The departure halls at Schiphol Airport serve to check-in all passengers for their upcoming flights. The area is accessible for everyone and pedestrian flows enter from other departure halls, Schiphol Plaza or outside. However, it is mainly used by departing travelers with their entourage and staff. Departure Hall 2 consists of check-in desks, a coffee bar and access to the security filters and the mezzanines. The hall is functionally divided into waiting areas (check-in counters) with 1781 square meter useful floor space, and flow areas with 1957 square meter useful floor space (Büttner, Christensen, Kasper Halbak, Grecu, et al., 2019; Drewes et al., 2018).

The C-pier at Schiphol Airport is used for docking airplanes in order to ease passenger flows in- and out of the plane. It consists of a long hallway with some catering venues and gates on either side. The pier has two floors but only the first floor is used in this study. In this area, there are three passenger types: arrivals, departures and transfers. The C-pier has 8555 square meter useful floor space (Büttner, Christensen, Kasper Halbak, & Foged, 2019; Valkonet, 2009).

Lounge 4 is a relatively small area with a few shops and cafés. It consists of 1935m^2 useful floor space and is dedicated for passengers passing the security check and now in wait for their gate display. Therefore, mainly departing passengers occupy the lounge. The only exceptions are arriving passengers that missed the sign to the exit and therefore entering the lounge accidentally (Büttner et al., 2018).

4.2 Data collection methods

This research studies the effect of different levels of density of crowd on the comfort and safety perception of individuals. A constructed survey measured the dependent variable during a certain level of crowding. The survey was created using research software Qualtrics and distributed to individuals at Schiphol airport by handing them an iPad with the survey. It was available in 5 languages: Dutch, English, Spanish, French and Arabic. In order to include the passengers in haste, cards with a QR-code were distributed. The QR-code redirected to the survey and could have been used at any time until the questionnaire was closed. Since it is a field experiments and respondents had limited time to fill in a questionnaire, the survey was designed with a limited number of questions and fast reply options.

Survey questions

The survey consisted of multiple sections. The first section included questions about socio-demographics and trip factors. The factors age, gender and nationality are highly relevant and easy to include in the questionnaire. Travel experience provides information about the familiarity with airports as well as with the process of travelling itself. Therefore, this was included as a question. The studies about the effects of education level were so far inconclusive. This may be because it is a difficult variable to operationalize. Education can be related to income, but does not necessarily has to be so (Jurado et al., 2013; Rasoolimanesh et al., 2016) . Additionally, different levels of education are not easily comparable across different nations. Due to these complexities and the limited length of the survey, this study excluded the factor education from the survey.

From the situational factors, the emotional state is a complex variable. Previous studies showed that emotions are difficult to express and do not always reflect the situation (Zuurbier, 2019). Due to the interest of this research in the comfort levels, the emotional state was measured as a mental comfort scale, which is more precise and easy to answer. The influence of alcohol and drugs at the airport was considered minimal because of security reasons. Additionally, their effect on safety and crowding perception is small. Therefore, this was not included in the survey. Other situational factors such as goal-orientation, urgency and group size and –composition have proven to be of great influence and were therefore included in the survey.

The environmental factors are the third category that needs attention. Since the independent variable varied in a constant space, the architectural effect did not affect the studied relationship. Unfortunately, there was no possibility to measure the amount of lighting in the area of measurement. As a solution, questions were added about the perception of light and the level of comfort related to lighting.

Crowd dynamics

Amsterdam Airport Schiphol makes use of a Flow Measurement System (FMS) to measure passenger flows throughout the airport. In order to do this, FMS uses Blipnode sensors and Blickstream people counter sensors. Blipnode sensors are able to detect and track mobile devices of passengers, based on their Bluetooth and Wi-Fi signals. Every mobile device regularly probes for Bluetooth access points and Wi-Fi networks, if these functions are enabled. When probing, the mobile device sends a package of data via radio waves. These packets can be registered and identified as a unique identity by Blipnode sensors. (Christensen & Büttner, 2019, pp. 4–7). Blickstream people counter sensors are placed at entrances and exits of areas and count all people passing through. This technique has an accuracy of at least 95% but higher rates are possible (2019, p. 13). Both techniques are combined to determine the area occupancy: “the amount of persons within this areas’ predefined boundaries” (Christensen & Büttner, 2018, p. 3). All sensors were fine-tuned in order to achieve an accuracy of “nearly 100” with a validation test. This test has been performed in all areas included in this research. (Christensen & Büttner, 2018).

Levels of crowding

The FMS system measures the occupancy in the studied areas in real time. The levels of crowding to compare are established in relation to the fire safety standard. This standard determines the maximum amount of people allowed in an area, based on the time needed to evacuate in case of emergency. The levels display a specific percentile of the fire safety standard. The exact range depends on the available occupancy during data collection.

4.3 Pilot

The data collection for this study contained a two-month period. In order to make sure the method worked as intended and the survey questions were clear and valid, a pilot was conducted.

The survey was distributed among individuals in the areas. In order to evaluate the survey, time measurement was added to see how long respondents spend on certain questions. Additionally, some questions had an extra text-box as answer option to determine if answer options are missing. On a similar note, an extra open question was added to the pilot in order to evaluate if all significant emotions were covered in the standard questions. All verbal comments and questions from respondents were noted.

Results

The pilot was performed without any major concerns. Some small changes had to be made in the survey due to a translation mistake and a missing question. The questions with an open text box were evaluated on missing multiple-choice options. As a result, one answer possibility was added. Additional to the content of the survey, some operational difficulties were noted. First of all, respondents may have to leave before they finished the survey due to, for example, their plane leaving. This results in incomplete responses. Additionally, it is necessary that the researchers approach all people in the area at random. During the pilot, some people were difficult to reach due to other people standing around them. All researchers received explicit instructions about this aspect.

4.4 Execution of the research

In area 1, 2 & 3, passengers check-in, relax & shop or arrive from their flight. In 24 hours, these areas experience different crowding levels due to the logistical planning of plane departure. Data collection took place over the course of 6 weeks. During these weeks, the surveys were manually distributed and collected via iPads among the passengers in the areas. Individuals that were waiting, shopping or walking around were easily targeted. QR-codes were distributed in order to include the hurried respondents. All responses were connected to different levels of crowding by comparing the time of reply to the FMS data. In order to reach a similar amount of responses for every crowding level in every area, a crowding forecast was used. This forecast provided a six-week timeframe of all areas in sections of 15 minutes, displaying the predicted crowd. As a result, specific crowding levels were targeted to balance all responses. The data was analyzed using Multiple Regression Analysis.

Evaluation of execution

The research was conducted successfully and without any major issues. However, a few difficulties arose. First, the higher levels of crowding were much less common than lower levels. Therefore, it was a challenge to balance the amount of respondents in all levels of crowding. Second, on one of the data collection days, the FMS malfunctioned. This led to the inability to collect data on that day. Furthermore, over 200 QR-codes were distributed but only three replied to the questionnaire. Consequently, people in haste are significantly under-represented in the collected data.

Alternative methods

As all methods, the natural field experiment has limitations which are discussed in Chapter 6. Due to these limitations, alternative methods were considered. This section argues why the chosen method was preferred above other options.

One to consider is an observational study. However, this study is interested in the perceived safety, comfort and perceived conflicts of individuals inside different levels of crowding. These states of mind are difficult to observe accurately from the outside. Therefore, observational methods are not suited for this research.

Another option would be to conduct a controlled experiment instead of a field experiment. An important advantage of a controlled experiment is the possibility to study the relationship between the independent variable and the dependent variable while eliminating all covariates. However, this is not feasible for multiple reasons. First, simulating an airport is extremely difficult and extensive, which does not fit the scope of a thesis project. Additionally, it is impossible that a simulated airport environment evokes all internal, emotional processes that are present during the time that a person is actually in an airport. For example, it makes a difference if someone just travelled on a long, inter-continental flight and is ready to head home or if someone arrives at the airport to depart for holidays. Furthermore, it matters if people have been at this airport before and what nationality they have. These are just a few examples of all factors that need to be brought into the simulation. Therefore, a field experiment provides the opportunity to include relevant factors into the study, in contrast to a controlled experiment.

Third, a method that would be feasible for the scope of this thesis is a stated preference survey. Hereby, video and audio footage could be used to ask people about their preference of different crowding levels. However, an earlier project showed a large difference between revealed preference and stated preference research (Galama, 2016). Another option would be to send surveys to airport passengers after their visit but asking about experiences that happened a significant time before is well known to cause a great decrease in validity of the data (Neuman, 2013). Even more, this option leaves out the opportunity to use crowding levels as a true independent variable, since airport visitors experience different areas and crowding levels during their visit which will all influence the results. Therefore, it would be impossible to determine if the difference in perception is related to difference in crowding.

Thus, the most suitable method for the stated research question is a natural field experiment in combination with a survey.

Chapter 5: Results

This chapter presents the results of the conducted study. After six weeks of data collection, a total of N=871 was obtained. The data was collected in three different areas of the Schiphol airport: N=236 in Departure Hall 2 (DH2), N=391 in Lounge 4 (L4) and N=236 in C-Pier. The data was analyzed separately for each area as well as for all areas combined. First, this chapter describes the ranges for crowding density levels and motivates the choices for the particular ranges in each area. Second, the descriptive statistics for the obtained data are presented. Subsequently, the results of the exploratory factor analysis are discussed. The fourth section presents the results of the multiple regression analysis and the variation in results for the separate areas. The final section offers a discussion of the results of the analyses.

5.1 Levels of Crowding

As described in the method section, the levels of crowding (occupancy) correspond to a specific percentile of the fire safety standard. For this study, the actual crowding of the areas during the time of data collection determined the different percentile ranges used in the analysis. The main focus of this study is comparing the effect of different crowding levels on perceived comfort and safety. Therefore, the three levels of crowding that occurred during the data collection (low, medium, and high) represent three distinctive experimental conditions that can be compared within one area. In addition, combining data from all three areas allows comparing the effects of different levels of crowding across different areas. The number of participants per area in each experimental condition, are provided in Table 7.

In the first area, the Departure Hall 2, the fire safety standard is set at 1600 people. During data collection, the occupancy varied between 20-95% of this standard, but the predominant occupancy level was at around 50%. Following from this, the level ranges set for the analysis are as follows: 20-40% (low: level 1), 41-60% (medium: level 2), >60% (high: level 3).

In the second area, the C-Pier, the fire safety standard is set at 1800 people. During data collection, the occupancy varied between 50% and 120% with an approximately even distribution across three levels. Following from this, the level ranges set for the analysis are as follows: 50-75% (low: level 1), 76-100% (medium: level 2), >100% (high: level 3).

In the third area, Lounge 4, the fire safety standard is set at 700 people. During data collection, the occupancy varied between 0 and 60% but predominant around 40%. Following from this, the level ranges set for the analysis are as follows: 15-30% (low: level 1), 31-45% (medium: level 2), 46-60% (high: level 3).

Table 7. *Number of Participants per level of occupancy (experimental group).*

	Experimental Group			
	Level 1 (N)	Level 2 (N)	Level 3 (N)	Excluded (N)
DH2	98	72	71	-
C-Pier	87	96	48	-
L4	110	135	117	29

5.2 Descriptive statistics:

Profile of respondents

The socio-demographic characteristics are reported in Table 8. They largely correspond with the profile of the areas (Ruysenaars & Wolfers, 2018). The reported nationalities were recoded into world regions and further referred to as 'origin'. The gender of respondents was distributed relatively evenly (51.8% male). Most respondents were of Dutch origin (46.7%) and between 25 and 44 years of age (39%). Additionally, most respondents travelled in a group of two (39%) and as a couple (19.9%). Most respondents travel by plane 1 or 2 times a year (37.3%).

Table 8. *The Socio-demographic Characteristics of the Respondents*

Characteristics		Frequency	Percentage
Gender	Male	451	51.8
	Female	410	47.1
	Other	3	.3
Age	18-24	197	22.7
	25-44	340	39
	45-54	155	17.8
	55-64	106	12.2
	65-74	51	5.9

	75 or older	15	1.7
Origin	African	2	.2
	Asian	29	3.3
	Dutch	407	46.7
	Non-Dutch European	329	37.8
	Middle East	5	.6
	North American	53	6.1
	South American	26	3
	Oceania	2	.2
	Other	9	1
Group size	1	305	35
	2	340	39
	3	72	8.3
	4	76	8.7
	5	28	3.2
	6	10	1.1
	7	2	.2
	8	5	.6
	9	0	0
	10	3	.3
	More than 10	30	3.4
Group composition	Family with children below the age of 8	37	4.2
	Family without children below the age of 8	132	15.2
	Friends	126	14.5
	Colleagues	53	6.1
	Couple	173	19.9
	Mixed	47	5.4
Travel experience	Less than one trip a year	101	11.6
	1 or 2 trips a year	325	37.3
	3-5 trips a year	215	24.7
	More than 5 trips a year	222	25.5

Descriptive analysis

The mean response to questions about the mental comfort, physical discomfort, physical safety concerns and emotional safety are indicated in Table 9. The first three scales are composed of multiple questions and range from 1 to 5 with different labels for each scale. Mental comfort and physical discomfort measured the perception of different factors from none at all (1) to a great deal (5). Physical safety concern ranges from not at all afraid (1) to very afraid (5) and emotional safety measures the safety of the location from very unsafe (1) to very safe (5). Therefore, the scores for the scales present mean responses over the relevant questions. As shown in the table, both mental comfort and emotional safety have a high mean score. On average, respondents experienced ‘a little’(2) discomfort and felt somewhere between ‘not at all afraid’ (1) and ‘rather not afraid’(2) about their physical safety.

