屏幕使用时间与步行活动关系的探索性研究
An Exploratory Research on the Correlation Between Screen Time and Walking

陈纯
清华大学建筑学院客座硕士研究生，广州市城市更新土地整备保障中心（广州市空间规划实施促进中心、广州市自然资源测绘中心）专业技术人员

龙瀛*
清华大学建筑学院、清华大学恒隆房地产研究中心研究员、博士生导师

黄贵恺
清华大学建筑学院硕士研究生

CHEN Chun
Guest Master Student at School of Architecture, Tsinghua University; Research fellow at Guangzhou Urban Renewal Land Consolidation Security Center

LONG Ying
Research fellow and PhD supervisor at School of Architecture and Hang Lung Center for Real Estate, Tsinghua University

HUANG Guikai
Master Student at School of Architecture, Tsinghua University

*通讯作者：
地址：北京市海淀区双清路30号
邮编：100084
邮箱：ylong@tsinghua.edu.cn

编辑 | 王胤瑜、崔婧沄、田乐
翻译 | 嵇扬、王胤瑜、田乐
EDITED BY | WANG Yinyu, CUI Jingyun, Tina TIAN
TRANSLATED BY | JI Yang, WANG Yinyu, Tina TIAN

摘要

信息技术的革命极大地改变了现代人的生活方式，智能手机的出现成为越来越多人的生活必需品，人们比之前花费更多时间关注屏幕上的虚拟世界。本文梳理了现有的研究，假设智能手机屏幕使用时间与步数存在相关性，并通过探索性研究对此进行验证：研究聚焦“步行”和“屏幕使用”两种行为，借助线上线下问卷向大众收集数据并进行分析，研究发现：1）每日屏幕使用时间与每日步数之间存在相关性。当每日屏幕使用时间在4.99～15.25小时范围内时，两者呈负相关关系，即屏幕使用时间增加，步行数会相应减少；2）人们每日平均使用屏幕的时间是6.3小时，且更多用在社交上（2.8小时），每日平均步数是6 750步（近0.8小时）；3）人们周末的每日屏幕使用时间与步数要低于工作日；4）高学历、高个人收入或低龄的群体每日使用手机的时间较少，高学历、低运动频次或较年轻的群体每日步数较少，故这些因素均有可能影响每日屏幕使用时间和每日步数之间关系。未来需要进一步探讨两者间关系及其影响因素，并关注物质空间要素对步行行为的影响。

关键词

屏幕使用时间；步行；步数；智能手机；体力活动；虚拟空间；物质空间

ABSTRACT

With the revolution of information technology greatly changing contemporary's lifestyle, smartphone becomes a necessity to more and more people, and individuals' screen time is increasing as people are spending more time on the virtual world. Through literature review, this paper proposes a hypothesis that there is a correlation between smartphone screen time and walking step counts, which is verified through an exploratory research: data of walking step counts and screen usage were widely collected by online and onsite questionnaires, and the analyses reveal that 1) when daily screen time ranges from 4.99 to 15.25 hours, it is negatively correlated with daily walking step counts; 2) the respondents' average daily screen time is 6.3 hours, more of which (2.8 hours) is spent on social Apps, and their average daily walking step counts are 6,750 (takes nearly 0.8 hour); 3) daily screen time and walking step counts at weekends are less than those on weekdays; 4) people with higher education level, higher income, or younger age use screen less daily; people with higher education level, lower exercise frequency, or younger age walk less daily, so these factors are likely to affect the correlation between daily screen time and daily walking step counts. The correlation of both behaviors and the affecting factors need to be further clarified, and the impact of physical environmental elements on walking also requires more attention.

KEYWORDS

Screen Time; Walking; Walking Step Counts; Smartphone; Physical Behaviors; Virtual World; Physical Space

https://doi.org/10.15302/J-LAF-0-020014
收稿时间 RECEIVED DATE | 2021-02-20

中图分类号 | TU981
文献标识码 | A

1 引言

第四次工业革命在逐渐提高人们生活水平的同时，也悄无声息地改变了人们的日常生活习惯——人们愈发依赖科技，享受甚至沉迷于科技所带来的便捷与其构建的“新世界”。不可否认，此次革命带来的科技力量让人们愈加投入到虚拟空间，越来越脱离物质空间，也让人和自己的身体更加疏远。人们在虚拟与现实来回切换的过程中构建自我，建设“第二人生”。

“数字孪生体”（Digital Twin）是以数字化方式创建物理实体的虚拟模型，借助数据模拟物理实体在现实环境中的行为，为物理实体增加或扩展新的能力[1][2]。在数字孪生中，一个是存在于现实世界的实体，另一个只存在虚拟世界之中，是利用数字技术营造的与现实世界对称的镜像。手机即是人类为自己制造“数字孪生”的重要媒介之一。

近年来，信息通信技术和基于互联网的App发展迅速，使移动互联网蓬勃发展。根据互联网世界统计（IWS）数据显示，截至2021年3月，全球互联网用户超51亿[3]，而截至2018年1月，手机用户数量已超51亿[4]。以中国为例，截至2020年末，互联网上网人数9.89亿人，其中手机上网人数就达9.86亿人[5]。智能手机的出现极大地促进了虚拟活动、虚拟社群的产生和活跃，让人们可以随时实现虚拟—现实切换。显而易见，当今大部分人的生活已经与手机捆绑在一起。

当使用手机成为生活中的常态时[6]，部分研究机构与手机研发中心已开始关注这一行为是否会劫持人们的注意力，导致人们对手机上瘾。研究者基于查看手机的次数或手机屏幕使用时间来判定使用者是否上瘾，其中屏幕使用时间即人们把主要注意力集中在手机屏幕上的时间，是目前应用较为广泛的指标。《移动消费大未来：2015中国移动（微博）消费者行为》报告称，目前智能手机“上瘾症”已经成为普遍现象，58%的受访消费者每天查看11～50次手机[7]。人们频繁使用手机的行为促进了相关应用和功能的开发：自2016年开始就陆续出现了一些如“小容”“24PI”等跟踪记录人们使用手机情况的应用；2018年6月发布的苹果手机iOS 12系统加入了屏幕使用时间统计功能；同年9月，基于安卓系统开发的EMUI 9.0系统增加了健康使用手机功能，也允许用户查询和限制自己使用手机的时长（图1）。

这种社会现象也引起了学术界的关注：国内外多位学者已从“屏

1. 苹果手机操作系统（左）和一款安卓手机操作系统（右）的屏幕使用时间查看界面

1. The interfaces for screen time checking on iOS (left) and Android (right) operation systems

1 Introduction

The Fourth Industrial Revolution, while improving people's living quality, has also changed our lifestyles: the advance of science and technology brings great convenience to humans, constructing a new virtual world which many people are obsessed with. Undeniably, such attraction from the virtual world has led to the reduction of people's access to physical spaces, as well as body movements and perceptions. Humans are shaping their "second life" by switching between the virtual and the reality.

"Digital Twin" is a virtual model that digitally simulates people's actions in real physical environment, so as to add or improve the capacities of physical entities[1][2]. A Digital Self builds up a twin-image in the virtual world for a certain entity in reality. For a person, the mobile phone is an important medium for creating his/her "Digital Self."

In recent years, information and communication technology and Internet-based applications keep rapidly advanced, boosting the development of mobile Internet. According to the data of Internet World Stats (IWS), by March, 2021 the number of global Internet users exceeded 5.1 billion[3], which was also the figure of global mobile phone users by January, 2018[4]. Taking China as an example, by the end of 2020, the Internet users had reached 989 million, among which 986 million have surfed the Internet via mobile phone[5]. The emergence of smartphones enables the immediate switchover between the virtual world and the reality, greatly contributing to the boom of virtual social activities and communities. Obviously, nowadays most people's life is being defined by mobile phones somehow.

When using mobile phones become part of the norm of people's daily life[6], some research institutes and mobile phone R&D centers have begun to wonder whether it will over-attract people's attention and result in smart phone addiction, which can be measured by the times people check their phones, or more widely used, the screen time (i.e. the time people focus their attention to the screen). According to The Future of Mobile Consumption: China Mobile (Weibo) Consumer Behaviors 2015, "smartphone addiction" is common: 58% surveyed consumers check their phones for 11 ~ 50 times daily[7]. Thus some Apps and smartphone functions for recording the time of screen watching have been developed since 2016, such as Apps "Realizd" and "24PI" that track and record phone usage; the iOS 12 of iPhone released in June 2018 that contains a module of screen time statistics; the EMUI 9.0 of Android phones released in September 2018 with a new built-in program "Digital wellbeing" to record phone usage time and set limit for that (Fig. 1).

