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Review

The Contribution of Mobile Apps to the Improvement of Walking/Cycling Behavior Considering the Impacts of COVID-19 Pandemic

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Abstract: More than one hundred and fifty cities around the world have expanded their emergency cycling and walking infrastructures to increase their resilience in the face of the COVID-19 pandemic. In addition, the role of mobile apps is prominent in respect to developing a smart city during this pandemic, which raises the questions of how mobile apps contribute to the improvement of walking/cycling behavior and how such a relationship is influenced by the situation imposed by COVID-19. The role of mobile apps in the three relevant fields of physical activity, transport, and urban planning are reviewed. Next, the associations between walking/cycling behaviors and their contributing factors and the impacts of the COVID-19 pandemic on these relationships are reviewed. Studies on physical activity have emphasized the role of motivational social factors in improving the function of mobile apps. In regard to transport, mobile apps have the potential to facilitate data collection in macroscale environments. In addition, mobile apps may facilitate people's recognition of positive/negative environmental aspects, and this may in turn lead to greater pedestrian/cyclists' awareness and better organization of their walking/cycling behavior. Moreover, based on a participatory approach, the classification of current mobile apps and certain suggestions on the development of future mobile apps are presented. Finally, complementary suggestions are provided for maintaining and improving the use of mobile apps to improve the level of walking/cycling.

Keywords: COVID-19; smart city; walking behavior; cycling behavior; mobile apps; participatory approach

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1. Introduction

Resilience refers to a system's ability to efficiently absorb shocks [1]. The recent COVID-19 pandemic has influenced many aspects of our daily life. It has meant various changes to the physical and social arrangements of our cities have been needed in order to increase urban resilience in the face of this pandemic. Concerning urban transport, in many cities the provision of public space and infrastructure for the development of active travel, including walking and cycling, has been adopted as the main approach to increasing urban resilience in the face of the COVID-19 pandemic [1]. These active transport modes are the most sustainable modes of transport. More than 150 cities have expanded emergency cycling and walking infrastructures as of late April 2020 [2]. Many cities such as Auckland, Barcelona, Bogota, New York, Quito, and Rome, have been aiming to improve city infrastructure to facilitate socially distanced walking and cycling, and other cities such as Montreal, Oakland, Portland, San Diego, San Francisco, and Vienna are trying to create slow/safe street networks that prioritize pedestrians and cyclists and limit car access [2]. For instance, the retiming of traffic lights was adopted in Brussels to give more time to pedestrians and cyclists and to avoid crowding at junctions [2].

Although as of mid-2021 the duration of this pandemic is still unclear, it seems that this approach toward walking/cycling behavior has a long-term view due to the high expense invested in this area in many cities. This tendency of policy makers as well as inhabitants toward active travel modes has made them the predominant modes of transport for daily trips.

Furthermore, mobile devices have become increasingly widespread in urban life. Mobile apps also play the main role in developing smart mobility, which is about modern, safe, and sustainable transport systems, as one of the main dimensions of smart city [3]. Mobile applications have provided location-based information, and this kind of information has garnered significant interest from a variety of disciplines, including urban planning and transportation, for their ability to show how people intermingle and move throughout cities [4,5]. The tracking possibility offered by mobile apps, in spite of its disadvantages such as intruding on people's privacy, has been shown to have many advantages for different purposes. Indeed, the smart phones which incorporate GPS technology allow for mapping and a better understanding of human spatial behavior [6].

The role of technology and various mobile apps in different aspects of daily life has also come into focus during the pandemic. This shows the great potential of mobile apps for enhancing the resilience of our environments in the face of such a pandemic. The stated orientation of urban transport towards walking/cycling during this pandemic, and the significant role of mobile apps observed during the pandemic raises the questions: How do mobile apps contribute to the improvement of walking/cycling behavior? How is such a relationship influenced by the situation imposed by the COVID-19 pandemic?

Walking and cycling behavior has been considered in the three fields of Physical Activity, Transport, and Urban Planning. Walking and cycling are two types of daily physical activity in addition to being different modes of active transportation. Furthermore, encouragement of residents to use active transportation has also been highlighted as a part of the participatory urban planning process to improve the planning of a healthy city. As one of the primary characteristics of smart city governance, participation in the decision-making process is one of the most important components [3,7]. In this regard, the first section (Section 2), reviews the use of different types of mobile apps in these fields of study in order to better understand the function of different types of mobile apps in improving issues related to walking/cycling behavior.

Furthermore, to improve walking/cycling behavior, the contributing personal, social, and built environment factors and the relevant theories are to be reviewed, and the influence of COVID-19 on these relationships is to be recognized. In this regard, Section 3 considers the association between walking/cycling behaviors and their relevant personal, social, and built environment factors, and considers the impacts of the COVID-19 pandemic on these relationships through the previous studies on these relationships. In regard to the built environment, the classification presented by Pikora et al. [8] was applied to explain the results. This classification has been used by the majority of the studies that consider the relationships between walking/cycling behavior and built environment factors. The impacts of the COVID-19 pandemic on these relationships were also reviewed [9].

Finally, by reviewing and comparing the contents of the Sections 2 and 3, Section 4 tries to answer the questions of this study with the required details together with the relevant discussion. Next, the section of Conclusions presents the summary of the main findings in regard to the raised questions.

2. Reviewing the Contribution of Mobile Apps to Physical Activity, Transportation, and Urban Planning as the Areas Related to Walking/Cycling Behavior

Enhancing exercise and physical activity contributes to the improvement of the health of inhabitants [10,11]. A minimum of 30 min of moderate to vigorous aerobic physical activity on the majority of days of the week is recommended for adults to promote and maintain health [10]. Walking and cycling are two types of daily physical activity which contribute to the maintenance and improvement of the minimum rate of physical activity and health. For instance, walking is an excellent form of physical activity for older

adults because it is familiar, cheap, safe, easy, convenient, and can be performed in social settings [10]. In this regard, the first subsection reviews the function of different types of mobile apps to the improvement of physical activity through the relevant studies.

