Universitat Autònoma de Barcelona

LA DIMENSIÓN ESPACIAL DE LA MOVILIDAD COTIDIANA
Una aproximación multiescalar en la Región Metropolitana de Barcelona

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Tesis doctoral

La dimensión espacial de la movilidad cotidiana:

Una aproximación multiescalar en la Región Metropolitana de Barcelona

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Prefacio

La presente tesis doctoral sigue la normativa vigente relativa al formato de presentación de tesis doctorales por compendio de publicaciones, aprobada por la Comisión Académica del Programa de Doctorado (CAP) de Geografía de la Universitat Autònoma de Barcelona, regulada por el RD 1393/2007, sección 7ª, artículo 275, y según la disposición transitoria aprobada por la CAP el 10 de abril de 2015 para el alumnado matriculado anteriormente al curso académico 2015-2016. Según la mencionada normativa, esta tesis consta de las siguientes partes:

- En la Parte I se realiza la presentación de la tesis, los objetivos, preguntas e hipótesis, el marco teórico y la metodología de la investigación.
- En la Parte II se incluyen los cuatro estudios de caso publicados en revistas académicas.
- Finalmente, la parte III presenta la discusión general de los resultados y las conclusiones de la tesis.

Para esta tesis, se aportan cuatro contribuciones científicas originales que responden a la misma línea de investigación, es decir, la relación entre las características urbanas de las áreas metropolitanas y la dimensión espacial de la movilidad cotidiana. A fecha de hoy, las cuatro contribuciones, presentadas en formato de artículo científico, han sido aceptadas por el equipo editorial de las revistas receptoras y aprobadas por la CAP de Geografía el día 15 de febrero de 2019.

A continuación, se detallan las referencias bibliográficas de cada una de las publicaciones, el factor de impacto (FI) y el ranking del Journal Citation Report® (JCR) de Thomson Reuters:

- Vich, G., Marquet, O. y Miralles-Guasch, C. (2017). Suburban Commuting and Activity Spaces: Using Smartphone Tracking Data to Understand the Spatial Extent of Travel Behaviour. *The Geographical Journal,* 183(4): 426–39. FI: 2,563 (Q1).

- Vich, G., Marquet, O. y Miralles-Guasch, C. (2018). The Scales of the Metropolis: Exploring Cognitive Maps Using a Qualitative Approach Based on SoftGIS Software. *Geoforum,* 88 (November 2017): 49–56. FI: 2,566 (Q1).

- Vich, G., Marquet, O. y Miralles-Guasch, C. (2018). Green exposure of walking routes and residential areas using smartphone tracking data and GIS in a Mediterranean city. *Urban Forestry and Urban Greening* (August 2018): 1-11. FI: 2,782 (Q1).

- Vich, G., Marquet, O. y Miralles-Guasch, C. (2019). Green Streetscape and Walking: Exploring Active Mobility Patterns in Dense and Compact Cities. *Journal of Transport & Health*, 12 (June 2018): 50–59. FI: 2,774 (Q1).

El autor de la tesis doctoral ha recibido apoyo económico para la realización de su investigación a través de las "Ayudas para contratos predoctorales para la formación de doctores 2014" con la beca BES-2014-068239 otorgada por el Ministerio de Economía y Competitividad del Gobierno de España, bajo el Programa Estatal de Promoción del Talento y su Empleabilidad en I+D+i. La presente tesis doctoral se enmarca en los siguientes proyectos de investigación:

- "La movilidad cotidiana y las dinámicas de proximidad. Un enfoque territorial, social y medioambiental" (CSO2013-42513-P). Ministerio de Economía y Competitividad (Gobierno de España). Periodo: 01/01/2014 – 31/12/2016. Investigadora principal: Dra. Carme Miralles-Guasch.

- "Movilidad cotidiana activa y saludable en entornos urbanos de proximidad. Enfoques multimetodológicos: tracking living labs, encuestas de movilidad y estudios cualitativos" - CSO2016-74904-R - Ministerio de Economía y Competitividad (Gobierno de España). Periodo: 01/01/2017 – 31/12/2019. Investigadora principal: Dra. Carme Miralles-Guasch.

Resumen

La expansión de las áreas metropolitanas a nivel global ha repercutido en la vida cotidiana de sus residentes a través del aumento de las distancias que deben recorrer para realizar sus actividades diarias, afectando su calidad de vida y, a la vez, la sostenibilidad de estos territorios. No obstante, debemos preguntarnos también si: ¿existen otras características del entorno urbano construido que determinen el comportamiento espacial de las personas más allá de la estructura territorial?, ¿estos territorios pueden ser percibidos de diferente manera por sus residentes, dando lugar a distintos patrones de movilidad?, ¿existen diferencias según el perfil de la persona?, ¿cómo interactúan estos factores entre ellos? Con el objetivo de responder a estas preguntas, esta investigación pretende comprender la configuración de la dimensión espacial de la movilidad cotidiana en la Región Metropolitana de Barcelona.

La hipótesis principal de esta tesis de que el espacio que utilizan los residentes en áreas metropolitanas está influenciado por la combinación de distintos factores como son las características del entorno construido, los procesos cognitivos y las características individuales de las personas. Para conseguirlo, se aprovechará las nuevas fuentes de datos provenientes de las Tecnologías de la Información y de la Comunicación (TIC), las cuales permiten, como nunca antes había sido posible, obtener información espaciotemporal altamente detallada del comportamiento espacial de las personas.

Esta tesis doctoral se basada en cuatro casos de estudio, en forma de artículos científicos en revistas internacionales indexadas, que exploran el efecto de distintos condicionantes del comportamiento espacial. Los resultados obtenidos pueden informar futuras estrategias de planificación urbana orientadas a la reducción de la extensión espacial resultante de los patrones de movilidad cotidiana de los residentes en áreas metropolitanas.

Resum

L'expansió de les àrees metropolitanes a nivell global ha repercutit en la vida quotidiana dels seus residents a través de l'augment de les distàncies que han de recórrer per realitzar les seves activitats diàries, afectant la seva qualitat de vida i, a la vegada, la sostenibilitat d'aquests territoris. Tanmateix, hem de preguntar-nos també si: hi ha altres característiques de l'entorn urbà construït que determinin el comportament espacial de les persones més enllà de l'estructura territorial?, aquests territoris poden ser percebuts de diferent manera pels seus residents, donant lloc a diferents patrons de mobilitat?, hi ha diferències segons el perfil de la persona ?, com interactuen aquests factors entre ells? amb l'objectiu de respondre a aquestes preguntes, aquesta investigació pretén comprendre la configuració de la dimensió espacial de la mobilitat quotidiana a la Regió Metropolitana de Barcelona.

La hipòtesi principal d'aquesta tesi de que l'espai que utilitzen els residents en àrees metropolitanes està influenciat per una combinació de diferents factors com son les característiques de l'entorn construït, els processos cognitius i les característiques individuals de les persones. Per aconseguir-ho, s'aprofitarà les noves fonts de dades provinents de les Tecnologies de la Informació i de la Comunicació (TIC), les quals permeten, com mai abans havia estat possible, obtenir informació espacio-temporal altament detallada del comportament espacial de les persones.

Aquesta tesi doctoral està basada en quatre casos d'estudi, en forma d'articles científics en revistes internacionals indexades, que exploren l'efecte de diferents condicionants del comportament espacial. Els resultats obtinguts poden informar futures estratègies de planificació urbana orientades a la reducció de l'extensió espacial resultant dels patrons de mobilitat quotidiana dels residents en àrees metropolitanes.

Abstract

The expansion of metropolitan areas globally has had an impact on the daily life of its residents through the increase in the distances they must travel to carry out their daily activities, which affects their quality of life and, at the same time, the sustainability of these territories. However, additional questions must be raised: Beyond the territorial structure, are there other characteristics of the urban built environment that determine the spatial behaviour of people? Can these territories be perceived differently by their residents, giving place to different patterns of mobility? Are there differences according to the individual profile of the residents? If these factors are determinant, how do they interact? In order to answer these questions, this research aims to understand the configuration of the spatial dimension of daily mobility in the Metropolitan Region of Barcelona.

The main hypothesis of this thesis points that the space used by residents in metropolitan areas is influenced by the combination of different factors such as the characteristics of the built environment, cognitive processes and individual characteristics of people. To achieve this, new data sources obtained from Information and Communication Technologies (ICT) will be used, which allow to obtain highly detailed time-space information on the spatial behaviour of people as has never been before.

This doctoral thesis is based on four case studies, in the form of scientific articles in indexed international journals, which explore the effect of different spatial behaviour conditioning factors. The results obtained can inform future urban planning strategies aimed at reducing the spatial extent resulting from the daily mobility patterns of residents in metropolitan areas.

Agraïments

Aquesta tesi és fruit de esforç i dedicació personals empleats al llarg dels darrers quatre anys. No obstant, aquesta tesi és fruit també de la feina i el suport de moltes persones a les quals estic sincerament agraït.

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En tercer lloc, voldria agrair a tots els companys amb qui he compartit el lloc de treball al Grup d'Estudis en Mobilitat, Transport i Territori (GEMOTT) aquests anys. En especial, un agraïment pel Xavier Delclòs amb qui he compartit la realització d'aquesta tesi des de l'inici fent front de manera conjunta a dubtes, complicacions metodològiques, relats i èxits acadèmics que espero segueixin produint-se durant molts més anys. També, agrair a tots els companys del grup amb qui he coincidit durant la tesi: la Maribel Arcos, la Monika Maciejewska, el Dani Montané, l'Oriol Roig, la Camila González, la Mónica Castañeda, l'Eva Pulido, el Cesc Maneja i la Irene Gómez. Moltes gràcies pels vostres comentaris, per compartir-vos la meva recerca i per les incomptables i interessants converses a l'hora de dinar.

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Tabla de contenidos

Lista de figuras

Lista de tablas

PARTE I

1. Presentación de la tesis

1.1. La metropolización de la vida cotidiana

Los fenómenos urbanos de finales del siglo XX y principios del siglo XXI a nivel global se caracterizan por su dimensión metropolitana. Los procesos de cambio a nivel sociológico, económico o ambiental no ocurren espacialmente en lugares aislados, sino en territorios interrelacionados con distintas características morfológicas y funcionales (Dupuy 1992; Nel·lo 2001).

Estas interrelaciones de carácter metropolitano han ido de la mano de procesos de desarrollo urbano expansivos que han hecho expandir las áreas urbanas en todo el mundo y, en consecuencia, la de la vida cotidiana de sus residentes (Ewing 1997; Ewing et al. 2016). Estas dinámicas se deben en parte a la influencia de los postulados del planeamiento urbano y territorial funcionalista de principios de siglo XX (Corbusier 1933), que abogaron por la fragmentación y la localización diferenciada de las actividades, conectadas por infraestructuras viarias de gran capacidad (Foster 1981). Esta separación funcional ha implicado en mucho casos un aumento de las distancias, tiempos y velocidades de viaje para la realización de las actividades diarias de los residentes de estos territorios (Banister 2008; Clark, Huang, y Withers 2003; Delclòs-Alió y Miralles-Guasch 2017; Miralles-Guasch y Cebollada 2009). Estos cambios en los patrones de movilidad han ido asociados a una mayor dependencia del automóvil, mayores niveles congestión del tráfico, de consumo de combustible o de contaminación del aire, entre otras externalidades, que tienen un impacto en la gestión de estos territorios y la calidad vida de sus habitantes (Ewing et al. 2016; Fernandez Milan y Creutzig 2016; Ríos Bedoya, Marquet, y Miralles-Guasch 2016).

De esta manera, la configuración de los territorios metropolitanos ha devenido uno de los principales determinantes del comportamiento espacial de sus residentes (Buliung y Kanaroglou 2006; Naess 2015). Bien sea por su lejanía como por proximidad, la localización de las actividades cotidianas influye en las decisiones espaciales de los individuos tanto a corto como a largo plazo. Decidir dónde residir, trabajar, realizar actividades recreativas o cómo nos desplazamos entre estas ubicaciones depende en gran medida de la estructura espacial y las características morfológicas de un territorio (Golledge y Stimson 1987).

Sin embargo, las particularidades a nivel individual de cada persona pueden condicionar también sus patrones de movilidad. La forma en se percibe mentalmente el entorno construido o las características sociodemográficas de los residentes en un territorio metropolitano son factores igualmente determinantes de su comportamiento espacial (Ren 2016). Por un lado, el comportamiento espacial está influenciado por la imagen cognitiva del mundo real que tienen las personas y que se organizan en forma de mapas cognitivos su mente (Downs y Stea 1973; Golledge y Stimson 1987; Lynch 1960). El almacenaje y gestión de información espacial en la mente de las personas sobre dónde se ubican las actividades cotidianas de las personas, las distancias entre ellas, las preferencias espaciales y cómo llegar a ellas devienen claves para comprender el comportamiento y la toma de decisiones espaciales (Gärling 1989). Por el otro lado, el perfil sociodemográfico de las personas influye también de manera determinante en el comportamiento espacial de las personas. En este sentido, el género, la edad o el nivel socioeconómico de las personas son algunos de los factores que influyen, entre otras decisiones, sobre qué lugares hay que visitar, con qué frecuencia, las distancias a recorrer o en qué modo de transporte, etc. (Buliung y Kanaroglou 2006; Horton y Reynolds 1971; Kwan y Kotsev 2015; Miralles-Guasch, Martínez-Melo, y Marquet 2016).

Por estos motivos, el estudio de los distintos tipos condicionantes que afectan el comportamiento espacial de las personas y, en especial, aquel relacionado con la movilidad cotidiana de los residentes en áreas metropolitana deviene clave para el diseño de políticas de desarrollo urbano y territorial (Buliung y Kanaroglou 2006; Naess 2015).

1.2. Objetivos e hipótesis de la tesis

El objetivo principal de la presente tesis doctoral es estudiar la configuración de la dimensión espacial de la movilidad cotidiana. Esta investigación contribuye en la exploración de los factores que configuran el comportamiento espacial derivado de la movilidad cotidiana en el contexto de la Región Metropolitana de Barcelona (RMB). Para conseguirlo, se analizan las posibilidades que ofrecen las nuevas fuentes de datos para estudiar este tipo de comportamiento humano.

Esta investigación parte de la **hipótesis principal** de que:

- **Hipótesis principal.** En un contexto metropolitano, el espacio que utilizan sus residentes para la realización de las actividades cotidianas está condicionado tanto por las características del entorno construido como por los procesos cognitivos y las características individuales de las personas.

Para responder la hipótesis principal, se han formulado tres preguntas de investigación que son correspondidas con cuatro sub-hipótesis:

Pregunta 1. *¿Qué papel juega la imagen cognitiva de un territorio metropolitano en el comportamiento espacial de sus residentes*?

- **Sub-Hipótesis 1.** La imagen cognitiva sobre el entorno urbano construido condiciona los patrones de movilidad de los residentes de una metrópolis.