The "smartphone addiction" also draws the attention of academia: By studying screen time, scholars have explored the impact of media technology on people's health and behaviors, empirically proving the correlation between screen time and sedentariness[8][9], attention loss[10][11], physical activity decrease[12], and the increase of physiological diseases (e.g. obesity[13][14]) and

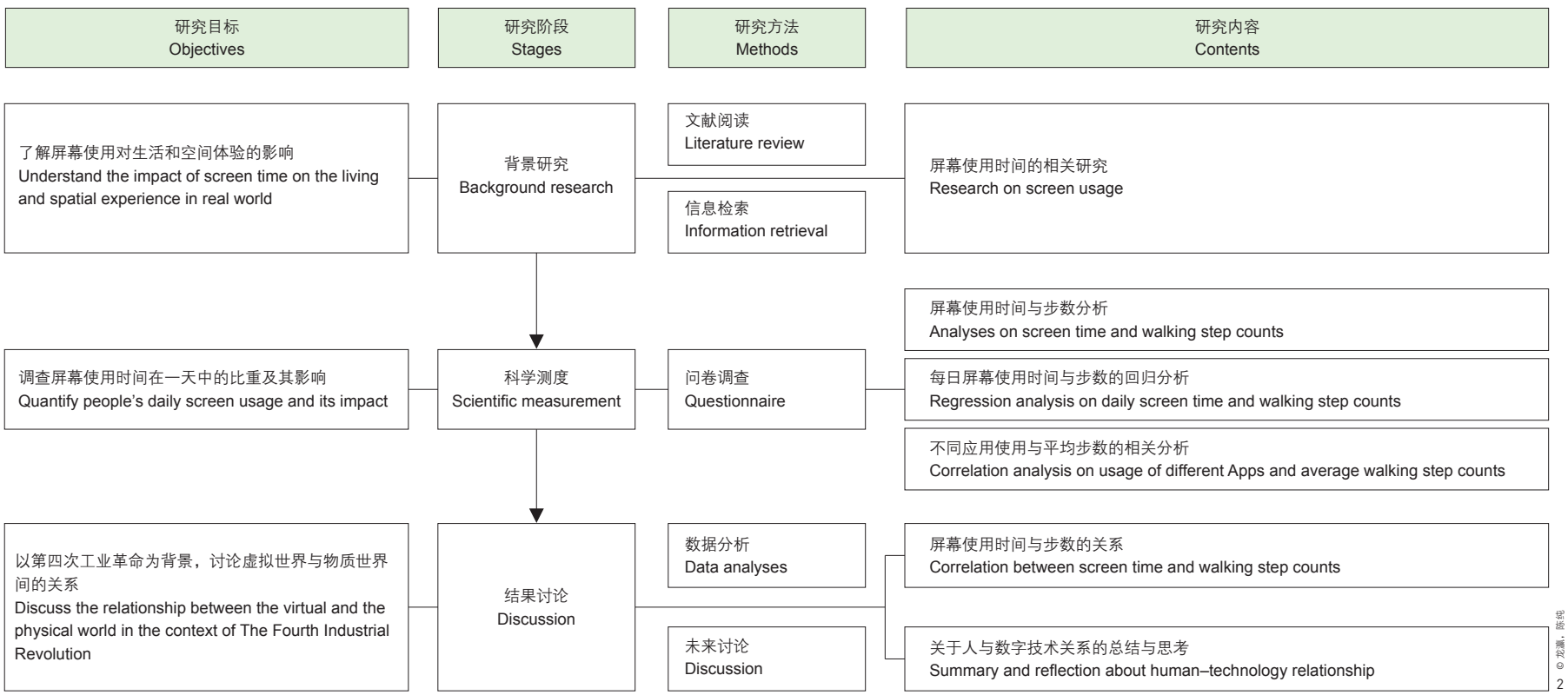
幕使用时间”（screen time）方向切入研究媒体技术如何影响人的健康和行为活动，实证了屏幕使用时间与久坐行为[8][9]、注意力下降[10][11]、体力活动频率减少[12]、生理疾病（如过度肥胖[13][14]）和心理疾病（如抑郁[15]、失眠[16][17]、上瘾[18][19]、焦虑[20][21]）的增多都有一定程度的关联。杰弗里·李等人的研究证明学生的屏幕使用时间和体力活动之间存在负相关关系[22]；姜斌等人通过注意力测试，发现移动电子设备的使用会显著抵消绿地对注意力的恢复作用[23]；西胁正人等人的研究发现，2003～2012年间大阪工业大学男性新生步数下降主要与手机或电脑使用增加，以及玩电子游戏导致的体力活动频率减少有关[24]。周江评等人论证了智能手机的使用能够有效提升人们对长时间通勤的忍耐度[25]。尽管也有学者发现减少屏幕使用时间并不能增加体力活动[26]，但总体来说，当代人智能手机的使用频率很高，虽然这是影响人类健康与行为的常见因素，但鲜有针对具体体力活动行为的研究，尤其是针对步行这项对大多数人来说最简单、最基本的运动。

本文通过问卷调查的方式获取人们的手机屏幕使用时间与步数数据，对二者的关系进行探索性研究，试图由此描绘第四次工业革命背景下，人们的注意力在现实空间和虚拟空间中的往复转移过程，并思考人与数字技术的关系（图2），以尝试填补智能手机使用者的屏幕使用行为和步行行为之间关系的研究空白。

mental illness (e.g., depression[15], insomnia[16][17], addiction[18][19], anxiety[20][21]). Jeffrey Lee et al. proved the negative correlation between screen time and students' physical activity[22]; Through attention tests, Jiang Bin et al. found that the use of mobile electronic devices counteracts the attention enhancement benefits of green spaces[23]; Masato Nishiwaki et al. found that the decrease of walking step counts of male college freshmen of Osaka Institute of Technology from 2003 to 2012 was mainly related to the increase of mobile phone or computer usage and the decrease of physical activity since the time spent on playing electronic games increased[24]. Zhou Jiangping et al. proved that using smartphones could increase people's tolerance of a long commuting trip effectively[25]. Although some scholars claimed that decreasing screen time could not increase physical activities[26], in general, given the high frequency of using smartphones and its common impact on people's health and behaviors, the research on specific physical activity types is insufficient, especially walking, the basic physical activity for most people.

In this research, the authors acquired data of people's screen time and walking step counts via questionnaire survey, and conducted exploratory research on the relation between them, trying to answer that how people's attention switches between the reality and the virtual world, and to reflect on the relationship between people and digital technology (Fig. 2), by filling up the research gap on the relation between screen usage and walking.

2. 研究框架
2. Research framework



© 龙瀛，陈纯
2

表1：调查问卷问题设置
Table 1: Investigation items of questionnaire

类别 Type	个体行为信息 Behaviors	个体社会人口信息 Socio-demographics	个体健康信息 Health status	其他信息 Other information
问题内容 Investigation items	一周屏幕使用时间；一周步数 Weekly screen time; weekly walking step counts	性别；年龄；文化程度；所在城市；月生活费（面向学生）/个人月收入（面向社会人士） Gender; age; education background; city; monthly expense (for students)/monthly income (for non-student adults)	每周运动频次；自评健康水平；BMI Weekly exercise frequency; self-assessed health status; BMI	所属院校与专业（面向学生）/职业（面向社会人士） College and major (for students)/ occupation (for non-student adults)

表2：本研究涉及的不同品牌智能手机的功能特点
Table 2: Function requirements for different mobile phone models in this research

品牌 Brand	操作系统版本 Operation system version	机型示例 Typical model	功能特点 Function requirements			
			是否可以查看每周屏幕使用时间 Allow for checking weekly screen time	是否可以查看统计一周内每日的屏幕使用时间 Allow for checking daily screen time in a week	是否可以查看一周内不同类别应用的使用时间 Allow for checking screen time of different App categories in a week	是否可以查看步数 Allow for checking walking step counts
苹果 iPhone	iOS 12及以上 iOS 12 +	iPhone 8/8s	是 Yes	是 Yes	是 Yes	是（自带） Yes (with built-in program)
华为 HUAWEI	EMUI 9.1及以上 EMUI 9.1 +	HUAWEI P30/P40	是 Yes	否 No	否 No	是（自带） Yes (with built-in program)
其他 Others	无特殊要求 No specific requirements	安装有可查看屏幕使用时间的App 7天以上 With Apps supporting screen time checking for more than 7 days	是 Yes	是 Yes	部分机型可以 Yes for some models	是（自带或可借助微信运动等计步应用） Yes (with built-in program or third-party Apps like WeChat)

2 研究方法

本文研究对象为中国智能手机用户，年龄、性别、职业、所在城市不限，采用的数据收集方法为问卷调查法。在设计问卷时，研究团队首先阅读国内外相关文献资料，设计初版问卷，并在2018年12月开展线下预调研，对问卷内容进行完善。正式问卷总共包含18个问题，可分为4类，主要调查受访个体一周的屏幕使用时间、步数数据以及其他个人基本信息（表1）。

为了尽可能多地收集中国各地的智能手机用户的数据，本研究采用线上和实地问卷调查两种形式。问卷发放时间为2019年1～5月，都是借由问卷星平台制作的电子问卷来邀请受访者填写。其中线上发放主要是通过微信转发的滚雪球方式进行；实地发放一个月平均1～2次，考虑到调研的便利性和覆盖人群面的广度，发放地点选在北京市清华大学、武汉市武汉大学、广州市华南师范大学，以及广州天河商贸大厦门口（中山大道西路口），在11:00～12:00或17:00～20:00这两个人流相对密集的时段内随机邀请过往行人填写问卷。

2 Research Methods

Via questionnaire survey, this research takes smartphone users in China as respondents, regardless of their ages, genders, occupations, and cities where they live. The research team first conducted broad literature review to develop a questionnaire for on-site pre-survey in December, 2018, which was then improved. The formal version totally contains 18 questions in 4 categories, mainly investigating the respondents' screen time and walking step counts in a week, and their individual socio-demographic background, etc. (Table 1).