In addition, as is expected, the mobile apps used in the daily transportation of inhabitants are mostly related to walking/cycling behavior. Thus, the second subsection reviews the contribution of mobile apps to the most relevant aspects of transportation and walking/cycling behavior. Furthermore, encouragement of inhabitants to use active travel has been also emphasized in participatory urban planning process to improve the healthy city planning. Mobile apps have been widely involved in different aspects of urban planning, especially participation in urban planning processes [12,13]. In addition, participation in decision-making process is one of the main components of Smart governance as one of the main dimensions of smart city [3,7]. Therefore, the third subsection reviews the role of mobile apps in the participatory process of urban planning.

2.1. The Contribution of Mobile Apps to the Improvement of Physical Activity Including Walking and Cycling

MOVES+ (Advanced version of *MOVES*) is an app that tracks and rewards the user for each activity. It can automatically detect walking, cycling, and running. Users can use the *MOVES* app to view the distance, duration, steps, and calories burned for each activity. Memon et al. [14], who evaluate physical activity increase and weight loss in university students using *MOVES*, found notable weight loss in participants after 5 weeks. However, there was a significant decline in the number of steps in the intervention group from weeks 4 and 5 compared to the baseline physical activity [14]. Mayer et al. [15] assessed the *Survivor-CHESS* app's impact on physical activity in colon cancer survivors. Participants using *Survivor-CHESS* increased their moderate to vigorous physical activities from 19.4 min at baseline to 50 min during the study [15]. Naimark [16] who assessed the impact of a web-based app on levels of physical activity found that this app motivates users to significantly increase physical activity. *MapMyWALK* is an app which has been designed to enhance the level of walking and thus the physical activity of its users. It provides the information such as the time and distance of the walking trips and needs to be activated by the users before each walking trip in order to record the information regarding their walking trips. *BActive* is other kind of app which records the steps of users continuously without the need for user activation. Harries et al. [17] examined the impacts of this app and the receipt of feedback on the level of walking. They found that both the feedback on one's own walking and social feedback contribute to the enhancement of the level of walking, thus increasing physical activity among the participants.

King et al. [18], developed three types of physical activity apps based on conceptually different motivational frameworks including cognitive or analytical apps, social apps, and emotional apps to examine their effects on the level of physical activity. These apps were designed based on motivational frames drawn from behavioral science theory and evidence. An "analytically" framed custom application focused on personalized goal setting, self-monitoring, and active problem solving around barriers to behavior change. A "socially" framed custom application focused on social comparisons, norms, and support. An "affectively" framed custom application focused on operant conditioning principles of reinforcement scheduling and emotional transference to an avatar, whose movements and behaviors reflected the physical activity and sedentary levels of the user. They found that all the three applications were sufficiently robust to significantly improve regular moderate-to-vigorous intensity physical activity and decrease leisure-time sitting during the study time (8-week behavioral adoption period).

Tu et al. [19] evaluated the contribution of two types of mobile apps to the enhancement of walking and physical activity. The first type of app with game elements focused on enhancing emotional value (*Walkup*) and the other focused on increasing social value (*WeChat Sports*). For instance, *WeChat Sports* presents a daily leaderboard that compares users' activity to their friends' numbers. A longitudinal study was conducted and participants were recruited for the seven-week fitness-tracking study. Both apps recorded

participants' daily step counts and tracked their physical activities. One week after the fitness-tracking study, participants' intentions to continue using the app were measured. The results indicate that even though making the fitness app more fun can encourage consumers to adopt and participate in physical activity, making it more social can be much more effective to help them sustain a walking routine in their daily living [19].

Furthermore, the role of different types of games on enhancing the physical activity has been explored by other studies. For instance, Howe et al. [20] examined the effect of playing *Pokémon GO* on the number of steps taken daily up to six weeks after installation of the game. *Pokémon Go* is a free smartphone app that combines gaming with the real world. The game uses location tracking and mapping technology to create an 'augmented reality' where players catch and train Pokémon characters in real locations. It was found that *Pokémon GO* was associated with an increase in the daily number of steps after installation of the game [20]. However, the association was moderate and no longer observed after six weeks.

2.2. The Contribution of Mobile Apps to Transportation

Nowadays, mobile apps are used in different aspects of transportation such as traffic data collection, traffic safety, travel information, navigation or route planning, parking, and ridesharing. These mobile apps have been useful for both transportation agencies and the traveling public. Citizens carry their phones with them at all times and can now provide real-time information. Most of the transport related apps are location-based or dynamic and provide online transport information using built-in, location-sensing capabilities such as GPS [21]. This takes into account the nature of the transport as a dynamic entity.

Applications that provide travel information for users are the first type of transport related apps which provide real-time traffic information and other types of real-time travel information so that the apps' users can be aware of the traffic information of the street networks and other required travel information. Examples of these apps are *Sigalert.com*, *Georgia 511*, and *UK Bus Checker*. Road users can utilize this real-time travel information to make an early lane change to unblocked lanes or adjust their route. The second types of app with certain functional similarities to the first type of apps are the applications for navigation and route planning. These apps have been designed to assist travelers in navigating cities easily and quickly, as well as determining the most effective route from one point to another. Examples of these apps are *Mapquest*, *Flightmap*, *Onfleet*, *Route4Me*, etc. The majority of these apps allow the user to select the optimal route based on a variety of parameters such as route length, grade, and speed. In fact, the major difference between this type with the first type is that the users of the first type can adjust their route based on the real-time travel information provided by the app, but the second type can provide the most optimum route for multipurpose trips between the origin and the given destination. For instance, the route-planning tools for bicyclists and walkers give road users the choice of selecting the shortest or quietest cycle or walk paths. The majority of these apps give route grade information by allowing the nondrivers to select the routes based on their ability to handle the grades. According to Riggs and Gordon [13], these kinds of apps are categorized into two types, synchronous and asynchronous. In synchronous apps, the user and application interact in real time which means that the apps need real-time database updates regarding transit, traffic, and route times to provide immediate information upon the user's request. However, with asynchronous apps the user and application interact in nonreal time and they only include static data for maps and route information. It is also to be noted that, in regard to the mobile apps for navigation, plenty of mobile apps such as *Be My Ayes* and *Aira* offer orientation in an urban setting for pedestrians with visual as well as hearing impairments [22].