Pregunta 2. *¿Qué relación existe entre el perfil individual de las personas y su comportamiento espacial?*

- **Sub-Hipótesis 2.** Existen diferencias en el espacio metropolitano utilizado para realizar las actividades cotidianas según las características sociodemográficas y las preferencias de movilidad cotidiana.

Pregunta 3. *¿Qué rol juega los espacios verdes en la configuración del comportamiento espacial y la promoción de la movilidad activa?*

- **Sub-Hipótesis 3.** Las características morfológicas de un territorio pueden influir en accesibilidad y utilización de determinados espacios urbanos como los espacios verdes.

- **Sub-Hipótesis 4.** La provisión de espacios verdes influye en el comportamiento espacial de las personas favoreciendo el caminar como modo de transporte activo.

1.3. Estructura de la tesis

Como se ha indicado en el prefacio, la presente tesis doctoral se vertebra a través de cuatro casos de estudio, siguiendo el formato de tesis por compendio de publicaciones. La estructura final de esta investigación, representada en la **Figura 1**, consta de tres partes y ocho capítulos:

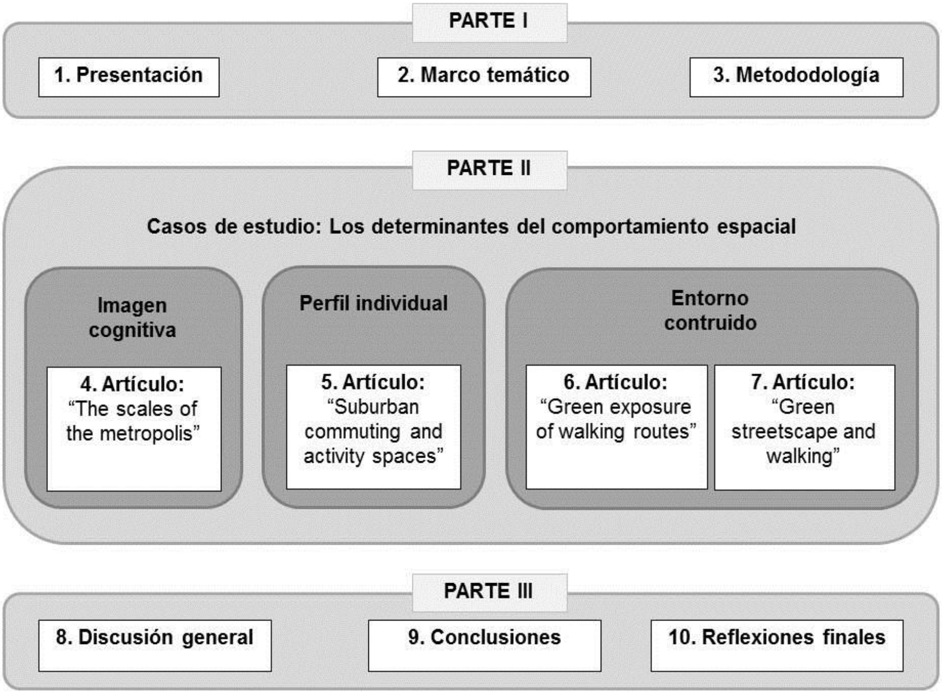
La Parte I está compuesta por los tres primeros capítulos de la tesis. Una vez presentadas las preguntas de investigación e hipótesis de la tesis en el presente Capítulo 1, en el Capítulo 2 se realiza una revisión del marco teórico en el que se enmarca la tesis y los conceptos necesarios para responder a las preguntas e hipótesis y que permiten comprender el análisis realizado en los casos de estudio. Se pondrá énfasis en explicar una de las ideas centrales de esta investigación como es concepto de *espacio de actividad*, el cual sirve para analizar el comportamiento espacial de las personas y sus factores explicativos.

El Capítulo 3 introduce la metodología utilizada para la realización de esta tesis. Después de situar el contexto metropolitano en el que se enmarca el trabajo –la Región Metropolitana de Barcelona– y describir sus características territoriales, se presentan los distintos tipos de fuentes de información utilizadas –tradicionales y nuevas fuentes– para estudiar la dimensión espacial de la movilidad cotidiana. Finalmente, se describe el proceso metodológico seguido para responder a cada una de las preguntas de investigación y sus hipótesis: escala territorial de análisis, enfoque metodológico, fuentes de datos y tipo de análisis realizado.

La Parte II se compone de los cinco siguientes capítulos de la tesis, los cuales incluyen los cuatro casos de estudio, en formato de artículo científico publicado, que componen el análisis de datos principal realizado para responder a las preguntas de investigación y contrastar las hipótesis de trabajo. En el Capítulo 4 se explora la influencia de distintas escalas territoriales que caracterizan la Región Metropolitana de Barcelona en las imágenes cognitivas de las personas. El Capítulo 5 analiza distintos factores a nivel individual que influyen en la extensión de los espacios de actividad de personas que se caracterizan por tener un largo desplazamiento cotidiano a una ubicación suburbana dentro de este mismo territorio. El propósito del Capítulo 6 es explorar la exposición a distintas tipologías de espacios verdes urbanos como parques, jardines, plazas públicas, bulevares y playas, por parte de residentes en zonas morfológicamente distintas de la ciudad de Barcelona. El Capítulo 7 de esta tesis analiza la relación entre la exposición a estos tipos de espacios verdes y el tiempo caminado diariamente en esta misma ciudad.

La Parte III de la tesis concluye el trabajo de investigación realizado. En ella, el Capítulo 8 presenta la discusión final sobre los resultados obtenidos en los casos de estudio de la tesis y en la cual se resumen los principales hallazgos obtenidos. Finalmente, en el Capítulo 9 se presentan las conclusiones generales de la tesis, resaltando sus fortalezas y sus limitaciones, a la vez que se detallan las futuras líneas de investigación.

Figura 1. Estructura de la tesis.



Fuente: Elaboración propia.

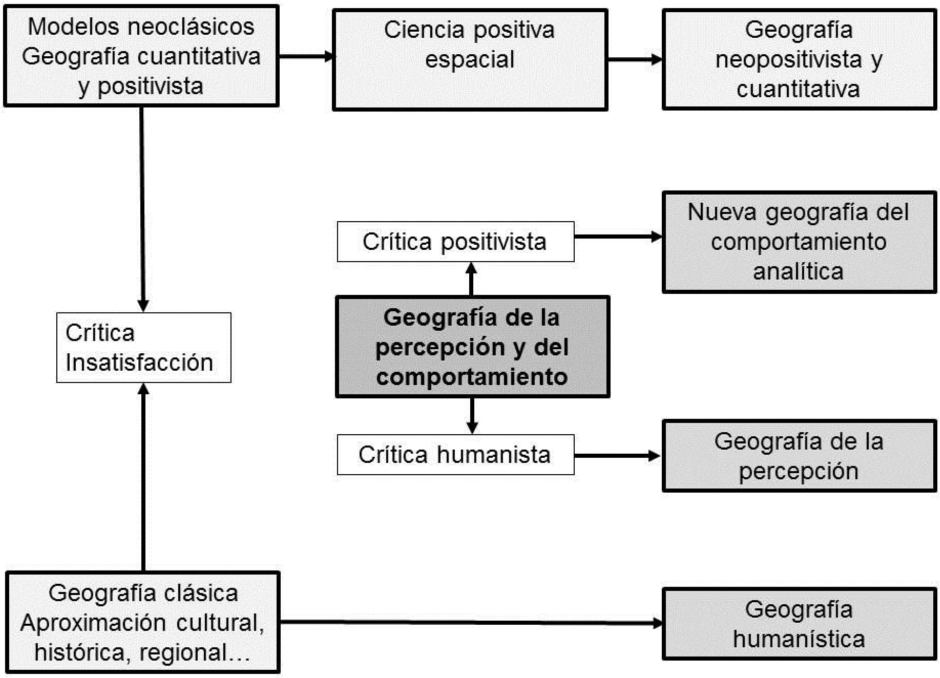
2. El marco temático de la investigación

2.1. Antecedentes teóricos: la Geografía de la Percepción y del Comportamiento

La relación entre las características del entorno construido y el comportamiento espacial de las personas se ha analizado desde distintas corrientes de la geografía, entre ellas la denominada Geografía de la Percepción y del Comportamiento. Esta rama de la geografía aparece en los años 60 y 70 del siglo pasado, principalmente en Norteamérica, como reacción al giro cuantitativo que experimentó la geografía en los años 50 y 60 (Gold 2009), reinstalando el individuo como agente activo y sensible en el centro del análisis sobre la toma de decisiones espaciales, alejándolo del rol tradicional asignado a los individuos desde enfoques clásicos de la geografía según el cual éstos actúan *a priori* y siguiendo motivaciones económicas y racionales (Garcia Ramon y Albet i Mas 2002). Por el contrario, las personas, según este enfoque geográfico, son agentes sociales individuales que actúan en condiciones de conocimiento imperfecto y de racionalidad limitada (Argent 2017).

Este enfoque geográfico recoge todas aquellas investigaciones que han puesto el foco en la conceptualización cognitiva del espacio geográfico y que pueden resumirse en dos grandes áreas de investigación: 1) la investigación sobre comportamiento cognitivo y 2) la investigación sobre toma de decisiones, elección, preferencias y estudio de movimiento espacial (Golledge y Timmermans 1990). Estas dos áreas de investigación responden a dos preguntas básicas: 1) cómo y por qué las personas perciben el entorno geográfico que las rodea, y 2) cómo estas interpretaciones afectan su comportamiento espacial. Según Boira Maiques (1992) y como se muestra en la **Figura 2**, dentro de este enfoque de la geografía pueden distinguirse tres grandes corrientes con métodos y objetos de estudio distintos: a) la Geografía del Comportamiento Analítica, b) la Geografía de la Percepción y c) la Geografía Humanista.

Figura 2. Corrientes dentro de Geografía de la Percepción y del Comportamiento.



Fuente: Adaptación de Boira Maiques (1992).

En primer lugar, los estudios que se enmarcan dentro de la corriente de la Geografía del Comportamiento Analítica toman un enfoque fundamentalmente positivista para estudiar qué hay detrás del comportamiento espacial, los factores determinantes de la utilidad y elección espaciales, los problemas de localización, la configuración de trayectos y distancias urbana o el estudio de la estructura y geometría de los mapas cognitivos, etc. (Couclelis et al. 1987; Golledge y Timmermans 1990; Timmermans y Golledge 1990). La presente tesis doctoral se enmarca en esta corriente para analizar el comportamiento espacial en el contexto de la Región Metropolitana de Barcelona.

En segundo lugar, el enfoque metodológico de la Geografía de la Percepción parte también en general de una visión positivista, con métodos adaptados de la psicología y la estadística, pero sus objetos de estudio incluyen aspectos de carácter más humanista. Los estudios que se sitúan en este segundo enfoque analizan patrones de representación de la información espacial que determinan el posterior comportamiento espacial: los estereotipos, la imagen mental del entorno (barrios, ciudades o regiones) o las preferencias residenciales, entre otros (Downs y Stea 1973; Gould y White 1986; Lynch 1960).

Finalmente, desde la Geografía Humanista, aun siendo considerada una rama de la Geografía Humana *per se*, también se ha abordado el estudio de la conceptualización del espacio geográfico (Boira Maiques 1992). Su influencia en la Geografía de la Percepción y del Comportamiento se evidencia tanto en las metodologías empleadas (métodos cualitativos, uso de fuentes de datos alternativas como la pintura o literatura, visión antropocéntrica, etc.) y los temas de estudio (los valores morales del espacio y del paisaje, el rol de la simbología urbana, el papel de la cultura en los procesos cognitivos, etc.). Aunque muchos de los trabajos con un enfoque humanista pueden ser incluidos en la anterior corriente de la Geografía de la Percepción (Lowenthal 1961; Tuan 1976; Wright 1947), su enfoque no positivista y aceptación como rama de la geografía por si sola posibilita distinguirla de las demás corrientes.

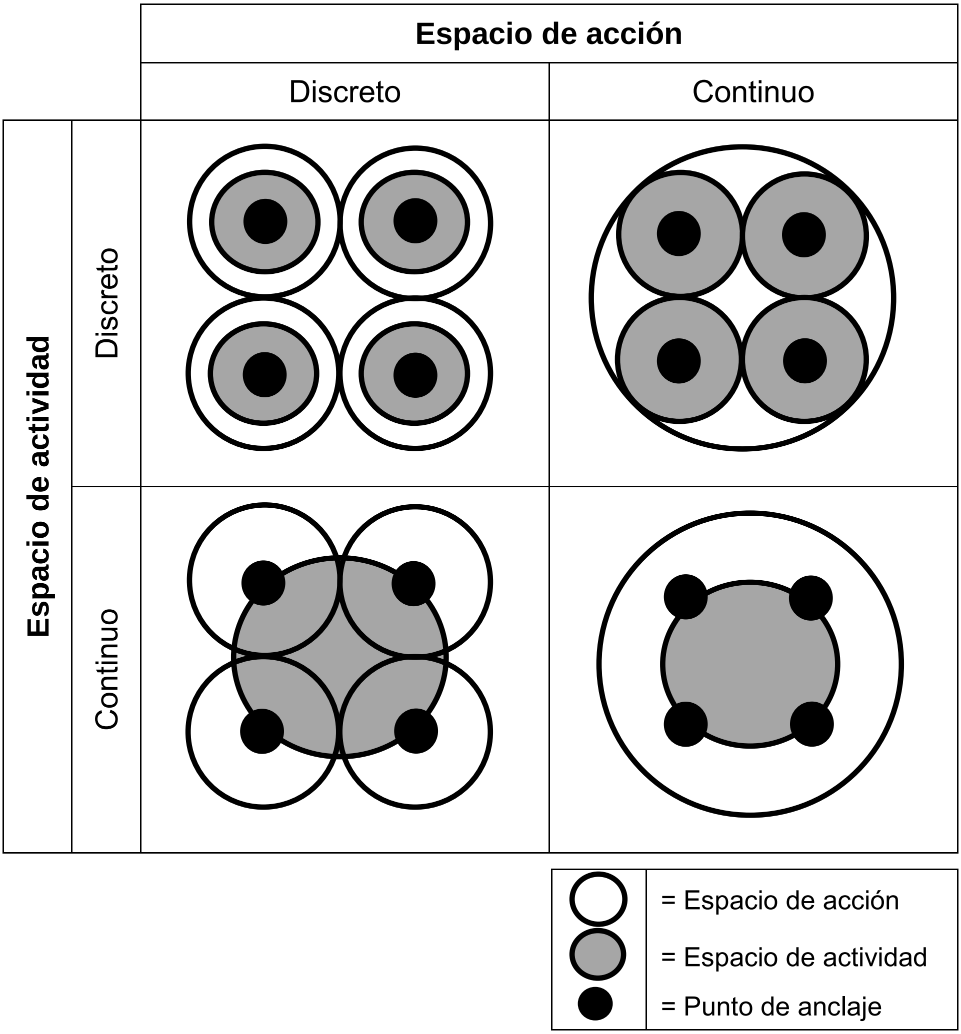
2.2. El espacio de actividad como medida de comportamiento espacial

En esta tesis, el concepto central que permite estudiar el comportamiento espacial y los patrones de movilidad de las personas es el de *espacio de actividad*. Desde el enfoque de la Geografía de la Percepción y del Comportamiento, este concepto ha servido para describir la extensión geográfica que utilizan los individuos en su día a día (Patterson y Farber 2015). Concretamente, fueron Horton y Reynolds (1971) quienes describieron por primera vez la idea que hay detrás del *espacio de actividad*, refiriéndose al espacio comprendido entre las ubicaciones reales “con las que los individuos tienen un contacto directo como resultado de las actividades del día a día" (Horton y Reynolds 1971:37). Esta idea ha recibido otras denominaciones siendo descrita en los *espacios de acción de contacto* de Higgs (1975), los *campos de viaje* de Zahavi (1979) y, más recientemente, los *espacios de acción real* de Dijst (1999), haciendo referencia al área geográfica dentro de la cual los individuos realizan actividades cotidianas.

