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Possibilities and Opportunities of Mobile Devices to Measure the Physical (In)Activity of Young Citizens – First Results of a Case Study in Vienna

Florian Reinwald, Thomas Schauppenlehner, Franz Mairinger, Irene Bittner, Anna Höglhammer, Rosa Diketmüller, Doris Damyanovic

(DI Florian Reinwald, University of Natural Resources and Life Sciences, Vienna, Department of Landscape, Spatial and Infrastructure Sciences, Institute of Landscape Planning, Peter-Jordan-Straße 65, 1180 Vienna, Austria, florian.reinwald@boku.ac.at)
(DI Dr. Thomas Schauppenlehner, University of Natural Resources and Life Sciences, Vienna, Department of Landscape, Spatial and Infrastructure Sciences, Institute of Landscape Development, Recreation and Conservation Planning, Peter-Jordan-Straße 65, 1180 Vienna, thomas.schauppenlehner@boku.ac.at)
(Mag. Franz Mairinger, University of Vienna, Centre for Sport Science and University Sports, Institute of Sport Science, Auf der Schmelz 6a, 1150 Vienna, Austria, franz.mairinger@univie.ac.at)
(DI Irene Bittner, University of Natural Resources and Life Sciences, Vienna, Department of Landscape, Spatial and Infrastructure Sciences, Institute of Landscape Planning, Peter-Jordan-Straße 65, 1180 Vienna, irene.bittner@boku.ac.at)
(DI Anna Höglhammer, University of Natural Resources and Life Sciences, Vienna, Department of Landscape, Spatial and Infrastructure Sciences, Institute of Landscape Development, Recreation and Conservation Planning, Peter-Jordan-Straße 65, 1180 Vienna, anna.hoeglhammer@boku.ac.at)
(Ass.Prof. Mag. Dr. Rosa Diketmüller, University of Vienna, Centre for Sport Science and University Sports, Institute of Sport Science, Auf der Schmelz 6a, 1150 Vienna, Austria, rosa.diketmueller@univie.ac.at)
(Ass.Prof. DI Dr. Doris Damyanovic, University of Natural Resources and Life Sciences, Vienna, Department of Landscape, Spatial and Infrastructure Sciences, Institute of Landscape Planning, Peter-Jordan-Straße 65, 1180 Vienna, doris.damyanovic@boku.ac.at)

1 ABSTRACT

"New Media" starting with the introduction of television followed by Video to DVDs and computer games are often made responsible for the lack of movement and outdoor exercises of young people. With the spread of mobile devices such as smartphones and tablet computers, digital tools became spatially independent which offers new options and possibilities especially among young people (Direito et al. 2014). Instead of blaming new media as a reason that the young people increasingly stay at home and neglecting physical activities, the possibilities and opportunities of particularly mobile devices are to be examined in the project "ActivE Youth". The project aims to determine how mobile devices can contribute for collecting data regarding the mobility behavior of the youth and how mobile devices can be used to reduce the lack of physical activity of young people.

2 MEASURING PHYSICAL ACTIVITIES AND MOBILITY BEHAVIOUR OF YOUNG PEOPLE - THEORETICAL AND METHODICAL BACKGROUND

Due to the heterogeneous composition of the group of adolescents and the rapid changes of youth trends there is little knowledge in Austria about young peoples' physical activity and mobility behaviors in public spaces (BMFLUW 2009). Furthermore, the contribution of these different activities to their health has not been researched sufficiently.

Studies such as those of the research network "Health Behavior in School-aged Children" (Schnohr et al. 2013) show that only one out of five adolescents achieves the recommended minimum of 60 minutes of moderate exercise activity per day (Edwards & Tsouros 2008; Titze et al. 2010). Additionally the physical activity of 15-24 year olds is decreasing with increasing age and the gender gap (men are more engaged in physical activity and sports than women) within this age group is specifically high (European Commission 2014). Different factors are responsible for this situation (Sallis et al. 2000; Smith & Biddle 2008): In addition to a variety of internal and behavioral factors, environmental factors play an important role in motivating and enabling movement activities for young people (Owen et al. 2004; Salmon et al., 2008; Fein et al. 2004).