Mobile apps which were designed to improve traffic safety are also potentially related to cycling. For instance, *DriveSafe.ly* reads incoming text messages and emails as they come in and prevents drivers from looking down at the phone when they're on the road. Likewise, *AT&T's DriveMode* can silence texts, message alerts, and phone calls while driving

and then, sends an automatic response to people who try to contact the driver by informing them that the driver is unable to react at that time. Other types of apps such as *ParkMobile* that provide parking information for drivers are also potentially related to cycling behavior. They make it easier for people or organizations to get parking as they go across a city or region. Thus, it helps to alleviate traffic congestion especially in the cities which are faced with this challenge. Most parking apps give users the information such as real-time parking availability and pay-by-phone alternatives [23].

Furthermore, other type of mobile apps include those designed for transport data collection such as time and location of the departure and arrival of each trip, types of transport mode, road traffic including the density of vehicles, passengers in vehicles, etc. [24,25]. Examples of this type of app are *SpeedClock* and *TurnCount*. The apps for travel survey data use built-in location sensing capabilities such as GPS to show current location and maximum and average speeds. According to Vlassenroot et al. [25] for individual travel behavior, smartphone GPS apps offer the most direct observation of a person's trips which is fundamental information for analyzing and understanding the rationale behind individual transportation choices. Research on these types of mobile apps can cover different aspects of trip behavior such as transport mode choice [26], route choice [27,28], departure-time choice, etc. In this regard, the use of GPS apps to measure walking behavior has increased in the recent decades [29–31]. In fact, mobile apps have significantly improved the traditional methods of recognizing the path trajectories of pedestrians. For instance, Hahm et al. [32] used "myTracks—The GPS-Logger 3.2.2" to reveal pedestrians' preference on built environments in a retail district in Seoul, Korea.

2.3. The Contribution of Mobile Apps to the Participatory Process in Urban Planning

As stated earlier, mobile apps have been widely involved in different aspects of the urban planning process especially in terms of the urban participation [12,13]. Titiana-Petra [12] presented the typology of mobile apps based on theories of urban participation. He classified the participatory apps based on three dimensions: type of data collected, information flow and empowerment of citizens. Mobile apps based on the dimension 'type of data collected', can be categorized into *people-centric apps* and *environment-centric apps* [33]. *People-centric apps* document user activities and aim at understanding user behavior while *environment-centric apps* collect environmental parameters [34]. The other dimension is information flow which indicates the direction of information when using the app [13,35]. The mobile apps based on this dimension are classified into two types. The first type are *Informing apps* which employ a one-way direction of information, and most of the current apps are of this type. The second type is *transactional/interactive apps* which allow for a multidirectional flow of information in which citizens can participate and share their input on a variety of issues. Thus, these *interactive apps* enable a shared user experience normally through aggregation and visualization on a map of individual contributions.

In addition, *Informing apps* are classified into two subtypes of *prepopulated apps* and *reporting apps*. Prepopulated apps are apps where one-way information, normally through a map, flows from the organization managing the app to its users. While citizens' knowledge and awareness will increase through these maps, nothing is transmitted in the other direction. Therefore, this type of app does not contribute to citizens' participation in the planning process. An example of these types of apps is *Walk Score* which helps users to understand different types of destinations in their surrounding environment. The second subtype of informing apps is *reporting apps*. A reporting app allows citizens to inform the city administration about different aspects of their living environment such as public violations, broken lights, potholes, or street cleaning. Using these apps, citizens could monitor the state of their environment and upload photos onto the app before sending them directly to the respective city administration. Reporting apps such as *MyDelaware* have been widely used in the city of Delaware, USA [36]. Furthermore, informing apps may also be categorized into location-based or *dynamic apps* when involved with the users'

location, and non-location-based apps or *static apps* when the app does not depend on where the user is located [37].

The empowerment of citizens is the next dimension in relation to the participatory planning process. According to Roberts [38], participation is a process by which members of a society share power with public officials in making substantive decisions and in taking community-related actions. In other words, citizens are not mere tenets of local knowledge, but aim to be involved in shaping the policies that affect them. Thus, the power sharing or empowerment of citizens is one of the main dimensions of the participation process. This citizen power can be classified into operational and strategic power [39]. Strategic power is concerned with the ability to determine a policy or service, setting objectives, and creating performance standards. Operational power refers to the ability to decide how a particular policy or service is carried out in practice.

3. Walking/Cycling, Its Contributing Factors, and the Impacts of the COVID-19 Pandemic

As stated earlier, to improve walking/cycling behavior through mobile apps, the contributing personal, social, and built environment factors and the relevant theories need to be reviewed. Additionally, the influence of COVID-19 on these relationships is to be recognized. This section focuses on these issues.

According to the ecological model, walking as well as cycling is influenced by a variety of factors including socioeconomic, personal, social, and the built environment [40]. In addition, the evaluation of walking and cycling besides their contributing personal, social, and built environment factors has been approached from two fields of research including studies on transport and studies on physical activity and health. Studies along these two lines of research have shown many similarities in terms of the contributing personal and environmental factors to walking and cycling behavior. Concerning the relationship between the walking behavior of citizens and their walking needs, there are five levels of needs that are considered within the walking decision-making process. These needs progress from the most basic need, feasibility (related to personal limitations), to higher-order needs (related to urban landscape) that include accessibility, safety, comfort, and pleasure, respectively [41]. The relationships between the hierarchy of walking/cycling needs and walking/cycling behavior have been influenced by the situation imposed by the COVID-19 pandemic. Some of these changes on the relationships between the hierarchy of walking needs and walking behavior imposed by this pandemic have been addressed by previous studies [9].

The first subsection reviews different measurement methods of walking/cycling behavior, since the mobile apps may contribute to facilitating such measurements. Then, the contribution of different built environment factors to walking/cycling behavior is reviewed. In this regard, the classification of built environment used by Pikora et al. [8] in relation to walking/cycling behavior is applied to explain the results. As stated before, this classification has been used by the majority of the studies which consider the relationships between walking/cycling behavior and built environment factors. The impacts of the COVID-19 pandemic on these relationships were also reviewed [9]. Finally, the contribution of the sociodemographic, personal, and social factors to walking/cycling behavior and the impacts of the COVID-19 pandemic on these relationships are reviewed through the previous studies which considered such relationships.