El concepto de espacio de actividad deriva de otra conceptualización previa sobre la dimensión espacial de la vida cotidiana de las personas, el *espacio de acción*. Este término, introducido por primera vez por Wolpert (1965) en su análisis sobre migraciones residenciales, hace referencia al territorio del cual las personas tienen conocimiento a través de su experiencia diaria personal. Este tipo de espacio recoge todas las ubicaciones urbanas sobre las que el individuo tiene información, las cuales pueden tener asociadas carácter subjetivo, distinto para cada individuo (Golledge y Stimson 1987). De este modo, el espacio de acción incluye una dimensión de comportamiento espacial real y otra de comportamiento potencial, ya que recoge tanto las ubicaciones cotidianas que utiliza una persona, el espacio de actividad, pero también aquellas que conoce y puede alcanzar. Por lo tanto, puede afirmarse que el espacio de actividad está condicionado por la concepción mental del espacio de acción y puede entenderse como una parte de este último.

Como se esquematiza en la **Figura 3**, la representación geométrica del comportamiento humano a través del espacio de acción y del espacio de actividad puede adquirir la forma de superficie generalizada, tanto discreta como continua, pero con ciertas diferencias. En este sentido, la representación del espacio de acción denota el nivel de preferencia o utilidad individual asociado con cada ubicación (Bunge 1966), mientras que el espacio de actividad añade un componente de intensidad del comportamiento espacial real sobre porciones del espacio de acción (Horton y Reynolds 1971). Tanto la preferencia o intensidad de estos espacios individuales se estructuran, principalmente, a través de ciertos lugares concretos organizados jerárquicamente, también conocidos como *puntos de anclaje* (Ver **Figura 3**). Éstos puntos suelen ser los destinos espaciales cotidianos más importantes en la vida de las personas (Couclelis et al. 1987; Golledge y Timmermans 1990). Para la mayoría de las personas, el principal punto de anclaje de su espacio de actividad o de acción es su lugar de residencia, pero otros lugares, como el lugar de trabajo, la casa de un amigo cercano o el centro cívico que visita frecuentemente también ejercen como puntos de anclaje.

Figura 3. Relación entre espacio de acción y espacio de actividad.



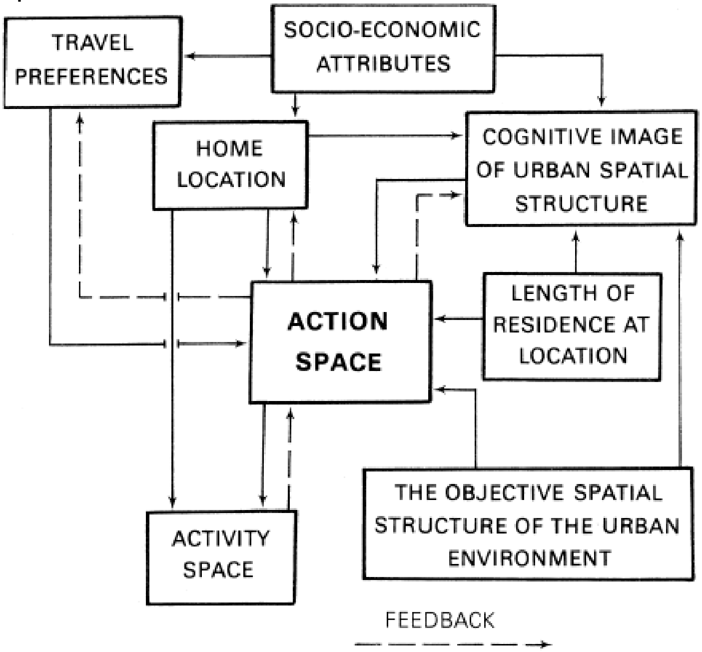
Fuente: Elaboración propia.

Más allá de la forma y la coincidencia entre espacio de acción y de actividad, éstos espacios pueden adquirir distintos tamaños, los cuales repercuten de manera distintas tanto en la vida cotidiana de las personas como en el territorio en el que se realiza. Por ejemplo, los espacios de actividad de gran tamaño, debido a largas distancias recorridas, generalmente, implican un mayor uso de modos de transporte motorizados (Banister 2008) y que, en el caso de vehículo privado, puede implicar una mayor congestión del tráfico, un mayor consumo de energía o la contaminación del aire, entre otras, de un territorio (Ewing et al. 2016; Soria-Lara, Aguilera-Benavente, y Arranz-López 2016). Estas diferencias de comportamiento espacial se deben a restricciones, necesidades, preferencias o recursos disponibles de las personas que pueden explicarse por distintos tipos de condicionantes (Sherman et al. 2005). Esta investigación profundiza en la comprensión de los condicionantes del comportamiento espacial derivado de la movilidad cotidiana poniendo el foco en las diferencias en el tamaño del espacio de actividad de las personas residentes en un entorno metropolitano.

2.3. Los condicionantes del comportamiento espacial de las personas

En la exploración de las diferencias en comportamiento espacial, la aportación principal de este enfoque conductista de la geografía ha sido incluir los procesos cognitivos y las percepciones como determinantes del comportamiento espacial de las personas. Sin embargo y siguiendo el modelo de Horton and Reynolds (1971) de la **Figura 4**, la influencia de estos procesos en el espacio de actividad de las personas viene acompañada también por otros tipos factores como es el papel clave que ejercen las características objetivas del entorno construido del territorio de residencia, la localización de las residencias respecto las demás actividades cotidianas, el perfil socioeconómico de la persona o el tiempo de residencia en un determinado lugar.

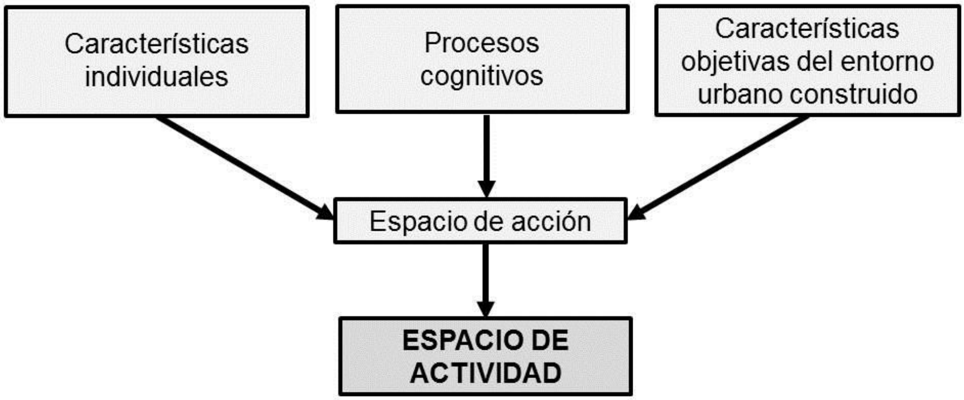
Figura 4. Modelo conceptual de los condicionantes del espacio de acción y espacio de actividad.



Fuente: Horton and Reynolds (1971).

En esta línea, el marco conceptual sobre los tipos de condicionantes del comportamiento espacial en que se basa el análisis realizado en la presente tesis se muestra en la **Figura 5**. Según este marco, los condicionantes del comportamiento espacial de las personas pueden agruparse en diferentes tipos de factores explicativos según hagan referencia a los procesos cognitivos de cada persona, a sus características individuales o a las características del entorno construido del territorio en el que reside una persona. Estos factores son determinantes en la configuración del espacio de acción de cada individuo, incluyendo las dimensiones tanto de comportamiento espacial real como potencial, y, en consecuencia, en el espacio de actividad resultante de los patrones de movilidad.

Figura 5. Tipos de condicionantes del comportamiento espacial de las personas.



Fuente: Elaboración propia.

2.3.1. Los procesos cognitivos y el comportamiento espacial

La exploración de los aspectos subjetivos como las preferencias, valores y creencias individuales es determinante para entender el comportamiento espacial de las personas dado que éstos influyen en la elección de lugares dónde residir y trabajar pero también donde realizar las actividades de ocio y las comerciales, las rutas elegidas o el modo de transporte utilizado (Downs y Stea 1973; Mondschein, Blumenberg, y Taylor 2010). Por estos motivos, es importante estudiar los procesos cognitivos y de percepción que determinan el tamaño del espacio de actividad.

De todos elementos de percepción que pueden determinar las decisiones espaciales, la configuración mental sobre el mundo real es el proceso cognitivo que ha centrado la mayor atención en los trabajos de la Geografía de la Percepción y del Comportamiento. Desde este enfoque, las personas pasan por un proceso de aprendizaje en el que se adquiere, codifica, almacena, recuerda y descifra información sobre localizaciones y atributos del espacio que les rodea (Downs y Stea 1973), la cual es almacenada en su mente formando mapas cognitivos (Kitchin 1994). Los mapas cognitivos de las personas incluyen información esencial para su comportamiento espacial sobre rutas, ubicaciones, distancias, direcciones o significados que es integrada a través de la experiencia extraída de sus desplazamientos cotidianos (Downs y Stea 2011). De este modo, las diferencias intrapersonales en relación a la experiencia espacial resultan en variaciones en su mapeo cognitivo (Mondschein et al. 2010), haciendo que un mismo contexto geográfico, ya sea un barrio, una ciudad o una región, pueda adquirir imágenes mentales muy diversas por parte de sus residentes (Matthews y Yang 2013).

En los mapas cognitivos se almacena la información relativa al territorio utilizado por las personas de forma cotidiana, es decir, los límites subjetivos de su espacio de acción y, en consecuencia, determina las características de su espacio de actividad (Greenberg Raanan y Shoval 2014). Esta configuración mental individual influye en lo que puede ser físicamente accesible y/o más deseable durante la toma de decisiones espaciales a largo y corto plazo, como los hábitos de movilidad cotidiana resultando en espacios de actividad de distinto tamaño (Golledge y Stimson 1987; Weston y Handy 2004).

2.3.2. Las características individuales y el comportamiento espacial

Más allá de los procesos cognitivos, la configuración del espacio de actividad de los residentes en entornos metropolitanos puede verse influenciado también por las características individuales de cada persona (Golledge y Stimson 1987). En este sentido, pueden existir diferencias en el tamaño de los espacios de actividad de las personas, el cual puede repercutir en su acceso a oportunidades, debido a diferencias en el perfil sociodemográfico (género, edad, renda, estatus socioeconómico…) o particularidades en la organización temporal del día a día de cada individuo.

En este sentido, el género de la persona puede influir en las características de su espacio de actividad, dado que los hombres han demostrado tener espacios de actividad de mayor extensión que las mujeres (Kwan y Kotsev 2015). Asimismo, la extensión espacial recorrida a nivel diario puede verse condicionado también por la edad del individuo ya que, por ejemplo, se ha demostrado que las personas de mediana edad suelen tener un espacio de actividad mayor que personas más jóvenes o personas de la tercera edad (Fan y Khattak 2008; Tana, Kwan, y Chai 2015). De la misma forma, las personas con mayores ingresos suelen recorrer mayores distancias a nivel cotidiano y obtienen espacios de actividad de mayor tamaño (Buliung y Kanaroglou 2006; Fan y Khattak 2008).

Un factor importante en la configuración del espacio de actividad de las personas es el tiempo. Las contribuciones de la Geografía del Tiempo han demostrado que las variables temporales son básicas para comprender el comportamiento espacial de las personas debido a la limitada asignación de tiempo para realizar actividades cotidianas y su repercusión en el espacio accesible (Hägerstrand 1970a; Kwan 1998; Miller 2005). Por este motivo, la organización del tiempo es otro factor a tener en cuenta en el comportamiento espacial a nivel individual.

Dado que el tiempo de viaje suele implicar de manera estable entre 1 o 2 horas diarias (Ahmed y Stopher 2014), un larga jornada de trabajo puede implicar que las personas se vean obligadas a reducir el tiempo dedicado –o no participar– en otras actividades como por ejemplo, actividades relacionadas con el ocio o la socialización. De esta manera, el espacio de actividad de estas personas puede reducirse (Farber y Páez 2011; Susilo y Kitamura 2005). Asimismo, la rutina o frecuencia con la que se accede a ciertos lugares y actividades como el lugar de trabajo ha demostrado influir en el tamaño, la forma o la orientación de los espacios de actividad de las personas. En este sentido, las personas tienden, en la medida que les es posible, a recorrer menores distancias para realizar aquellas actividades más frecuentes y pueden desplazarse más lejos para aquellas más ocasionales (Sherman et al. 2005).

2.3.3. El entorno construido y el comportamiento espacial

Las características espaciales de un territorio metropolitano tienen un papel determinante en el consecuente comportamiento espacial de sus residentes. Elementos relativos a la estructura territorial metropolitana, como la distancia, la concentración de funciones o el sistema de transporte, son algunos de los principales condicionantes de los patrones de movilidad cotidiana, los cuales se ven reflejados en la estructura de los espacios de actividad de los individuos (Buliung y Kanaroglou 2006; Zahavi 1979).

En este sentido, la distancia entre los nodos de actividad cotidiana, como el hogar y el lugar de trabajo, es determinante en el espacio de actividad de las personas (Couclelis et al. 1987; Horton y Reynolds 1971), al aumentar el tamaño de estos espacios debido a largas distancias que deben recorrerse (Buliung y Kanaroglou 2006; Tana et al. 2015). Asimismo, características como la compacidad y densidad urbanas, la mixtura de usos del suelo o un determinado diseño de los espacios abiertos están relacionadas con la obtención de espacios de actividad más pequeños de sus residentes (Hirsch, Winters, et al. 2014) debido a dinámicas de proximidad urbana, las cuales implican desplazamientos cotidianos de corta distancia y un mayor uso de los modos de transporte activo (Cervero y Kockelman 1997; Lachapelle et al. 2011; Marquet y Miralles-Guasch 2014; Rodríguez, Brown, y Troped 2005). Por otro lado, las características del sistema de transporte metropolitano determinan también el comportamiento espacial al permitir a las personas desplazarse menores o mayores distancias. El sistema de vías rodadas y el sistema de transporte público posibilita los desplazamientos diarios de larga distancia en modos de modos de transporte motorizados, incrementado, de esta manera, el espacio de actividad de las personas (Banister 2011; Farber y Páez 2011).