Table 9. *Frequency, Mean and Standard Deviation of the Outcome Variables Mental Comfort, Physical Discomfort, Physical Safety Concerns and Emotional Safety.*

Dependent variable	Frequency (N)	Mean	Standard deviation
Mental comfort	854	3.61	.82
Physical discomfort	849	1.97	.74
Physical safety concerns	860	1.41	.67
Emotional safety	868	3.91	.83

5.3 Exploratory factor analysis

In order to find a valid and reliable measure of dependent variables, exploratory factor analysis was performed on the fifteen questions asked to tap into the comfort and safety perceptions of people at the airport. This was done for all areas of the airport separately. The results of the area with most respondents, Lounge 4, are presented here, while the remaining results can be found in Appendix A.

To investigate the underlying structure of the fifteen-item questionnaire assessing perception in different crowding circumstances, data collected from 381 participants were subjected to principal axis factoring with direct oblimin rotation.

Prior to running the principal axis factoring, examination of the data indicated that not every variable was perfectly normally distributed. Given the robust nature of factor analysis, these deviations were not considered problematic (Browne, 1987). Furthermore, a linear relationship was identified among the variables.

Four factors (with Eigenvalues exceeding 1) were identified as underlying the fifteen-item questionnaire (see Table 10). In total, these factors accounted for 52% of the variance in the questionnaire data.

Table 10. *Direct Oblimin Rotated Factor Structure of the 15-Item Perception in Different Crowding Circumstances Questionnaire – Area Lounge 4*

Item	Loadings			
	Factor 1	Factor 2	Factor 3	Factor 4
1. How would you rate the attractiveness of this location?				.803
2. How would you rate the ambiance of this location?				.798
3. How do you feel about the light at this location?				.492
4. In this area, how afraid are you of falling?			.835	
5. In this area, how afraid are you of becoming trampled?			.827	
6. In this area, how afraid are you of severe injury?			.797	
7. How often have you changed your walking speed or direction due to other people?	-.674			
8. How often have you experienced movement difficulties through this area?	-.832			
9. How often have you had physical contact with other people?	-.706			
10. How often have you experienced a violation of your personal space?	-.625			
11. In relation to the space that you are in, to what extent do you agree that you are informed		.507		
12. In relation to the space that you are in, to what extent do you agree that you are at ease		.815		

13. In relation to the space that you are in, to what extent do you agree that you are calm	.806
14. In relation to the space that you are in, to what extent do you agree that you are in control	.821
15. In relation to the space that you are in, to what extent do you agree that you are content	.701

Based on the results of the factor analysis, four scales measuring dependent variables were created. The first scale includes questions 7 until 10, as displayed in Table 10 and represents the first factor: Physical Discomfort. The second scale includes questions 11 until 15 and represents the second factor: Mental Comfort. The third factor includes questions 4 until 6 and represents the scale of Physical Safety Concerns. The fourth scale is constructed with questions 1 until 3 and represents Locational Qualities. Factor analysis of data from the other two areas yielded similar results (see Appendix A).

The four constructed scales were subjected to a reliability analysis. The Cronbach's alpha for the 6-item Mental Comfort Scale was $\alpha = .84$. Although this can be considered adequate for research purposes, a closer examination of the questionnaire item total statistics indicated that α would increase to .86 in case the first item were removed. This item asked to what extent participants agreed to be informed. However, this item was not dropped from the scale, due to its factor loading in the exploratory factor analysis and the small improvement of Cronbach's alpha in an already highly reliable scale.

The Cronbach's alpha for the 3-item Physical Safety Concerns Scale was $\alpha = .85$ indicating high reliability of the scale. The Cronbach's alpha for the 4-item Physical Discomfort Scale was $\alpha = .80$. Closer examinations of the questionnaire item-total statistics did not indicate the need for alterations in these scales.

The Cronbach's alpha for the 4-item Physical Discomfort Scale was $\alpha = .80$. A closer examination of the questionnaire item-total statistics did not indicate the need for alterations.

The Cronbach's alpha for the 3-item Locational Qualities Scale was $\alpha = .74$. Although this can be considered adequate for research purposes, a closer examination of the questionnaire item total statistics indicated that alpha would increase to $\alpha = .78$ if the third item was removed. This third item asked how participants felt about the light at the location. This item was dropped from the created scale and all subsequent analyses are based on participants' responses to the remaining two items. Perceptions of lighting were included in the models as a separate variable.

5.4 Results

To estimate the proportion of variance in comfort and perceived safety that can be accounted for by objective crowding and subjective crowding, a standard multiple regression analysis (MRA) was performed. As previously mentioned, the MRA was performed for all areas separately as well as on the data from all the areas combined. This section presents the results of the combined data set. The remaining MRA results can be found in the appendix.

The regression models tested the effects of multiple variables on mental comfort, physical discomfort, emotional safety and physical safety concerns. Based on the theories and previous studies, the models included the following independent variables: 'crowding', measured both objectively and subjectively, gender, age, origin, group size, travel purpose, travel experience, haste, light comfortability, locational qualities (scale), and the total number of people on the airport that day. Additionally, a variable for location was created to test for the possible differences in outcome variables in different airport areas. All categorical variables were recoded into dummies. All continuous variables were rescaled to range from 0 to 1 in order to compare the effect sizes.

Prior to conducting the MRA, the assumptions of multiple regression were evaluated. As a result of the assumption tests, it was determined that for the model for Physical Safety Concerns bootstrap method needs to be performed. The remaining models use standard multiple regression analysis (for details, see Appendix A).

The results of the MRAs are discussed per hypothesis. Additionally, a separate section elaborates on the differences in outcome variables between the airport areas.

Hypothesis 1: Higher levels of crowding decrease perception of safety

Perception of safety was measured using two outcome variables: emotional safety and physical safety concerns.

Emotional safety

Table 11. *Results of Multiple Regression Model for Emotional Safety. Data Aggregated across the Airport Areas. The table shows Unstandardised (B) Regression Coefficients, Standard Error, t-statistic and Significance For Each Predictor.*

Variable	B [95% CI]	Std. Error B	t	p
(Constant)	2.880 [.969, 4.790]	.972	2.961	.003*
Objective Crowding	-.002 [-.011, .007]	.005	-.378	.706
Subjective Crowding	-.655 [-.938, -.372]	.144	-4.551	.000*
Travel Experience	.243 [-.031, -.516]	.139	1.754	.082
Hurry	-.529 [-.912, -.147]	.195	-2.718	.007*
Light Comfortability	.353 [-.056, .762]	.208	1.697	.090
Locational Qualities: Ambiance and Attractiveness	1.307 [.876, .738]	.219	5.955	.000*
Total Number of People in the Airport that Day	.222 [-1.628, 2,072]	.942	.236	.813
Gender (female)				
Male	.067 [-.046, .181]	.058	1.166	.244
Age (25-45)				
Below average (18-24)	-.005 [-.158, .148]	.078	-.062	.951
Above average (>45)	-.035 [-.168, .098]	.068	-.518	.605
Origin (Dutch)				
Non-Dutch	.042 [-.086, .170]	.065	.643	.520
Groupsize (small, 2-3 people)				
Large (≥4 people)	-.095 [-.225, .036]	.066	-1.428	.154
Purpose of Trip (holiday)				
Business		.094	-.763	.446

	-.071 [-.255, .112]			
Other	.054 [-.134, .242]	.096	.561	.575
Location (Lounge)				
Departure Hall	-.053 [-.247, .140]	.099	-.540	.589
C-Pier	.036 [-.121, .192]	.080	.448	.655
Interaction Effect Gender x Objective Crowding	-.017 [.064, -.034]	.009	-1.856	.064

Note. N = 871. CI = Confidence Interval.

The model accounted for a significant 19% of the variability in emotional safety, $R^2 = .19$, adjusted $R^2 = .16$, $F(17, 536) = 7.39$, $p < .001$. Unstandardised (B) regression coefficients, significance and semi-partial correlations for each predictor in the regression model are reported in Table 11. Significant effects are marked with an asterisk.

The first hypothesis states that higher levels of crowding decrease perception of safety. The independent variable was measured as objective crowding, the number of people in the area, and subjective crowding, measured on a scale from one to five (not crowded at all - extremely crowded). Therefore, the hypothesis is sub-divided into two statements:

H1a. Higher levels of objective crowding decrease perception of safety.

H1b. Higher levels of subjective crowding decrease perception of safety.

In contrast to hypothesis H1a, the variance in objective crowding (low: level ,1 until high: level 3) did not cause significant change in the perception of emotional safety (table 11). This outcome does not support the hypothesis. The model shows that subjective crowding has a significant effect on the perception of emotional safety, with a relatively large negative effect size (B=-.655, table 11). This supports hypothesis H1b: higher levels of subjective crowding, or how crowding is perceived by the individual, decreases perception of safety.

Apart from the hypothesis, the model (table 11) reveals two other variables with a significant effect on the perceived emotional safety. First, being in a hurry is negatively related to emotional safety (B=-.529). Thus, respondents who said that they are in a hurry reported lower levels of perceived emotional safety. Second, the ambiance and attractiveness have a large positive effect (B=1.307) on how safe individuals feel in a given location.

Physical safety concerns

Table 12. *Results of Multiple Regression Model for Physical Safety Concerns. Data Aggregated across the Airport Areas. The table shows Unstandardised (B), Bias, Std. Error and Significance For Each Predictor.*

Variable	B [95% CI]	Bias	Std. Error	p
(Constant)	1.015 [-.758, 2.873]	.021	.922	.287
Objective Crowding	-.001 [-.010, .008]	.000	.005	.796
Subjective Crowding	.296 [.030, .567]	-.001	.138	.035*
Travel Experience	-.148 [-.412, .101]	.001	.129	.248
Hurry	1.069 [.633, 1.484]	-.019	.221	.001*
Light Comfortability	-.738 [-1.191, -.318]	-.010	.223	.001*
Locational Qualities: Ambiance and Attractiveness	-.509 [-.990, -.039]	.010	.231	.036*
Total Number of People in the Airport that Day	.882 [-.799, 2.536]	-.014	.868	.317
Gender (female)				
Male	.034 [-.077, .139]	-.005	.054	.526
Age (25-45)				
Below average (18-24)	.168 [.022, .330]	.002	.076	.035*
Above average (>45)	-.155 [-.268, -.031]	.002	.061	.017*
Origin (Dutch)				
Non-Dutch	.030 [-.083, .154]	.001	.059	.612
Groupsize (small, 2-3 people)				
Large (≥4 people)	-.012 [-.131, .113]	.002	.063	.854
Purpose of Trip (holiday)				

Business	-.015 [-.199, .142]	-.006	.086	.867
Other	-.021 [-.168, .131]	.001	.077	.781
Location (Lounge)				
Departure Hall	.107 [-.055, .278]	-.003	.085	.224
C-Pier	.085 [-.079, .255]	-.001	.084	.311
Interaction Effect Gender x Objective Crowding	.013 [-.002, .031]	-7.978E-5	.008	.113

Note. N = 871. CI = Confidence Interval.

The model accounted for a significant 18% of the variability in perceived physical safety concerns, R^2 =.18, adjusted R^2 =.16, $F(17, 534) = 7{,}00$, $p < .001$. Unstandardised (B) regression coefficients, significance and semi-partial correlations for each predictor in the regression model are reported in Table 12. Significant effects are marked with an asterisk.

A non-significant relation is found between objective crowding and perceived physical safety concerns (Table 12), providing no support for hypothesis H1a. In contrast, subjective crowding has a significant effect on the same dependent variable. In this model the effect size is medium and positive (B=.296), which means that the perception of crowding in this study increased the perception of physical safety concerns. This outcome does support hypothesis H1b.

Similar to the perceived emotional safety, physical safety concerns is associated with the ambiance and attractiveness of the location (B= -.509), the light comfortability (B= -.738), and the level of haste (B= 1.069). Thus, positive locational qualities and light comfortability decrease the physical safety concerns. These effects can be classified as medium to large. By contrast, being in a hurry strongly increases the physical safety concerns. The physical safety concerns are associated with the age of respondents. The effects of age on the level of physical safety concerns differ between different age groups. Respondents younger than average experience somewhat more physical safety concerns than the respondents in the mid-age group (B= .168), respondents older than average experience somewhat less physical safety concerns than respondents in the mid-age group (B= -.155).