3.1. Measuring Walking and Cycling

Levels of walking and cycling have been usually measured using standard survey questionnaires from selected neighborhoods and random households and participants. For instance, the "International Physical Activity Questionnaire" has been used to determine walking and cycling patterns [42,43]. The studies on evaluation of walking and cycling have used different approaches for this evaluation. Some studies focused on walking behavior and the others focused on tendency to walk or the level of attractiveness of walking, in order to recognize the microscale environmental factors which influence the

level of attractiveness of walking [44]. The evaluation of microscale walking behavior or tendency to walk has been also approached from studies that examined the path choice process of pedestrians [45,46]. In these studies, path choices of pedestrians have been recognized through different methods such as observation and counting of people in each segment [47], by following of the participants between origin and destinations point [46], and the path trajectories are recognized by asking the respondents to draw their pathways toward their destination through the given maps.

3.2. The Contribution of Built Environment Factors to Walking/Cycling Behavior and the Impacts of the COVID-19 Pandemic

Enhancing population/housing density contributes to the improvement of walking and cycling behavior [48–50]. Access to different facilities such as shops, restaurants and services contribute to the enhancement of walking and cycling [8,51–53]. Likewise, access to recreational spaces such as parks and playgrounds as well as other recreational facilities contributes to the enhancement of walking and cycling behavior [42,54–57]. In addition, mixed land use in terms of both diversity and accessibility is positively correlated with walking and cycling [49,57,58]. The creation of a compact city which maximizes the active use of space and land is the main approach to creating and maintaining sustainable urban environments. Factors including density, diversity, and mixed land uses are key to this process [9,59,60]. Furthermore, creating a compact city is reckoned to be one of the approaches for creating resilient cities [59,61,62]. High-density cities could be more vulnerable to the spread of infectious diseases as has been shown during the COVID-19 pandemic. However, the contagion risk does not necessarily increase with density (the number of people per unit of land), it is actually associated with crowding (the number of people within a limited space) [1]. The widening of walkways/cycling path were the main approach in regard to adapting infrastructure for walking/cycling during the recent pandemic.

In addition, infrastructure or functionally related aspects of walking environments are associated with walking behavior of elderly people. The presence of sidewalks/cycling network and the quality of pavement are positively related to active travel [42,58,63,64]. More length of the sector as well as width of the walking/cycling pathways contributes to the enhancement of active travel [47]. The presence of sidewalks and the quality of pavement are another functional aspect of the pedestrian/cycling network which are positively related to active travel [42,58,64]. Several of these functional aspects such as width of the pathway and density of people along the path are indeed the factors that contribute to subjective utility/disutility of path choice as well as choice of walking patterns of pedestrians in local environments [9,65,66]. These factors are also related to the sense of comfort/discomfort along the pathways [9]. Comfort, as the fourth level of needs for walking, refers to a person's level of ease, convenience, and contentment [41]. Sense of comfort/discomfort has become one of the most relevant perceptual factors influencing the level of stress while encountering crowded spaces during walking in this pandemic [9]. Before this pandemic, the expected number of pedestrians in crowded spaces contributed to an increase in stress only in conditions where the number of interactions with other pedestrians effectively impeded pedestrian movement in such areas [67]. Indeed, an average number of expected interactions with other pedestrians provides more opportunities for reinforcing social interaction and the vitality of urban public spaces, and therefore it was recommended by studies in urban design before this pandemic [68]. This situation has changed dramatically due to this pandemic in which crowding and the expected number of interactions with others have become the main source of stress during walking [9]. In fact, a high convergence has been created between the factors including the expected number of interactions in crowded spaces, sense of comfort/discomfort, and level of stress when faced with crowded spaces during this pandemic [9].

Stress as a relational concept is viewed as a relationship between individuals and their environment [69,70]. Psychological stress is generated in a situation where a person evaluates something that is important for his/her wellbeing during his/her relationship

with the surrounding environment, and that situation exceeds their biological, psychological or social resources for coping with it [71,72]. Thus, when faced with a potentially stressful situation, two basic forms of appraisal based on different sources of information are formed. Primary appraisal concerns whether something of relevance to the individual's wellbeing occurs, whereas secondary appraisal concerns coping mechanisms [69]. Indeed, these are two aspects which affect mental stress when faced with potentially stressful situations such as being in crowded places during the COVID-19 pandemic. The effects of these two aspects on mental stress when faced with crowded spaces is supported by the results of studies on crowding [73,74]. Perceived crowding refers to how people perceive a crowded situation, which could be either different from, or similar to, the actual level of crowding. In fact, for a fixed level of crowding, perceived crowding can vary depending on the situations and the people involved. Furthermore, people generally feel better and have better mental health when they can control their surroundings [75–77]. Perceived control is the perception people have about how they can control and maintain their wellbeing when faced with crowded spaces. Indeed, perceived crowding corresponds to primary appraisal and perceived control corresponds to secondary appraisal when faced with crowded spaces. Therefore, one of the main aspects of a walking/cycling network which contributes to the encouragement of people to walk/cycle during this pandemic is the provision of situations in which people's perceived control is enhanced during walking/cycling while faced with the crowded spaces [9].

In addition, a more connected walking/cycling network contributes to enhanced walking as well as cycling behavior [49,64,78–81]. Moreover, more safety from traffic and higher personal security are positively correlated with walking/cycling behavior [54,82–84]. In this regard, more presence of people along the path has been one of the factors which contribute to enhanced natural surveillance along the walkways and thus improved perceived security of the pedestrian [85]. However, as stated earlier, more presence of people has lost its positive function and contributes to enhance the sense of insecurity during this pandemic [9]. Furthermore, there was a theoretical debate in terms of the relationships between types of street network in terms of degree of its connectivity and walking behavior in the previous studies before this pandemic [86–89]. This debate could be extended to the relationships between the type of street connectivity and walking behavior during this pandemic as well [9].