La presencia de espacios abiertos provistos de vegetación como parques, jardines o calles arboladas puede influenciar el comportamiento espacial de las personas en un entorno urbano. Por un lado, los parques y jardines públicos devienen lugares seguros, accesibles y atractivos para andar y realizar actividades recreativas por lo que el acceso a ellos ha sido asociado a mayores niveles de actividad física y a beneficios para la salud (Almanza et al. 2012; Douglas, Lennon, y Scott 2017; Markevych et al. 2017). Por otro lado, otros espacios abiertos como las calles arboladas también han sido relacionados con hábitos recreativos saludables pero, además, devienen espacios que permiten caminar como modo de transporte cotidiano a través de rutas estéticamente agradables (Lu, Sarkar, y Xiao 2018; Sarkar et al. 2015).

2.4. La utilización del concepto de espacio de actividad en la actualidad

Desde los años 80 hasta la actualidad, se ha producido un estancamiento en los avances científicos de la Geografía de la Percepción y del Comportamiento. Uno de los motivos principales del estancamiento es la incursión de las teorías radicales y humanísticas dentro de la geografía y su dominio predominantes durante estas últimas décadas. La omisión en los trabajos de la geografía conductual de los condicionales económicos y sociales (Rieser 1973) y el trasfondo precognitivo emanante de la historia, el arte, la literatura o la religión para entender el comportamiento espacial de las personas (Tuan 1976) son algunas de las principales críticas realizadas desde estas corrientes. Sin embargo, aunque la posición de la Geografía de la Percepción y del Comportamiento como subdisciplina de la geografía humana es actualmente marginal, sus conceptos y metodologías nunca desaparecieron del todo. Es más, se ha producido un resurgimiento en la aplicación de sus aportaciones.

Concretamente, el estudio del comportamiento espacial y los procesos cognitivos de grupos específicos de población, como los niños o los ancianos, ha continuado produciendo cantidades importantes de trabajos desde disciplinas distintas a la geografía como la psicología ambiental. Temas como el desarrollo de la cognición ambiental y sus implicaciones pedagógicas, el uso de territorios e instalaciones, las preferencias espaciales y las limitaciones perceptivas, entre otras, han seguido siendo estudiados y han sido aplicados, por ejemplo, en la formulación de políticas públicas de planificación urbana (Argent 2017). No obstante, y especialmente en la última década, conceptos como el espacio de actividad, el espacio de acción o los mapas cognitivos han recobrado un especial interés tanto en los estudios urbanos y la movilidad como en disciplinas más alejadas como la criminología, la epidemiología o la salud pública (Patterson y Farber 2015).

Un factor clave de esta proliferación de nuevos trabajos en los cuales se emplean conceptos ideados inicialmente desde la Geografía de la Percepción y del Comportamiento se debe, en parte, a las mejoras metodológicas que han aportado los avances tecnológicos. Hay que destacar aquí el papel de los Sistemas de Información Geográfica (SIG) y la tecnología de teleseguimento o *tracking*. Por un lado, las nuevas aplicaciones basadas en los SIG han permitido recopilar, estandarizar y procesar grandes cantidades de información geográfica (Gold 2009; Rantanen y Kahila 2009) y, por otro, el *tracking* ha permitido obtener de manera precisa y georreferenciada los recorridos y localizaciones de las personas (Kestens, Thierry, y Chaix 2016; Kwan y Schwanen 2018).

Concretamente, el concepto de espacio de actividad ha recuperado un papel protagonista en la literatura académica actual y es aplicado para propósitos distintos. De esta literatura, puede destacarse un primer grupo de estudios que utiliza este concepto para entender el comportamiento espacial relativo a la movilidad cotidiana y los factores que lo determinan (Babb et al. 2017; Harding et al. 2012; Hirsch, Winters, et al. 2014; Kamruzzaman et al. 2011; Loebach y Gilliland 2014; Tana et al. 2015; Xu et al. 2016). Asimismo, este concepto también es empleado para explorar la exclusión o segregación espaciales de ciertos grupos de población en entornos urbanos (Farber et al. 2015; Farber, Páez, y Morency 2012; Wang y Li 2016; Wong y Shaw 2011). Otro propósito destacable está aplicando el concepto de espacio de actividad para evaluar la accesibilidad a las oportunidades de la población en un territorio (Kamruzzaman et al. 2011; Kamruzzaman y Hine 2012; Parthasarathi, Hochmair, y Levinson 2015; Rogalsky 2010; Tribby et al. 2016), pero también para analizar la accesibilidad a oportunidades concretas como, por ejemplo, servicios públicos (hospitales, parques, etc.) o comercios (Sherman et al. 2005; Vallée et al. 2010; Vallée y Chauvin 2012). Otro grupo de estudios de carácter más metodológico destaca por tener como objetivo común la comparación de distintos métodos de cálculo del espacio de actividad y el estudio de las posibilidades de las nuevas fuentes de información (Hirsch, Winters, et al. 2014; Holliday et al. 2017; Laatikainen, Hasanzadeh, y Kyttä 2018; Li y Tong 2016; Sherman et al. 2005; Zenk et al. 2011).

Finalmente, otro tipo de trabajos que ha propiciado un particular impulso en la aplicación del concepto de espacio de actividad proviene del ámbito de la salud. En disciplinas como la salud pública o la epidemiología, ha existido históricamente el interés por obtener medidas sobre el comportamiento espacial humano que permitan explorar la relación entre factores ambientales y la salud de las personas. Para ello, una conceptualización ampliamente utilizada en estas disciplinas es la del *exposoma humano*. Éste hace referencia a la compilación de exposiciones, tanto sociales como ambientales, experimentadas durante la vida de un individuo que influencian en su salud (Wild 2005). La idea detrás de este concepto coincide, en gran medida, con la idea planteada por los geógrafos de la percepción y del comportamiento al describir el espacio de actividad. Así, pues el espacio de actividad ha servido para explorar los beneficios o riesgos que ejerce el entorno urbano sobre la salud como, por ejemplo, las diferencias en los niveles de actividad física (Hirsch et al. 2015; Howell et al. 2017; Lee et al. 2016; Vich, Marquet, y Miralles-Guasch 2019) o el consumo de tabaco y otras substancias perjudiciales para la salud (Lebel et al. 2012; Mason 2011; Mennis y Mason 2011; Shareck et al. 2015).

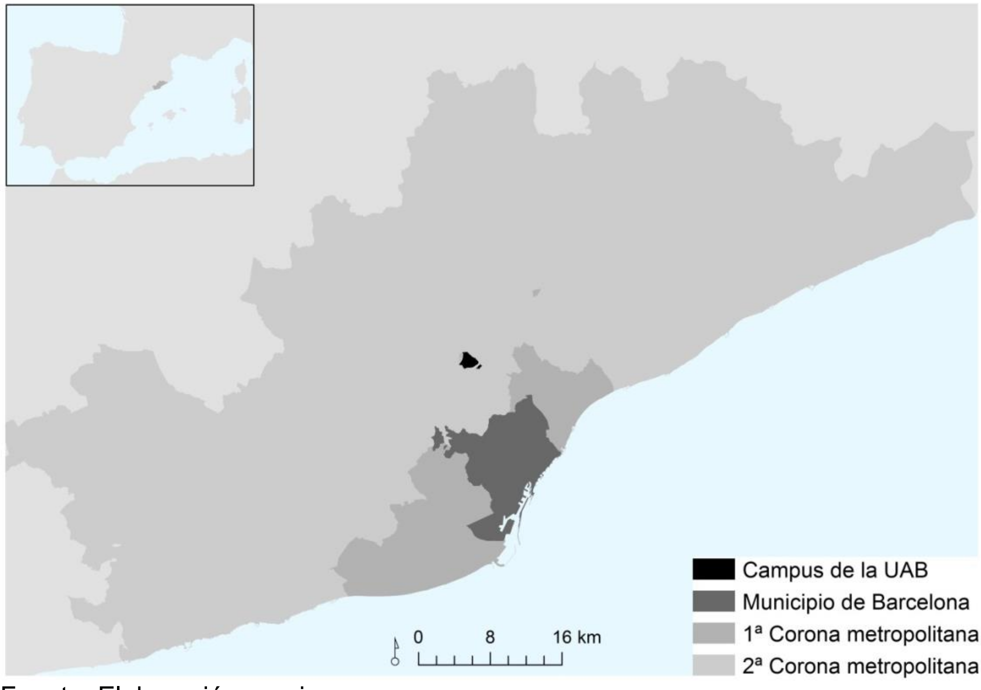
De esta forma, la presente tesis se enmarca tanto en este creciente cuerpo de literatura que se beneficia de las posibilidades que ofrecen las nuevas fuentes de datos para obtener medidas precisa del espacio de actividad de las personas residentes en entornos metropolitanos para entender los las diferencias en el comportamiento espacial debido a distintos factores explicativos.

3. Metodología

3.1. El área de estudio de la tesis

El área de estudio elegida para la presente tesis es la Región Metropolitana de Barcelona (RMB), la cual consta de más de 5 millones de habitantes y un territorio de 3.242 km² (**Figura 6**). Este territorio está caracterizado por una diversidad tanto funcional y como morfológica por lo que devine un territorio de análisis con muchos matices en el que explorar el comportamiento espacial de sus residentes. En este sentido, aunque la corona central de este territorio –en especial la ciudad de Barcelona– ejerce un mayor protagonismo a nivel funcional (residencial, económico, cultural, social…), la segunda corona periférica también atrae una cantidad importante de actividades económicas más allá de funciones únicamente residenciales.

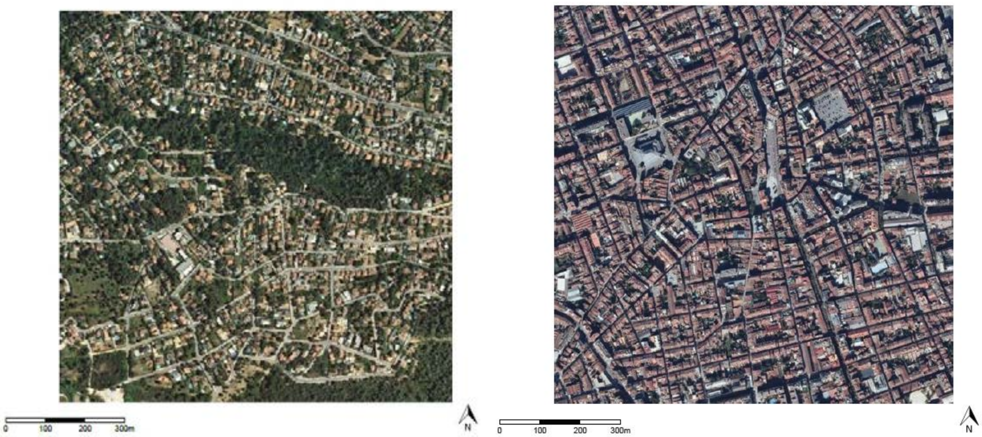
Figura 6. La Universitat Autònoma de Barcelona en el contexto de la Región Metropolitana de Barcelona (RMB).



Fuente: Elaboración propia.

A nivel morfológico, este territorio está caracterizado, como muestra la **Figura 7**, por albergar distintas tipologías de formas urbanas que van de la compacidad a la dispersión urbana (Miralles-Guasch y Tulla-Pujol 2012). Por estos motivos, esta diversidad de características urbanas en un mismo territorio da lugar distintos comportamientos espaciales y patrones de movilidad cotidiana que pueden implicar tanto desplazamientos de largas distancias como recorridos de proximidad (Delclòs-Alió y Miralles-Guasch 2017; Marquet y Miralles-Guasch 2015a).

Figura 7. Tipologías de forma urbana presentes en la RMB.



Área urbana dispersa	Área urbana compacta

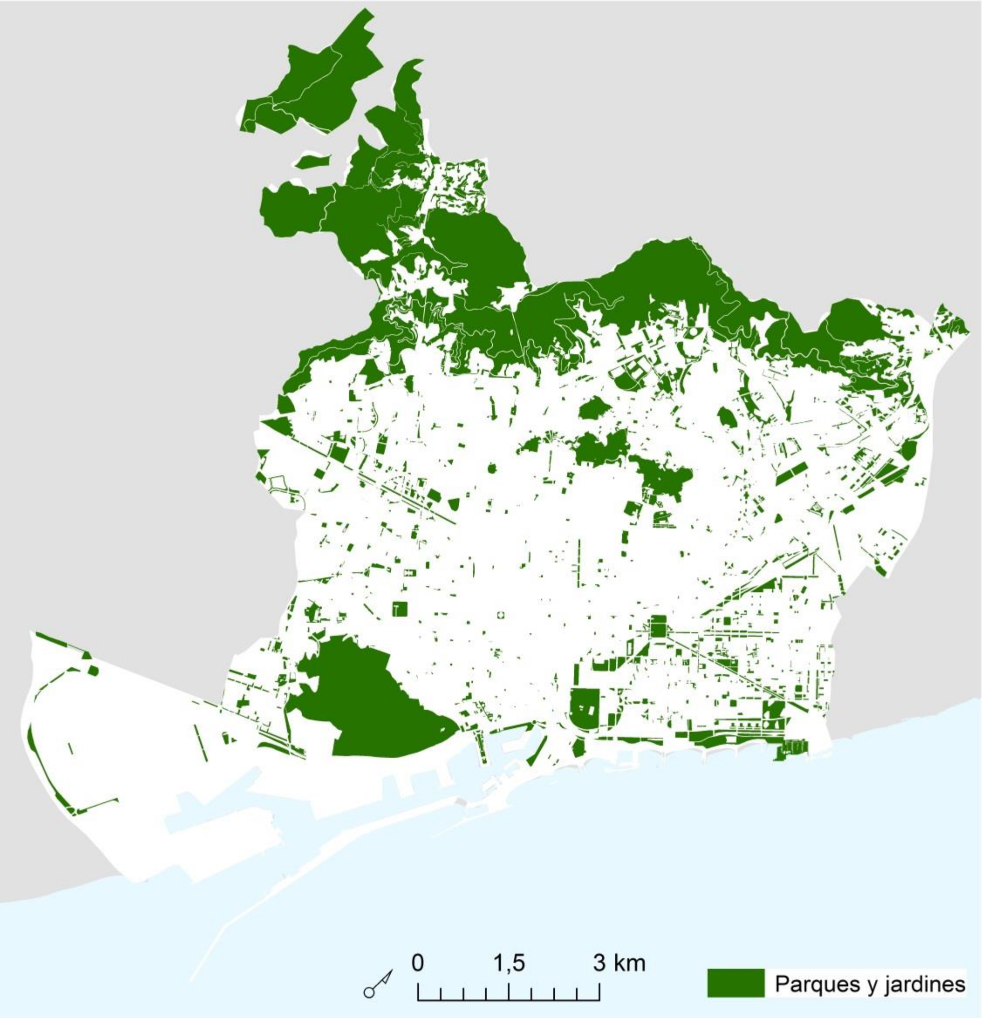
Fuente: Institut Cartogràfic i Geològic de Catalunya (2018).