Hypothesis 2: Higher levels of crowding increase levels of physical discomfort

To measure physical discomfort, a scale was used from none at all (1) to a great deal (5). The results of this model are displayed in Table 13.

Table 13. *Results of Multiple Regression Model for Physical Discomfort. Data Aggregated across the Airport Areas The table shows Unstandardised (B) Regression Coefficients, Standard Error, t-statistic and Significance For Each Predictor.*

Variable	B [95% CI]	Std. Error B	t	p
(Constant)	.636 [-1.301, 2.574]	.986	.645	.519
Objective Crowding	.001 [-.009, .010]	.005	.149	.881
Subjective Crowding	1.138 [.852, 1.424]	.146	7.808	.000*
Travel Experience	.197 [-.079, .473]	.140	1.403	.161
Hurry	.926 [.538, 1.314]	.198	4.687	.000*
Light Comfortability	-.367 [-.782, .047]	.211	-1.741	.082
Locational Qualities: Ambiance and Attractiveness	-.758 [-1.195, -.321]	.223	-3.407	.001*
Total Number of People in the Airport that Day	1.106 [-.770, 2.982]	.955	1.158	.247
Gender (female)				
Male	-.059 [-.174, .056]	.059	-1.012	.312
Age (25-45)				
Below average (18-24)	.142 [-.013, .297]	.079	1.801	.072
Above average (>45)	-.195 [-.330, -.061]	.068	-2.861	.004*
Origin (Dutch)				
Non-Dutch	-.079 [-.208, .051]	.066	-1.193	.234
Groupsize (small, 2-3 people)				
Large (≥4 people)	-.028 [-.160, .104]	.067	-.416	.677

Purpose of Trip (holiday)				
Business	-.015 [-.201, .171]	.094	-.160	.873
Other	-.090 [-.280, .101]	.097	-.927	.355
Location (Lounge)				
Departure Hall	.299 [.104, 494]	.099	3.018	.003*
C-Pier	.295 [.137, .454]	.081	3.663	.000*
Interaction Effect Gender x Objective Crowding	.005 [-.013, .023]	.009	.508	.612

Note. N = 871. CI = Confidence Interval.

The variables entered in the model accounted for a significant 25% of the variability in physical discomfort, $R^2 = .25$, adjusted $R^2 = .23$, $F(17, 527) = 10.314$, $p < .001$. Due to the two methods of measuring crowding, this hypothesis is divided:

H2a. Higher levels of objective crowding increase physical discomfort.

H2b. Higher levels of subjective crowding increase physical discomfort.

An alteration in objective crowding (low: level 1, until high: level 3) did not affect the physical discomfort of respondents significantly (Table 13). Therefore, H2a is not supported by this outcome. The model shows a significant relation between subjective crowding and physical discomfort with a relatively large positive effect size (B=1.138). Respondents who experienced the area as more crowded did also experience more physical discomfort, supporting H2b.

In addition, five other variables show a significant relation with physical discomfort (Table 13). First, being in a hurry strongly increases the experienced physical discomfort (B = .926). Second, positive locational qualities (B = -.758) as well as being older than average (B= -.195) decrease the experienced physical discomfort. The area in which respondents were situated at the time of the interview had a significant effect too. Respondents in the area Departure Hall 2 and C-Pier reported higher levels of experienced physical discomfort than respondents in the Lounge area. The effect size was relatively small though (DH2 B=.299, C-Pier B=.295).

Hypothesis 3: Higher levels of crowding decrease levels of mental comfort
The outcome of the model mental comfort is shown in Table 14.

Table 14. *Results of Multiple Regression Model for Mental Comfort. Data Aggregated across the Airport Areas. The table shows Unstandardised (B) Regression Coefficients, Standard Error, t-statistic and Significance For Each Predictor.*

Variable	B [95% CI]	Std. Error B	t	p
(Constant)	1.719 [-.290, 3.728]	1.023	1.681	.093
Objective Crowding	.004 [-.006, .013]	.005	.774	.439
Subjective Crowding	-.626 [-.922, -.330]	.151	-4.159	.000*
Travel Experience	.315 [.030, .601]	.145	2.168	.031*
Hurry	-.516 [-.115, -.091]	.204	-2.526	.012*
Light Comfortability	1.007 [1.435, .166]	.218	4.612	.000*
Locational Qualities: Ambiance and Attractiveness	1.600 [1.149, 2.051]	.230	6.967	.000*
Total Number of People in the Airport that Day	.487 [-1.461, 2.435]	.992	.491	.623
Gender (female)				
Male	.174 [.056, .293]	.060	2.887	.004*
Age (25-45)				
Below average (18-24)	-.020 [-.180, .141]	.082	-.242	.809
Above average (>45)	.079 [-.060, .218]	.071	1.121	.263
Origin (Dutch)				
Non-Dutch	-.542 [-.676, -.408]	.068	-7.944	.000*
Groupsize (small, 2-3 people)				
Large (≥4 people)	.013 [-.123, .150]	.069	.193	.847

Purpose of Trip (holiday)				
Business	-.118 [-.310, .075]	.098	-1.202	.230
Other	.136 [-.062, .335]	.101	1.350	.178
Location (Lounge)				
Departure Hall	.080 [-.123, .283]	.103	.776	.438
C-Pier	.193 [.030, .356]	.083	2.320	.021*
Interaction Effect Gender x Objective Crowding	.004 [-.015, .022]	.009	.392	.695

Note. N = 871. CI = Confidence Interval.

The variables entered in the model shown in Table 14, accounted for a significant 32% of the variability in mental comfort, $R^2 = .32$, adjusted $R^2 = .29$, $F(17, 531) = 14.401$, $p < .001$. Due to the two methods of measuring crowding, this hypothesis is divided:

H3a. Higher levels of objective crowding cause lower mental comfort.

H3b. Higher levels of subjective crowding cause lower mental comfort.

The relation between objective crowding and mental comfort is not statistically significant. Thus, H3a is not supported.. In contrast, subjective crowding shows a significant, negative relationship with mental comfort (B = -.626). Therefore, higher levels of subjective crowding seem to have a medium negative effect on the mental comfort of an individual. This supports hypothesis H3b.

The model predicting mental comfort shows that other variables have significant effect on how comfortable the respondents feel in a particular airport area (Table 14). Besides subjective crowding, being in a hurry (B=-.516) and non-Dutch origin (B=-.542) have medium negative effects on the perceived mental comfort. In contrast, travel experience (B=.315), being male (B=.174) light comfortability (B=1.007), and positive locational qualities (B=1.600) have small to large effects on the mental comfort of respondents. Additionally, the area C-Pier recorded higher levels of mental comfort than the lounge area (B=.193).

Area variance

Based on the presented models, no significant differences in the levels of emotional safety (Table 11) and physical safety concerns (Table 12) can be found across the different airport areas. Physical discomfort is on average significantly higher in the Departure Hall (B=.299) and C-Pier (B=.295) than in the Lounge (Table 13). In contrast, the mean mental comfort is slightly higher in the C-Pier (B=.193) than in the Lounge area (Table 14). As mentioned in the introduction of this chapter, the MRAs were performed on a combined data set as well as the separate areas. The complete models for all areas can be found in the Appendix A.

Social-demographic hypotheses

In addition to the main hypotheses that provide insight into the research question, multiple hypotheses were proposed to test theories about social demographical and circumstantial factors influencing the research question. Most of these hypotheses suggest an interaction effect. In order to gain understand these interactions, graphs are presented below (Figure 2-12).

H4. Older people feel less safe and comfortable in higher levels of crowding than younger people

In order to understand the effect of crowding on safety and comfort across different age groups, the graphs in Figures 2-5 show the means with standard error for emotional safety, physical safety concern, mental comfort, and physical discomfort at different levels of crowd per age group.

Figure 3 shows that younger and mid-aged respondents experience similar levels of emotional safety irrespective of the level of crowding. However, respondents older than average experience higher levels of emotional safety in the highest level of crowding. Figure 2 demonstrates that respondents younger than average experience more physical safety concern than the average age groups in the low level of crowding. However, in medium and high crowding levels the physical safety concern of the younger and average group is similar. Additionally, the age group older than average shows less physical safety concern than the average age group, irrespective of the level of crowding. This does not support hypothesis four.

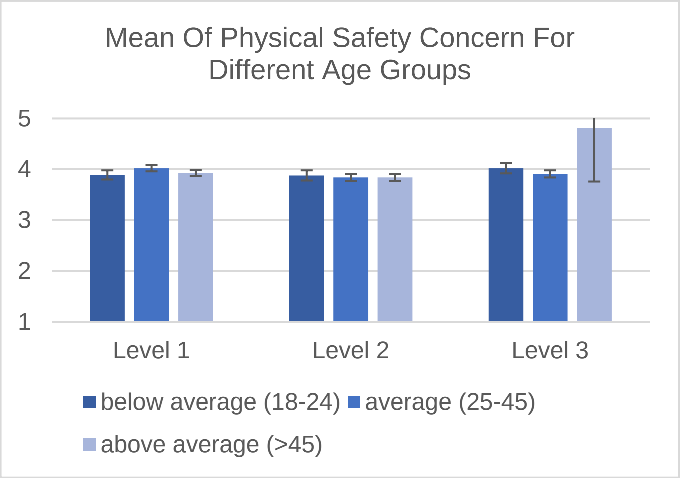

Figure 2. *Perceived Physical Safety Concern (1. Not at all afraid – 5. Very afraid) per Crowding Level for Three Age Groups with Standard Error of Mean*

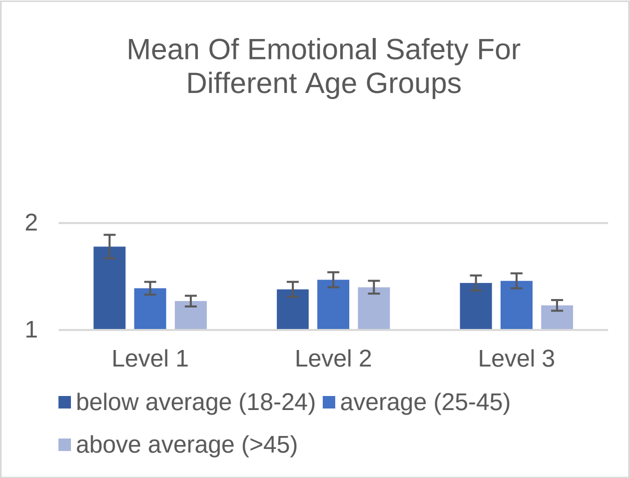

Figure 3. *Perceived Emotional Safety (1. very unsafe – 5. very safe) per Crowding Level for Three Age Groups with Standard Error of Mean*

Figure 4 and 5 show that, irrespective of the level of crowding, the age group older than average experiences more mental comfort and less physical discomfort. In contrast, respondents younger than average experience less mental comfort and more physical discomfort than the average age group in crowding levels low and medium, but no such difference is seen in the highest crowding level. The results do not support H4.

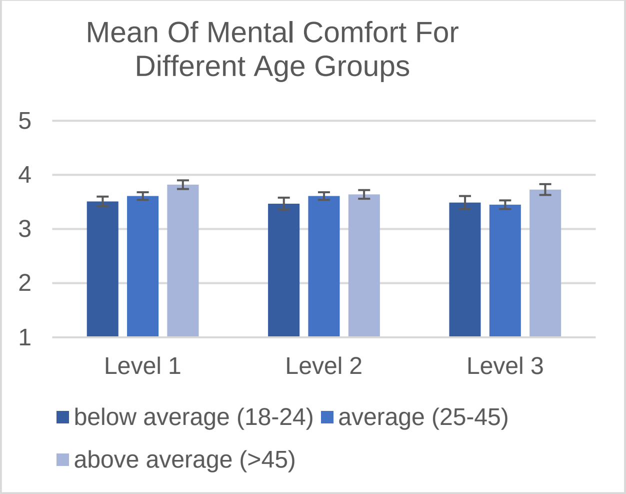

Figure 4. *Perceived Mental Comfort (1. None at all – 5. A great deal) per Crowding Level for Three Age Groups with Standard Error of Mean*

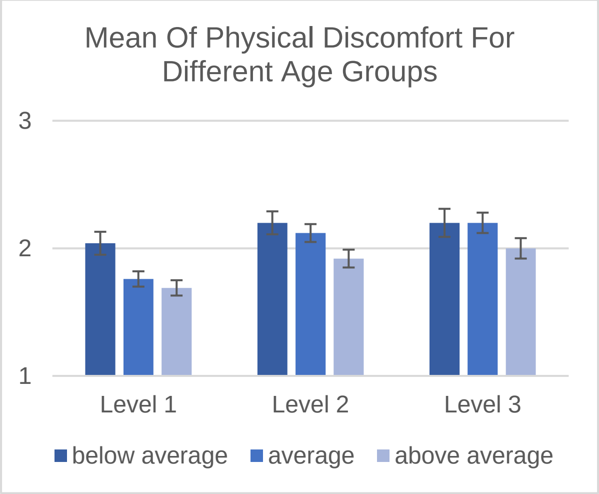

Figure 5. *Perceived Physical Discomfort (1. None at all – 5. A great deal) per Crowding Level for Three Age Groups with Standard Error of Mean*

H5. Women feel less safe in all levels of crowding than men

In order to gain insight into the difference in interaction between levels crowding and perceived safety between males and females, a separate variable is created and included in the MRA models (Interaction Effect Gender x Objective Crowding). Both the emotional safety model as well as the physical safety concern model showed no significant effect of the interaction variable on the two safety outcome variables (Table 11-12). These results do not support the hypothesis that women feel less safe in all levels of crowding than men.