Furthermore, more attractive and aesthetically pleasing walking environments contribute to enhanced walking/cycling behavior [10,44,90–92]. The "pleasurability", which includes aesthetic-related factors along the pathways, as the last categorization of walking needs refers to the level of appeal that a setting provides with respect to a person's walking experience. The example of aesthetic related features along the path which contribute to walking/cycling behavior are the presence of natural sights, litter along the sidewalks, presence of parks and green spaces, number of trees, types of buildings' façade and their level of maintenance, and height of the buildings [10,31,45,51,92,93]. Most of these aesthetic related features along pathways are counted as motivational factors towards the enhancement of walking/cycling behavior. One of the main roles of these aesthetic-related factors is to reduce the overload of mental stress generated during COVID-19 pandemic-in order to improve the public health of citizens. Accordingly, natural environments as well as urban greenery have a remarkable impact on reducing mental stress and improving mental health [44,75,94–98]. "Psycho-physiological stress reduction theory" and "Attention Restoration Theory" provide the theoretical basis for the restorative effect of interaction with the natural environment as well as urban greenery [99].

"Psycho-physiological stress reduction theory" proposes that contact with nature (e.g., views of natural settings) can have a positive effect for those with high levels of stress, by shifting them to a more positive emotional state [100,101]. "Attention Restoration Theory" suggests that involuntary attention given to interesting and rich stimuli in natural settings helps to improve performance in cognitively demanding tasks [102–104]. In addition, experimental and empirical studies have found evidence regarding the association between

relief from stress or mental fatigue and exposure to natural environments and urban greenery [94,95,97,98,105–108].

Finally, it is to be noted that the built environment factors have been measured through two types of perceived and objective measures in the studies on walking/cycling behaviors and their contributing factors [109,110]. Audit (SPACES, PEDS, or other types) and GIS have been used for the process of objective measurements of the built environments [31,111,112]. The perceived built environment has been measured through standard survey questionnaires such as "Neighborhood Environment Walkability Scale" (NEWS) [31,93,113]. According to Smith [114], perceived measures of microscale built-environment features such as the aesthetic-related features contribute to predicting walking behavior more effectively. This is while the objective measures of macroscale built-environmental features such as street network and land use better contribute to predicting the walking behavior [114].

3.3. The Contribution of Sociodemographic, Personal, and Social Factors to Walking/Cycling Behavior and the Impacts of the COVID-19 Pandemic

Previous studies have shown that cycling behavior is influenced by individual and sociodemographic attributes. Men and youth are linked with cycling more than others [115,116]. Women are less likely to ride partly due to concerns regarding private safety [117]. In a few cases however, ladies cycle more for traveling than men [118]. Gender and age were found to be related to walking behavior as well [119–122]. People's positive attitude toward cycling is also the main determinant of cycling preference and behavior [123,124]. People who consider cycling to be a comfortable mode of travel prefer to cycle more [125]. Similarly, those with a more positive attitude towards both cycling and public transport and those with environmental concerns cycle more than others [126,127]. In addition, the role of lifestyle in cycling behavior has been indicated by previous studies [109]. Walking attitudes such as enjoyment, importance, and positive experience of walking behavior in the past were indicated as the affective factors of walking behavior as well [110,128,129]. Middleton [130] found that habit is an important part of the sequentially organized and occasioned performance of journeys on foot. "Theory of planned behavior" is the main theory that describes the relationships between attitudes, intention, and behavior. This theory proposes that intention is the proximal determinant of behavior. Intentions are indications of how much a person wants to perform a behavior and how hard they are willing to try in order to perform it [131]. Intentions are, in turn, determined by three constructs: attitude, subjective norm and perceived behavioral control [131]. To our knowledge, still it is not clear that how the COVID-19 pandemic has influenced the components of this theory in regard to walking/cycling behavior. This should be investigated by early future studies.

Furthermore, there has been a reciprocal relationship between walking and social interactions. On one hand, walking is a practice that encourages "social mixing", "community cohesion", and "social interaction"; and thereby may create more livable public spaces [9]. On the other hand, past studies have found that a supportive social environment increases physical activity and walking behavior [132,133]. The social environment refers to the influence that friends and family can have on an individual's walking [29]. Neighborhood social cohesion is one of the main social factors which contribute to the enhancement of walking of elderly people [29,134]. These social-related factors play an important role in motivating pedestrians, especially elderly people to walk [9]. According to Krogstad et al. [120], the "want to" dimension of walking—including the motivational aspect of walking—makes walking enjoyable for elderly people and it is one of the most important dimensions to improve their walking. However, the COVID-19 pandemic has affected and destroyed those social relations. One solution to reviving the role of these social motivational factors is to strengthen the possibility of passive engagement rather than active engagement with the environment [9].

4. The Contribution of Mobile Apps to Improved Walking/Cycling Behavior and the Impacts of the COVID-19 Pandemic on This Relationship

By reviewing and comparing the contents of the previous sections, the raised questions of this study could be answered with the required details. These questions include: How do mobile apps contribute to improved walking/cycling behavior? How are such relationships influenced by the situation imposed by the COVID-19 pandemic?

The studies that examined the role of mobile apps in promoting physical activity including walking and cycling found that such mobile apps contribute to promoting physical activity [14–16]. However, the use of mobile apps decreased over time even if the users had showed interest in continuing using the app [14,16,20,135,136]. In this way, these mobile apps may lose their effects on enhancing physical activity including walking and cycling over time. The function of mobile apps in enhancing physical activities depends on the type of motivational aspects in design of the mobile apps. According to behavioral science theory and evidence, there are three types of motivational aspects including cognitive or analytical motivational factors such as providing certain information on cost-benefit issues for users, social motivational factors, and emotional motivational factors such as making the app more fun [14]. However, all of these motivational aspects embedded in design of the mobile apps have been effective in the impacts of mobile apps on the level of physical activity [14], but the impact of social motivational factors on enhancing the level of walking/cycling and physical activity has been emphasized by several studies in this field [14,17,19]. Thus, the mobile apps which provide the possibility of interpersonal contacts and social interactions which leads to sharing the information and experiences between the users, effectively contribute to enhanced physical activity including walking and cycling behavior. This is supported by the studies on walking/cycling behavior which examined the influence of social support on the level of walking/cycling [9,120]. For instance, the social-related factors play an important role in motivating pedestrians, especially elderly people to walk [9]. In fact, this social feedback from the apps' users support both the tendency of users to continue using such mobile apps and the enhancement of physical activity.