Con el propósito de estudiar el comportamiento espacial en la RMB se ha elegido estudiar los patrones de movilidad cotidiana de los miembros de la comunidad universitaria de la Universitat Autònoma de Barcelona por la particular localización del campus y por la especificidad de esta comunidad como grupo de población (Soria-Lara, Marquet, y Miralles-Guasch 2017). La ubicación suburbana de esta universidad dentro de la RMB, como se puede observar en la **Figura 6**, ejemplifica perfectamente la segregación de funciones urbanas dentro de la estructura de un territorio metropolitano al estar situada 1) a 15 km del centro de la ciudad de Barcelona, 2) dentro del segundo anillo metropolitano y 3) separado del continuo urbano. En consecuencia, los hábitos de movilidad cotidiana de los miembros de esta comunidad se caracterizan por estar condicionados por un desplazamiento interurbano, normalmente largo y realizado principalmente mediante transporte motorizado. Estas condiciones permiten explorar el efecto del entorno construido y de los procesos cognitivos en el comportamiento espacial de un grupo específico de personas, con sus particularidades a nivel sociodemográfico y de organización temporal.

Para analizar la relación entre la presencia de espacios verdes y el comportamiento espacial -en concreto la movilidad activa- se ha reducido la escala territorial poniendo el foco en la parte central del territorio de la RMB, la ciudad de Barcelona. Esta ciudad sirve de óptimo ejemplo de ciudad mediterránea con una provisión de áreas verdes particular.

La característica forma urbana de la ciudad y su legado urbanístico heredado al largo de la historia es uno de los principales condicionantes del tipo de espacio verde presente en Barcelona. Los distintos períodos históricos de desarrollo y expansión urbana han dado lugar a morfologías físicas diferenciadas que van desde el trazado de calles estrecho e irregular heredados la ciudad medieval de Barcelona y las aldeas circundantes del siglo XVIII, los espacios abiertos y trama ortogonal de calles anchas del "Ensanche" de Cerdà del XIX, hasta los últimos desarrollos del XX (Pallares-Barbera, Badia, y Duch 2011). Como resultado, Barcelona se caracteriza, a pesar de la mejora de las últimas décadas, por tener una baja densidad de parques públicos y jardines, especialmente en la parte central de la ciudad en comparación con otras ciudades del norte de Europa (Fuller y Gaston 2009; Kabisch et al. 2016) (Ver **Figura 8**). En 2017, por ejemplo, este tipo de área verde solo representaba el 11,12% del territorio (Ajuntament de Barcelona 2018). Aunque en Barcelona existen áreas verdes de gran extensión, como la sierra de Collserola o la montaña de Montjuïc, éstas no son de fácil acceso debido a su ubicación en la periferia de la ciudad y a una altitud considerable en comparación al resto de la ciudad. Sin embargo, esta baja provisión de parques y jardines es compensada por la presencia de otro tipo de espacios abiertos provistos de vegetación en los cuales la población puede socializarse, realizar ejercicio físico o relajarse como son plazas públicas, calles, avenidas, paseos o ramblas. En este sentido, la ciudad de Barcelona disponía en 2017 de 157.098 árboles en las calles (96,93 árboles por 1000 habitantes) (Ajuntament de Barcelona 2018), cifra superior a la media de las ciudades europeas (Pauleit 2003). Adicionalmente a las áreas verdes y calles arboladas, la ciudad dispone una gran extensión de espacios abiertos, como son las playas, distribuidas a lo largo de 5 km de la línea de costa.

Figura 8. Parques y jardines de la ciudad de Barcelona.



Fuente: Elaboración propia a partir del Mapa de usos del suelo de Barcelona (Ajuntament de Barcelona 2016b).

3.2. Fuentes de datos

El interés por el estudio de la relación entre el entorno y el comportamiento humano de las últimas décadas ha dado lugar a una búsqueda de nuevas metodologías que permitan comprender los fenómenos urbanos como el comportamiento espacial de manera más precisa y profunda en comparación con enfoques metodológicos tradicionales (Naess 2015). En concreto, la aparición de nuevas fuentes de datos provenientes de las Tecnologías de la Información y Comunicación (TIC) ha impulsado el estudio de este tipo de comportamiento y su relación con su entorno. En este contexto, la presente tesis doctoral aprovecha los beneficios que aportan estas nuevas fuentes de información para estudiar los condicionantes, tanto espaciales como a nivel del individuo, de los patrones de movilidad cotidiana de personas residentes en un contexto metropolitano. Para ello, es conveniente evaluar primero la idoneidad de los distintos enfoques metodológicos disponibles, ya sean tradicionales como nuevos, para el objetivo principal de la tesis.

3.2.1. Fuentes de datos tradicionales

a) Fuentes cuantitativas

La aproximación metodológica de carácter cuantitativo en ciencias sociales ha permitido obtener históricamente una imagen representativa sobre un fenómeno social en particular en un territorio específico. Mediante la utilización de fuentes de datos oficiales como encuestas o censos poblacionales, el enfoque cuantitativo tiene como objetivo principal identificar patrones que describan de manera representativa un fenómeno (Bryman 2012).

El enfoque cuantitativo en estudios sobre movilidad cotidiana permite conocer patrones de comportamiento relativos a los desplazamientos cotidianos a nivel general (Mars, Arroyo, y Ruiz 2016). Este enfoque ha tenido como fuente de datos más utilizada las encuestas sobre hábitos de movilidad o las encuestas de origen-destino (Miralles-Guasch 2012). Este tipo de fuentes permite obtener información relativa al número de desplazamientos de un territorio determinado, los tiempos y distancias de desplazamiento, los modos de transporte, la intermodalidad, entre otras, así como información sobre el perfil de las personas en base a variables sociodemográficas (género, edad, nivel socioeconómico, etc.) (Miralles-Guasch, Vich, y Delclòs-Alió 2018). Sin embargo, la utilización de las encuestas de hábitos y de origen y destino presentan ciertos desafíos a la hora de estudiar la dimensión espacial de la movilidad cotidiana.

Por un lado, la calidad de la información oficial tanto de carácter demográfico (ej. el Censo de Población y Viviendas de 2011) como relativa a la movilidad cotidiana en España se ha visto reducida en la última década. En Cataluña, la última edición disponible de la Encuesta de Movilidad Cotidiana (EMQ) se remonta al año 2006. Esto ha hecho que la información estadística relativa a los patrones movilidad cotidiana dependa de los órganos metropolitanos como es el caso de la edición anual de la Encuesta de Movilidad en Días Laborables (EMEF) de la Región Metropolitana de Barcelona. De este modo, las principales área metropolitanas, con mayor disposición de recursos, resultan ser los únicos territorios que pueden ser analizados académicamente en detrimento de territorios más pequeños (Bellet y Llop 2004).

Por el otro, las encuestas oficiales sobre patrones de movilidad cotidiana en general suelen carecer de información precisa sobre las localizaciones de las actividades de las personas, salvo de algunos casos a nivel internacional (Buliung y Kanaroglou 2006; Li y Tong 2016). En Catalunya, la EMEF provee únicamente información sobre el municipio de origen y la comarca de destino de los desplazamientos realizados por los encuestados. Por este motivo, no es posible representar espacialmente de forma detallada los espacios de actividad de las personas utilizando este tipo de datos.

b) Fuentes cualitativas

Otro tipo de enfoque utilizado para explorar el comportamiento espacial es el cualitativo. El enfoque cualitativo en ciencias sociales permite responder preguntas a nivel micro en relación a las experiencias subjetivas de los individuos. Fuentes de datos como las entrevistas semiestructuradas, entrevistas en profundidad, los grupos de discusión, los diarios de viaje o los mapas cognitivos permiten obtener información sobre opiniones, costumbres, motivaciones y percepciones individuales sobre los hábitos de movilidad cotidiana y su dimensión espacial. Este enfoque permite, además, explicar en detalle aquellas relaciones entre variables detectadas mediante la utilización de métodos cuantitativos (Mars et al. 2016).

De los distintos métodos cualitativos, el dibujo de croquis o esbozo de mapas cognitivos ha sido la técnica más utilizada para obtener la imagen cognitiva del entorno que rodea a las personas (Downs y Stea 2011; Golledge y Timmermans 1990). Ya sea utilizando mapas cartográficos o sobre un fondo blanco este método permite, entre otros, representar gráficamente el espacio de actividad de las personas (Greenberg Raanan y Shoval 2014). El esbozo a mano ha permitido detectar la importancia de ciertos lugares para cada individuo, los cuales pueden condicionar su comportamiento espacial (Lynch 1960). No obstante, la utilización de la técnica del esbozo a mano sobre fondo blanco ha sido cuestionada al ser considerarla altamente dependiente de las habilidades individuales para dibujar y así como del nivel de educación de las personas, pudiendo dar lugar a representaciones imperfectas de la cognición espacial (Blaut, McCleary, y Blaut 1970). Por otro lado, la obtención de mapas cognitivos mediante mapas cartográficos han servido históricamente para extraer imágenes cognitivas de las personas por su parecido a territorios conocidos y uniformizar las diferencias en los mapas esbozados con la mano, pero perdiendo así cierta información sobre sus preferencias espaciales (Gärling, Book, y Lindberg 1984).

3.2.2. Nuevas fuentes de datos: las TIC

Los avances de las Tecnologías de la Información y de la Comunicación (TIC) en las últimas décadas como es la aparición de Internet y la tecnología de comunicación móvil ha implicado que éstas sean presentes de manera casi generalizada en la vida cotidiana de las personas (Castells et al. 2004). La comunicación y la capacidad de almacenamiento y transmisión de grandes cantidades de información a distancia –como la de carácter geográfico– son algunas de las ventajas de las TIC que han propiciado que estas nuevas fuentes de información sean utilizadas para el estudio de fenómenos humanos, especialmente en entornos urbanos (Kwan 2006, 2007; Ratti et al. 2006). La presente tesis se sitúa en este marco de innovación metodológica empleando dos nuevos tipos de fuentes de datos que facilitan la comprensión de las percepciones sobre el entorno geográfico, así como la configuración del comportamiento espacial relativo a la movilidad cotidiana: las aplicaciones SoftGIS y los datos de teleseguimiento o *tracking*.

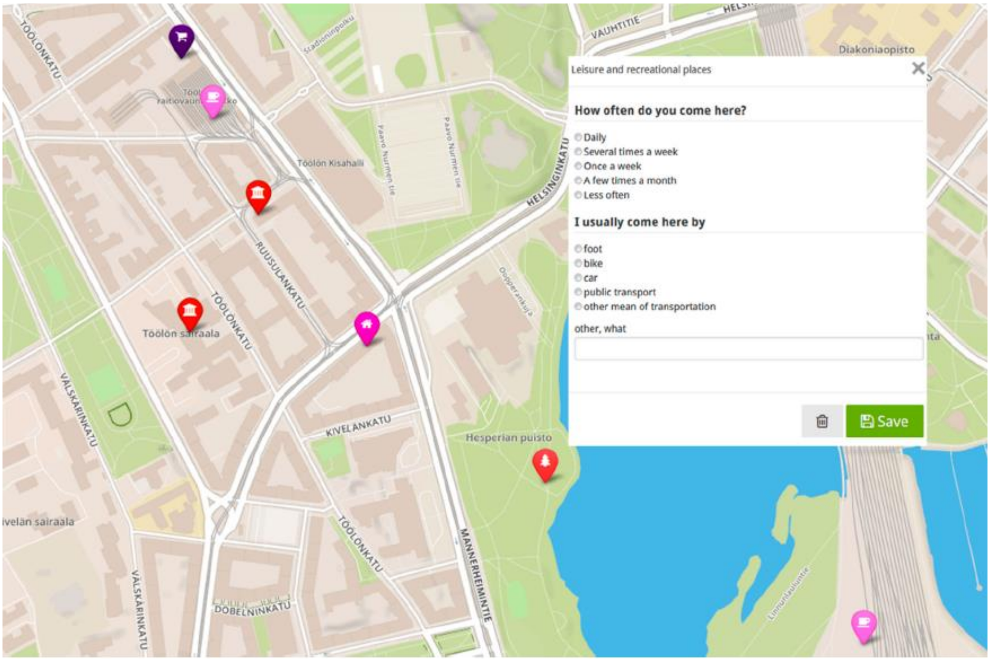
a) Datos de SoftGIS

Las TIC han aprovechado la capacidad de recopilar, estandarizar y procesar grandes cantidades de información geográfica que ofrecen los Sistemas de Información Geográfica (SIG) para desarrollar herramientas que posibilitan la obtención de información espacial sobre la población. Asimismo, esta información puede ser transmitida fácilmente a través de Internet y la tecnología de comunicación móvil. Una de las innovaciones derivadas de los SIG son los métodos SoftGIS.

El SoftGIS, desarrollado en Finlandia hace más de una década, es un ejemplo avanzado de una aplicación *SIG para la Participación Pública* (PPGIS) que permite la georreferenciación de experiencias y prácticas de comportamiento cotidianos de forma agregada a través de Internet (Rantanen y Kahila 2009). Esta metodología puede ser utilizada como método de recolección de datos para la investigación académica, pero también como como herramienta para obtención de conocimiento espacial de la población en procesos participación ciudadana en planificación urbana u otros ámbitos como la salud pública y el sector social, cultural o educativo (Broberg, Salminen, y Kyttä 2013). La característica principal del SoftGIS es la incorporación de servicios de mapas cartográficos digitalizados en línea, como pueden ser Google Maps© u Open Street Maps, en encuestas o entrevistas con el propósito de recopilar el conocimiento espacial de los entrevistados como ubicaciones concretas, áreas, rutas u opiniones georreferenciadas (Rantanen y Kahila 2009). Esta metodología minimiza el sesgo de memoria, provee información geográfica actualizada, permite el cambio de escala y acceder a amplias muestras de población, a la vez que estandariza las habilidades de esbozo de las personas (Chaix et al. 2012; Leyshon, DiGiovanna, y Holcomb 2013). En relación a los objetivos de la presente tesis, las aplicaciones de SoftGIS posibilitan la obtención de imágenes mentales sobre el mundo real a través del dibujo de mapas cognitivos de las personas en formato digital y referenciado. Aunque la información espacial recogida esté limitada por la misma planaridad de los mapas cartográficos en formato papel, su flexibilidad y capacidad de agregación hacen del SoftGIS una herramienta útil para estudiar la dimensión espacial de la movilidad cotidiana.