H6. Domestic visitors experience more physical discomfort due to crowding than other nationalities

The results of the multiple regression model show no significant effect of being non-Dutch on the experienced physical discomfort (Table 13). However, in relation to crowding the graph in Figure 6 shows respondents from different world origins. The graph shows that the mean physical discomfort for respondents of Dutch origin is lower in crowding level one than other origins. However, in the second crowding level the mean is approximately similar and in level 3 it is higher than other origins. This partly supports the hypothesis that domestic visitors experience more physical discomfort due to crowding than other nationalities.

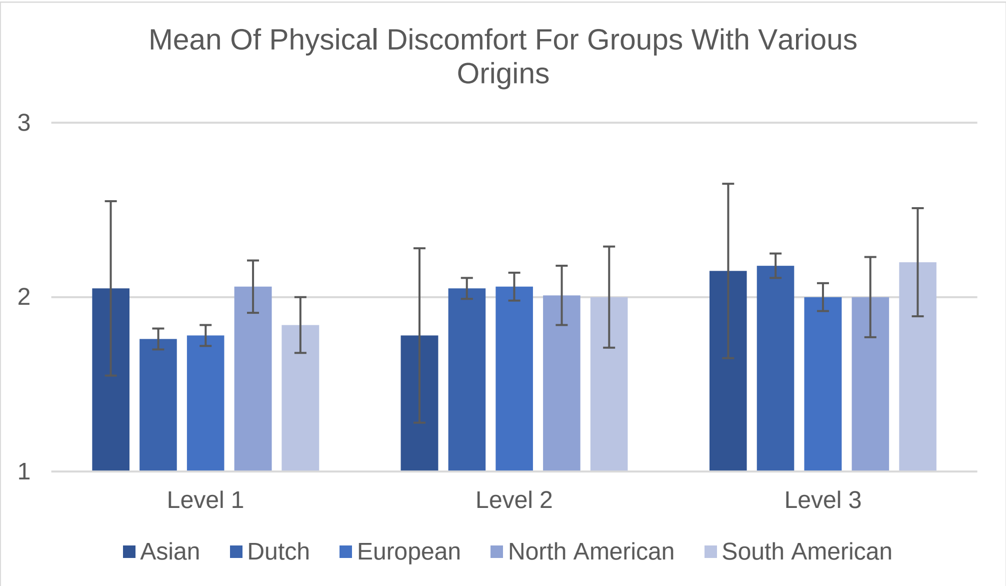

Figure 6. *Perceived Physical Discomfort (1. None at all – 5. A great deal) per Crowding Level for Five Groups with Various Origins*

H7. People with more travel experience feel more safe and comfortable in higher levels of crowding than people with less experience.

The graph in Figure 7 shows that in the highest levels of crowding, groups with more travel experience (3-5 trips a year and >5 trips a year) experience less mental comfort. For physical discomfort, groups with varied travel experience show mixed results across all levels (Figure 8). Both observation do not support the stated hypothesis.

Figure 9 shows that experienced travelers (>5 trips a year) have less physical safety concern in level 1 and level 3 of crowding. In the medium level, this group shows a similar mean of physical safety concern as other groups. Similar observations can be stated about the graph in Figure 10. Experienced travelers (>5 trips a year) perceive higher levels of emotional safety in level 1 and level 3 of crowding. Again, in the medium level this groups shows a similar mean to other groups. This does not support the stated hypothesis.

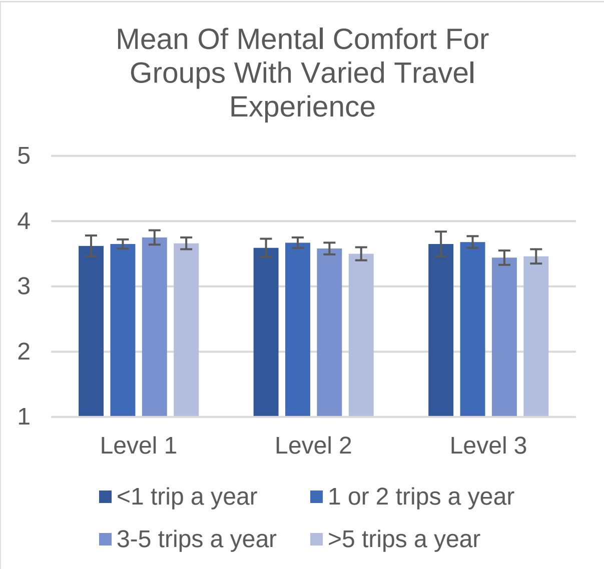

Figure 7. *Perceived Mental Comfort (1. None at all – 5. A great deal) per Crowding Level for Four Groups with varied Travel Experience*

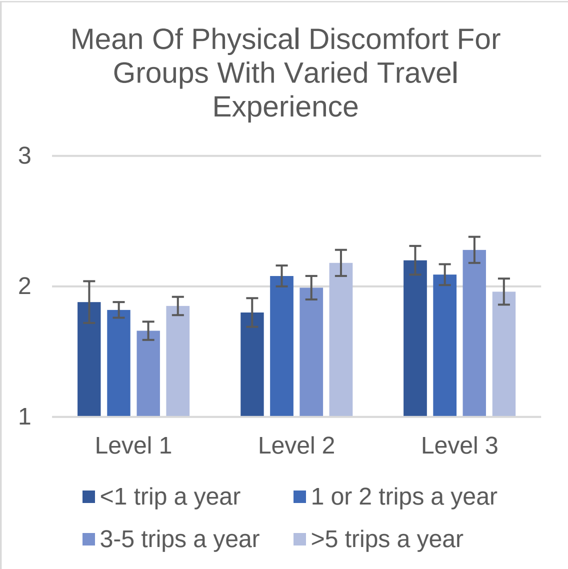

Figure 8. *Perceived Physical Discomfort (1. None at all – 5. A great deal) per Crowding Level for Four Groups with varied Travel Experience*

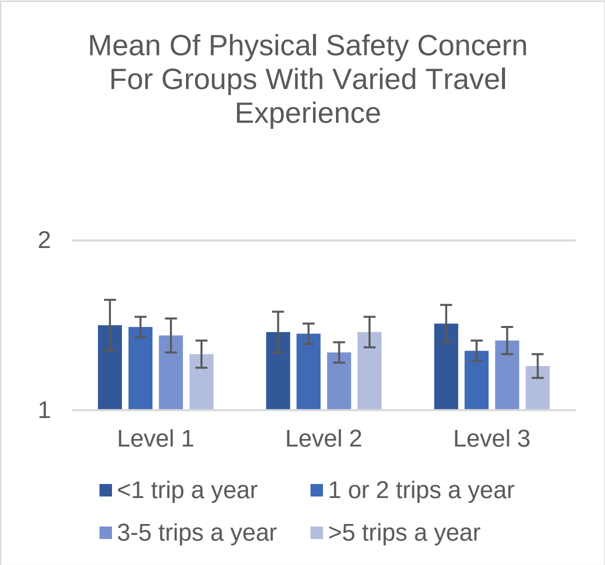

Figure 9. *Perceived Physical Safety Concern (1. Not at all afraid – 5. Very afraid) per Crowding Level for Four Groups with varied Travel Experience*

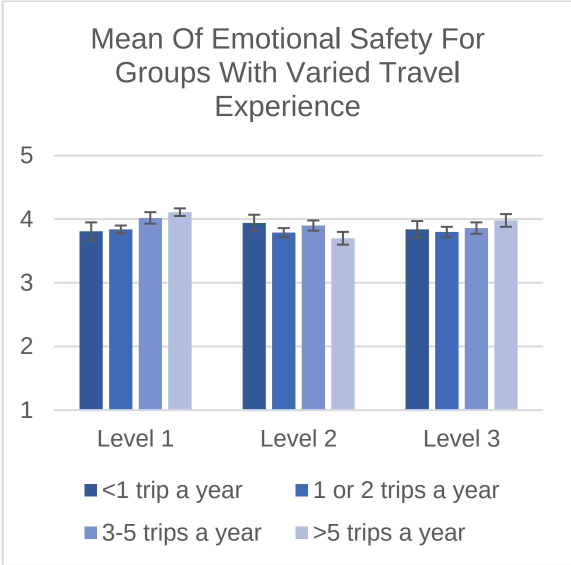

Figure 10. *Perceived Emotional Safety (1. very unsafe – 5. very safe) per Crowding Level for Four Groups with varied Travel Experience*

H8. People in larger groups are less comfortable with higher levels of crowding. Figure 11 shows that small and large groups have similar means of mental comfort in crowding levels 1 and 3. In the medium crowding level, large groups show on average more mental comfort. Figure 12 shows that large groups experience more physical discomfort in crowding levels 1 and 3, but less in crowding level 2. This supports the hypothesis only partially.

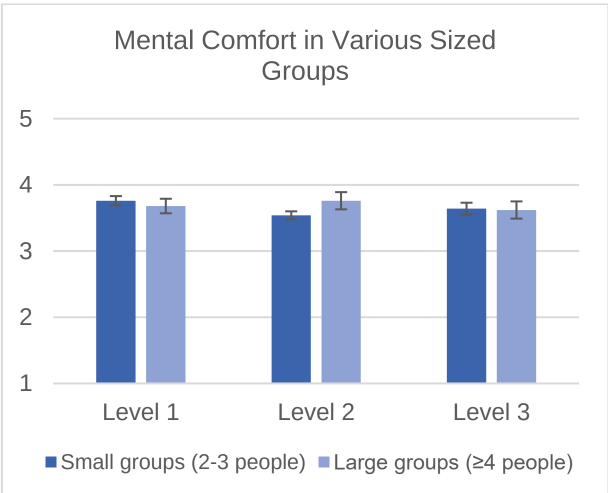

Figure 11. *Perceived Mental Comfort (1. None at all – 5. A great deal) per Crowding Level for Small and Large Groups*

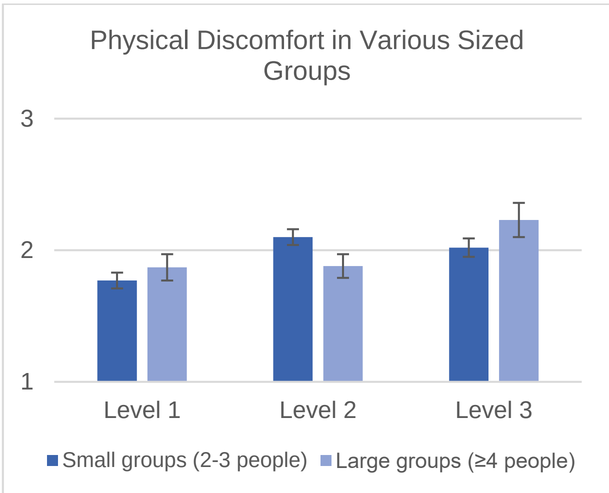

Figure 12. *Perceived Physical Discomfort (1. None at all – 5. A great deal) per Crowding Level for Small and Large Groups*

Relation between subjective and objective crowding

As the results of the multiple regression analysis showed, safety and comfort are not influenced by objective and subjective crowding in the same way. Table 15 shows a significant but small to medium association between objective crowding and subjective crowding. This indicates that objective crowding is associated with subjective crowding, although the link between the two is limited. This supports the result of the MRAs that objective crowding and subjective crowding have different effects on dependent variables.

Table 15. *Correlation Matrix of Objective Crowding and Subjective Crowding (Kendall's tau)*

Variables	**Correlations**
	Subjective crowding
Objective crowding	.306**

**. Correlation is significant at the 0.01 level (2-tailed)

To gain insight in the factors that account for the variation in subjective crowding, a standard multiple regression analysis (MRA) was performed. Based on the theories and previous studies, the model included the following independent variables: objective crowding, gender, age, origin, group size, travel purpose, travel experience, haste, light comfortability, locational qualities (scale), the area location and the total number of people on the airport that day. No assumptions of multiple regression were violated.

The variables entered in the model accounted for a significant 29% of the variability in mental comfort, $R^2 = .28$, adjusted $R^2 = .26$, $F(16, 515) = 12.850$, $p < .001$. The results of this model are provided in Table 16.