In regard to transport, the mobile apps effectively contributed to transport data collection processes in the studies which examined walking/cycling behavior. For instance, the GPS apps have been used to recognize the traced pathways of the pedestrians and measure walking behavior [29–31]. However, signal loss can be a limitation to using GPS in hilly and dense environments [137]. In addition, mobile apps have the potential to effectively contribute to measuring the perceived built environment especially in macroscale environments. In the macroscale environments such as the scale of a region, the measurement of perceived built environmental features along the traced pathways of the respondents could be a very difficult and time-consuming task. Using mobile apps could facilitate such a data collection process. Moreover, the level of intervention of the users with these apps in the transport data-collection process depends on the type of data collection. While the traced pathways of the participants are to be recognized, GPS tracking could be passive with minimum involvement of the users with mobile apps. However, more interaction of the users with the mobile apps is required to evaluate perceived built environment. In fact, the level of interaction of the users with the mobile apps during the study could be an important issue which affects the performance of these apps in measuring the determined factors. This could be the focus of the future studies in regard to the function of mobile apps in the transport data collection process.

Other types of transport related apps are those that provide real-time traffic and other types of required information for the users as general traveling public. These include a wide range of required information regarding the types of destination, traffic-related information, etc. As stated before, the next type of app, with certain functional similarities to the former type, is the mobile apps for navigation and route planning which have been designed to assist travelers in navigating cities easily and quickly. In regard to walking/cycling environments, the positive and negative aspects of the walking/cycling environment in regard

to walking/cycling behavior have been reviewed in Section 3. For instance, insecurity and its related features contribute to impeded pedestrian movement especially among women [85]. As stated before, crowding (the number of people within a limited space) has a role as an insecurity-related feature regarding walking/cycling during this pandemic. Instead, the aesthetic restorative factors such greenery and natural elements are considered positive, motivational factors especially for the walking of elderly people [9,44,92,138]. These aesthetic/restorative features along the pathways also significantly contribute to reducing the overloaded stress generated by the situation imposed by the COVID-19 pandemic, and the improvement of the mental health of the inhabitants. Mobile apps may facilitate people's recognition of these aspects, and this may in turn lead to greater pedestrian/cyclists' awareness and better organization of their walking/cycling behavior. For instance, pedestrians/cyclists need more awareness regarding certain environmental features such as the situation of crowding along the walking/cycling pathways in order to adjust their walking/cycling pathway, and mobile apps could be designed to provide such microscale information along the walking/cycling network. These types of apps specifically in regard to walking/cycling environments need to be developed further in the future (Figure 1).

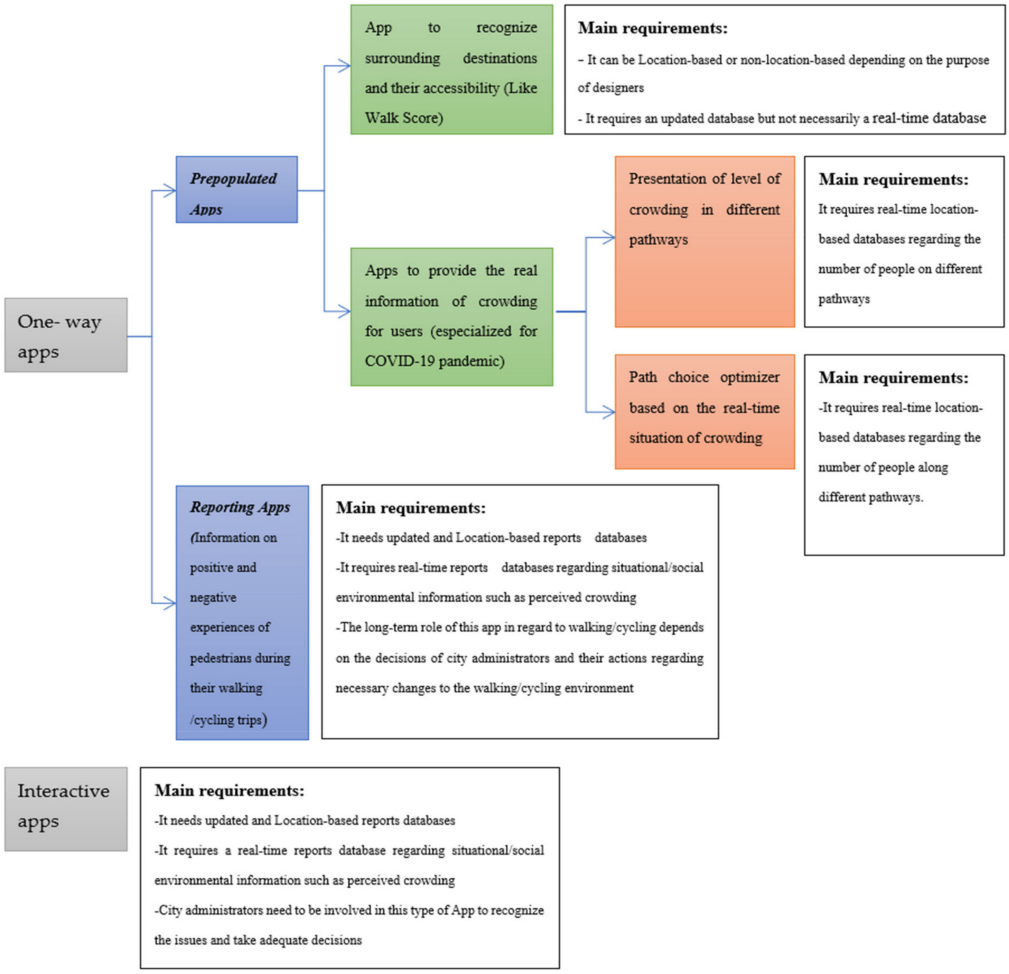

Figure 1. The types of mobile apps related to walking/cycling behavior based on participatory approach (in both a normal situation and during the pandemic.).