2.1 The project "ActivE Youth"

One approach of the research project "ActivE Youth" aims to analyze which active mobility forms are chosen by young people depending on the spatial setting. Active mobility within the project is primary defined as walking or cycling and also includes mobility forms which need more advanced physical abilities and practice (e.g. skateboards, rollerblades, micro-scooters).

To answer the complex and multifaceted research questions an interdisciplinary and transdisciplinary approach is chosen. Traffic and landscape planning, social science, technical and sports-science skills and methods are combined for the analysis and the development of measures. The key approaches and methods

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that guide the processing of the research questions are (1) a socio-spatial access (2) a triangulation of theories, methods and results for detecting the different dimensions of the mobility and movement behavior of young people, and (3) the approach of "living labs" that allows early involvement of future users in the development of innovative instruments and tools.

A socio-spatial access means that the social and spatial structures and physical parameters but also qualitative and "soft" factors are included in the analysis by employing and combining subject-specific, qualitative and quantitative methods (Riege & Schubert 2005; Urban & Weiser 2006; Kessl & Reutlinger 2010). The socio-spatial analysis combines physical and social aspects as well as their functional linkages with the space in relation to each other (Damyanovic et al. 2012).

Together with school students aged 15 to 16 years from two different secondary schools (one school located in the inner City of Vienna the other one in the urban fringe) we investigate their daily mobility behaviors with the aim to identify strolling areas and physical activity patterns. This requires a link between spatial information and activity measurements.

2.2 Accelerometer to gather physical activity data

For measuring human activity, a circumspect approach is necessary to ensure that the measurement instrument does not influence the activity of the test-person. Accelerometers are used in many sports- or health-science areas for measuring the intensity of physical activities. Accelerometers were for example used to analyse the effects of reconstructions of school grounds and parks (Colabianchi et al. 2009) or for gait analyses of convalescent patients.

In the research project “ActivE Youth” the ActiGraph GT3X+ (an international standard) is used to measure physical activity. In addition to the acceleration data this accelerometer provides data on the number of steps and body positions. The measured acceleration data can be classified in levels of intensity (e.g. light, moderate or intense) (Sasaki et al. 2011). So it can be estimate whether the person is rather sitting or inactive, mild, moderate or of high intensity physical active.

Accelerometers record the movement activities and intensities of the test person, but have the disadvantage that no spatial data are collected. Thus no correlation between the activities and the spaces used can be analyzed. For the purposes of the research project, it is therefore necessary to additionally record spatial data.

2.3 GPS and Apps for gathering quantitative spatial data

The rapid development of mobile and positioning technologies like GPS or WI-FI positioning has influenced mobility behaviors but also the possibilities for planners to collect spatially explicit data. As mobile devices are usually also equipped with accelerometer and gyro sensors they are often used as fitness tools to measure, share, compare or analyze different types of activities (running, cycling…). Combined with additional hardware (fitness tracker) this type of applications are widespread and extensively used. So far, research focusing on both accelerometer data and positioning devices to measure physical activity patterns in a spatial context, rarely use mobile devices or apps to collect spatial data (Demant et al. 2015; Hurvitz et al. 2014; O’Connor et al. 2013; Oreskovic et al. 2012).

Conventional GPS devices can generally be used for collecting spatial data, though study participants have to carry an additional device with them, and they need to carry them in a specific way, as GPS receivers need a visual connection to the open sky to ensure a correct data logging with a high accuracy and without missing data.

In contrast, mobile devices like smartphones offer greater possibilities for collecting spatial data. On one hand, especially within the group of adolescents smartphones are widespread and there are hardly any situations, where they do not carry them with them. Additionally to GPS as positioning technology, also WIFI positioning or cell phone tower triangulation can be applied. Therefore a reasonable positioning accuracy is possible especially within urban environments without specific carrying rules. Additionally, smartphones allow to combine position tracking with incentive measurements as for example Location Based Games, mobile Apps, Data sharing, GPS drawing,… (see also Chapter 4).

2.4 Spatial analysis and travel diaries to gather qualitative data

By combining activity data with geo data new opportunities for analyzing activity behaviors of young people in their home or school environment, as well as streets and open spaces they choose as additional activity areas are arising (Maddison et al. 2010; Cooper et al. 2010). The characteristics of the places visited by adolescents e.g. their design, form or usage as well as behavioral aspects e.g. the motivation and meaning of physical activity at certain places are central aspects which also influence the physical activities of young people. The combination of quantitative and qualitative methods allows to examine socio-spatial characteristics and the influences of built environment on the everyday physical activity of adolescents.