Table 16. *Results of Multiple Regression Model for Subjective Crowding. Data Aggregated across the Airport Areas. The table shows Unstandardised (B) Regression Coefficients, Standard Error, t-statistic and Significance For Each Predictor.*

Variable	Unstandardised B	Std. Error B	t	p
(Constant)	.419 [-.199, .956]	.274	1.529	.127
Objective Crowding	.281 [.218, .343]	.032	8.860	.000*
Travel Experience	.023 [-.054, .100]	.039	.583	.560
Hurry	.107 [-.001, .216]	.055	1.944	.052

Light Comfortability	-.091 [-.206, .023]	.058	-1.564	.119
Locational Qualities:				
Ambiance and Attractiveness	-.257 [-.377, -.137]	.061	-4.224	.000*
Total Number of People in the Airport that Day	.188 [-.328, .704]	.263	.715	.475
Gender (female)				
Male	.044 [-.095, .183]	.071	.617	.537
Age (25-45)				
Below average (18-24)	.028 [-.016, .072]	.022	1.265	.206
Above average (>45)	-.018 [-.055, .020]	.019	-.933	.351
Origin (Dutch)				
Non-Dutch	-.016 [-.053, .020]	.019	-.880	.379
Groupsize (small, 2-3 people)				
Large (≥4 people)	.013 [-.024, .050]	.019	.678	.498
Purpose of Trip (holiday)				
Business	-.009 [-.062, .044]	.027	-.350	.727
Other	.055 [.002, .107]	.027	2.053	.041*
Location (Lounge)				
Departure Hall	-.134 [-.187, -.082]	.027	-4.998	.000*
C-Pier	-.082 [-.125, -.038]	.022	-3.712	.000*
Interaction Effect Gender x Objective Crowding	.028 [-.096, .151]	.063	.436	.663

Note. N = 871. CI = Confidence Interval.

The model predicting subjective shows that multiple variables have significant effect on how crowding is perceived (Table 16). First, higher levels of objective crowding (B=.281) and going on a trip with another purpose than business or holiday (B=.055) increase the perception of crowding. On the other hand, locational qualities (B=-.257) decrease the perceived crowding. Additionally, the Departure Hall 2 (B=-.134) and the C-pier (B=-.082) recorded slightly lower levels of subjective crowding than Lounge 4.

5.5 Discussion

This study has examined the responses of 871 participants in a natural field experiment. This section discusses the results presented above.

Multiple regression

The first three hypotheses were developed to answer the research question: "how do different levels of crowding affect individual safety perceptions and comfort?" and state predictions about this question based on existing literature. In this study, a distinction is made between objective crowding and subjective crowding. Throughout all models (Table 11-14), objective crowding did not affect the dependent variables mental comfort, physical discomfort, emotional safety and physical safety concerns. In contrast, subjective crowding appeared to be a constant significant factor. Thus, in the levels of crowding measured in this study, objective crowding did not affect individual safety perception and comfort. The subjective experience of this crowding did have effect.

It was expected that objective and subjective crowding would affect the outcome differently, since perceptions are influenced by a variety of factors which is also confirmed with the multiple regression results in Table 16. However, it is unexpected that the objective variation in crowding had no significant effect on comfort and safety levels at all, since insufficient space is related to crowd risk (Alkhadim et al., 2018). The lack of significance can be related to the following factors; first, the third level (high) was still relatively uncrowded, compared to other studies in the field of crowd safety. Thus, the levels of crowding used in this study indicate no effect on comfort and safety perception but in higher levels of crowding, this relation might change and become relevant. Second, the studied areas were rather big and the local crowding could vary while the whole area remained in the same level. Respondents in high levels of crowding were able to see less crowded parts, possibly reducing the effects of objective crowding close to them. Nonetheless, this potential cofounder was controlled for by measuring the number of people in the airport that day.

Besides subjective crowding, multiple variables were consistently significant across all models (Table 11-14): attractiveness, ambiance and haste. Positive locational qualities increase comfort levels and safety perception. In contrast, being in a hurry negatively affects these outcome variable. These correspond with previous studies and are therefore expected (Iliadi, 2016; Kendrick & Haslam, 2010). Furthermore, light comfort had a significant effect on all dependent variables except emotional safety. The lack of significant effect of lighting on emotional safety is somewhat surprising, as previous studies suggested that individuals felt less safe in poorly lit places in other studies (Ariffin & Zahari, 2013; Boyce et al., 2000; Hagen, 2011). The lack of effect of lighting in this study might be explained by the fact that the airport is relatively well lit at all times with little variation, creating sufficient lighting to provide for high general level of safety.

The predictive models show some variation across the studied areas. First, physical discomfort is higher in both the C-Pier as well as Departure Hall 2 compared to Lounge 4 area (Table 13). This is in line with the expectations, since a lounge area is specifically designed to be both physically and mentally comfortable. Additionally, most people in the lounge area are seated and relatively separated from the flow section, where other travelers are moving past. In the other areas, the flow and waiting processes are more intertwined, potentially increasing the physical discomfort.

The variation in mental comfort might be related to the functionality of the area (Table 14). When travelling by plane, passengers will move to the areas in the following order: Departure Hall, Lounge, Pier (gates). All areas require different actions that impose different emotions. It is possible that the general level of stress and sensitivity to their surroundings decreases after each process-step, knowing that their goal will be reached. In this case: arriving at the required gate in time. Most of the respondents in the area C-Pier were already at their gate, which might made them less susceptible to any type of crowding effects. This theory is supported by the fact that travel experience and haste proved significant for mental comfort: more travel experience often increased the level of mental comfort while being in a hurry decreased it.

Social-demographic hypotheses

Aside from the performed multiple regression analysis, data was analyzed for variation across different groups of social-demographic characteristics.

The graphs in Figure 2 and 3 suggest that people above 45 years of age are less concerned about safety related to crowding. This was unexpected, since previous studies indicated people above 30 years of age to be more sensitive to crowding (Jurado et al., 2013).

However, the variation in the means of physical safety concern and emotional safety can be caused by the standard error, which is relatively large due to the low number of respondents in the oldest age group in this study. Therefore, further research is necessary to analyze the effect of crowding on age and perception of safety.

In previous studies, it was often concluded that women feel less safe in particular situations than men (Hoskam, 2017; McGrath & Chananie-Hill, 2011). However, the models in this study (Table 11-12) did not show that women perceive a location less safe than men or that they are more concerned with their physical safety. This difference in outcome might be explained that in general, airports can be assessed as a safe place to be. There is constant presence of security companies and other personnel. Additionally, it is a semi-public place which might provide a general sense of protection. These factors might explain the difference in outcome between this study and other research.

The literature review revealed that more travel experience decreases worry about crowding (Hoskam, 2017; Jin & Pearce, 2011). Therefore, it was expected that groups with more travel experience would show higher levels of comfort and perceived safety. When analyzing the graphs in Figures 7-10, it seems like this expectation was not met. However, it cannot be stated that any variation shown is caused by inter-group differences, since the variation is small and the standard error of the mean must be taken into account.

Before data was collected, it was predicted that domestic visitors experienced more physical discomfort than non-dutch travelers. The graph in Figure 6 shows mixed results, although it does suggest that domestic visitors are more sensitive to high crowding levels. However, the standard error of the mean is relatively large due to a small number of respondents (N). Therefore, this study cannot conclude if this variation is due to the differences between groups of origin, as was concluded in earlier studies (Jin & Pearce, 2011).

The graphs in Figure 11-12 show some variation in mean of mental comfort and physical comfort between different sized groups in different levels of crowding. However, no conclusion can be drawn on the significance of this variation. Additionally, unlike previous studies (Hoskam, 2017; Zuurbier, 2019), the variation did not show a clear effect. This difference in outcome might be caused by the following factor. There was a fine line between small and larger groups, since 2-3 people were considered to be small whereas more than 4 were marked as a large group. The frequency of substantially larger groups was relatively low in this study, which possibly explains the inconsistency with previous conducted studies.

Chapter 6: Conclusion

This study has aimed to provide an answer to the question “how do different levels of crowding affect individual safety perception and comfort?” by conducting a natural field experiment in different areas at Amsterdam Airport Schiphol. As a result of the literature review, a distinction was made in objective levels of crowding and subjective levels of crowding in order to answer the research question. By use of a multiple regression analysis, several conclusions can be drawn. First, the individual safety perception and comfort levels are more affected by subjective crowding than objective crowding. Even though objective and subjective crowding are correlated, the effect size of the latter on multiple outcome variables was often significant when the same relation for objective crowding was not. More specifically, different levels of objective crowding did not affect either physical discomfort, mental comfort or any of the dimensions of safety. Thus, the levels of crowding used in this study indicate no effect on comfort and safety perception. Further research is necessary to analyze if this relation might change in higher levels of crowding.

In contrast, higher levels of subjective crowding increased physical discomfort and decreased mental comfort (Table 13-14). Moreover, several factors were identified as affecting the perception of crowding (Table 16) such as locational qualities, although further research is necessary to gain insight into potential other factors. This study also confirmed the hypothesized relation between subjective crowding and safety. Higher levels of perceived crowding increased physical safety concern and decreased emotional safety.

The results of this study contribute to the existing body of literature. In relation to crowdedness, multiple movement patterns were identified such as lack of free flow and the path adjustments based on the social force model (1971). This study reveals that these patterns can not only be observed, but are also perceived by individuals. Additionally, the sensation of these patterns increase in alignment with an increase in perception of crowdedness. Contrarily, objective crowding does not seem to affect the perception of patterns, at least not in the low densities that were present in this study. Further research should reveal if this remains non-related in higher densities.

The perception of crowding is known to be influenced by a variety of factors. It has been sorted into 5 categories Safety, Comfort, Ambiance, Crowdedness and Attractiveness (2019) and displayed as a multi-factorial model (Westover, 1989, p. 261). The results of this study confirm the importance of the 5 categories but suggest an additional factor that has relation to the functionality of the area the individuals are located, due to the effect of different locations on subjective crowding (Table 16).

6.1 Limitations

Conducting a natural field experiment with a survey provides the opportunity to gain knowledge about people's attitudes in a natural environment. However, the following limitations apply to the chosen method.

First, no random assignment was possible. The natural variance in the independent variable occurs due to preference of people in departure and arrival times, the availability of flights determined by airlines, delay in processes at and around the airport and the presence of 'peak season' and 'peak days'. To minimize this effect of potential non-equivalent groups, the study has aimed to collect a large sample.

Second, it is possible that participants were exposed to a variation of the independent variable while it is assumed they only experienced one level of crowding. This is because levels of crowding potentially varied during the time that a passenger is present in an area. Even though the survey asks about the perception at that given time, earlier experiences both in that area as well as in other areas at the airport influence the perception. In order to minimize this effect, data about the level of crowding at the airport in total was collected to provide insight about the crowding the respondents experienced during their stay.

A third limitation is the generalization of the sample. Only a certain type of people participate in a survey. To minimize this effect, travelers were approached as randomly as possible. Furthermore, as expected, hurried passengers rarely responded to the survey. The QR-code received a low response rate and therefore this group was not included.

Additionally, a survey itself comes with disadvantages. There is a possibility that the study omitted a relevant variable that was not identified through literature review or simply not yet recognized as relevant. Additionally, respondents may have chosen the last answer option offered out of convenience rather than carefully considering all answers. To minimize these effects, the survey was designed to be easy and quick to conduct and a 'neutral' option was included as an answer.

Another limitation is the technical inability to measure other indicators of crowdedness. Previous research demonstrates that crowdedness is determined by not only occupancy and collisions but also speed, flow and flow type (Zuurbier, 2019). These factors could not be included because of the complexity to connect these factors with the survey and the limited scope of the study.

As mentioned before, an important factor to place this study into the literature of crowd dynamics is the studied level of crowding. This study succeeded in creating different experimental conditions of crowding. However, the highest level of crowding was still relatively uncrowded compared to other studies in this field of research. Therefore, further research must reveal if the same conclusions apply in conditions of higher density.

Similarly, as revealed by the literature review and confirmed in this study, the context and location matters to the perception of crowding. Therefore, the conclusions are limited to the location used in this study.

This thesis has extended the existing knowledge about crowd behavior by bridging the gap between objective and subjective crowding. It has successfully aligned both values in order to compare the differences in effect on perception and thereby it can be considered a worthwhile contribution to the field.

Appendix A – Sequel of the Results

This appendix is a sequel of chapter 5. It is subdivided into the following sections:

A.1 Exploratory Factor Analysis, a presentation of the EFA and its reliability testing in the areas other than Lounge 4 which was presented before.

A.2. Scale Reliability, a reliability check of the constructed scales.

A.3 Multiple Regression Analysis, a presentation of the MRA results of all the separate areas.

Section 1: Exploratory Factor Analysis

Departure Hall 2

To investigate the underlying structure of a fifteen-item questionnaire assessing perception in different crowding circumstances, data collected from 236 participants were subjected to principal axis factoring with Direct Oblimin rotation.

Prior to running the principal axis factoring, examination of the data indicated that not every variable was perfectly normally distributed. Given the robust nature of factor analysis, these deviations were not considered problematic. Furthermore, a linear relationship was identified among the variables.