The required environmental information along the walking/cycling network could be transmitted to the pedestrians/cyclist through a map within the mobile apps. Moreover, the mobile apps could also be designed for better navigation of these users along the walking/cycling network. Then, their function may be similar to the current apps for

route optimization which provide the most optimum path between a given origin and a destination. Regarding the design of such prepopulated mobile apps for the future, the following issues need to be considered. Firstly, these types of apps need to provide real-time information especially in regard to people-centric types of information such as density of the people along each pathway. Otherwise, such information could not be reliable to use by the app's users. This sensitivity does not exist for environment-centric types of information, since this type of information, such as the existence of insecurity-related features along a path, remain for a while until the situation is changed by the people or the respective authorities. Secondly, it is important to understand how to form and adjust the database of these apps in regard to the *people-centric* information. For instance, if the number of people in each pathway is taken from the sensors embedded on several traffic tools along the streets, such information is reliable. However, if such information is provided from the reports of other users of the app, that real-time information could be unreliable for the users due to possibility of rapid changes in the real-time situation of such people-centric features along the network. In this case, it is required that the app provides an average historic level of that specific information along the path rather than offering the real-time type of such information to the users [25]. Third, the pedestrian network could be different from the street network, since pedestrians use shortcuts in their movements which sometime do not conform to the maps which are based on the actual situation of street network. Thus, future apps regarding the walking environment need to work on developing maps which are updated based on all possible trajectories of the pedestrians in order to provide the possibility of maximum adjustment in the process of path optimization for the apps' users.

Moreover, as stated before, the participation in the decision-making process is one of the main components of Smart governance as one of the main dimensions of smart city [3,7]. Mobile apps may help to improve the participation of citizens in decision-making processes in regard to the improvement of walkability and bike-ability of each urban sector. In this regard, first the authorities need to make the assessment of the current situation of walking/cycling networks of each urban sector in order to take the required policies to improve the actual walking/cycling environments. However, this information could be taken from the results of different studies which have focused on the relationships between walking/cycling and their contributing factors in each context. In this regard, how the mobile apps contribute to improving the data collection processes in these studies was explained. However, the next possibility for this assessment is that the transport/city administrators use mobile apps to enhance their information on the actual situation of walking/cycling environments through the information taken from the citizens. For instance, the city administration needs to implement a rapid rearrangement of the walking/cycling environment in order to facilitate walking/cycling trips for citizens in the light of this pandemic. In this regard, mobile apps facilitate the quick assessment of walking/cycling environments through providing location-based real-time information taken from inhabitants in respect to their different positive and negative experiences during walking/cycling. As stated before, the *reporting app MyDelaware* has been widely used in the city of Delaware, United States, and allowed citizens to inform the city administration about different aspects of their living environment such as public violations, broken lights, potholes, or street cleaning [36]. As previously mentioned, the positive aspects could be related to physical and social factors which can have a motivational/restorative impact during walking/cycling. Likewise, the negative aspects during walking could be related to stressful environments caused by elements such as fear of crime and perceived crowding during the COVID-19 pandemic. Reporting apps could be people-centric if the information reported by users refers to social aspects of the environment and environment-centric if the reported information refers to physical aspects of the walking environments. However, this type of app has two main weaknesses. Firstly, environmental information related to walking/cycling is only provided to city administrations and is not shared with other citizens. To fix this weakness of reporting apps, this type of app could provide the possibility of sharing such information among the users of this app, which would enhance the

motivation of the users to keep using this app. Second, the long-term performance of this app depends on the required environmental changes being made by the respective city administrators based on the received reports. If the necessary environmental changes are not made, citizens will no longer feel involved in planning and designing their surrounding walking/cycling environments.

Therefore, the rapid feedback of respective city administrations regarding the implementation of the required environmental changes would help to strengthen the participation process through the reporting apps, and this process may finally contribute to improved walking/cycling behavior. In this regard it is necessary to consider two issues. First, there is a need for the active engagement of city administrators and planners with these apps in their decision-making process. Riggs and Gordon [13] found that one of the important weaknesses concerning the function of mobile apps is that city administrators as well as urban planners do not use these mobile apps effectively in their decision-planning process. The main reason is that they do not have enough confidence in using these apps effectively to make their decisions. In this regard, the training of city administrators and urban planners is necessary in order to become more familiar with the use of mobile apps for their decision-making processes. Moreover, these environmental changes could be implemented through adequate techniques defined in tactical urbanism. Tactical Urbanism aims to recover and activate spaces through fast and easily applied actions that demonstrate the possibility of large-scale and long-term changes in cities [139]. Therefore, the city administrators and urban planners need more familiarity with tactical urbanism and its different techniques in order to provide the required environmental changes that will improve walking behavior.

In addition, the role of habits, attitudes, and lifestyle in improving walking/cycling behavior has been emphasized by the previous studies [38,128]. Research could recognize the types of habits, attitudes, and lifestyles which contribute to walking/cycling behavior in each context. These results could help the respective urban/transport policy makers in each city to understand what changes on habits, attitudes, and lifestyle are required to improve the walking/cycling behavior in each context. The changes of these factors are much more difficult than the changes of the environmental aspects and require selection of appropriate long-term educational- and cultural-related policies by the city administrators. Designing certain mobile apps may help to both recognize the related habits, attitudes, and lifestyles of the citizens to their active travel as well as potentially make the necessary changes in these factors in order to improve the walking/cycling behavior in each context.

By reviewing the function of current mobile apps in three fields of study in relation to walking/cycling, this study tries to introduce the classification of current mobile apps together with certain suggestions for developing future type of mobile apps to improve walking/cycling behavior. This classification is shown in the Figure 1. This figure introduces and classifies different types of mobile apps concerning the improvement of walking/cycling behavior both inside and outside of the situation imposed by the COVID-19 pandemic. The participatory approach of apps' users is the basis of organizing this classification. The main requirements for each app are also mentioned in the Figure 1.