Studies so far mostly used basic theoretical classifications that combine indoor and outdoor spaces found in the movement patterns. For example Oreskovic et al. (2012) classified the visited spaces of young people according to findings of Papas et al. (2007) in either

- „home" that also included private open space such as gardens or backyards,
- "school" that included school indoor and outdoor spaces,
- "car" that included public transport or even active mobility such as cycling (!) because of its velocity higher than 5 km/h,
- "indoor/other" used in the meaning of non-home and non-school spaces,
- "park/playground" that included all outdoor recreational spaces, or
- "street/walking" that meant all linear physical activity slower than 5 km/h and did not differentiate the spatial characteristics of streets e.g. if it is a small quiet street or a highway.

Van Loon and Frank (2011) stated that quantitative methods are able to assess frequency, duration and intensity of physical activities at classified locations whereas qualitative descriptors are needed to distinguish between different types or modes of physical activity. At the moment, independent vs. supervised activities of children and youth and active transportation are the main research fields of qualitative studies within the sport scientific and public health community (van Loon and Frank 2011).

From a landscape an open space planning perspective the quantitative classification of locations are insufficient. Therefore also a qualitative analysis of visited places is needed and goes beyond these basic classifications of visited spaces in order to gain more specific information regarding active everyday mobility in differentiated and unique urban open spaces. Schubert (2000) and Herlyn et al. (2003) identified six types of urban open spaces that the young use and perceive as positive spaces:

- open space of the neighborhood,
- green open spaces,
- youth related infrastructures (e.g. football yards, youth centres),
- (pedestrian) streets,
- central city squares and
- vacant plots and forgotten spaces.

The findings of the GPS and activity levels measurements will show the daily frequented areas for further qualitative investigations. This is important, because predefinition of youth neighborhoods (e.g. census defined areas or other administrative areas) seems to be inadequate due to the fact, that adolescent (same as adults) use multiple 'neighborhood areas' and are physically active in various contexts not in a single area nor in a single context as many study designs are based upon (Robinson & Oreskovic 2013).

The aim is to develop a typological comparison of identified open spaces important for adolescents' daily active mobility. Therefore we combine the findings from the geospatial data with in-situ survey of places used by adolescents. Discussions with adolescents about the suitability of the existing open spaces will be included in the research process. This will generate a more precise and differentiated view regarding open spaces characteristics.

Travel diaries will be used to complement and validate the measurement methods. The state of discussion tends to be inspired by the KONTIV Design – a well-established method to conduct travel diaries (Socialdata

2009; Axhausen 1995) combined with physical activity entries. Additionally feedback workshops after the primarily quantitative survey weeks (accelerometer, moves-app, mobility diaries) will be used to discuss the accessibility, the design, the furnishings and equipment of the specific streets and open spaces from the adolescent's point of view. The workshops should also clear the motivation why they are active or inactive in certain open spaces.

3 FIRST RESULTS FROM A PRE-TEST TO DEVELOP THE SETTING FOR TEST CASES

For the development of the test cases with the schools a pre-test was conducted to analyze different apps and their possibilities to gather spatial data and to link them with the accelerometer data. Concerning applicability several aspects have to be considered. Especially impacts on battery life are often reported, as particularly pure GPS-based apps are very energy consuming. Furthermore some applications decelerate the system software and can cause abnormal system end, especially on outdated systems and also privacy aspects needs to be considered as many apps use personal data for marketing or profiling purposes.

During the pre-test different application were tested on different mobile devices (hardware and software). Several applications were tested over a week. A precondition was the availability of the apps for Android and IOS platforms as these operating systems are with about 90% penetration rate are dominant in Europe (Kantar Worldpanel 2015).

3.1 Selection of appropriate apps to gather spatial data and movement patterns

To identify potential apps for the research purpose, we performed a combined web and app store (iTunes store, Google Playstore) research, using initial keywords and continuing using the snowball method. Additionally, we applied a literature research to identify apps that were developed and/or used within comparable research projects. The main evaluation criteria for the tested apps are battery life impacts, data accuracy and export options, app usability and stability as well as privacy issues (see Chapter 3.2).