En la literatura académica pueden encontrarse ejemplos recientes de la aplicación del SoftGIS para el análisis del comportamiento y la percepción espacial de grandes cantidades de personas. Dado el origen de la metodología, existe una cantidad considerable de estudios localizados en Finlandia para analizar, por ejemplo, la influencia de las preferencias residenciales en los hábitos de movilidad activa de 3.403 adultos (Haybatollahi et al. 2015) o de 844 personas mayores (Laatikainen, Haybatollahi, y Kyttä 2018) (Ver ejemplo en la **Figura 9**). Esta metodología ha servido también para examinar la accesibilidad de 2.151 personas a entornos acuáticos como playas, lagos, ríos, arroyos y lagunas según su perfil sociodemográfico (Laatikainen et al. 2015), o las experiencias y preferencias en relación a los espacios abiertos urbanos de finlandeses y japoneses (Kyttä et al. 2018). También se encuentran estudios localizados en otros lugares como Nueva Zelanda y Francia que exploran, por ejemplo, la coincidencia entre rutas registradas con datos de GPS y las rutas obtenidas mediante la tecnología SoftGIS de un grupo de adolescentes (Stewart et al. 2015; Stewart, Schipperijn, et al. 2017), o que evalúan las rutas, destinos de viaje y espacios de actividad de 4.383 adultos para explorar sus exposiciones ambientales (Chaix et al. 2012; Perchoux et al. 2016).

Figura 9. Ejemplo de interfaz de una encuesta en línea con ejercicio de mapeo SoftGIS.



Fuente: Laatikainen, Haybatollahi y Kyttä (2018).

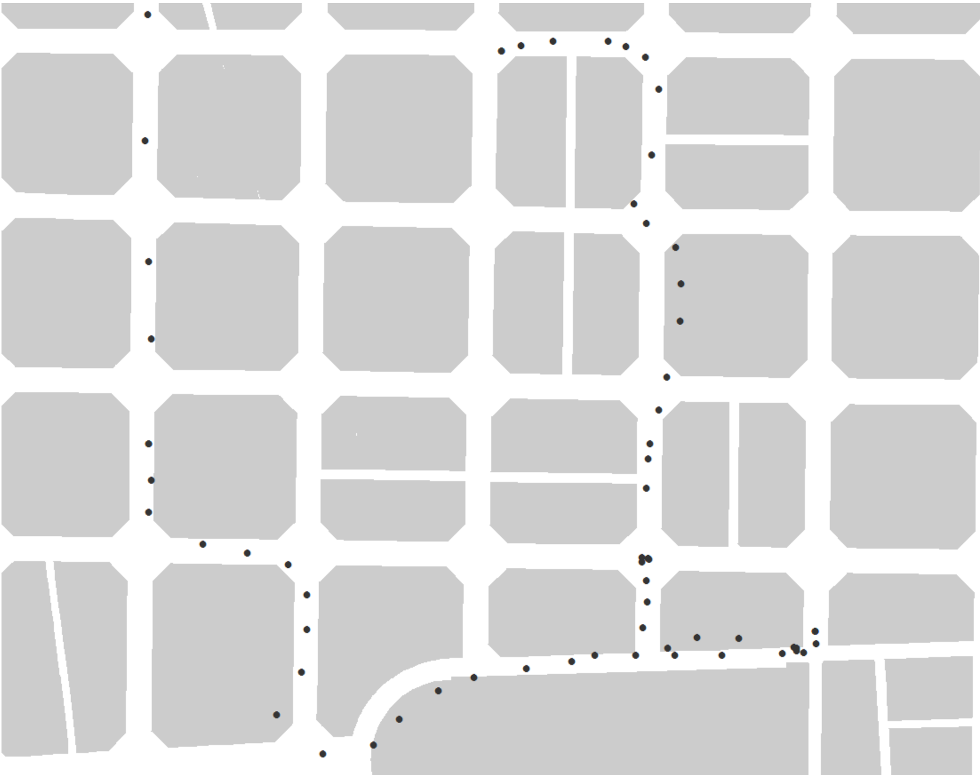
b) Datos de teleseguimiento o *tracking*

El gran avance metodológico en el estudio del comportamiento espacial de las personas gracias al desarrollo de las TIC se debe a su capacidad de obtener gran cantidad de datos agregados sobre el posicionamiento espaciotemporal de las personas. Estas fuentes de información pueden servir incluso de complemento o sustituir, a veces, las fuentes de información tradicionales (Cottrill et al. 2013; Stopher, Xu, y Fitzgerald 2007).

Los estudios basados en datos de localización proveniente de las TIC pueden dividirse entre *posicionamiento georreferenciado pasivo* o *activo*, dependiendo de si el individuo que las genera es consciente o no de ello (Palmer et al. 2013). En primer lugar, en el grupo de estudios que utilizan el posicionamiento pasivo pueden encontrarse referencias basadas en localización por IP's (Townsend 2001), en la señal de WiFi (Hampton, Livio, y Sessions Goulet 2010), en las transacciones de tarjetas de crédito (Sobolevsky et al. 2014), en la torres de red de telefonía móvil (Louail et al. 2014; Vieira et al. 2010) o en la geolocalización provista en las interacciones las redes sociales (Frias-Martinez y Frias-Martinez 2014; Llorente et al. 2015; Noulas et al. 2012). Este tipo de información sobre la ubicación de la persona se origina de manera indirecta, dado que no es el propósito principal de la tecnología que las obtiene. En segundo lugar, los estudios basados en posicionamiento activo se basan principalmente en la geolocalización de las personas por satélite a través de los Sistemas de Posicionamiento Global (GPS) (Van der Spek et al. 2009). Este tipo de información, ya sea en forma de dispositivos especializados o a través de la geolocalización de teléfonos móviles inteligentes –o *smartphones*–, recoge la ubicación en el tiempo y espacio de las personas de manera periódica, precisa y digitalizada. En este caso, la persona es consciente de que está registrando esta información. En la **Figura 10** se muestra la visualización de este tipo de datos cartografiados y en el **Anexo 12.1** puede verse una muestra de sus datos brutos en formato de base de datos.

La creciente penetración y uso cotidiano de la tecnología de teleseguimiento o *tracking* vía satélite durante las dos últimas décadas ha permitido profundizar en la exploración del comportamiento espacial y temporal de las personas. En este sentido, este tipo de información será la base del análisis de tres de los casos de estudio de la presente tesis.

Figura 10. Visualización de una ruta geolocalizada mediante datos de tracking.



Fuente: Elaboración propia.

Dentro de los estudios basados en datos de *tracking* pueden diferenciarse trabajos tanto de carácter metodológico como estudios aplicados ambos en ámbitos tan distintos como la salud, medio ambiente o estudios urbanos en general.

Por un lado, los estudios metodológicos tienen como principal objetivo la validación de este tipo de datos como fuente de información para estudiar temas relacionados con el comportamiento espacial. Estos trabajos suelen abordar el procesamiento y depuración de datos brutos (Jun, Guensler, y Ogle 2006; Rasmussen et al. 2015; Schuessler y Axhausen 2009), la identificación de rutas (Hanaoka et al. 2014; Hood, Sall, y Charlton 2011; Quddus y Washington 2015), la detección de modo de transporte (Dalumpines y Scott 2017; Ferrer y Ruiz 2014; Gong et al. 2012) y la comparación de análisis realizados con datos de *tracking* con los realizados con fuentes tradicionales como, por ejemplo, las encuestas (Nitsche et al. 2014; Patterson y Fitzsimmons 2016). Por el otro, los estudios de caso específicos tienen como denominador común el estudiar los recorridos de las personas, mayoritariamente en modos de transporte no motorizado en bicicleta o caminando.

La mayoría de estos estudios obtienen los datos de *tracking* a través de dispositivos GPS especializados, los cuales fueron diseñados inicialmente para almacenar rutas georreferenciadas en actividades de senderismo. La aparición de estos receptores de señal GPS, ligeros y de bajo coste económico ha permitido recoger objetivamente la ubicación de las personas en el tiempo y el espacio de manera más precisa que las fuentes tradicionales las encuestas de viaje o los diarios de viaje (Badland et al. 2010). El potencial de esta metodología aumenta, además, al poder ser combinados con datos objetivos de acelerómetros, los cuales son comúnmente utilizados en investigación en actividad física (Duncan, Badland, y Mummery 2009; Kerr, Duncan, y Schipperijn 2011).

El ámbito de investigación en el que ha proliferado más esta fuente de datos es el de la salud. En este ámbito, el uso de esta información ha servido a numerosos estudios para explorar la influencia de las características del entorno urbano construido en los niveles de actividad física de las personas, con un foco especial en los niños o las personas mayores (Andersen et al. 2015; Prins et al. 2014). Este tipo de datos ha permitido también estudiar la relación entre la exposición a fenómenos ambientales nocivos para la salud como es la contaminación atmosférica (Dewulf et al. 2016) o beneficiales como el verde urbano (James et al. 2017). Por otro lado, también encontramos ejemplos en el ámbito de los estudios urbanos con trabajos que exploran la segregación urbana (Greenberg Raanan y Shoval 2014) o para estudiar los itinerarios de los visitantes a destinos turísticos concretos, como un parque temático o una ciudad (Birenboim et al. 2013; Domènech, Gutiérrez, y Anton Clavé 2019; Shoval y Ahas 2016). Finalmente y en la línea de la presente tesis doctoral, existen también ejemplos que utilizan estas fuentes para analizar la influencia del entorno urbano en la extensión espacial de la movilidad cotidiana en distintos contextos (Tana et al. 2015).

La inclusión de tecnología GPS en teléfonos inteligentes o *smartphones* también ha permitido utilizar estos dispositivos para estudiar el comportamiento espacial de las personas. El creciente uso generalizado de estos dispositivos como herramientas de uso cotidiano ha elevado el potencial de los datos de teleseguimiento –o *smartphone tracking*– en la literatura al incorporar características similares de los dispositivos GPS especializados, pero mejorando ciertos aspectos (Queirós et al. 2016).

El uso de dispositivos *smartphone* facilita la logística del trabajo de campo en estudios sobre el comportamiento espacial al detectar las trayectorias espaciotemporales de las personas con una carga mínima para ellos, permitir el acceso a mayores muestras participantes y con un menor coste para los investigadores dado que se puede utilizar el dispositivo en propiedad de los participantes en el estudio (González, Hidalgo, y Barabási 2008). Asimismo, esta tecnología puede mejorar los problemas de recepción de la señal GPS mediante el acceso complementario a las geolocalización de las personas a través de la triangulación de señales de las torres de telefonía móvil y las redes Wi-Fi (Kerr et al. 2011). Además, los acelerómetros incorporados dentro de los *smartphones* pueden detectar también movimientos en el interior de edificios y ayudan en la detección de los modos de transporte (Miluzzo et al. 2008). Otro beneficio de esta tecnología es el hecho de solventar problemas de memoria y recolección subjetivas de las encuestas sobre distancias y tiempos de viaje (Delclòs-Alió, Marquet, y Miralles-Guasch 2017), permitir hacer preguntas a los usuarios en movimiento (Marquet, Alberico, y Hipp 2018) y poder recomendar hábitos saludables de salud

(Bopp et al. 2016). Debido a sus ventajas, pueden encontrarse múltiples trabajos que utilizan los espacios de actividad como medida de comportamiento espacial mediante la utilización de datos de *smartphone tracking*. Existen trabajos en los mismos ámbitos de estudio que en trabajos realizados con dispositivos GPS especializados como la exposición ambiental en estudios de salud (Babb et al. 2017; Hirsch et al. 2015; Zenk et al. 2011), vitalidad y accesibilidad urbana (Delclòs-Alió, Gutiérrez, y Miralles-Guasch 2018; James et al. 2017; Tana et al. 2015; Tribby et al. 2016) o estudios sobre segregación urbana (Greenberg Raanan y Shoval 2014).

La utilización de datos de *tracking* para el análisis del comportamiento espacial también presenta ciertos desafíos técnicos y metodológicos a tener en consideración. Su principal reto a nivel técnico es poder mantener un equilibrio entre la precisión de la ubicación y el consumo de batería de los dispositivos, con especial incidencia en los *smartphones* al no ser el *tracking* su única función (Birenboim y Shoval 2015). Un intervalo preciso de localizaciones georreferenciadas requiere un uso más intensivo de procesamiento de datos y, por lo tanto, esto requiere un consumo más elevado de energía. Otro desafío es la detección del modo de transporte de los recorridos registrados ya que esta tecnología puede detectar movimientos realizados en distintos modos con velocidades y aceleraciones muy similares (Ferrer y Ruiz 2014). Además, en referencia al diseño del trabajo de campo de un estudio de *tracking*, las muestras de personas suelen ser estadísticamente no representativas a nivel poblacional, como también ocurre en los estudios de carácter cualitativo, debido al elevado coste de la recogida de datos. Sin embargo, estas muestras sí pueden ser representativas del comportamiento de un determinado grupo de población en un determinado contexto. Por último, el reto de la privacidad de los datos georreferenciados es otra cuestión a tener en cuenta en estudios que utilicen datos de *tracking*, ya que la información relativa al sujeto de estudio y sus ubicaciones debe de ser protegida y tratada de manera confidencial, mediante la firma de consentimientos informados y la supervisión de los órganos reguladores de las instituciones académicas.

3.2.3. Nuevas medidas del espacio de actividad

Otra ventaja metodológica de los estudios basados en el *tracking* es la obtención de medidas más realistas del contexto espacial con el que las personas están en contacto. Tradicionalmente, la dimensión espacial del comportamiento humano se ha basado en los límites administrativos de un territorio, ya sean a nivel municipal, de barrio administrativo o de sección censal. Esta aproximación al contexto espacial de las personas ha sido utilizada, por ejemplo, en epidemiología para entender los efectos de la exposición al medio ambiente sobre la salud o para estudiar la desigualdad social en relación a la segregación residencial en ciencias sociales (Matthews y Yang 2013). Sin embargo, esto implica basar el análisis en una imagen no precisa y sesgada del comportamiento espacial de las personas.

Otros métodos tradicionales de cálculo basados en información proveniente de encuestas han permitido obtener mediciones del espacios de actividad de las personas un poco más precisas como son el polígono convexo mínimo, la elipse de desviación estándar o métodos más modernos como los mapas de densidad de puntos de Kernel o las áreas de influencia a través de la red de calles (Patterson y Farber 2015; Sherman et al. 2005). *El polígono convexo mínimo* es una adaptación del rango de movimientos de las especies animales aplicada por los ecólogos que consiste en el cálculo del área dentro del polígono resultante de la unión de las localizaciones más alejadas que un individuo visita (Worton 1987). La *elipse de desviación estándar* resume la dispersión y orientación general de las actividades diarias a través de un polígono elíptico, excluyendo el efecto de las ubicaciones periféricas (Buliung y Kanaroglou 2006). Los mapas de densidad de ubicaciones, como el *mapa de Kernel*, interpolan datos sobre puntos a una superficie continua en función de su densidad (Bailey y Gatrell 1995). Por su lado, los enfoques basados en redes, como el búfer basado en la red de calles, se basan en la noción de que el espacio con las que una personas está en contacto está restringido por las redes de transporte y se calculan creando un área de influencia alrededor de las rutas más cortas que conectan las actividades de una persona (Kwan 1999). Todos estos métodos permiten un cálculo y una representación más o menos sencillos de las áreas de espacios de actividad (en km^2), sin embargo, su imagen sigue siendo sesgada al sobregeneralizar el espacio utilizado real por los individuos.