To collect data of Chinese smartphone users as much as possible, the team conducted both online and on-site questionnaire surveys from January to May, 2019. The questionnaires were supported by sojump.com. The online questionnaire adopted snowball sampling through forwarding by WeChat; the on-site questionnaire was conducted 1 or 2 times a month on average, randomly selecting passers-by in Tsinghua University (Beijing), Wuhan University (Wuhan), South China Normal University (Guangzhou), and at the entrance area of Tianhe Trade Building (at the west intersection of Zhongshan Avenue, Guangzhou), from 11:00 to 12:00 or 17:00 to 20:00 when pedestrian traffic was large enough.

由于研究需要的部分数据由智能手机统计，研究团队事先对满足研究需求的不同品牌智能手机的屏幕使用时间与步数统计功能特点进行了整理（表2），并以此为依据筛选有效样本。针对屏幕使用时间的获取，所选有效研究对象的手机须为具备iOS 12及以上系统的苹果手机、具备EMUI 9.1及以上系统的华为手机，或已安装可查看屏幕使用时间应用（如24PI）7天以上的任意一款其他品牌手机。线上调查时，不符合上述条件者提交的问卷将被视为无效；线下调查时，调研人员可以现场确认意向受访者的手机类型，并指引其调取研究所需数据。

针对步数的获取，目前智能手机大多通过内置的三轴加速度传感器、陀螺仪和重力传感器等来获取用户的步数信息。由于步行是一种连续的周期性活动，左右脚交替踏步的行为具有一定的规律性[27]，这种规律运动可被手机的内置惯性传感器识别[28]，不受受访者携带智能手机位置的影响。在准确性方面，目前手机自带的计步程序及第三方计步应用的准确性基本不受路面状况影响，主要与人的步行速度有关[29]；对安卓、苹果手机进行简单测试后发现，这些程序应用也不会将单纯的“摇手机”行为误识别为步行活动，为数据收集的准确性提供了保障。针对使用“手机摇步器”等设备修改步数的可能性，研究认为该情况较特殊且仅为个例，故不纳入考虑范围。

3 结果与分析

3.1 样本基本情况

研究最终获得来自线上、实地的问卷共500份，其中线上212份，线下388份，有效问卷共395份。有效样本主要为苹果手机用户（95.5%），总样本数据主要来自北京、广州、武汉三个城市，女性用户略多（59.2%），学生（50.9%）与社会人士（49.1%）比例基本持平，年龄集中在18～25岁（80.3%），文化程度为本科在读或本科毕业的受访者超过半数（53.9%），每周运动频次集中在1～2次（44.0%），过半样本（55.2%）的自评健康水平为亚健康，70.5%的人BMI（身体质量指数）处于正常范围。表3为屏幕使用时间与步数数据统计情况。

3.2 屏幕使用时间与步数统计

经统计可得，样本个体一周每日平均步数为6 705步，其中工作日的每日平均步数为6 827步，周末的每日平均步数为6 370步。根据李一敏等人的研究成果，全因死亡风险并非随着每日步数的增加而持续降低，当后者超过7 500步时，前者几乎不再下降，7 500步／天可视为每日最优步数[30]。因此，可以认为本研究受访者的每日平均步数，尤其是在工作日的步数已接近于最优步数标准。

As some data must be collected by smartphones, the team sorted out the function requirements of screen time and walking step counts statistic of different brands of smartphones (Table 2), according to which the valid samples were then screened out. For acquiring screen time, the respondents' smartphones must at least be iPhone with iOS 12, Huawei smartphones with EMUI 9.1, or smartphones of any other brand with Apps that can check screen time (such as 24PI) for more than 7 days. The online respondents whose smartphones did not meet the requirements were regarded invalid; the on-site surveyors could screen out those respondents whose smartphones did not meet the requirements.

Currently, most smartphones count users' walking steps through built-in three-axis acceleration sensors, gyroscopes, gravity sensors, etc., which capture and identify the periodical alternate stepping of both feet during continuous walking, not disturbed by how the walker carries the phone[27][28]. The counting accuracy of built-in program or third-party Apps mainly depends on the user's walking speed[29], regardless of environmental conditions. Besides, tests were conducted for Android smartphones and iPhones to ensure that they would not mis-count the shaking of mobile phones as walking. This research also did not take the rare possibility of modifying walking step counts with Apps such as “mobile phone shaker” into consideration.

3 Results and Analyses

3.1 Basic Information of Respondents

Finally, this research completed 500 questionnaires (212 online ones and 388 on-site ones), 395 of which were valid after screening. They are mainly iPhone users (95.5%) in Beijing, Guangzhou, and Wuhan; female are slightly more (59.2%) than male; half were students (50.9%); most were 18 ~ 25 years old (80.3%); more than half were undergraduates, bachelors or with higher educational background (53.9%); most did physical exercises once or twice per week (44.0%); 55.2% self-assessed as sub-health, while 70.5% were with normal BMI (Body Mass Index). Table 3 shows the statistics of the respondents' screen time and walking step counts.

3.2 Statistics of Screen Time and Walking Step Counts

According to the statistics, on average, one respondent walks for 6,705 steps per day in the surveyed week (6,827 steps per weekday and 6,370 at weekend). Based on the findings of I-Min Lee et al., people's all-cause mortality may continuously decrease as daily walking step counts increase, reaching the lowest point at 7,500 steps per day and hardly decline anymore, so 7,500 steps can be regarded as the optimum daily walking steps[30], and the respondents' average daily walking step counts, in this research, especially that on weekdays, are approximately optimum.

表3：屏幕使用时间与步数数据的统计结果
Table 3: Statistics of screen time and walking step counts

数据类别 Data category		单位 Unit	N	平均值 Mean	最大值 Max.	最小值 Min.	标准差 SD
每日平均屏幕使用时间 Average daily screen time		小时 / 天 h/d	395	6.3	12.0	0.1	2.1
每日平均步数 Average daily walking step counts		步 / 天 Steps/d	395	6,697.0	18,748.4	896.9	3,159.5
每日步数 Daily walking step counts		小时 / 天 h/d	2,719[a]	6.3	18.5	0.1	2.9
每日屏幕使用时间 Daily screen time		步 / 天 Steps/day	2,719[a]	6,705	32,870	8	4,755.2
不同类别的应用屏幕使用时间[b] Screen time for different categories of App[b]	社交（如微信） Social (e.g. WeChat)	小时 / 天 h/d	383	2.8	8.1	0.1	1.2
	阅读与参考（如图书） Reading and reference (e.g. iBooks)	小时 / 天 h/d	100	0.8	3.6	0.0	0.7
	效率（如Notability） Efficiency (e.g. Notability)	小时 / 天 h/d	80	1.1	6.7	0.1	1.0
	娱乐（如腾讯视频） Entertainment (e.g. Tencent Video)	小时 / 天 h/d	201	1.3	5.2	0.1	1.0
	游戏（如王者荣耀） Game (e.g. Lions' Glory)	小时 / 天 h/d	93	1.9	5.2	0.2	1.4
	教育（如学堂在线） Education (e.g. XuetangX)	小时 / 天 h/d	42	0.8	6.7	0.1	1.0
	创意（如相机） Creation (e.g. Camera)	小时 / 天 h/d	59	0.7	3.0	0.1	0.7
	健康健美（如Keep） Health and bodybuilding (e.g. Keep)	小时 / 天 h/d	8	0.3	0.7	0.1	0.2
	其他（如Photo Booth） Others (e.g. Photo Booth)	小时 / 天 h/d	184	0.7	2.4	0.1	0.5

注
a. 将收集到的395个有效样本个体一周内（周一到周日）每天的屏幕使用时间和步数单独列出，由于部分受访者会因操作不当而少记录一或数天的数据，故最终得到2 719组数据。
b. 此分类标准直接沿用苹果手机中“屏幕使用时间”功能中对不同应用的分类。

NOTES
a. After listing the daily screen time and daily walking step counts for each of the totally 395 valid respondents in one week (from Monday to Sunday), it was found that some respondents omitted the data of one or several days due to operation errors, so there were 2,719 pairs of valid data.
b. In this research, Apps were categorized according to the default categorization in the “Screen Time” program of iOS.

统计得到样本一周内每日平均屏幕使用时间为6.3小时，约占一天总时长的26.3%。其中，工作日的每日平均屏幕使用时间为6.4小时，周末平均为5.6小时。

根据《2019喜临门中国睡眠指数报告》[31]统计的数据，国人每日平均睡眠时长为7.4小时。若忽略屏幕使用时间中伴随微小位移的小部分时间（如边步行边使用手机），可以发现受访者一天平均有13.7小时——超过半天的时间——近乎没有主动发生位移（表4）。

通常情况下，步数与时间的换算主要受身高影响，成人的步幅是身高的0.37倍[32]；人的平均步行速度一般为5.4km/h[33]，但步行速度也会受到年龄、性别、胖瘦、是否健康等因素的影响。由于本研究的受访者

The respondents' average daily screen time in one week is 6.3 hours (6.4 hours on weekdays and 5.6 hours at weekend), taking about 26.3% of a day.

According to the data of China Sleep Quality Index Report in 2019[31], Chinese's average daily sleep time is 7.4 hours. Regardless of the little time span of users' body movement during screen time (such as using smartphones while walking), it can be discovered that the respondents had no active mobility for 13.7 hours on average per day (Table 4)—more than half a day.