The market of location-based tracking app is huge, but only a few fits the main specific project demands mainly regarding data resolution and export formats for data integration as well as battery life impacts. The first aspect is important to link activity data from the accelerometer with spatial information from the smartphone. The battery life impacts are crucial, as there should be no significant impact on the normal smartphone usage of the participants. It is necessary to record full day patterns (24h) which means, that the phone battery needs to last for one day minimum (with loading cycles during the night).

Impacts on battery life vary highly depending on the recording methods and specific algorithms to identify movements and steadiness of the user. Apps, that only uses the GPS module to record data, have the highest impact on battery life accompanied often with significant heat generation. For example, the app SmartMo consumes about 15% of battery capacity each hour and is therefore only useful for short recording periods. Alternative positioning methods such as Wi-Fi based positioning or cell phone tower triangulation can help to reduce impacts on battery life significantly – especially in urban environments with a high density of Wi-Fi router and cell phone base stations.

Regarding data accuracy and export options we identified some apps that are lacking export options – especially fitness apps often allows data analysis only within the own environment. When a data export is possible, supported formats are usually text-based data structures such as GPX, KML or CSV which it is easy to integrate into existing data structures and GIS applications. Data accuracy depends on different factors and is therefore hardly to compare. One fact that influences position accuracy significantly is not the app itself, but the storage location of the smartphone. Most time of the day, users are carrying their phones in trouser pockets or bags. With means, that GPS as the most accurate positioning method is not working properly. This technology needs a visual conjunction to at least four GPS satellites. This can produce errors up to a few kilometers especially outside the urban environment. Within urban fabrics, additional methods such as Wi-Fi positioning and mobile phone tracking works highly accurate (up to a few meters) and can therefore compensate missing GPS signals.

Usability is central when it comes to practical application and a bad user experience is often a reason to refuse an app. Especially among adolescents, the user interface, simple usability, self-explaining procedures and a nice design is very important. Regarding usability, the app Moves comes with a very clear and stylish interface which is very easy to use. Other apps need some settings to be done (e.g. activity selection etc.) or needs an active recording start (e.g. SmartMo, Garmin Forerunner, Mobile Motion Advisor…). The latter apps requires and active involvement of the users to start and stop recording or to enter additional categories etc. which means that recording gaps can be expected. Apps like Moves or OpenPaths can run fully in the background without any necessary manual tasks. A few apps were excluded from the test due obvious high battery usage or difficult applicability. Two apps were identified as generally suitable for data gathering – Moves and OpenPaths.

Moves is available for iOS and Android and has a very clear and easy to use interface. Main goal of the app is to record daily routes and auto-recognize the form of mobility (especially waking, cycling and running). The data can be stored on a server that requires a registration with an email and password (no other personal data is required). For positioning, Moves uses A-GPS and WIFI and has algorithms to deactivate positioning when stationary which means, that the app has very little impact on the battery life.

OpenPaths serves also the two dominating mobile operating systems and is also very easy to operate. Compared to Moves, the Graphical User interface is not that fancy, but straight forward. OpenPaths recognizes position changes and saves a point when being stationary, which means, that the spatial resolution is much lower compared to Moves. The points can be joined when being processed in GIS but there are limited opportunities to indicate detailed paths and activity types. Regarding the battery life, OpenPaths performs very well, which means, that there is no significant impact on battery life when running the app in the background. Data is also stored on a server and requires a simple registration. Additionally, personal data can be automatically shared with projects, so every user can participate in research or citizen science projects.

Privacy issues are an important topic when gathering personal data with third party apps on smartphones. The companies behind the apps often give the apps away free of charge, but for the price of personal data for consumer analysis, location- based marketing, etc. Moves as well as OpenPaths store the user data in an encrypted format, nevertheless it is not impossible to hack and access these data by third parties. The major problem in this context is the use of weak passwords. This risk can therefore be actively reduced by choosing strong password and avoid multi-use of passwords.

Moves is part of the facebook group and in their privacy policy they remark, that data can be shared for analysis and service improvement. It is possible to register with an anonymous account, but as other things like phone identifier number are also submitted, it seems to be possible to link the data to existing social media accounts or other cloud services. OpenPaths has a more closed data policy. Data will be only provided to research projects when a user actively grants rights to a specific project.