Four factors (with Eigenvalues exceeding 1) were identified as underlying the fifteen-item questionnaire (see Table A1). In total, these factors accounted for 53% of the variance in the questionnaire data.

Table A1. *Direct Oblimin Rotated Factor Structure of the 15-Item Perception in Different Crowding Circumstances Questionnaire – Area Departure Hall 2*

Item	Loadings			
	Factor 1	Factor 2	Factor 3	Factor 4
1. How would you rate the attractiveness of this location?				.806
2. How would you rate the ambiance of this location?				.680
3. How do you feel about the light at this location?				.421
4. In this area, how afraid are you of falling?			-.717	
5. In this area, how afraid are you of becoming trampled?			-.804	
6. In this area, how afraid are you of severe injury?			-.785	
7. How often have you changed your walking speed or direction due to other people?	.705			
8. How often have you experienced movement difficulties through this area?	.848			
9. How often have you had physical contact with other people?	.657			
10. How often have you experienced a violation of your personal space?	.601			
11. In relation to the space that you are in, to what extent do you agree that you are informed		.635		
12. In relation to the space that you are in, to what extent do you agree that you are at ease		.881		
13. In relation to the space that you are in, to what extent do you agree that you are calm		.854		
14. In relation to the space that you are in, to what extent do you agree that you are in control		.909		
15. In relation to the space that you are in, to what extent do you agree that you are content		.822		

C-Pier

To investigate the underlying structure of a fifteen-item questionnaire assessing perception in different crowding circumstances, data collected from 236 participants were subjected to principal axis factoring with Direct Oblimin rotation.

Prior to running the principal axis factoring, examination of the data indicated that not every variable was perfectly normally distributed. Given the robust nature of factor analysis, these deviations were not considered problematic. Furthermore, a linear relationship was identified among the variables.

Five factors (with Eigenvalues exceeding 1) were identified as underlying the fifteen-item questionnaire (see Table A2). In total, these factors accounted for 54% of the variance in the questionnaire data. However, when taking a look at the structure matrix, the factors remain inconclusive due to the high correlation with a variety of questions. Additionally, factors overlap each other and are in contradiction with previous research. Therefore, the factor analysis of the C-Pier is not used in the analysis the previous constructed scales are used in the MRA.

Table A2. *Direct Oblimin Rotated Factor Structure of the 15-Item Perception in Different Crowding Circumstances Questionnaire – Area C-Pier*

Item	Loadings				
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1. How would you rate the attractiveness of this location?				-.802	
2. How would you rate the ambiance of this location?				-.607	
3. How do you feel about the light at this location?				-.305	.713
4. In this area, how afraid are you of falling?			-.749		
5. In this area, how afraid are you of becoming trampled?	.341		-.793		-.302
6. In this area, how afraid are you of severe injury?			-.864		-.328

7. How often have you changed your walking speed or direction due to other people?	.742			
8. How often have you experienced movement difficulties through this area?	.743		-.320	
9. How often have you had physical contact with other people?	.715		-.478	-.443
10. How often have you experienced a violation of your personal space?	.549		-.518	-.607
11. In relation to the space that you are in, to what extent do you agree that you are informed		.586		
12. In relation to the space that you are in, to what extent do you agree that you are at ease		.830		
13. In relation to the space that you are in, to what extent do you agree that you are calm		.814		
14. In relation to the space that you are in, to what extent do you agree that you are in control		.698	.333	.441
15. In relation to the space that you are in, to what extent do you agree that you are content		.793		

Section 2: Scale Reliability

Departure Hall 2

The Cronbach’s alpha for the 6-item Mental Comfort Scale was α=.91. Although this can be considered highly adequate for research purposes, a closer examination of the questionnaire item total statistics indicated that alpha would increase to α=.92 in case the first item were removed. This item asked to what extent participants agreed to be informed. However, this item was not dropped from the scale, due to its factor loading in the exploratory factor analysis and the small improvement of Cronbach's alpha in an already highly reliable scale.

The Cronbach's alpha for the 3-item Physical Safety Concerns Scale was α=.80 and therefore adequate for research purposes. A closer examination of the questionnaire item-total statistics did not indicate the need for alterations.

The Cronbach's alpha for the 4-item Physical Discomfort Scale was α=.79 and therefore adequate for research purposes. A closer examination of the questionnaire item-total statistics did not indicate the need for alterations.

The Cronbach's alpha for the 3-item Locational Qualities Scale was α=.69. This casts doubt about the reliability of the scale. A closer examination revealed that Cronbach's alpha would increase to α=.72 if the third item were removed. This item asked how participants felt about the light at the location. Consequently, this item was dropped from the questionnaire and all subsequent analysis are based on participants' responses to the remaining two items.

C-Pier

The Cronbach's alpha for the 6-item Mental Comfort Scale was α=.85. This can be considered highly adequate for research purposes. A closer examination of the questionnaire item total statistics indicated no need for alterations.

The Cronbach's alpha for the 3-item Physical Safety Concerns Scale was α=.83 and therefore adequate for research purposes. A closer examination of the questionnaire item-total statistics did not indicate the need for alterations.

The Cronbach's alpha for the 4-item Physical Discomfort Scale was α=.78 and therefore adequate for research purposes. A closer examination of the questionnaire item-total statistics did not indicate the need for alterations.

The Cronbach's alpha for the 3-item Locational Qualities Scale was α=.63. This casts doubt about the reliability of the scale. A closer examination revealed that Cronbach's alpha would increase to α=.72 if the third item were removed. This item asked how participants felt about the light at the location. Consequently, this item was dropped from the questionnaire and all subsequent analysis are based on participants' responses to the remaining two items.

Section 3: Multiple Regression Analysis

Assumption testing
First, stem-and-leaf plots, histograms and boxplots revealed outliers and therefore interfered with the distribution. Outliers were deleted for the dependent variables mental comfort, physical discomfort and safety perception. After removing the outliers, the mentioned variables were relatively normally distributed. The dependent variable 'physical safety concerns' was extremely skewed and showed kurtosis. Removal of the outliers would not solve the distribution issue. Therefore, a bootstrap method was performed in the analysis for this variable. Second, the normal probability plot of standardized residuals as well as the scatterplot of standardized residuals against standardized predicted values indicated that the assumptions of normality, linearity and homoscedasticity of residuals were met. Third, the Mahalanobis distance did exceed the critical x^2 for df=17 (at α=.001) of 33.409 for 23 cases in the data file when analyzing the mental comfort outcome variable. However, for all 23 cases the Cook's distance was <.021. The analysis of different dependent variables showed similar results. Therefore, multivariate outliers were present but not influential and therefore ignored. Fourth, the tolerances for all predictors in the regression model were relatively high, which indicated that multicollinearity would not interfere with the ability to interpret the outcome of the MRA.

Multiple Regression Analysis Lounge 4
The model that was tested via MRA consisted of multiple variables. Identical to the all-area model the following predictive variables were included: crowding (objective, subjective) gender, age, origin, group size, travel purpose, travel experience, haste, light comfortability, locational qualities (scale) and the total Number of people on the airport that day. In addition, in this area respondents were asked about their goal orientation (staying in the lounge area or going somewhere else). All categorical variables were recoded into dummies. All continuous variables are rescaled from 0 to 1 in order to compare in effect size. Prior to interpreting the results of the MRA, several assumptions were evaluated. The same steps as in the all-area model were followed (Chapter 5).

The following pages display the results of the different models for the dependent variables 'mental comfort', 'physical discomfort', 'perceived safety' and 'physical safety concerns'(Table A3-A7).

Table A3. *Summary of the Predictive Models for the Dependent Variables in Area Lounge 4*

Model	R^2	Adjusted R^2	F	p
Mental Comfort	.34	,28	6.31 (16, 200)	<.001
Physical Discomfort	.33	,28	6.17 (16, 200)	<.001
Safety Perception	.37	.21	4.67 (16, 201)	<.001
Physical Safety Concerns	.32	.26	5.83 (16, 203)	<.001

Table A4. *Results of Multiple Regression Model for Mental Comfort. Data Aggregated in Area Lounge 4. The table shows Unstandardised (B) Regression Coefficients, Standard Error, t-statistic and Significance and Semi-Partial Correlations (sr) For Each Predictor.*

Variable	B [CI]	Std. Error B	t	p
(Constant)	6.866 [-2.231, 15.964]	4.614	1.488	.138
Objective Crowding	-.192 [-.569, .186]	.191	-1.002	.318
Subjective Crowding	-.646 [-1.143, -.149]	.252	-2.562	.011*
Travel Experience	.041 [-.412, -.494]	.230	.177	.860
Hurry	-.265 [-.943, .412]	.344	-.772	.441
Light Comfortability	1.434 [.752, 2.117]	.346	4.142	.000*
Locational Qualities: Ambiance and Attractiveness	1.381 [.717, 2.046]	.337	4.098	.000*
Total Number of People in the Airport that Day	-4.486 [-13.602, 4.629]	4.623	-.970	.333
Gender (female)				
Male	.103 [-.088, .293]	.097	1.065	.288
Age (25-45)				
Below average (18-24)	-.116 [-.364, .131]	.125	-.928	.355

Above average (>45)	-.028 [-.248, .192]	.112	-.250	.803
Origin (Dutch)				
Non-Dutch	-.646 [-.883, -.408]	.120	-5.362	.000*
Groupsize (small, 2-3 people)				
Large (≥4 people)	.009 [-.221, .238]	.116	.077	.939
Purpose of Trip (holiday)				
Business	-.115 [-.410, .181]	.150	-.765	.445
Other	.165 [-.300, .629]	.236	.698	.486
Goal Orientation (To Gate)				
Staying	.032 [.215, .279]	.125	.255	.799
Interaction Effect Gender x Objective Crowding	-.226 [-.936, .484]	.360	-.627	.531

Note. N = 391. CI = Confidence Interval.

Table A5. *Results of Multiple Regression Model for Physical Discomfort. Data Aggregated in Area Lounge 4. The table shows Unstandardised (B) Regression Coefficients, Standard Error, t-statistic and Significance and Semi-Partial Correlations (sr) For Each Predictor.*

Variable	B [CI]	Std. Error B	t	p
(Constant)	7.724 [-1.196, 16.644]	4.524	1.707	.089
Objective Crowding	-.077 [-.448, .294]	.188	-.409	.683
Subjective Crowding	1.005 [.516, 1.495]	.248	4.050	.000*
Travel Experience	.055 [-.392, .502]	.227	.241	.810
Hurry	1.141 [.475, 1.808]	.338	3.376	.001*
Light Comfortability	-.275 [-.950, .401]	.343	-.803	.423
Locational Qualities: Ambiance and Attractiveness	-1.126 [-1.782, -.471]	.332	-3.388	.001*
Total Number of People in the Airport that Day	-5.773 [-14.706, 3.160]	4.530	-1.274	.204

Gender (female)				
Male	-.195 [-.383, -.008]	.095	-2.056	.041*
Age (25-45)				
Below average (18-24)	.200 [-.044, .443]	.123	1.617	.107
Above average (>45)	-.190 [-.407, .026]	.110	-1.731	.085
Origin (Dutch)				
Non-Dutch	.057 [-.176, .291]	.118	.485	.628
Groupsize (small, 2-3 people)				
Large (≥4 people)	-.055 [-.281, .172]	.115	-.474	.636
Purpose of Trip (holiday)				
Business	.123 [-.166, .412]	.146	.839	.402
Other	.144 [-.313, .601]	.232	.623	.534
Goal Orientation (To Gate)				
Staying	-.030 [-.274, .214]	.124	-.246	.806
Interaction Effect Gender x Objective Crowding	-.641 [-1.339, .058]	.354	-1.808	.072

Note. N = 391. CI = Confidence Interval.

Table A6. *Results of Multiple Regression Model for Emotional Safety. Data Aggregated in Area Lounge 4. The table shows Unstandardised (B) Regression Coefficients, Standard Error, t-statistic and Significance and Semi-Partial Correlations (sr) For Each Predictor.*

Variable	B [CI]	Std. Error B	t	p
(Constant)	1.582 [-7.305, 10.470]	4.507	.351	.726
Objective Crowding	.566 [.194, .938]	.189	3.003	.003*
Subjective Crowding	-.665 [-1.153, -.177]	.247	-2.689	.008*
Travel Experience	.048 [-.401, .496]	.227	.209	.834
Hurry	-.739 [-1.403, -.075]	.337	-2.195	.029*
Light Comfortability	,537 [-.143, 1.217]	.345	1.556	.121
Locational Qualities: Ambiance and Attractiveness	1.277 [.628, 1.926]	.329	3.881	.000*
Total Number of People in the Airport that Day	1.260 [-7.642, 10.161]	4.514	.279	.781
Gender (female)				
Male	.097 [-.090, .284]	.095	1.024	.307
Age (25-45)				
Below average (18-24)	-.022 [-.265, .222]	.123	-.175	.861
Above average (>45)	-.011 [-.227, .204]	.109	-.103	.918
Origin (Dutch)				
Non-Dutch	.010 [-.223, .242]	.118	.082	.935
Groupsize (small, 2-3 people)				
Large (≥4 people)	-.113 [-.339, .113]	.115	-.988	.324
Purpose of Trip (holiday)				
Business	-.283 [-.572, .005]	.146	-1.940	.054

Other	.236 [-.221, .693]	.232	1.019	.310
Goal Orientation (To Gate)				
Staying	.121 [-.124, .366]	.124	.971	.333
Interaction Effect Gender x Objective Crowding	-.387 [-1.087, .312]	.355	-1.092	.276

Note. N = 391. CI = Confidence Interval.