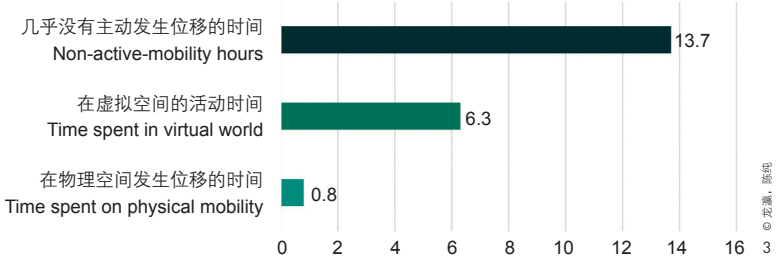
Generally, a person's stride length is mainly determined by his/her height: The stride length of an adult is 0.37 times of his/her height[32]. A person's average walking speed is 5.4 km/h[33], but often affected by age, gender, weight, and health status, which could be ignored in this research since the majority of the respondents were young with normal BMI and little gender disparity. Thus, this

表4：受访者一周内每日未发生物理空间上的主动位移时长统计
Table 4: Respondents' non-active-physical-mobility hours per day in a week

	工作日睡眠时长 Sleeping hours on weekdays	周末睡眠时长 Sleeping hours at weekends	一周平均睡眠时长 Average sleeping hours	一周平均屏幕使用时间 Average screen time	未发生物理空间上的主动位移时长 Non-active-physical-movement hours
时间（小时） Time (hour)	7.0	8.3	7.4	6.3	13.7

注
工作日睡眠时长、周末睡眠时长、一周平均睡眠时长数据均来自参考文献[31]。

NOTES
The sleeping hours on weekdays/at weekends, and the average sleeping hours are sourced from Ref. [31].



3. 每日花费在物理空间与虚拟空间的时长（单位：小时）
4. 每日屏幕使用时间和步数正态Q－Q图
5. 基于每日屏幕使用时间和步数原始数据的散点图
6. 数据处理前后对比图

3. Daily time spent in physical world and virtual world (unit: hour)
4. Normal Q-Q plots of daily screen time and walking step counts
5. Scatter plot based on raw data of daily screen time and walking step counts
6. Data distributions before and after outlier elimination

年龄集中在18～25岁，主要为中青年群体，男女比例差异不大，多数人的BMI处于正常值范围，故可忽略上述因素的影响，取受访者平均身高为1.68m，平均步幅为0.62m，平均步行速度为5.4km/h，计算可得步行6 705步所需时间约为0.8小时，即本研究受访者每日平均在物理空间的主动位移时间不足1小时（图3）。

3.3 每日屏幕使用时间与步数的关系

本研究首先对样本数据进行正态分布检验，发现每日屏幕使用时间和步数均服从正态分布（图4）。随后，使用SPSS 24.0的线性回归模型分析2 719组每日步数与屏幕使用时间原始样本数据的关系，结果如图5所示，R^2=0.005。由于R值较小，回归模型拟合优度差，故判断原始数据中两个变量之间不存在显著的线性相关关系。然而，上述分析同时得到sig=0.0002<0.001，表明两者间存在极其显著关系，故两个变量之间的关系有待进一步探索。

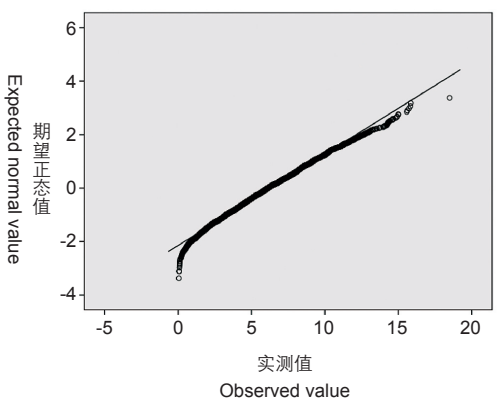
为了能得到更优的拟合效果，研究尝试对原始数据进行进一步处理，包括将时间、步数数据全部转换成自然对数，以及剔除离群值两种方法。但进行自然对数转换后，拟合结果仍然不佳，所以采用剔除离群值的处理。首先查看每日步数和每日屏幕使用时间的直方图和箱型图，发现均存在少数离群值，将其剔除后与剔除前后进行比较，发现剔除后的数据均更接近正态分布（图6），因而选用剔除离群值后的2 610组每日步数和每日屏幕使用时间数据做进一步分析，其中每日屏幕使用时间为自变量，每日步数为因变量。

research took the respondent's average height as 1.68 m, average stride length as 0.62 m, and average walking speed as 5.4 km/h. The calculation reveals that the respondents average daily time on active mobility in physical spaces was less than one hour (about 0.8 h) (Fig. 3).

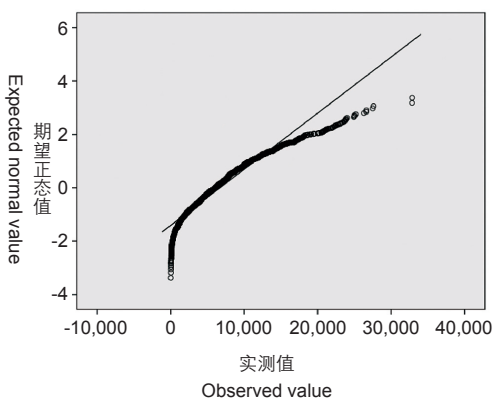
3.3 The Correlation between Daily Screen Time and Daily Walking Step Counts

First, a normal distribution test was conducted for sample data, revealing that daily screen time and daily walking step counts were both in normal distribution (Fig. 4); second, for the original 2,719 pairs of daily screen time–daily walking step counts, linear regression was conducted in SPSS 24.0, the results of which is shown in Figure 5: As r^2 = 0.005 means poor goodness of fit of regression model, it can be concluded that there is no significant linear correlation between the two variables, but their correlation needs further exploration because the analysis also showed that sig = 0.0002 < 0.001.

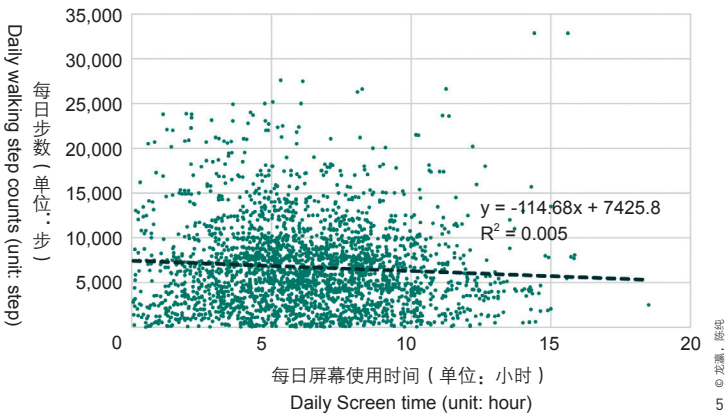
To obtain a better goodness of fit, the authors tried two processing methods—natural logarithm transformation and eliminating the outliers—for the original data of both variables, but the former was proved not effective enough. When applying the latter, the outliers were firstly spotted by histograms and box charts based on the original data for both variables, respectively, and eliminating them indeed made the data samples more normally distributed (Fig. 6). After that 2,610 pairs of daily screen time and daily walking step counts were kept for further analyses, the former as the independent variable and the latter as the dependent variable.



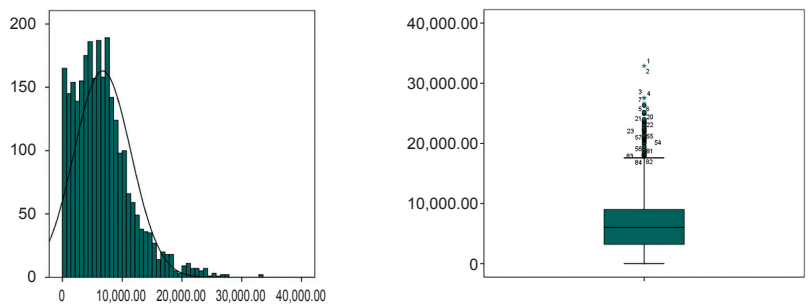
a. 每日屏幕使用时间正态Q–Q图
Normal Q–Q plot of daily screen time



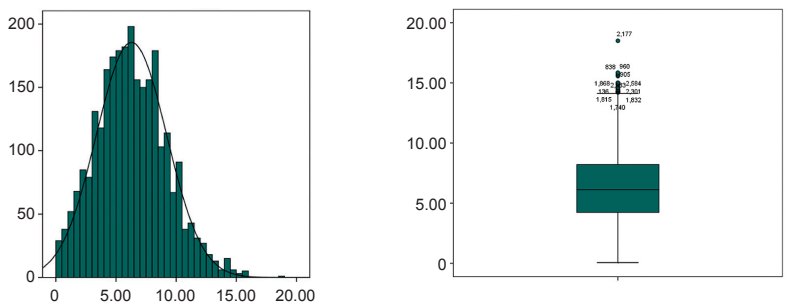
b. 每日步数正态Q–Q图
Normal Q–Q plot of daily walking step counts



剔除前
Before elimination (N = 2,719)