Smartphone App	Usa-bility	Use of resour-ce	Platform Indepen-dency	Pri-vacy	Costs	Suitability for reseach purpose	Notes
Moves	++	++	++	-	++	++	Detailed recordings of point locations and routes possible
OpenPaths	+	++	++	++	++	+	Only point recordings of locations
Ohmage	?	?	++	++	0	-	High Administration effort (Server infrastructure)
Mobile Motion Advisor	?	--	--	?	?	--	Not on the market yet
SmartMo	--	--	++	++	++	--	High energy consumption; instable (crashes reported), manual adjustment of form of mobility
Runtastic (Orbit)	++	++	++	-	-	-	No geo data recording
iHealth	0	++	++	-	-	-	No geo data recording
Garmin Forerunner 210	++	-	k.A.	+	--	--	high energy consumption, high GPS accuracy
PROVAMO – App	?	?	++	? (+)	?	?	This App is a still a prototype and is not published for end users yet.

Table 1: Comparison of different available apps regarding their suitability for the research purpose

In combination with accelerometer data, the apps Moves and OpenPaths prove to be the best applications. Moves also provides the incentive to look at a ranking over the last few days and generates daily reports on the performance on the previous day, which can be a motivating factor for the school-children. OpenPaths provides better data protection policy as Moves, but records only places and no paths and thus has a much lower temporal resolution than Moves. Thus Moves was chosen for the pre-test.

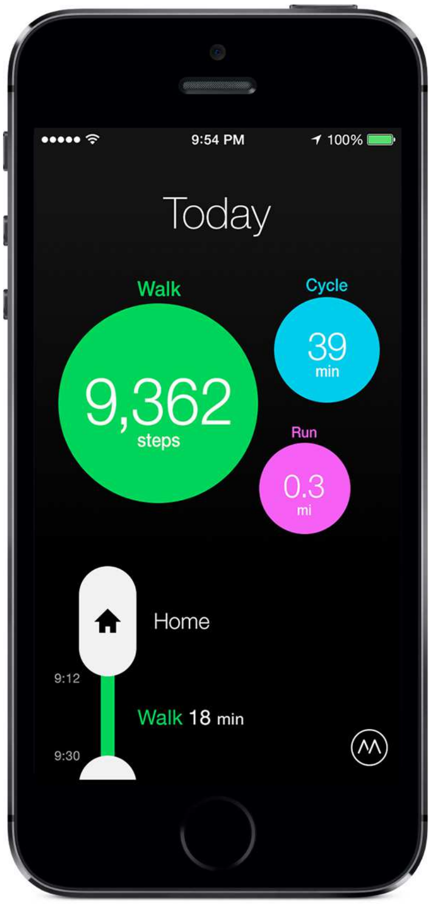

Fig. 1: MovesApp (Source: https://www.moves-app.com/assets/moves-on-iphone5s.jpg)