El sesgo inherente de los métodos de cálculo basados en los censos o en encuestas es conocido como el *Problema del Contexto Geográfico Incierto* (Kwan 2012) o la *trampa local* y ha sido explorado ampliamente en estudios del ámbito de la exposición ambiental (Cummins 2007; Purcell y Brown 2005; Vallée et al. 2014). Esta imprecisión metodológica se debe al carácter dinámico del comportamiento espacial (Gatrell 2011), ya que las personas se desplazan a través del espacio y tiempo continuamente para satisfacer sus necesidades cotidianas en su día a día (Kwan y Schwanen 2018). Para ello, las personas atraviesan los límites de múltiples barrios o áreas residenciales, más allá del suyo, durante el transcurso de un día viéndose influenciadas por diferentes contextos (Matthews y Yang 2013; Sampson, Morenoff, y Gannon-Rowley 2002). En este sentido, la utilización de datos de *tracking*, los cuales son precisos en el tiempo y el espacio, permiten minimizar este sesgo en el análisis de la relación del entorno y el comportamiento espacial de las personas y permitiendo la obtención de nuevas medidas del espacio de actividad de las personas.

Un ejemplo de nuevo método es el denominado *área de ruta diaria*, inspirado en el búfer vía red de calles de Kwan (1999), a través del cual se recoge en tiempo real no solo la ubicación de las actividades cotidianas de las personas sino también las rutas elegidas (Patterson y Farber 2015). Existen en la literatura cada vez más ejemplos de aplicación de este nuevo método, sobretodo en el campo de los estudios en exposición ambiental y la salud (Hirsch et al. 2015; Hirsch, Winters, et al. 2014; Lee et al. 2016; Zenk et al. 2011). Por estos motivos, este método será la base de tres de los casos de estudio de la presente tesis.

3.3. El proceso metodológico de la tesis

Esta investigación se caracteriza por un enfoque multimetodológico, con información de carácter cuantitativo y cualitativo, para comprender la dimensión espacial de la movilidad cotidiana mediante el uso principalmente de datos *smartphone tracking*, con de datos provenientes de una aplicación SoftGIS y entrevistas, y complementadas con datos de una encuesta de movilidad.

El proceso metodológico seguido para responder a las preguntas e hipótesis de investigación se resume en la **Tabla 1**.

Tabla 1. Resumen del proceso metodológico de la tesis.

Pregunta	Hipótesis	Artículo	Escala territorial	Enfoque metodológico	Fuentes de datos	Tipo de análisis
Pregunta 1	Hipótesis 0 Sub-Hip. 1	Artículo 1	RMB	Cualitativo	SoftGIS + Entrevista	Descripción tipológica + preferencias
Pregunta 2	Hipótesis 0, Sub-Hip. 2	Artículo 2	RMB	Cuantitativo	Smartphone tracking app + Encuesta	Descriptivo + Regresión múltiple
Pregunta 3	Hipótesis 0, Sub-Hip. 3	Artículo 3	RMB	Cuantitativo	Smartphone tracking app + Encuesta	Descriptivo + Regresión múltiple
Pregunta 3	Hipótesis 0, Sub-Hip. 4	Artículo 4	Barcelona	Cuantitativo	Capas SIG + Smartphone tracking app + Encuesta	Descriptivo + Regresión múltiple

Fuente: Elaboración propia.

3.3.1. Enfoque cualitativo de la tesis

Con el propósito de responder a la primera pregunta de investigación e hipótesis relacionada, incluida en el primer artículo de la tesis, se ha elegido un enfoque cualitativo. Con el objetivo de obtener la imagen cognitiva del espacio de actividad de personas residentes en la RMB, se planteó un ejercicio de esbozo de mapas cognitivos a través de una aplicación de SoftGIS y en combinación con la realización de entrevistas semiestructuradas. Se pidió a los participantes que dibujaran el espacio utilizado cotidianamente con un polígono y situaran en el mismo mapa una lista cerrada de las actividades diarias que recibían (residencia, lugar de trabajo, compras, ocio, destinos sociales, etc.), mediante la herramienta de creación de mapas de Google Maps©, como se muestra en el **Anexo 12.3**. Esta aplicación permitió a los entrevistados ampliar o disminuir la escala del mapa para buscar la localización de sus actividades cotidianas, utilizando las mismas herramientas de dibujo, hecho que facilitó detectar patrones cognitivos en la conceptualización de la dimensión espacial de la movilidad. El hecho que todos los participantes conocieran Google Maps© y utilizaran sus servicios con más o menos frecuencia ayudó a la realización del ejercicio. Además, las preguntas de la entrevista semiestructurada como complemento del esbozo de mapas cognitivos, que se muestran en el **Anexo 12.4**, posibilitaron la indagación de la percepción espacial de los participantes obteniendo matices, multiplicidad de escalas y opiniones que no podrían detectarse mediante esbozos.

Una vez grabadas todas las entrevistas y recogidos todos los mapas cognitivos, el análisis de datos realizado en el primer artículo fue de carácter temático. A través del análisis temático se identificaron diferentes patrones de representación cartográfica en los mapas, además de temas y grupos estratificados, discursos y opiniones que respondían al objetivo del estudio.

3.3.2. Enfoque cuantitativo de la tesis

Con el objetivo de responder a las preguntas 2, 3 y 4 se optó por emplear una metodología cuantitativa basada en datos de *smartphone tracking* a través de una aplicación (app) para *smartphone*.

En el caso de la segunda pregunta e hipótesis específica, la app elegida para el trabajo de campo fue CAMPUS MOBILITY, la cual sirvió de fuente de datos principal del estudio sobre los patrones de movilidad cotidiana "Campus Mobility 2015", coordinado por el Grup d'Estudis en Mobilitat, Transport i Territori (GEMOTT). Para la realización de este estudio se invitó a los encuestados de la Encuesta de Hábitos de Movilidad de la Comunidad Universitaria de la UAB (EHMCU) de 2015 a participar en él descargando la app CAMPUS MOBILITY desde Google© Play Store© y manteniéndola en funcionamiento en sus dispositivos *smartphone* durante una semana. El motivo de la elección de esta app fue la fiabilidad de su funcionamiento, ya que se basaba en una versión de otra app utilizada previamente para un propósito similar (Palmer et al. 2013). El acceso público a esta app se cerró al terminar la recogida de datos. Para este análisis se utilizó también la información referente al perfil sociodemográfico y a los hábitos de movilidad proveniente de las respuestas de la encuesta EHMCU.

Con el objetivo de afrontar la tercera pregunta de investigación, que se responden a los casos de estudio 3 y 4, se utilizó una metodología similar al seguido en el anterior artículo, pero en este caso a través del proyecto de investigación "Campus Mobility 2017". En este caso, además de los participantes de la edición del 2017 de la Encuesta de Hábitos de Movilidad de la Comunidad Universitaria de la UAB (EHMCU) se realizó una campaña de comunicación en las redes y un proceso de bola de nieve. La app elegida para el proyecto de investigación "Campus Mobility 2017" fue MOVES©, la cual era gratuita y estaba disponible tanto en Google© Play Store© como en Apple Store©. Esta app utiliza también la tecnología GPS y el acelerómetro disponible en los dispositivos *smartphone* para proporcionar rutas recorridas, tiempos de viaje, pasos e incluso calorías diarias consumidas, lugares visitados y modos de transporte utilizados por sus usuarios a lo largo del día (Evenson y Furberg 2017; Queirós et al. 2016). La obtención de los modos de transporte de los usuarios de esta app, su acceso libre y la posibilidad de acceder a datos de los usuarios telemáticamente a través de los servicios API fueron los principales motivos de la elección de esta app. Gracias a esta app, tanto los recorridos geolocalizados para obtener la exposición a espacios verdes como el tiempo caminado diario por cada individuo fueron obtenidos a través de sus algoritmos avanzados basados en la aceleración y velocidad detectada por los dispositivos *smartphone*. A fecha de hoy, esta app ya no está disponible en el mercado de apps comerciales debido al cierre de la empresa desarrolladora. Finalmente, fue utilizada también la información referente al perfil sociodemográfico y sobre hábitos de movilidad que los participantes proveyeron previamente en EHMCU 2017.

En lo referente a la información sobre espacios verdes de la ciudad de Barcelona necesaria para los artículos 3 y 4, se han utilizado tres capas de SIG de acceso público: el Mapa de Usos del Suelo de Barcelona, el Mapa de Calles de Barcelona y el Mapa de Arbolado Viario, disponibles en los portales CartoBCN y Open Data BCN del Ajuntament de Barcelona (Ajuntament de Barcelona 2014, 2016b; BCC 2014). Esta información georreferenciada ha permitido obtener las áreas y localizaciones de distintos tipos de espacios verdes presentes en la ciudad y poder relacionarla con los recorridos a pie obtenidos por la app MOVES© a través de procesos de los SIG.

El análisis de datos realizado en los artículos 2, 3 y 4 se caracterizó por una primera descripción de las diferencias relativas la variable dependiente en cuestión por cada categoría de análisis de las variables independientes que hipotéticamente influyen en el comportamiento espacial. Este tipo de análisis fue seguido por un análisis de regresión para detectar qué variables independientes obtienen un mayor poder explicativo y así poder refutar las hipótesis y responder preguntas planteadas en cada uno de los casos de estudio. Este tipo de datos nos permitió analizar no solo diferencias entre individuos sino también a diferencias dentro de un mismo individuo al permitir a acceder a datos sobre geolocalizaciones de más de un día de participación. Por este motivo, la unidad de análisis utilizada de los artículos 2 y 4 son los *días de participación* de cada individuo, ya sea expresado por el área diaria de los espacios de actividad en el segundo artículo o a través del tiempo caminado diario en el cuarto artículo de esta tesis.

PARTE II

4. The scales of the metropolis: Exploring cognitive maps using a qualitative approach based on SoftGIS software

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The scales of the metropolis: Exploring cognitive maps using a qualitative approach based on SoftGIS software

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ABSTRACT

The spatial dimension of daily mobility depends on where people choose to perform their daily activities in urban environments. This study explores the influence of multiple geographical scales, characterising metropolitan regions on the cognitive images of individuals, whose daily mobility is restricted by an interurban daily commute to a university campus in the Metropolitan Region of Barcelona.

To do so, a sample of 28 adults from the Barcelona Metropolitan Region (RMB) were asked to describe perceived activity spaces using a combination of SoftGIS technology and interviews. Results have shown that different individuals can perceive the same geographic context in several manners, differentiating their utilised space between spatial continuums, fragmented territories or overlaid territories. Furthermore, factors such as the different spatial scales that affect a territory, the morphological characteristics of residential areas or the transport infrastructures, have proven to influence cognitive maps of individuals. Finally, different methods utilised for the exploration of cognitive maps have provided variations in the resulting cognitive images of participants.

Vich, G., Marquet, O. y Miralles-Guasch, C. (2017). Suburban Commuting and Activity Spaces: Using Smartphone Tracking Data to Understand the Spatial Extent of Travel Behaviour. *The Geographical Journal* 183(4): 426–39. doi.org/10.1016/j.geoforum.2017.11.009

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4.1. Introduction

The spatial scale at which everyday activities are located determines the daily travel costs for residents of metropolitan regions and the consequent transport-related externalities (Banister 2008; Ewing et al. 2016). Therefore, understanding the determinants affecting the spatial behaviour of metropolitan residents is essential for urban policymakers when tackling these externalities (Buliung y Kanaroglou 2006).

As well as the environmental setting and the sociodemographic characteristics (Fan y Khattak 2008), the structure of the extent of daily mobility of individuals, or activity space (Horton y Reynolds 1971) is influenced by an individual's cognitive image of the real world (Downs y Stea 1973). According to psychological and urban studies, the information required to understand where things are and how to get to where those things are is stored in the cognitive map of individuals, hence, becoming essential for spatial behaviour and decision-making (Gärling 1989). In consequence, such decisions and behaviour have an effect on where to carry out daily activities, and the routes and the mode of transport to be utilised between destinations (Kitchin 1994).

This study explores the influence of multiple geographical scales in metropolitan regions on the cognitive images of individuals. For this purpose, SoftGIS mapping exercises and interviews were used to obtain the cognitive maps of the territory utilised by a sample of 28 adults, whose daily mobility is constrained by an interurban daily trip to a university campus in the Barcelona Metropolitan Region (RMB).

This paper is structured as follows: Section 2 delves into the theoretical aspects of the concept of activity space and its explanatory factors, such as cognitive images. Section 3 contextualises the campus of the Autonomous University of Barcelona (UAB) within the RMB and the utilised methods and data for the analysis. Section 4 presents the resulting qualitative analysis. In Section 5, the main results are contextualised with past studies. Section 6 concludes and outlines future lines of research in this field.

4.2. Background

Dispersion, integration and specialisation are spatial dynamics that characterise metropolitan regions and imply increased travel distances and times (Banister 2008). However, these have been complemented by other urban dynamics such as urban proximity, which relates to the use of the immediate urban environment by residents in order to meet daily needs (Calonge Reillo 2017; Mateu, Seguí, y Ruiz 2017; Schmid, Sahr, y Urry 2011). These dynamics are characterised by the agglomeration of activities and the intensive use of space, while facilitating human interaction, economic efficiency and social cohesion (Huriot 1998), requiring certain morphological features such as urban compactness and density (Miralles-Guasch y Marquet 2013). Thus, the recognition of this duality of urban dynamics (expansion and proximity) evidences the coexistence of different relational layers at a particular place of interaction in urban contexts (Massey 1994), and the multiscale character of urban areas by linking the neighbourhood, the city and the metropolitan region (Atkinson, Dowling, y McGuirk 2009).

Consequently, these spatial dynamics influence the utilised space by metropolitan residents in their everyday life. This daily space, also known as activity space, is structured by the locations with which people have direct contact on a daily basis (Horton y Reynolds 1971) and has been a generally accepted measure of the geographic extent of the daily mobility of individuals (Gesler y Meade 1988; Vich, Marquet, y Miralles-Guasch 2017). However, the environmental factors influencing the extent of everyday life alone, such as physical distances between activities, might not fully explain spatial behaviour.

The anisotropic character of actual urban spaces means that spatial distances can be shaped by the combination of both objective and subjective factors, making perceptions, beliefs and preferences important determinants of spatial behaviour (Dumolard 2011). For this reason, the built environment also acquires certain subjective qualities due to the perceptions of individuals related to, for example, what may be physically reachable (Horton y Reynolds 1971). The mental configuration of the environment is the psychological process "by which an individual acquires, codes, stores, recalls and decodes information about the relative locations and attributes of phenomena in his everyday spatial environment" (Downs y Stea 1973:8), and can be represented through cognitive (or mental) maps.

This visual representation of cognitive structures is believed to internally delimit the external borders of people's activity space in their own minds (Greenberg Raanan y Shoval 2014) and, therefore, influence spatial decisions of individuals over both the short and long term (Gärling 1989; Golledge y Stimson 1987; Lynch 1960). Decisions on where to reside or work, and the locations, destinations for recreational activities, and how to travel between destinations also depend on the cognitive images of the surrounding environment of the individual (Downs y Stea 1977). In an urban context, these spatial decisions may represent consequences for the territory, such as rising levels of energy consumption, air pollution and increasing investment in transport infrastructure, and loss of agricultural land and open space (Ewing et al. 2016).