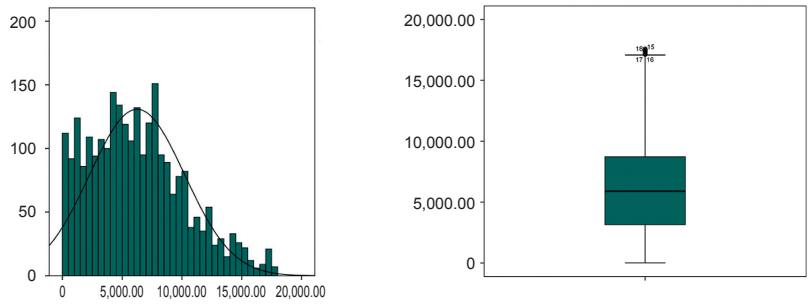


原始数据 – 平均步数
Raw data of average walking step counts

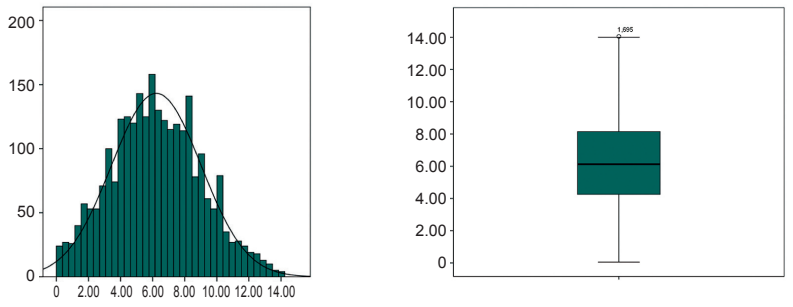


原始数据 – 平均屏幕使用时间
Raw data of average screen time

剔除后
After elimination (N = 2,610)



处理后数据 – 平均步数
Processed data of average walking step counts



处理后数据 – 平均屏幕使用时间
Processed data of average screen time

对处理后的数据进行曲线回归，比较后发现三次曲线模型拟合度最佳（R^2=0.016）（表5）。拟合曲线如图7所示，回归方程为：

$$S = 4.13t^3 - 125.24t^2 + 942.95t + 4600.7,$$

式中，S为每日步数，t为每日屏幕使用时间，单位为小时。

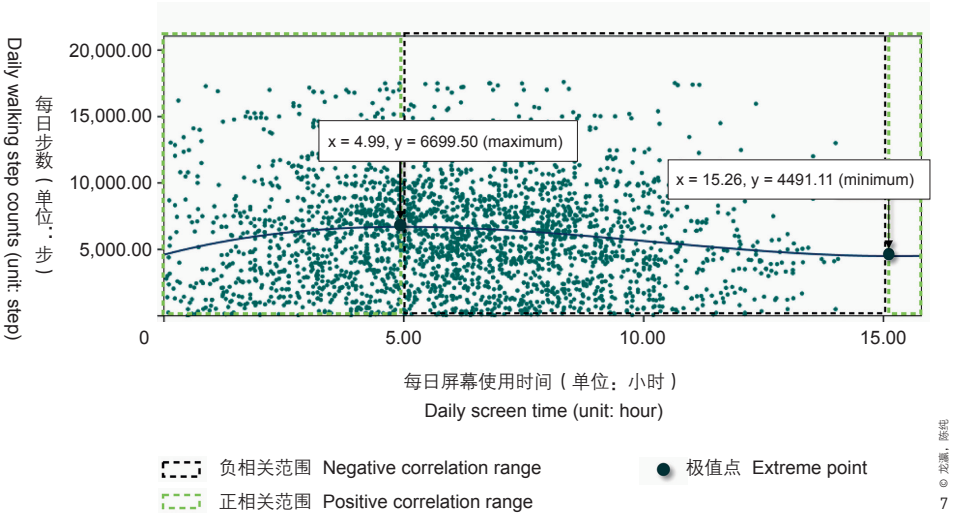
Then curvilinear regression was conducted on the processed data with different models, among which the cubic curve model performed the highest goodness of fit (R^2 = 0.016) (Table 5). The corresponding fitting curve is shown in Figure 7, the regression equitation of which is:

$$S = 4.13t^3 - 125.24t^2 + 942.95t + 4600.7,$$

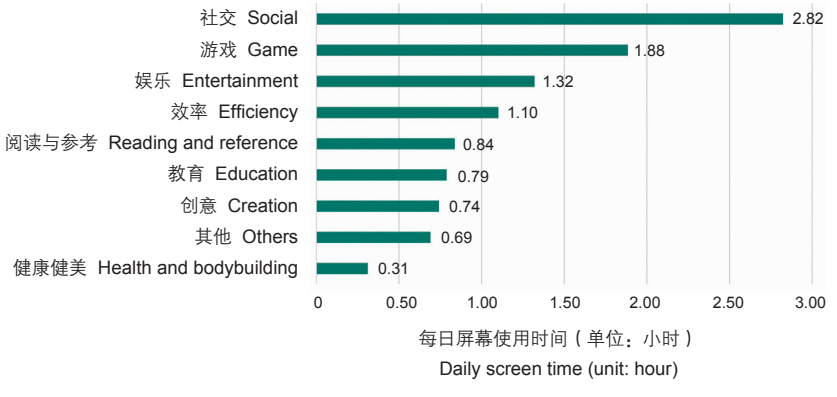
where S represents daily walking step counts, t represents daily screen time measured by hour.

表5: 曲线回归模型对比情况表
Table 5: Comparison of curve regression models

曲线回归模型 Type of curve regression	R	R^2
一次 Linear	0.050	0.003
二次 Quadratic	0.119	0.014
三次 Cubic	0.125	0.016
S	0.042	0.002



7



8

7. 每日屏幕使用时间和步数的回归模型图
8. 各类应用的人均每日使用时长（单位：小时）

7. Regression model diagram of daily screen time and walking step counts
8. Average daily screen time per capita for different App categories (unit: hour)

由图7可知，$0 \leqslant t \leqslant 4.99$时，步数和屏幕使用时间呈正相关，即随着屏幕使用时间的增加，步数也增加。可能的原因是这个时间范围包含了多种碎片化时间场景，如日常通勤、在家走动、上下楼梯等，使人们更容易发生“边走路边玩手机”的行为。

$4.99 < t \leqslant 15.25$时，步数和屏幕使用时间呈负相关，即随着屏幕使用时间的增加，步数也变少。可能的原因是：若人们使用屏幕时间超过5小时，伴随出现的行为更多的是久坐[9]而非移动，步数也相应变少。这意味着在一定范围内，将时间更多分配在屏幕使用上，可能导致人将注意力更多地集中在数字虚拟世界，降低对物理空间的关注，在物理空间中的主动位移也因此减少。

$15.25 < t \leqslant 24$时，步数和屏幕使用时间呈现正相关，即随着屏幕使用时间的增加，步数也增加。样本数据显示，每日屏幕使用时间超过15.25小时的情况更多集中在星期五（66.7%），这部分样本的身份均为学生，且数量较少，对其进行回访后发现，这些学生在周五放学后会搭乘远距离市内交通工具回家或进行跨区娱乐活动，在这种长距离通勤中更容易“且行且玩（手机）”。

3.4 每日平均步数与不同类型应用使用时间的关系

研究发现，受访者每日使用的应用主要包括社交、娱乐、游戏、阅读与参考等8个类别，其中人均每日使用社交类应用的时间多达2.82h，显著多于其他7类，表明整体上人们在处理社交关系上花费的时间最多；游戏和娱乐类应用的人均每日耗费时间位居第二，健康健美类应用用时最少（图8）。

用SPSS 24.0对各类别应用的每日平均使用时间与每日平均步数进行Pearson分析，结果如表6所示：社交、阅读与参考、娱乐和游戏这4类应用的使用时间与步数间存在显著相关性。其余类别与步数间的相关性均不显著，其中健康健美类应用由于样本量过少，其分析结果实际参考价值不大。

将社交、阅读与参考、娱乐和游戏这4类应用的每日平均使用时间分别与每日平均步数做线性回归分析，发现社交类应用使用时间与步数呈正相关，这意味着每日平均步数越多，耗费在处理虚拟社交关系上的时间也越多。而阅读与参考、娱乐和游戏这三类应用的每日平均使用时

In Figure 7, when *t* ranges from 0 to 4.99, walking step counts are positively correlated with screen time. This may be because during discontinuous body movements, such as commuting, moving around at home, and climbing stairs, people are more likely to use mobile phones.

When *t* ranges from 4.99 to 15.25, walking step counts are negatively correlated with screen time. The possible reason is that when people use mobile phones more than 5 hours each day, they tend to stay sedentary[9] instead of moving actively, which makes walking step counts decrease. Therefore, within certain time range, more screen time may lead to attention shifting from the physical world to the virtual world, reducing the active mobility in physical space.

When *t* ranges from 15.25 to 24, walking step counts are positively correlated with screen time. The respondents' daily screen time exceeding 15.25 hours was reported more on Friday (66.7%) and only by a few students. Via follow-up calls, it is found that these students would take long trip by public transportation home

表6：不同类别应用的每日平均使用时间与每日平均步数的相关性分析结果
Table 6: Correlation analysis results of average daily screen time for different application categories and average daily walking step counts

应用类别 App category	每日平均步数 Average daily step counts		
	Pearson相关系数 Pearson correlations	Sig.	N
社交 Social	0.136**	0.008	383
阅读与参考 Reading and reference	-0.218*	0.029	100
效率 Efficiency	-0.069	0.541	80
娱乐 Entertainment	-0.170*	0.016	201
游戏 Game	-0.224*	0.032	93
教育 Education	0.132	0.404	42
创意 Creation	-0.048	0.720	59
健康健美 Health and bodybuilding	-0.196	0.642	8
其他 Others	-0.114	0.123	184

注
**表示在α=0.01水平上显著；
*表示在 α=0.05水平上显著。

NOTES
** means a significance at α= 0.01 level;
* means a significance α= 0.05 level.