Table A7. *Results of Multiple Regression Model for Physical Safety Concerns. Data Aggregated in Area Lounge 4. The table shows Unstandardised (B) Regression Coefficients, Bias, Standard Error and Significance.*

Variable	B [CI]	Bias	Std. Error	p
(Constant)	3.614 [-4.107, 12.534]	.320	4.163	.399
Objective Crowding	-.367 [-.714, .001]	.003	.183	.048*
Subjective Crowding	.445 [-.056, .848]]	-.036	.229	.059
Travel Experience	-.058 [-.492, .441]	.014	.239	.820
Hurry	1.411 [.615, 2.263]	.002	.405	.003*
Light Comfortability	-1.274 [-2.093, -.462]	.012	.415	.006*
Locational Qualities: Ambiance and Attractiveness	-.723 [-1.460, -.097]	-.017	.343	.043*
Total Number of People in the Airport that Day	-1.235 [-9.796, 6.358]	-.312	4.129	.763
Gender (female)				
Male	-.048 [-.223, .147]	-.002	.095	.617
Age (25-45)				
Below average (18-24)	.171 [-.069, .429]	.001	.130	.191
Above average (>45)	-.155 [-.344, .032]	.000	.096	.114

Origin (Dutch)				
Non-Dutch	.185 [-.041, 425]	.001	.118	.130
Groupsize (small, 2-3 people)				
Large (≥4 people)	.014 [-.223, .250]	.002	.119	.909
Purpose of Trip (holiday)				
Business	-.155 [-.416, .072]	-.011	.120	.196
Other	-.091 [-.562, .379]	-.002	.240	.696
Goal Orientation (To Gate)				
Staying	-.022 [-.282, .204]	.003	.124	.863
Interaction Effect Gender x Objective Crowding	.040 [-.561, .667]	.015	.325	.902

Note. N = 391. CI = Confidence Interval.

Multiple Regression Analysis Departure Hall 2

In the Departure Hall, a similar model was used to predict the dependent variables. Identical to the all-area model the following predictive variables were included: crowding (objective, subjective) gender, age, origin, group size, travel purpose, travel experience, haste, light comfortability, locational qualities (scale) and the total number of people on the airport that day. In addition, in this area respondents were asked their goal orientation (security check, shopping or other) and if they were standing in line or not. All categorical variables were recoded into dummies. All continuous variables are rescaled from 0 to 1 in order to compare in effect size. Prior to interpreting the results of the MRA, several assumptions were evaluated. The same steps as in the all-area model were followed (Chapter 5).

The following pages display the results of the different models for the dependent variables ‘mental comfort’, ‘physical discomfort’, ‘perceived safety’ and ‘physical safety concerns’ (Table A8-A12).

Table A8. *Summary of the Predictive Models for the Dependent Variables in Area Departure Hall 2.*

Model	R^2	Adjusted R^2	F	p
Mental Comfort	.36	.28	4.21 (19, 142)	<.001
Physical Discomfort	.37	.28	4.30 (19, 142)	<.001
Safety Perception	.30	.20	3.17 (19, 144)	<.001
Physical Safety Concerns	.23	.13	2.23 (19, 142)	<.005

Table A9. *Results of Multiple Regression Model for Mental Comfort. Data Aggregated in Area Departure Hall 2. The table shows Unstandardised (B) Regression Coefficients, Standard Error, t-statistic and Significance and Semi-Partial Correlations (sr) For Each Predictor.*

Variable	B [CI]	Std. Error B	t	p
(Constant)	2.081 [-.917, 5.079]	1.517	1.372	.172
Objective Crowding	.055 [-.883, .993]	.475	.116	.908
Subjective Crowding	-.893 [-1.608, -.178]	.362	-2.469	.015*
Travel Experience	.839 [.241, 1.436[	.302	2.775	.006*
Hurry	-.393 [-1.191, .404]	.403	-.975	.331
Light Comfortability	2.003 [.873, 3.133]	.572	3.504	.001*
Locational Qualities: Ambiance and Attractiveness	1.103 [.046, 2.159]	.534	2.064	.041*
Total Number of People in the Airport that Day	-.617 [-3.609, 2.374]	1.513	-.408	.684
Gender (female)				
Male	.352 [.092, .613]	.132	2.674	.008*
Age (25-45)				

Below average (18-24)	-.102 [-.464, .260]	.183	-.557	.579
Above average (>45)	.233 [-.056, .522]	.146	1.591	.114
Origin (Dutch)				
Non-Dutch	-.321 [-.638, -.003]	.160	-1.998	.048*
Groupsize (small, 2-3 people)				
Large (≥4 people)	.032 [-.236, .300]	.136	.238	.812
Purpose of Trip (holiday)				
Business	-.348 [-.756, .059]	.206	-1.691	.093
Other	.391 [.009, .772]	.193	2.024	.045*
In line (No)				
Yes	.004 [-.354, .362]	.181	.023	.982
Goal Orientation (Check-in)				
Security Check	-.146 [-.502, .209]	.180	-.813	.418
Shopping	-.566 [-1.039, -.092]	.240	-2.362	.020*
Other	-.290 [-.747, .168]	.231	-1.252	.213
Interaction Effect Gender x Objective Crowding	.315 [-1.203, 1.833]	.768	.410	.682

Note. N = 241. CI = Confidence Interval.

Table A10. *Results of Multiple Regression Model for Physical Discomfort. Data Aggregated in Area Departure Hall 2. The table shows Unstandardised (B) Regression Coefficients, Standard Error, t-statistic and Significance and Semi-Partial Correlations (sr) For Each Predictor.*

Variable	B [CI]	Std. Error B	t	p
(Constant)	.566 [-1.999, 3.130]	1.297	.436	.664
Objective Crowding	.361 [-.442, 1.163]	.406	.889	.376
Subjective Crowding	1.316 [.704, 1.928]	.309	4.252	.000*
Travel Experience	-.159 [-.670, .353[	.259	-.613	.541
Hurry	1.243 [.561, 1.926]	.345	3.603	.000*
Light Comfortability	-.778 [-1.745, .189]	.489	-1.591	.114
Locational Qualities: Ambiance and Attractiveness	-.194 [-1.097, .710]	.457	-.424	.672
Total Number of People in the Airport that Day	1.421 [-1.137, 3.980]	1.294	1.098	.274
Gender (female)				
Male	-.064 [-.287, .159]	.113	-.567	.572
Age (25-45)				
Below average (18-24)	.102 [-.208, .412]	.157	.650	.517
Above average (>45)	-.242 [-.489, .006]	.125	-1.931	.055
Origin (Dutch)				
Non-Dutch	-.113 [-.385, .158]	.137	-.825	.411
Groupsize (small, 2-3 people)				
Large (≥4 people)	.022 [-.207, .251]	.116	.190	.850
Purpose of Trip (holiday)				

Business	-.089 [-.438, .259]	.176	-.508	.612
Other	-.196 [-.522, .131]	.165	-1.186	.238
In line (No)				
Yes	-.051 [-.357, .255]	.155	-.330	.742
Goal Orientation (Check-in)				
Security Check	-.211 [-.515, .094]	.154	-1.368	.173
Shopping	.106 [-.299, .511]	.205	.516	.607
Other	-.102 [-.493, .290]	.198	-.514	.608
Interaction Effect Gender x Objective Crowding	.050 [-1.249, 1.348]	.657	.076	.940

Note. N = 241. CI = Confidence Interval.

Table A11. *Results of Multiple Regression Model for Emotional Safety. Data Aggregated in Area Departure Hall 2. The table shows Unstandardised (B) Regression Coefficients, Standard Error, t-statistic and Significance and Semi-Partial Correlations (sr) For Each Predictor*.

Variable	B [CI]	Std. Error B	t	p
(Constant)	1.478 [-.708, 3.665]	1.106	1.336	.184
Objective Crowding	.257 [-.426, .939]	.345	.743	.459
Subjective Crowding	-1.035 [-1.557, -.512]	.264	-3.915	.000*
Travel Experience	.627 [.189, 1.065]	.222	2.829	.005*
Hurry	-.522 [-1.105, .061]	.295	-1.771	.079
Light Comfortability	.154 [-.680, .987]	.421	.364	.716
Locational Qualities: Ambiance and Attractiveness	1.253 [.475, 2.031]	.394	3.182	.002*
Total Number of People in the Airport that Day	1.729 [-.446, 3.904]	1.100	1.571	.118

Gender (female)				
Male	.088 [-.102, .279]	.097	.915	.362
Age (25-45)				
Below average (18-24)	.091 [-.173, .345]	.133	.679	.498
Above average (>45)	.028 [-.186, .241]	.108	.257	.798
Origin (Dutch)				
Non-Dutch	.078 [-.155, .312]	.118	.662	.509
Groupsize (small, 2-3 people)				
Large (≥4 people)	-.038 [-.234, .159]	.099	-.381	.704
Purpose of Trip (holiday)				
Business	-.295 [-.595, .005]	.152	-1.942	.054
Other	-.034 [-.306, .237]	.137	-.251	.802
In line (No)				
Yes	.036 [-.225, .297]	.132	.272	.786
Goal Orientation (Check-in)				
Security Check	-.082 [-.343, .180]	.132	-.616	.539
Shopping	-.141 [-.485, .202]	.174	-.814	.417
Other	-.027 [-.354, .300]	.166	-.164	.870
Interaction Effect Gender x Objective Crowding	.217 [-.892, 1.327]	.561	.387	.699

Note. N = 241. CI = Confidence Interval.

Table A12. *Results of Multiple Regression Model for Physical Safety Concerns. Data Aggregated in Area Departure Hall 2. The table shows Unstandardised (B), Bias, Std. Error and Significance For Each Predictor.*

Variable	B [CI]	Bias	Std. Error	p
(Constant)	.258 [-1.931, 2.320]	-.127	1.106	.832
Objective Crowding	-.136 [-.811, .599]	.024	.357	.717
Subjective Crowding	.586 [.111, 1.100]	.000	.247	.023*
Travel Experience	-.467 [-.883, -.021]	.013	.214	.032*
Hurry	1.158 [.400, 1.809]	-.038	.368	.004*
Light Comfortability	-.052 [-.818, .721]	.030	.394	.904
Locational Qualities: Ambiance and Attractiveness	-.299 [-1.166, .684]	.014	.449	.499
Total Number of People in the Airport that Day	1.230 [-.928, 3.331]	.100	1.107	.267
Gender (female)				
Male	.077 [-.109, .249]	-.013	.092	.416
Age (25-45)				
Below average (18-24)	.051 [-.213, .323]	.004	.133	.722
Above average (>45)	-.160 [-.362, .065]	.010	.110	.151
Origin (Dutch)				
Non-Dutch	-.047 [-.259, .171]	-.003	.109	.694
Groupsize (small, 2-3 people)				
Large (≥4 people)	-.067 [-.269, .128]	.000	.100	.511
Purpose of Trip (holiday)				
Business	.215 [-.084, .573]	.003	.168	.205
Other	-.017 [-.367, .312]	-.005	.169	.914

In line (No)				
Yes	-.139 [-.382, .116]	-.003	.129	.282
Goal Orientation (Check-in)				
Security Check	-.069 [-.334, .185]	-.004	.132	.592
Shopping	.061 [-.252, .408]	.005	.166	.709
Other	.001 [-.452, .426]	-.004	.221	.997
Interaction Effect Gender x Objective Crowding	-.400 [-1.523, .617]	-.016	.524	.434

Note. N = 241. CI = Confidence Interval.

Multiple Regression Analysis C-Pier

Identical to the all-area model the following predictive variables were included in the C-Pier model: crowding (objective, subjective) gender, age, origin, group size, travel purpose, travel experience, haste, light comfortability, locational qualities (scale) and the total number of people on the airport that day. In addition, in this area respondents were asked their goal orientation (departure, arriving, transfer) and if they were waiting at the gate or not. All categorical variables were recoded into dummies. All continuous variables are rescaled from 0 to 1 in order to compare in effect size. Prior to interpreting the results of the MRA, several assumptions were evaluated. The same steps as in the all-area model were followed (Chapter 5).

The following pages display the results of the different models for the dependent variables ‘mental comfort’, ‘physical discomfort’, ‘perceived safety’ and ‘physical safety concerns’ (Table A13-A17).