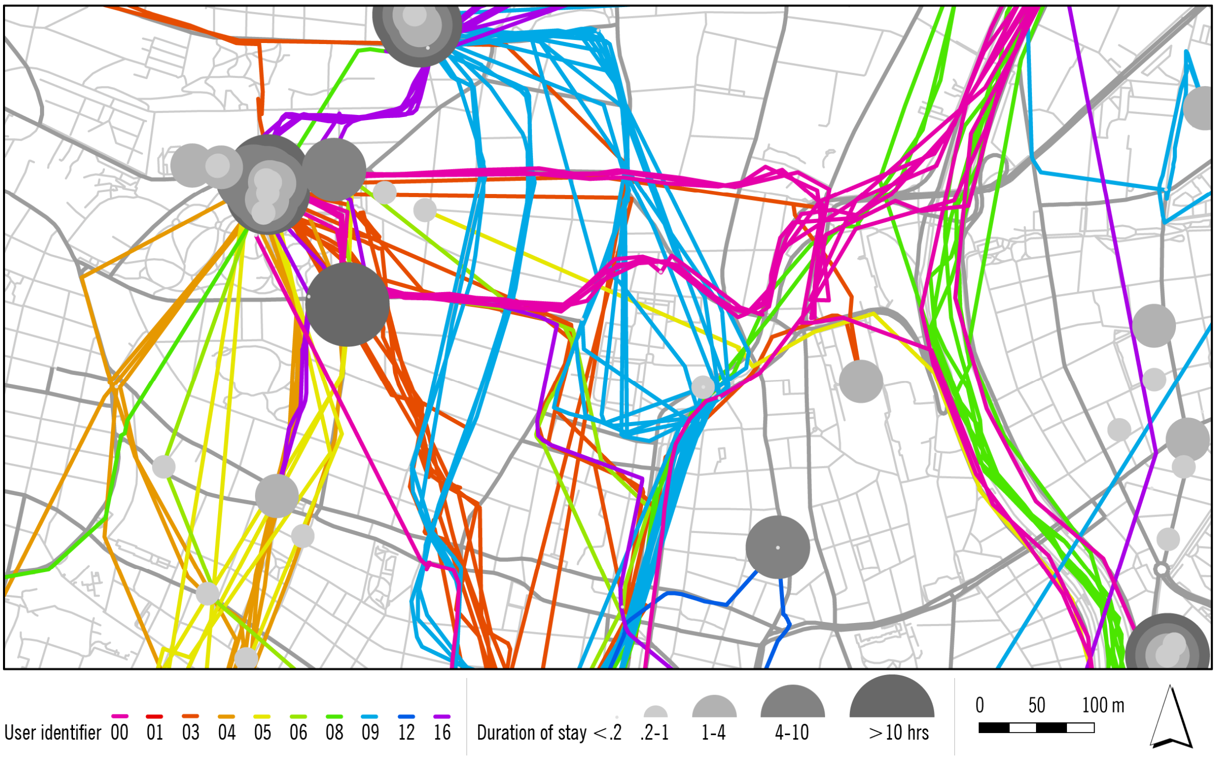

Fig. 2: Different user tracks from the pre-test week and visualization of the duration of stays

3.2 Results of the pre-test – combining and mapping the data of the app and accelerometer

The pre-test was performed by members of research team. The aim was to gather practical information on the usability of different applications on different smartphones and operating systems. Also the analysis of opportunities to combine and map the gained data was an aim of the pre-test. Therefore 10 persons tested the smartphone app Moves together with accelerometer for 7 days and reported issues on usability, stability and battery life. Analysis of the recorded data provides information on data quality. Additionally, the app OpenPaths runs on two devices to compare data quality.

The test pointed out, that Moves is generally suitable to record spatial data at a high resolution for a longer time period. To guarantee a suitable data accuracy, a few aspects need to be considered. Firstly, when carrying the phone in a bag, it is crucial that WIFI is permanent active; otherwise a lot of data gaps and inaccurate data are being recorded. Secondly, when leaving urban areas with a high density of WIFI routers and cell phone towers, it is highly recommended to place the phone as often as possible with a direct connection to the open sky, as in this context, GPS positioning is important for data accuracy. Thirdly, Moves comes with a special energy saving function that ensures, that the battery impact is significantly reduced. This option needs to be activated once, as it is inactive by default. The auto recognizing process works well but produces some mistakes in urban environments with a lot of stop-and-go movements. This causes that e.g. car rides in the city are sometimes identified as bicycle rides. Wrong allocations can be changed easily within the application, but can also be corrected semi-automatically later in professional GIS environments. Moves also counts steps with a build-in pedometer for walking activities, but compared to the accelerometer, this data seems very inaccurate. The reason for that is, not the accelerometer of the smartphone itself but the different carrying positions (e.g. carrying in bag, holding in the hand while walking, putting the phone away at home or other private environments). The accelerometer is fixed around the waist and can therefore produce data at much more constant conditions.