间与每日平均步数均呈负相关（图9），对此，可能的解释是这三类应用都具有使用连续性的特点，需要相对完整的大段时间与更集中的注意力，在步行时使用这些应用（尤其是娱乐与游戏类应用）会显著分散人们对步行空间物理环境的注意力，造成严重的安全隐患，所以人们一般非移动时使用这三类应用。这也反映出许多娱乐休闲方式的移动化虽然打破了进行娱乐活动的空间和时间局限，却也增加了人们对物理空间关注度缺失的风险。

3.5 个体基本信息与健康状况的影响

对所有受访者的个体基本信息及健康状况数据分别与每日平均屏幕使用时间及每日平均步数进行回归分析，结果见表7。每日平均屏幕使用时间与文化程度、个人收入分别呈极显著负相关，与年龄呈显著正相关，说明学历越高、个人收入越高、年龄越低的群体每日使用手机的时间越少。每日平均步数与文化程度呈极显著负相关，与每周运动频次、

or to recreational destinations on Friday after school, during which they would use mobile phone continuously.

3.4 The Correlation between Average Daily Walking Step Counts and Screen Time on Different Apps

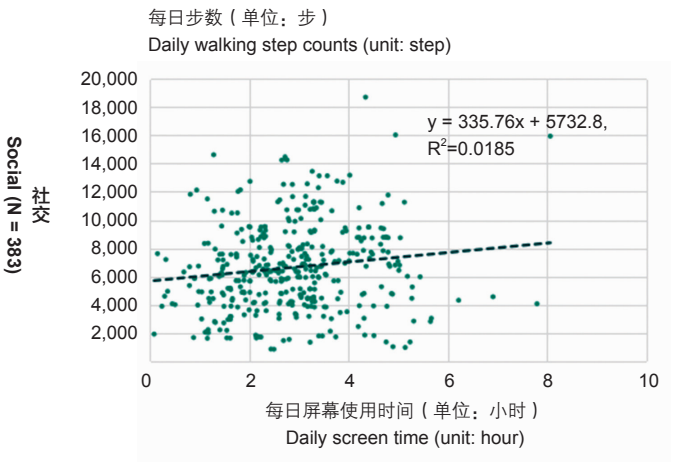
In this research, the respondents reported 8 categories of Apps they used every day, such as social, entertainment, game, and reading and reference. The respondents' average daily screen time on social Apps is 2.82 hours, remarkably more than that of the other categories, indicating that, in general, people spent the most screen time on social behaviors; the second most screen time was spent on game and entertainment Apps, and the least on health and bodybuilding Apps (Fig. 8).

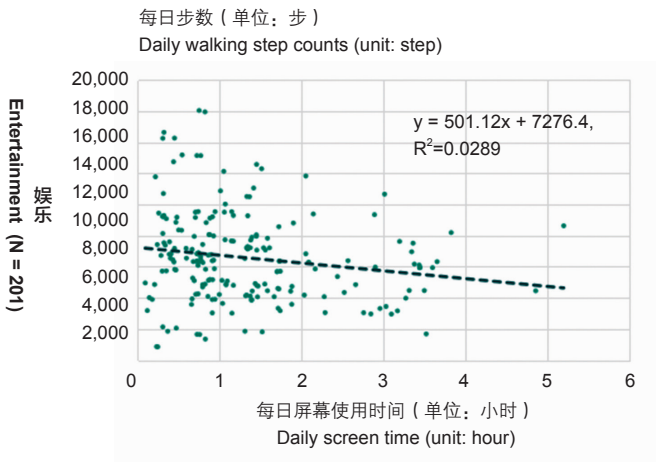
For the average daily screen time for each category, Pearson analysis was done with SPSS 24.0 to examine their correlations with average daily walking step counts, and the results are shown in Table 6: Significant correlation was found on social, reading and reference, entertainment, and game Apps; the data sample for health and bodybuilding Apps was too small to suggest scientific correlations.

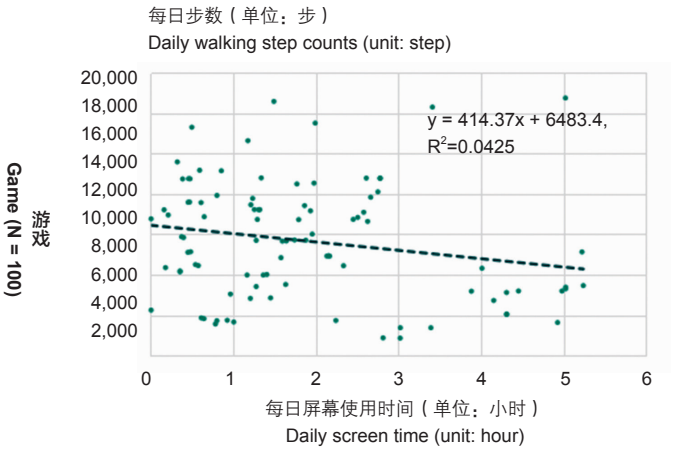
According to linear-regression analyses on the correlations between average daily walking steps and average daily screen time on social, reading and reference, entertainment, and game Apps, respectively, it was discovered that the time spent on social Apps positively correlates with walking step counts, which means that as average daily walking step counts increase, more time would be spent on dealing with virtual social contacts. The average daily screen time on reading and reference, entertainment, and game Apps negatively correlated with average daily walking step counts (Fig. 9), because usually such Apps are used continuously, requiring a longer period of time and more concentrated attention; but using these Apps (especially entertainment and game Apps) while walking will remarkably disperse people's attention to physical environment, and may lead to serious safety risks, so people prefer to use these Apps when they are not moving. Although entertainment Apps offer new recreational experience without spatial or temporal limitations, the usage of such Apps would increase people's ignorance to the physical world.

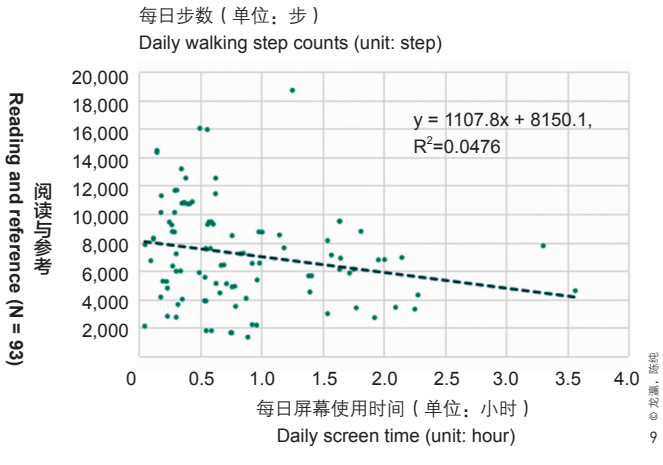
3.5 The Effects of Individual Socio-Demographics and Health Status

This research conducted regression analyses to examine the correlations between respondents' individual socio-demographics and health status with their average daily screen time and average daily walking step counts, respectively (Table 7). Average daily screen time significantly negatively correlated with education background and personal income, and significantly positively correlated with age, indicating that people with higher education level, higher income, and younger age tend to spend less time on smartphones every day. Average daily walking step counts are significantly negatively correlated with education background, and significantly positively correlated with weekly









9. 每日平均步数和4类应用每日平均使用时间的散点图

9. Scatter plots of average daily walking step counts and average daily screen time for 4 App categories

表7：个体信息与屏幕使用时间、步数的回归模型结果（N=395）

Table 7: Regression results of individual information and screen time/step counts (N = 395)

	变量 Variables	每日平均屏幕使用时间 Average daily screen time		每日平均步数 Average daily step counts	
		B	Sig.	B	Sig.
个体基本信息 Individual socio-demographics	年龄 Age	0.043	0.090*	0.075	0.004**
	月生活费 / 个人月收入 Monthly expense/monthly income	-0.062	0.009**	0.030	0.202
	文化程度 Education background	-0.204	0.000**	-0.086	0.000**
个体健康信息 Health status	BMI	0.027	0.184	0.016	0.428
	每周运动频次 Weekly exercise frequency	0.008	0.713	0.063	0.004**
	自评身体健康状况 Self-assessed health status	0.028	0.201	0.012	0.578
	R^2	0.047		0.013	