Furthermore, the main weakness concerning the use of these mobile apps in daily activities is that different groups of people do not use mobile apps effectively in their daily life. According to Riggs and Gordon [13] although high percentages of survey participants use a smart phone or tablet, just one-third of them use mobile apps effectively in their daily activities. According to Hou et al. [140], performance expectancy had the strongest influence on app-use intentions. Performance expectancy is defined as the citizens' beliefs that the app would be efficient, helpful, and convenient to use. There are also four principles constituting the required foundation to develop any accessible web and mobile content including being perceivable, operable, understandable, and robust [141].

Elderly people are the most vulnerable group regarding COVID-19. The percentage of use of mobile apps in daily activities could be lower for elderly people, as high percentages of old people do not have familiarity with technology and lack the required skills for

using mobile apps [142,143]. People with less technical knowledge had more problems adhering to technology-based interventions [135]. Therefore, older people need training to use these apps. In addition, prior to improving the function of mobile apps for older people in each context, there is a need to understand how much involvement they have with mobile apps in their daily activities. It is also important to understand which design aspects of mobile apps increase the tendency of old people to use them. Petrovi et al. [144] suggested a set of thirty-eight senior-friendly usability guidelines grouped within seven different dimensions associated with various interaction elements of smart phones. These dimensions include screen, touchscreen, keypad, text, menu, exterior, and content. For instance, having large buttons with clear feedback contributes to improve the visibility issues among older people [145].

Finally, habits, attitudes, and cultural aspects of the daily lives of older people may play an important role in their level of engagement with technology such as mobile apps in their daily activities. Thus, the relationships between these aspects and older people's attention to mobile apps needs to be further investigated. The results of these kinds of investigations may contribute to improving the level of use of mobile apps in the daily lives of older people. Therefore, this kind of research should be a prerequisite for designing mobile apps with a view to the improvement of walking/cycling behavior.

5. Conclusions

The recent COVID-19 pandemic has influenced many aspects of our daily life. Concerning urban transport, in many cities the provision of public space and infrastructure for the development of active travel, including walking and cycling, has been adopted as the main approach to increase urban resilience in the face of this pandemic. In addition, mobile apps play the main role in developing smart mobility as one of the main dimensions of the smart city. The role of technology and different mobile apps in different aspects of daily life has been highlighted which raises the questions: How do mobile apps contribute to improved walking/cycling behavior? How are such relationships influenced by the situation imposed by the COVID-19 pandemic?

The contribution of mobile apps to enhanced physical activity, including walking and cycling, have been shown by the previous studies. However, these mobile apps may lose their effect on enhancing the physical activity including walking and cycling over time. According to behavioral science theory and evidence, there are three types of motivational aspects including cognitive or analytical motivational factors, social motivational factors, and emotional motivational factors. From these types of motivational aspects, the impact of social motivational factors on enhancing the level of walking/cycling and physical activity has been emphasized by several studies in this field. In fact, this social feedback from the app's users supports both the tendency of users to continue using these mobile apps and the enhancement of physical activity including walking/cycling.

Regarding transport, mobile apps have effectively contributed to data collection including recognizing the traced pathways by pedestrians and measuring walking/cycling rates. Mobile apps also have the potential to be involved in the measurement of the perceived built environment especially in the macroscale environments. The level of interaction of the users with the mobile apps during the study affects the performance of these apps in measuring the determined factors. This could be the focus of future studies in regard to the function of mobile apps in the transport data collection process. The next type of mobile apps in relation to transport include the apps that provide real-time traffic and other types of required environmental information along the routes, and the apps that present the most optimum pathways between the origin and destinations of the pedestrians/cyclists. Section 3 reviewed the personal, social, and built environment factors which contribute to walking/cycling behavior and the effect of the COVID-19 on these relationships. For instance, insecurity and its related features contribute to impeded pedestrian movement and crowding (the number of people within a limited space) acts as an insecurity-related feature in regard to walking/cycling during this pandemic.

Instead, aesthetic restorative factors, such as greenery and natural elements, are considered positive, motivational factors and these aesthetic/restorative features along the pathways also significantly contribute to reducing the overloaded stress generated by the situation imposed by the COVID-19 pandemic and the improvement of the mental health of the inhabitants. Mobile apps may facilitate people's recognition of these aspects, and this may in turn lead to greater pedestrian/cyclists' awareness and better organization of their walking/cycling behavior. Therefore, the before-mentioned types of apps in regard to walking/cycling environments need to be developed further in the future. In this regard, "the need to provide real-time information for people-centric types of environmental data", "using the reliable source of data regarding people-centric type of information", and "presenting an average historic level of data to users in case of using the reports of app's users, as the sources of data in regard to people-centric type of information", are the most important issues in the process of the design of these types of apps. It should be also considered that the pedestrian network could be different from the street network and the mobile apps need to update of their maps to cover all of the possible pedestrian trajectories along the pedestrian network.

Moreover, mobile apps may help to improve the participation of citizens in the decision-making process in regard to improvement of walkability and bike-ability of each urban sector. In this regard, the mobile apps which are designed based on the reports of citizens could be used in the process of assessment by urban/transport administrators of the actual situation of walking/cycling environments. These mobile apps facilitate the quick assessment of walking/cycling environments through providing location-based real-time information taken from inhabitants in respect to their different positive and negative experiences during walking/cycling. However, this type of app has two main weaknesses including the information flow being only from users to administrators, and the dependence of long-term performance of these apps to the required environmental changes being made by the respective city administrators based on the received reports. Indeed, if the necessary environmental changes are not made, citizens will no longer feel involved in planning and designing their surrounding walking environments. Based on a participatory approach of apps' users, the classification of current mobile apps and certain suggestions on the development of future mobile apps were also presented.

Finally, the main weakness concerning the use of these mobile apps in daily activities is that different groups of people, especially elderly people, do not use mobile apps effectively in their daily life. Elderly people are also the most vulnerable group regarding the COVID-19 pandemic. This could be related to the lack of familiarity with technology and the required skills for using mobile apps. Therefore, older people need training to use these apps. It is also important to understand which design aspects of mobile apps increase the tendency of old people to use them. Furthermore, habits, attitudes, and cultural aspects of the daily lives of older people may play an important role in the level of their engagement with technology such as mobile apps in their daily activities. This should be further investigated by future studies. This kind of research should be a prerequisite for designing mobile apps with a view to improve walking/cycling behavior.

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