Table A13. *Summary of the Predictive Models for the Dependent Variables in Area C-Pier.*

Model	R^2	Adjusted R^2	F	p
Mental Comfort	.27	.17	2.63 (18, 128)	<.005
Physical Discomfort	.17	.05	1.44 (19, 125)	.125
Safety Perception	.26	.16	2.49 (18, 128)	<.005
Physical Safety Concerns	.19	.08	1.71 (18, 128)	.045

Table A14. *Results of Multiple Regression Model for Mental Comfort. Data Aggregated in Area C-Pier. The table shows Unstandardised (B) Regression Coefficients, Standard Error, t-statistic and Significance and Semi-Partial Correlations (sr) For Each Predictor.*

Variable	B [CI]	Std. Error B	t	p
(Constant)	.696 [-3.234, 4.626]	1.986	.350	.727
Objective Crowding	.086 [-.475, .646]	.283	.303	.763
Subjective Crowding	-.216 [-.965, .532]	.378	-.572	.569
Travel Experience	.547 [-.103, 1.197]	.328	1.666	.098
Hurry	-.209 [-1.144, .725]	.472	-.443	.659
Light Comfortability	.615 [-.163, 1.394]	.393	1.564	.120
Locational Qualities: Ambiance and Attractiveness	1.788 [.788, 2.789]	.505	3.539	.001
Total Number of People in the Airport that Day	1.491 [-2.241, 5.222]	1.886	.790	.431
Gender (female)				
Male	.061 [-.196, .318]	.130	.469	.640
Age (25-45)				
Below average (18-24)	-.037 [-.405, .331]	.186	-.199	.843

Above average (>45)	-.031 [-.322, .261]	.147	-.209	.835
Origin (Dutch)				
Non-Dutch	-.725 [-1.086, -.364]	.182	-3.974	.000*
Groupsize (small, 2-3 people)				
Large (≥4 people)	.071 [-.241, .382]	.157	.449	.654
Purpose of Trip (holiday)				
Business	.191 [-.361, .743]	.279	.684	.495
Other	.198 [-.370, .767]	.287	.690	.491
Waiting at the Gate (yes)				
No	.071 [-.439, .581]	.258	.275	.784
Goal Orientation (Departure)				
Arriving	.378 [-.327, 1.084]	.357	1.061	.291
Transfer	.213 [-.159, .585]	.188	1.134	.259
Interaction Effect Gender x Objective Crowding	.770 [-.316, 1.856]	.549	1.403	.163

Note. N = 239. CI = Confidence Interval.

Table A15. *Results of Multiple Regression Model for Physical Discomfort. Data Aggregated in Area C-Pier. The table shows Unstandardised (B) Regression Coefficients, Standard Error, t-statistic and Significance and Semi-Partial Correlations (sr) For Each Predictor.*

Variable	B [CI]	Std. Error B	t	p
(Constant)	-.629 [-4.541, 3.283]	1.977	-.318	.751
Objective Crowding	-.208 [-.770, .353]	.284	-.735	.464
Subjective Crowding	.840 [.086, 1.594]	.381	2.205	.029*
Travel Experience	.820 [.168, 1.473]	.330	2.489	.014*

Hurry	.161 [-.771, 1.092]	.471	.341	.734
Light Comfortability	-.246 [-1.019, .526]	.390	-.631	.529
Locational Qualities: Ambiance and Attractiveness	-.088 [-1.082, .907]	.502	-.174	.862
Total Number of People in the Airport that Day	2.374 [-1.338, 6.086]	1.876	1.266	.208
Gender (female)				
Male	-.004 [-.265, .256]	.132	-.031	.976
Age (25-45)				
Below average (18-24)	.033 [-.338, .404]	.188	.176	.861
Above average (>45)	-.228 [-.523, .066]	.149	-1.533	.128
Origin (Dutch)				
Non-Dutch	-.073 [-.438, .292]	.184	-.397	.692
Groupsize (small, 2-3 people)				
Large (≥4 people)	-.047 [-.362, .268]	.159	-.296	.768
Purpose of Trip (holiday)				
Business	.096 [-.452, .645]	.277	.347	.729
Other	-.442 [-1.006, .122]	.285	-1.552	.123
Waiting at the Gate (yes)				
No	-.052 [-.558, .454]	.255	-.203	.839
Goal Orientation (Departure)				
Arriving	.318 [-.388, 1.024]	.357	.891	.375
Transfer	-.054 [-.431, .323]	.190	-.285	.776
Interaction Effect Gender x Objective Crowding	-.271 [-1.362, .820]	.551	-.492	.624

Note. N = 239. CI = Confidence Interval.

Table A16. *Results of Multiple Regression Model for Emotional Safety. Data Aggregated in Area C-Pier. The table shows Unstandardised (B) Regression Coefficients, Standard Error, t-statistic and Significance and Semi-Partial Correlations (sr) For Each Predictor.*

Variable	B [CI]	Std. Error B	t	p
(Constant)	6.254 [2.818, 9.689]	1.736	3.602	.000
Objective Crowding	.454 [-.036, .944]	.248	1.832	.069
Subjective Crowding	-.555 [-1.209. .099]	.331	-1.680	.095
Travel Experience	-.024 [-.592, .544]	.287	-.084	.933
Hurry	-.157 [-.974, .660]	.413	-.381	.704
Light Comfortability	.180 [-.501, .860]	.344	.522	.603
Locational Qualities: Ambiance and Attractiveness	.889 [.015, 1.763]	.442	2.012	.046*
Total Number of People in the Airport that Day	-3.224 [-6.485, .038]	1.648	-1.956	.053
Gender (female)				
Male	.072 [-.153, .296]	.114	.633	.528
Age (25-45)				
Below average (18-24)	-.004 [-.325, .318]	.162	-.022	.982
Above average (>45)	.004 [-.251, .259]	.129	.032	.975
Origin (Dutch)				
Non-Dutch	.061 [-.255, .376]	.159	.381	.704
Groupsize (small, 2-3 people)				
Large (≥4 people)	-.234 [-.506, .038]	.137	-1.704	.091
Purpose of Trip (holiday)				
Business	.307 [-.176, .790]	.244	1.259	.210
Other	.507 [.011, .1004]	.251	2.021	.045
Waiting at the Gate (yes)				
No	-.522 [-.968, -.076]	.225	-2.318	.022*

Goal Orientation (Departure)				
Arriving	-.117 [-.733, .500]	.312	-.375	.709
Transfer	.175 [-.150, .500]	.164	1.068	.288
Interaction Effect Gender x Objective Crowding	.588 [-.362, 1.537]	.480	1.225	.223

Note. N = 239. CI = Confidence Interval.

Table A17. *Results of Multiple Regression Model for Physical Safety Concerns. Data Aggregated in Area C-Pier. The table shows Unstandardised (B), Bias, Std. Error and Significance For Each Predictor.*

Variable	B [CI]	Bias	Std. Error	p
(Constant)	.274 [-3.319, 3.451]	-.015	1.689	.888
Objective Crowding	-.413 [-.865, .004]	.017	.223	.064
Subjective Crowding	.072 [-.678, 1.060]	.061	.444	.888
Travel Experience	-.209 [-.847, .408]	-.012	.314	.507
Hurry	-.226 [-1.117, .592]	-.021	.435	.586
Light Comfortability	-.539 [-1.275. .208]	.025	.391	.176
Locational Qualities: Ambiance and Attractiveness	-.141 [-1.032, .721]	-.007	.443	.764
Total Number of People in the Airport that Day	2.119 [-.994, 5.361]	-.016	1.618	.192
Gender (female)				
Male	.063 [-.184, .309]	-.011	.125	.613
Age (25-45)				
Below average (18-24)	.269 [-.103, .589]	-.032	.177	.135
Above average (>45)	-.082 [-.372, .168]	-.015	.135	.543
Origin (Dutch)				

Non-Dutch	-.001 [-.399, .413]	.001	.208	.994
Groupsize (small, 2-3 people)				
Large (≥4 people)	.135 [-.104, .383]	.005	.124	.280
Purpose of Trip (holiday)				
Business	.265 [-.414, 1.054]	-.004	.368	.431
Other	-.438 [-.774, -.098]	.010	.173	.013*
Waiting at the Gate (yes)				
No	-.078 [-.491, .305]	.008	.196	.689
Goal Orientation (Departure)				
Arriving	.339 [-.598, 1.387]	.022	.477	.438
Transfer	-.135 [-.574, .339]	.005	.226	.528
Interaction Effect Gender x Objective Crowding	-.715 [-1.555, .200]	.059	.458	.137

Note. N = 239. CI = Confidence Interval.

Appendix B: Questionnaire

The survey consisted of standard structure which was adapted to the different areas. Some questions were only asked in one specific area. This is indicated in parenthesis.

Q1 On behalf of Leiden University and Amsterdam Airport Schiphol, I study the customer experience of crowding at the airport. If you choose to participate in this research, you will help to increase customer satisfaction and gain knowledge about this subject. Participation is voluntary and you have the possibility to drop out anytime. The survey takes no longer than 5 minutes. This study ensures confidentiality. If you choose 'accept', you give permission to process your data.

o Accept, I want to proceed with this survey

o Decline. I do not want to participate in this study

Q2 What is your gender?

o Male

o Female

o Other

Q3 What is your age?

o 18-24

o 25-44

o 45-54

o 55-64

o 65-74

o 75 or older

Q4 What is your nationality?

____

Q5 Are you here with company?

- o Yes, I am with others
- o No, I am alone

Q6 How many people are in your group?

▼ 2 ... More than 10

Q7 What is your group composition?

- o Family with children below the age of 8
- o Family without children below the age of 8
- o Friends
- o Colleagues
- o Couple
- o Mixed

Q8 What is the purpose of your trip?

- o Business
- o Holiday
- o Other: namely ____

Q9 How often do you travel by plane on average?

- o Less than one trip a year
- o 1 or 2 trips a year
- o 3-5 trips a year
- o More than 5 trips a year

Q10 Why are you at Schiphol Airport? *(C-Pier)*

- o Arriving
- o Departure

- o Transfer to another flight

Q11 C Are you waiting at your gate right now? *(C-Pier)*

- o Yes (1)
- o No (2)

Q12 C Where are you going to? *(C-Pier)*

- o My gate
- o To luggage reclaim
- o Shopping, café or lounge area
- o Other: namely ____

Q11 DH Are you waiting in line right now? *(Departure Hall 2)*

- o Yes
- o No

Q12 DH Where are you going to now? *(Departure Hall 2)*

- o Check-in desk
- o Security check
- o Shopping, café or lounge area
- o Home

Q12 L Where are you going to? *(Lounge 4)*

- o My gate
- o Staying in this lounge area
- o Other: namely ____

Q13 Are you in a hurry?

- o None at all (1)
- o A little (2)
- o A moderate amount (3)
- o A lot (4)
- o A great deal (5)

Q14 In your view, how crowded is this location?

- o Not crowded at all
- o A bit crowded
- o Relatively crowded
- o Very crowded
- o Extremely crowded

Note. The following questions are focused on your experiences in the area you are located in right now. Please answer them truthfully

Q15 How would you rate the safety at this location?

- o Very unsafe
- o Unsafe
- o Neutral
- o Safe
- o Very safe

Q16 How would you rate the attractiveness of this location?

- o Very unattractive
- o Unattractive
- o Neutral
- o Attractive
- o Very attractive

Q17 How would you rate the ambiance at this location?

- o Very bad
- o Bad
- o Neutral
- o Good
- o Very good

Q18 How would you rate the light at this location?

- o Very dark
- o Dark
- o Neutral
- o Light
- o Very light

Q19 How do you feel about the light at this location?

- o Very uncomfortable
- o Uncomfortable
- o Neutral
- o Comfortable
- o Very comfortable

Q20 In this area, how afraid are you of

	Not at all afraid	Rather not afraid	Neutral	Rather afraid	Very afraid
Falling	o	o	o	o	o
Becoming trampled	o	o	o	o	o
Severe injury	o	o	o	o	o

Q21 How often have you

	None at all	A little	A moderate amount	A lot	A great deal
a. changed your walking speed or direction due to other people	o	o	o	o	o
b. experienced movement difficulties through this area	o	o	o	o	o
c. had physical contact with other people	o	o	o	o	o
d. experienced a violation of your personal space	o	o	o	o	o

Q22 In relation to the space that you are in, to what extent do you agree that you are

	None at all	A little	A moderate amount	A lot	A great deal
Informed	o	o	o	o	o
At ease	o	o	o	o	o
Calm	o	o	o	o	o
In control	o	o	o	o	o
Content	o	o	o	o	o
Stressed	o	o	o	o	o

Q23 How would you rate the level of safety at this location now?

o Very unsafe

o Unsafe

o Neutral

o Safe

o Very safe

Q24 Do you have any other experiences related to this location that you would like to report?

o Yes, namely ____

o No

Still to be done:

Safe crowd densities can be assumed for 2-3 people per m2 (love parade report (Dirk Helbing & Mukerji, 2012) maar origineel van Still expert report on love parade). Above 4-6 people p m2 – congestion is very likely. Vanaf 7 p sqm = fluid (Fruin/loveparade)

Appendix C: Literature

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