注

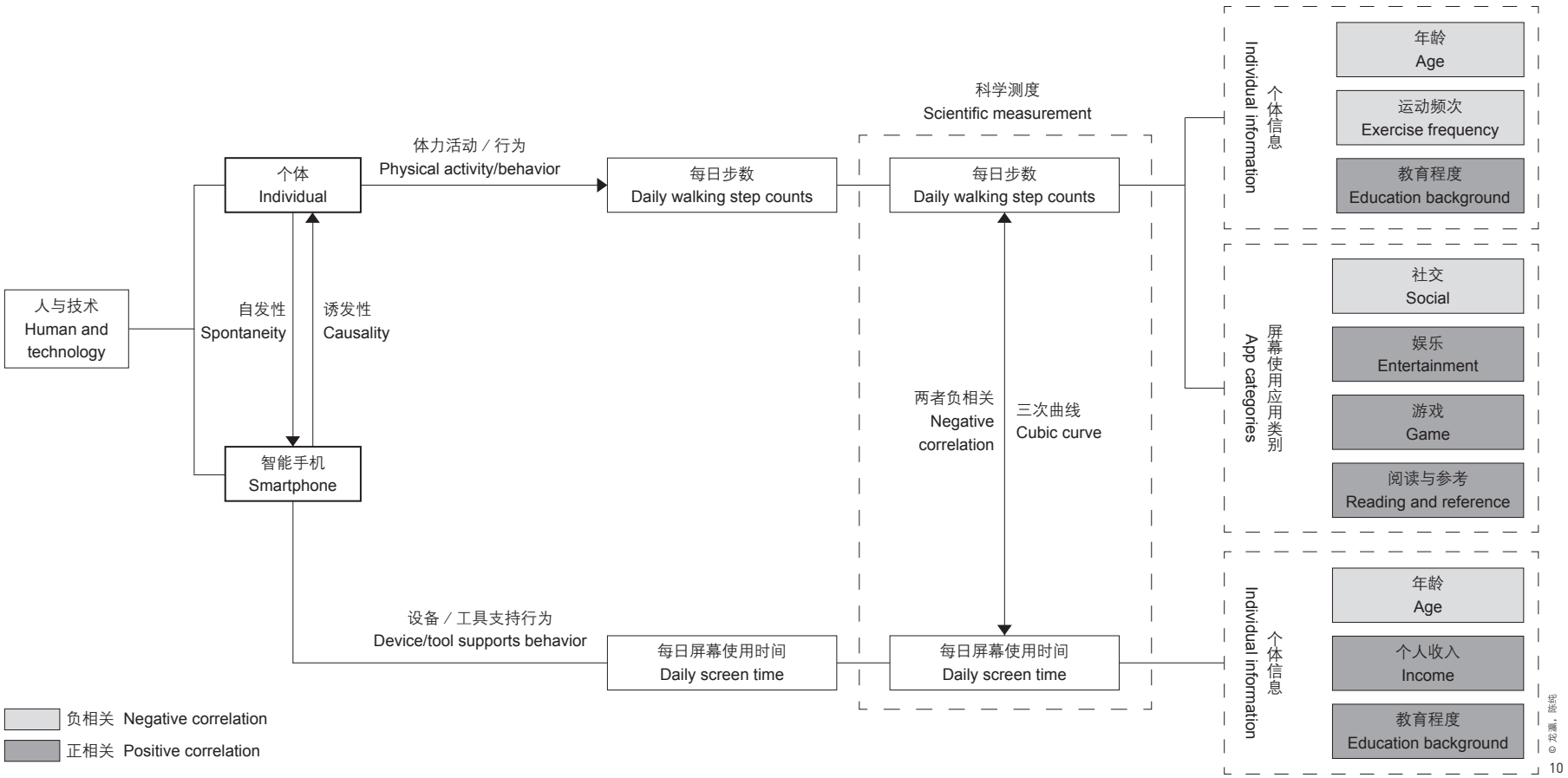
**表示在 α =0.01水平上显著；

*表示在 α =0.05水平上显著。

NOTE

** means a significance at α = 0.01 level;

* means a significance at α = 0.05 level.



10. 本研究关于人与技术关系的总结与思考

10. Summary and reflection about human-technology relationship in this research

年龄分别呈极显著正相关，说明学历越高、每周运动频次越低、年纪越小的群体每日花费在步行上的时间越少。

4 结论与讨论

本文以手机屏幕使用和步行间的相关性作为观察人—技术关系的新视角（图10）。通过实证研究发现，在一定时间范围内，样本的每日屏幕使用时间与每日步数呈现负相关，表明通过手机这一媒介，虚拟世界可能会降低人们对于物理空间的关注。作为对两者关系的探索性研究，本研究发现每日步数与每日屏幕使用时间大致呈现出三次曲线关系。拟合结果显示，当每日屏幕使用时间在4.99 ~ 15.25小时范围内时，两者呈现负相关；在本次研究中，有1 719个受访者样本的每日屏幕使用时间在此范围内，占剔除极端值后样本数量的65.8%，说明该结论具有一定的普遍意义。

在每日屏幕使用时间的分配上，社交类应用所占比例最高，可认为处理社交关系是当前智能手机用户的一种“刚需”，且使用此类应用

exercise frequency and age, indicating that people with higher education level, fewer weekly exercise frequency, and younger age tend to spend less time on walking every day.

4 Conclusions and Discussions

Focusing on the correlation between screen time and walking step counts, this paper explored the relationship between human and technology from a new perspective (Fig. 10). By empirical research, it is found that in a certain time span, people's daily screen time negatively correlated with daily walking step counts, suggesting that via mobile phones the virtual world may distract people's attention from physical environment. This exploratory research concludes that the correlation between daily walking step counts and daily screen time can be roughly presented as a cubic curve, which provides some enlightening results: when daily screen time ranges from 4.99 to 15.25 hours, the both are negatively correlated; given that this time span covered most respondents (65.8% of all respondents after eliminating outliers), this finding can offer a universal reference.

In addition, using social Apps spends the most daily screen time, showing that dealing with social contacts is a new “must do” for smartphone users, and

能更多地利用步行时间等碎片时间；娱乐和游戏类应用由于对使用时间长度及连续性有更高要求，故每日使用时间比社交类应用少；健康健美类应用的使用时间最少，可能是因为健身类行为不仅要求更长的使用时长，还存在场地限制。在使用者个体特征因素方面，教育程度则与每日屏幕使用时间和每日步数均呈显著负相关，表明拥有较高学历的人每日步行较少，使用手机的时间也更少。

当前，“查看屏幕使用时间的恐怖程度不亚于查看体检报告”“手机低电量恐惧症”等成为社会热议的现象，新冠肺炎疫情（COVID–19）之下的“宅生活”更加充分地展现了人们对智能手机的依赖。而使用屏幕不仅容易引发久坐，造成体力活动不足，在步行过程中使用屏幕也会对步行者本身带来安全隐患。本文通过对这一现象的探索性研究，证实了手机屏幕使用与步行活动间存在的相互影响，这将促使公众认识到智能手机如何影响以步行为代表的体力活动，特别是对于高频率手机使用者，更应督促他们定期休息、减少非必要的手机使用、进行更多的运动，以保障身体健康。

以互联网产业化和工业智能化为标志、以技术融合为主要特征的第四次工业革命不仅使人们的思维方式从传统的机械思维向大数据思维转变，同时也使人们的认知方式向虚实结合过渡。智能手机等移动设备不再仅仅是通信工具，而已经成为快速发展的数字化生活方式的重要载体，日常生活与工作的方方面面——从虚拟社交、流媒体娱乐到电子商务活动——都愈发依赖手机进行。人们以手机为媒介，平均每天有超过四分之一的时间（6.3小时）在虚拟世界中度过。随着城市“数字孪生体”的发展，这些投入或许会继续大幅增长。

当前，虚拟行为和现实实践的混杂不可避免地引发了线上、线下话语权的博弈，造成了“离身”与“具身”交织的复杂现象。在探讨这些问题的时候，一方面应承认移动设备迭代的技术合理性及其中立意义上的不可抗拒性，另一方面也需认识到大众容易沉溺于其所建构的虚拟世界中。但无论是通过虚拟路径还是现实路径，都可以不断认识世界。根据唐·伊德的人—技关系理论，人和手机之间属于“它异”关系，即人通过工具与技术直接互动，这种互动是以认识、感知和更好地生活于物质与虚拟空间为目的而发挥作用的。

本研究在以下方面仍有待改进：1）本次研究的有效样本量仅为395份，而且其中中老年人数量较少，无法充分代表这一年龄层手机使

such Apps can be used in “fragmentary time” such as during walking; using entertainment and game Apps spends less screen time as using them requires longer and continuous time span; using health and bodybuilding Apps spends the least screen time perhaps because doing physical exercise requires even longer time span and specific venues. Education background is significantly negatively correlated with daily screen time and daily walking step counts, which means better educated people spend less time on both walking and using mobile phones every day.

Nowadays, social phenomena such as “checking screen time can be as scary as checking a medical examination report” and “fear for low battery” are widely seen, and the “in-home life” under the current COVID-19 pandemic has manifested people’s dependence on smartphones, which may cause sedentariness and lack in physical activities, and watching screen while walking would increase safety hazards. Through empirical research on such phenomena, this paper has primarily proved the mutual impacts between screen usage and walking, which will help the public recognize how smartphones can affect physical activities such as walking, and encourage them to take regular breaks, reduce screen usage, and increase exercise for especially those who use smartphone in a high frequency.

Not only does The Fourth Industrial Revolution, marked by Internet industrialization and industrial intellectualization through technology integration, changes people’s mindset from the mechanical to the Big Data-based, but also fosters them with a new cognitive style that combines virtuality and reality. Mobile devices such as smartphones have become an important medium for the fast-advancing digital lifestyle rather than just a means of communication, fully and increasingly supporting people’s daily life and work such as virtual social contacts, streaming media entertainment, and e-commerce behaviors. Via smartphones, people spend more than a quarter of a day (6.3 hours) in the virtual world every day. Along with the “Digital Twin” of cities developing, people’s time spent on the virtual world may continue to grow significantly.