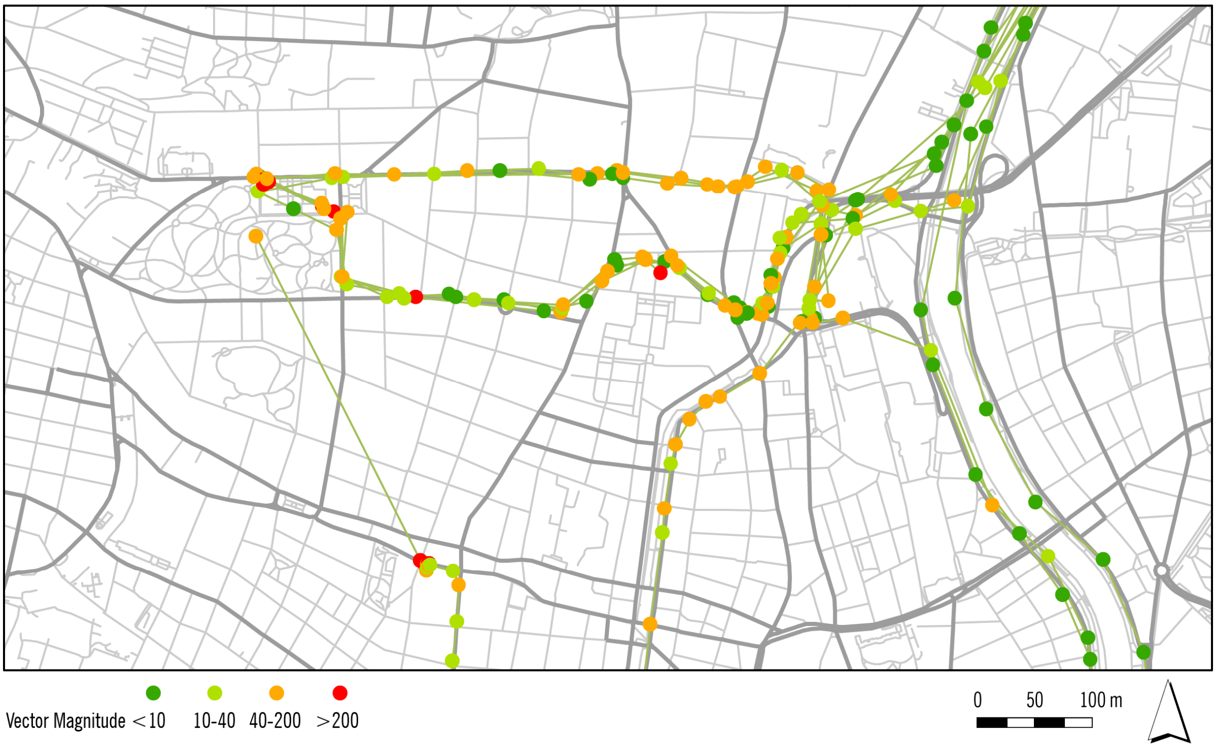

Fig. 3: Vector Magniture values from the accelerometer combined with the spatial explicit data from Moves for a single user

The data collected by the ActiGraph GT3X accelerometer were exported for 10 sec intervals (resolution up to one second possible) and on the basis of Sasaki et al. (2011) assigned to the intensity categories of activity: light-moderate-vigorous-very vigorous. Due to the time stamp the accelerometer data can be linked to the data of the Moves app.

Moves data as well as accelerometer data can be exported to simple table-based text files (coma-separated-values). Both tables contain timestamps for each event and can therefore be linked using database operations. Additionally, we developed a database script for automatic correction of mobility types based on speed

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statistics (mean, maximum and minimum statistics) and analysed the stays regarding length and daytime to identify potential public places for further analysis. The test persons are identified using a unique key that cannot be linked to the real person behind the tracking pattern. The combined data-table is transferred to the GIS environment using recorded position data in decimal degrees (WGS84).

4 OUTLOOK – TEST CASE WITH SCHOOLS AND INTERVENTION

The pre-test is the basis for a test case with classes from two secondary schools in Vienna. The school-children are aged 15-16 years when starting the project. In the first year the activity patterns of all participating school children are recorded for one week (Monday to Monday). The identified areas, streets and open space are analyzed using field mapping, workshops and interviews. In the second project year it is planned to develop together with the school-children interventions to change their mobility behaviors and physical activity.

Playful and communicative instruments on mobile devices, which are used by young people every day, can create incentives and motivation for choosing active forms of mobility. But there is little knowledge about the effects of these tools (Bort-Roig et al. 2014; Middelweerd et al. 2014). Therefore location-based-games such as alternate-reality-games (like Ingress or PacManhatten) geosocial games (multiplayer games), treasure-hunts (geo-cache, multi-caches) or GPS drawing (GPS art, figure running) and their possible effects and influence on the physical activities are going to be tested together with the school-children. To measure the impact a second measurement will take place a year after the first round.

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