At present, the blend of virtual and real behaviors in the real world inevitably leads to the battle of discourse power between online and offline communities, resulting in the complex interweaving of “disembodiment” and “embodiment.” These phenomena, on the one hand, reflect the technical rationality and irresistible trend of mobile device iteration, and on the other hand, warn the public of addiction to the virtual world constructed by devices. However, both the virtual and the reality approaches can help learn the world better and more. Based on Don Ihde’s theory on human-technology relationship, human and smartphone is in an “alterity relation,” i.e. humans directly interact with technology by a tool—smartphone, and the interaction plays a role in understanding, perceiving, and better living in physical and virtual spaces.

This research needs to be improved in the following aspects: 1) The valid samples of this research were only 395, and the sample size of middle-aged and

用者的情况；加之有效样本选取也受设备型号及系统版本影响（苹果手机与华为手机分别仅限iOS 12与EMUI 9.1及以上系统的用户），未来应提高受访者中中老年人的比例，并扩大所调查手机的品牌和操作系统版本范围。2）本次研究仅聚焦个体屏幕使用时间与步行活动之间的关系，未来需进一步探究物质空间要素对个体行为的影响。**LAF**

elderly respondents was too small to fully represent corresponding smartphone user groups; in addition, the valid samples were defined by respondents' mobile phone's model and operating system version (iPhone must be with at least iOS 12, and HUAWEI phone EMUI 9.1). In the future, more middle-aged and elderly users should be investigated, and more brands and operating system versions should be included. 2) More attention should be paid to the impact of wider range of physical environmental elements on individual behaviors, rather than only the correlation between screen time and walking step counts. **LAF**

REFERENCES

[1] Boschert, S., & Rosen, R. (2016). Digital Twin—The Simulation Aspect. *Mechatronic Futures* (P. Hehenberger & D. Bradley, Tran.), 59-74. Cham, Switzerland: Springer.

[2] Qi, Q., & Tao, F. (2018). Digital Twin and Big Data towards Smart Manufacturing and Industry 4.0: 360 Degree Comparison. *IEEE Access*, (6), 3585-3593. doi:10.1109/ACCESS.2018.2793265

[3] Miniwatts Marketing Group. (2021). World Internet Users Statistics and 2021 World Population Stats. Retrieved from https://www.internetworldstats.com/stats.htm

[4] Kemp, S. (2018). Digital in 2018: World's Internet users pass the 4 billion mark. *We Are Social*. Retrieved from https://wearesocial.com/uk/blog/2018/01/global-digital-report-2018/

[5] National Bureau of Statistics of China. (2021). *Statistical Communiqué of the People's Republic of China on the 2020 National Economic and Social Development*. Retrieved from http://www.stats.gov.cn/english/PressRelease/202102/t20210228_1814177.html

[6] Kuss, D. (2017). Mobile technology and social media: The extensions of man in the 21st century. *Human Development*, 60(4), 141-143. doi:10.1159/000479842

[7] China News Service. (2015, November 13). Deloitte: smartphone addiction has become a common phenomenon. *ITBear*. Retrieved from http://www.itbear.com.cn/html/2015-11/147025.html

[8] Fennell, C., Barkley, J. E., & Lepp, A. (2019). The relationship between cell phone use, physical activity, and sedentary behavior in adults aged 18–80. *Computers in Human Behavior*, (90), 53-59. doi:10.1016/j.chb.2018.08.044

[9] Barkley, J. E., & Lepp, A. (2016). Mobile phone use among college students is a sedentary leisure behavior which may interfere with exercise. *Computers in Human Behavior*, (56), 29-33. doi:10.1016/j.chb.2015.11.001

[10] Attia, N. A., Baig, L., Marzouk, Y. I., & Khan, A. (2017). The potential effect of technology and distractions on undergraduate students' concentration. *Pakistan journal of medical sciences*, 33(4), 860. doi:10.12669/pjms.334.12560

[11] Ravizza, S. M., Hambrick, D. Z., & Fenn, K. M. (2014). Non-academic internet use in the classroom is negatively related to classroom learning regardless of intellectual ability. *Computers and Education*, (78), 109-114. doi:10.1016/j.compedu.2014.05.007

[12] Kim, S. E., Kim, J. W., & Jee, Y. S. (2015). Relationship between smartphone addiction and physical activity in Chinese international students in Korea. *Journal of Behavioral Addictions*, 4(3), 200-205. doi:10.1556/2006.4.2015.028

[13] Wang, L., Zhang, Y., & Wang, L. (2016). Developments of foreign researchers on screen time affecting teenager physical health in recent 10 years. *Journal of Physical Education*, 23(2), 138-144. doi:10.16237/j.cnki.cn44-1404/g8.2016.02.019

[14] Boone, J. E., Gordon-Larsen, P., Adair, L. S., & Popkin, B. M. (2007). Screen time and physical activity during adolescence: longitudinal effects on obesity in young adulthood. *International Journal of Behavioral Nutrition and Physical Activity*, 4(1), 1-10. doi:10.1186/1479-5868-4-26

[15] Madhav, K. C., Sherchand, S. P., & Sherchan, S. (2017). Association between screen time and depression among US adults. *Preventive Medicine Reports*, (8), 67-71. doi:10.1016/j.pmedr.2017.08.005

[16] Li, X., Buxton, O. M., Lee, S., Chang, A. M., Berger, L. M., & Hale, L. (2019). Sleep mediates the association between adolescent screen time and depressive symptoms. *Sleep Medicine*, (57), 51-60. doi:10.1016/j.sleep.2019.01.029

[17] Thomée, S., Härenstam, A., & Hagberg, M. (2011). Mobile phone use and stress, sleep disturbances, and symptoms of depression among young adults – a prospective cohort study. *BMC Public Health*, 11(1), 1-11. doi:10.1186/1471-2458-11-66

[18] Chen, B., Liu, F., Ding, S., Ying, X., Wang, L., & Wen, Y. (2017). Gender differences in factors associated with smartphone addiction: a cross-sectional study among medical college students. *BMC Psychiatry*, 17(1), 1-9. doi:10.1186/s12888-017-1503-z

[19] Lee, Y. S., Han, D. H., Kim, S. M., & Renshaw, P. F. (2013). Substance abuse precedes internet addiction. *Addictive Behaviors*, 38(4), 2022-2025. doi:10.1016/j.addbeh.2012.12.024

[20] Liu, Q., Zhou, Z., Yang, X., Kong, F., Niu, G., & Fan, C. (2017). Mobile phone addiction and sleep quality among Chinese adolescents: A moderated mediation model. *Computers in Human Behavior*, (72), 108-114. doi:10.1016/j.chb.2017.02.042

[21] Hawi, N. S., & Samaha, M. (2017). Relationships among smartphone addiction, anxiety, and family relations. *Behaviour and Information Technology*, 36(10), 1046-1052. doi:10.1080/0144929X.2017.1336254

[22] Lee, J., Krallman, R., Montgomery, D., DuRussel-Weston, J., Kline-Rogers, E. M., Jackson, E., & Eagle, K. (2018). Trends in mobile device usage, physical activity, and sedentary screen time in project healthy schools students. *Journal of the American College of Cardiology*, 71(11S), A1802-A1802. doi:10.1016/S0735-1097(18)32343-X

[23] Jiang, B., Schmillen, R., & Sullivan, W. C. (2019). How to waste a break: Using portable electronic devices substantially counteracts attention enhancement effects of green spaces. *Environment and Behavior*, 51(9-10), 1133-1160. doi:10.1177/0013916518788603

[24] Nishiwaki, M., & Matsumoto, N. (2015). Physical activity and lifestyle intervention. *The Journal of Physical Fitness and Sports Medicine*, 4(2), 187-195. doi:10.7600/jpfsm.4.187

[25] Zhou, J., Yang, L., Liu, J., & Zhang, C. (2018). Beating long trips with a smartphone? A case study of Beijing residents. *Cities*, (73), 36-43. doi:10.1016/j.cities.2017.10.007

[26] Meier, M. D., Hager, R. L., Vincent, S. D., Tucker, L. A., & Vincent, W. J. (2007). The effects of leisure-based screen time. *American Journal of Health Education*, 38(3), 139-146. doi:10.1080/19325037.2007.10598959

[27] Chen, G., Zhang, Y., & Yang, Z. (2014). Realization of pedometer with auto-correlation analysis based on mobile phone sensor. *Journal of Chinese Inertial Technology*, 22(6), 749-798. https://doi.org/10.1080/19325037.2007.10598959

[28] Song, J. (2013). *Research on trading-off between accuracy and energy consumption of the auto-correlation based step counting algorithm* (Master's thesis). Retrieved from CNKI database.

[29] He, X. , Shi, W., & Sheng, Z. (2016). A research on the availability of smart bracelet/phone app in different walking speed or road surface for step calculation. *China Sport Science and Technology*, 52(6), 122-127. doi:10.16470/j.csst.201606019

[30] Lee, I. M., Shiroma, E. J., Kamada, M., Bassett, D. R., Matthews, C. E., & Buring, J. E. (2019). Association of step volume and intensity with all-cause mortality in older women. *JAMA Internal Medicine*, 179(8), 1105-1112. doi:10.1001/jamainternmed.2019.0899

[31] Sleemon. (2019). *China Sleep Quality Index Report 2019*. Retrieved from https://zk.cn-healthcare.com/doc-show-33020.html

[32] Yixue baike. (n.d.). *One step distance*. Retrieved from https://www.yixue.com/%E6%AD%A5%E5%B9%85

[33] Baidu baike. (n.d.). *Walking speed*. Retrieved from https://baike.baidu.com/item/%E6%AD%A5%E9%80%9F/4391491?fr=aladdin