The study of cognitive mapping within behavioural geography reached its heyday in the 1960s and 1970s. One of the main focal points was the exploration of how individuals built and organised spatial information in their own minds, in other words, how these mental structures evolve through learning (Downs y Stea 1973). Cognitive maps were also used to understand the nature of preferential cognition with regards to the environment, with special mention to the work of

Peter Gould and Rodney White in Mental Maps (1986:15). Finally, a very successful body of research, in which the present study falls, analyses the processes of cognition of urban environments or urban imagery, with the remarkable contribution by Kevin Lynch (1960) of The Image of the City, highlighting the five elements forming cognitive spatial structures, which was later followed by Donald Appleyard (1970): pathways (streets, roads, trails…) along which people travel, edges or boundaries (walls, buildings, and shorelines), districts/neighbourhoods, meaning relatively large areas within cities with particular identity, focal points such as nodes and, finally, landmarks or identifiable objects serving as reference points.

In the late 1970s, the study of cognitive maps and environmental cognition was relegated to the field of geography due to the dominance of radical and humanistic approaches that considered such research as conceptually and methodologically flawed. Common criticism included the omission of economic and social conditions of individuals (Rieser 1973) and their precognitive background emanating from the history, art, literature or religion, with which to understand people's behaviour (Tuan 1976). In terms of methodology, methods often utilised in those days, such as ranking procedures or the sketching of cartographic maps, were regarded as being highly dependent on abilities to draw maps and upon education, hence, resulting in imperfect representations of spatial cognition (Blaut et al. 1970).

After years of relegation within geography, a rekindled interest for cognitive and behavioural methodologies, such as cognitive maps, has emerged due to two main reasons. Firstly, the combination of sociodemographic characteristics of the population (age, gender, etc.) with psychological processes to understand human behaviour, instead of solely focusing on the latter, is gaining acceptance in geography. The use and perception of large-scale environments by particular sociodemographic groups through their cognitive boundaries is now a common field of study (Argent 2017; Walmsley y Lewis 1993). An example of that would be to understand how children, seniors or women perceive and represent their residential neighbourhood. Recent evidence shows that cognitive boundaries and used spaces do not coincide with administrative limits of neighbourhoods, census tracts or residential buffers, hence, they prove to be more accurate representations of their geographic scale of their everyday life (Robinson y Oreskovic 2013; Smith et al. 2010; Stewart, Duncan, y Schipperijn 2017; Veitch, Salmon, y Ball 2008). This coincidence between perceived and used territories is also confirmed by Greenberg Raanan and Shoval (2014) who explore the cognitive maps and GPS tracks of adult women in the highly segregated city of Jerusalem. Another area of study that takes into account cognitive processes influencing human behaviour is transport and urban planning (Arentze y Timmermans 2005; Gehrke y Clifton 2015). In this line, Mondschein et al. (2010) and Minaei (2014) analysed the differences in mental representations of the cities of Los Angeles (USA) and London (UK) by commuters travelling using different transport modes. Although some classic research from the 1970s already analysed the legibility and desirability of predefined administrative limits of metropolitan regions through cognitive maps (Johnston 1972; Pacione 1977), no recent examples could be found which explore the cognitive representation of the experienced activity spaces and the influence of geographic scales in metropolitan regions.

Secondly, the development of sophisticated quantitative methodologies and the appearance of new technologies, such as Geographical Information Systems (GIS), also helped to maintain the interest in cognitive mapping (Gold 2009). Furthermore, a geography-based approach in focusing on cognitive behaviour of specific population groups within a population, such as children or the elderly, continued being active and also continued yielding vast amounts of research. Issues such as the development of environmental cognition and its pedagogic implications, the usage of territories and facilities, spatial preferences and perceptual constraints, among others, are still being studied and applied in policymaking (Argent 2017). Advances in technology have also played a key role in allowing to collect, standardise and process large amounts of geographic information. Within GIS-derived applications, SoftGIS can be highlighted as containing useful tools for obtaining cognitive maps of individuals. Interactive on-line mapping applications, such as Google Maps© and Open Street Maps, allow the collection of spatial knowledge such as locations, routes and the delimitation of areas, while minimising memory bias (Chaix et al. 2012; Jarvis, Kraftl, y Dickie 2017), and are normally included in surveys or interviews (Rantanen y Kahila 2009). Whether used on computers, tablets or smartphones, these mapping applications are becoming a common tool of daily use among young people for wayfinding, since they provide 'up-to-date', scalable, 'more easily accessible' spatial information, standardising the drawing abilities of participants and, in consequence, they minimise the use of paper maps for research purposes (Leyshon et al. 2013). Existing studies have implemented this technique to explore, for instance, the barriers and facilitators of active transport among children (Broberg et al. 2013) and this technique has also recently been used to explore children's spatial literacy (Jarvis et al. 2017). Nonetheless, only on few occasions has this method been used to explore the perception of boundaries of spatial behaviour (Stewart et al. 2015). Although cartographic maps have traditionally been common tools for extracting the cognitive images of individuals for their closest resemblance to familiar territories (Gärling et al. 1984), cognitive maps may not always have the same functions as cartographic maps, since they do not always share the same pictorial characteristics (Blaut et al. 1970). Even though representing cognitive maps with SoftGIS methodologies could be constrained by the fixed planar characteristics of cartographic maps, the intractability and flexibility of this technology make them a useful method to obtain the boundaries, locations, shapes or structures and the scale of cognitive maps.

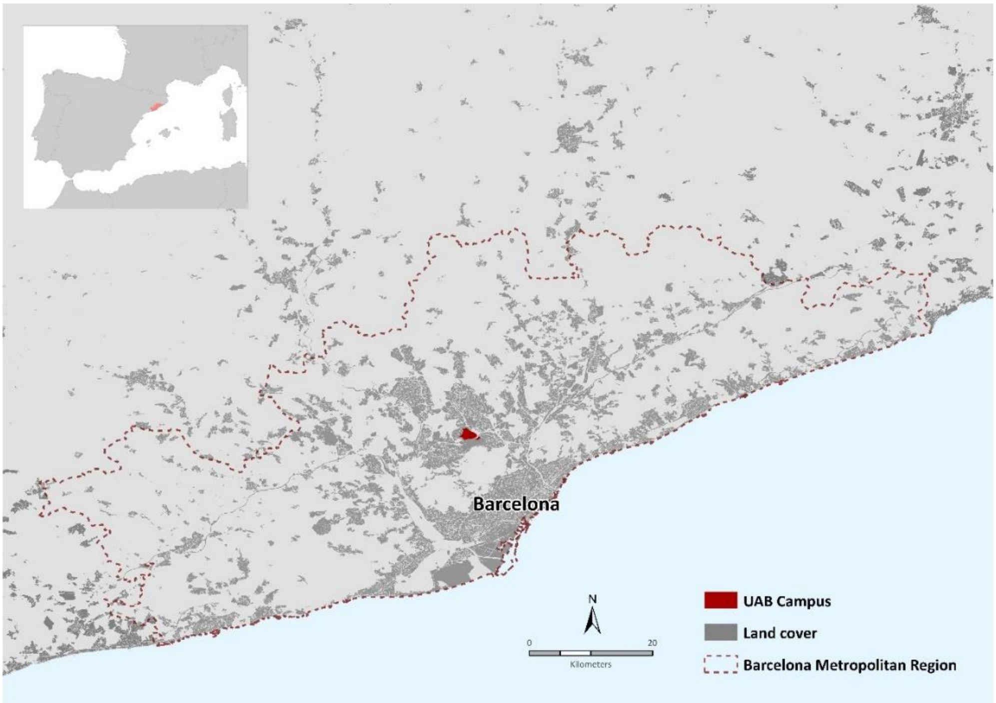
4.3. Methodology

4.3.1. Study area

The present study is focused on the members of the university community of the UAB that travel daily to the suburban location of its campus in the Barcelona Metropolitan Region (RMB) (**Figure 11**). The RMB is a region that is situated in the northeast of Spain and accounts for approximately 5 million inhabitants, 164 municipalities and covers an area of 3,242 km^2 and can be divided into two functional rings. In this line, the RMB represents an optimal example of a dual model of urban growth, since it alternates between the compact and the sprawling city types (Marmolejo y Cerda Troncoso 2017; Miralles-Guasch y Tulla-Pujol 2012).

The UAB campus is an important economic and knowledge node for the territory (Miralles-Guasch 2010). The suburban location of this campus makes this community an optimal example of the type of economically active population (18-64 years of age) whose daily mobility is constrained by an interurban commute that is generally carried out using motorised transport. The campus is located approximately 15 km from Barcelona city centre within the second ring, is connected with two major motorways (AP-7 and C-58) and includes three inner-campus train stations that link directly to Barcelona and other surrounding cities (Miralles-Guasch y Domene 2010) (see **Figure 11**).

Figure 11. The UAB campus in the Barcelona Metropolitan Region (RMB).



Source: Own production.

4.3.2. Sample

Participants in the study were contacted through the database of respondents of the UAB's biannual Survey on Mobility Habits, carried out by the university in April-May 2015. These were selected through a process of purposive sampling following the selection criteria of: 1) Residing in the RMB, 2) Being a member of the UAB, 3) Commuting to the UAB campus using motorised transport (private vehicle or public transport). From a total of 33 people that were contacted, 28 commuters to the UAB campus were finally interviewed, since 3 commuted to the UAB by bicycle and 2 others lived outside of the RMB.

Information on their sociodemographic profiles, based on age and gender, were extracted from the survey, and the level of land-use mixticity of their residential areas was used in order to classify the types of interviewees. Differences between monofunctional and mixed-used environments were extracted from the interviews, in which participants were asked to locate their everyday destinations (residence, work, groceries, socialising, and leisure). If more than 2 destinations were located at a walkable distance (15 minutes) from home, their residential area was considered as mixed-used, whereas, if only 1 or 2 destinations could be walked to, these areas were considered as monofunctional. When large-scale environments such as neighbourhood, town or county are mentioned in the text, they refer to the different levels of spatial scales perceived by participants.

These characteristics are summarised in **Table 2**. Participants commuted to the campus using public (14) or private transport (14). Their homes were located mostly in a mixed-used environment (21) that allowed walking to most daily destinations, although some other individuals lived in monofunctional and car-dependent residential areas (7). Regarding their sociodemographic characteristics, there were 15 male and 13 female participants, and their ages are comprised between 18-29 (9), 30-39 (10) and 40-64 (9) years. For confidentiality reasons, each participant was attributed with his/her initials using the Initials_Gender_Age (e.g. E_W_38) format.

Table 2. Main characteristics of the 28 interviewees.

n	Code (Initial_Gender_Age)	Commuting mode	Level of land use mix	Commuting distance to the campus (km)
1	A_W_21	Public	Monofunctional	13.87
2	J_M_22	Public	Monofunctional	19.50
3	S_M_23	Public	Mixed use	9.11
4	D_M_24	Private	Monofunctional	22.70
5	X_M_24	Public	Mixed use	11.03
6	M_W_27	Private	Mixed use	9.25
7	M_W_28	Private	Monofunctional	46.04
8	V_W_28	Public	Mixed use	11.54
9	O_M_29	Public	Mixed use	3.38
10	C_W_31	Public	Mixed use	10.19
11	J_W_32	Private	Monofunctional	49.29
12	A_M_33	Public	Mixed use	10.60
13	A_M_34	Public	Mixed use	48.13
14	D_M_36	Private	Monofunctional	43.25
15	A_M_37	Public	Mixed use	5.01
16	I_M_38	Private	Mixed use	9.69
17	G_W_39	Private	Mixed use	7.93
18	R_M_39	Public	Mixed use	10.13
19	J_M_39	Private	Mixed use	11.55
20	F_M_42	Public	Mixed use	2.34
21	M_W_42	Private	Monofunctional	2.27
22	F_M_44	Public	Mixed use	9.97
23	B_W_45	Private	Mixed use	8.08
24	M_M_47	Public	Mixed use	13.45
25	J_M_48	Private	Monofunctional	20.28
26	P_W_50	Private	Mixed use	8.32
27	T_W_56	Private/Public	Mixed use	2.13
28	J_M_63	Private	Mixed use	10.23

Source: Own production.

4.3.3. Data collection

The aim was to detect the cognitive image of the activity space of a group of economically active adults that commute to a suburban location using motorised transport modes. Since the qualitative methodology applied in this work could not statistically generalise its results, the main aim was to analytically generalise the cognitive image and discourses that were detected throughout the experiment. The mapping exercises and interviews were mostly held in December 2015 within the Department of Geography in order to secure the optimal technology conditions (computer and Internet connection), although, on several occasions the interviewers displaced themselves to the work place of the interviewees when requested.

Data were collected during 30 to 45 minutes through two map-sketching exercises combined with a series of interviews to obtain 3 types of information: a sketch map, an activity map and an oral map. Firstly, in order to obtain a sketch map, participants were asked to recall and refresh the main everyday activities via two questions: "What activities do you carry out in an average working week? Where are these located?". Then, participants were asked to draw a geometric polygon, the area of which would include their weekly activities using the shape-making tool provided by Google Maps©. The aim was to obtain their cognitive map, in other words, to measure how they perceive the boundaries of the spatial extension of their daily activities. Secondly, for obtaining the activity map, participants were asked to place on the same map a closed list of everyday activities they were provided (residence, workplace, groceries, leisure, social destinations, etc.), using the marker tool from Google Maps©. The purpose of this exercise was to delve into the reason for choosing the location of these activities and to detect which activities were not considered or were forgotten when delimiting the boundaries of their activity space. Then, these two maps were later tested against the spatial perception obtained by using the questions from the interviews, in order to gather further information that was not accessible from cartographic maps (Blaut et al. 1970). After the two first exercises, a series of open questions were asked to qualitatively assess the information previously provided and, therefore, to delve into the cognitive image of their everyday environment. Interviewees had to give their opinion during 10 minutes on the following topics: the reasons behind the shape of their sketch maps, the assessment of the closeness or farness of daily activities from home (in time units) and the reasons for choosing their daily destinations. After recording all the interviews, a thematic analysis was performed using the results. Different themes and stratified groups were identified after reviewing the obtained maps and transcript interviews and were assigned to the objectives of the study. The analysis in this study does not try to generalise, but rather aims at situating the discourses and opinions in this specific context.

4.4. Results

4.4.1. The perception of the activity space at one single scale

Most metropolitan residents in this study identify their activity space with the whole metropolitan area, since their daily activities are spread throughout different parts of this territory. This spatial dispersion of activities was represented through a cognitive image of activity spaces as polygons at one scale, the metropolitan scale. However, this single scale space was also represented either as a unit or as a group of fragmented entities. These two types of representation of the everyday spatial extent have been manifested through the exploration of the different methodologies used in the study.

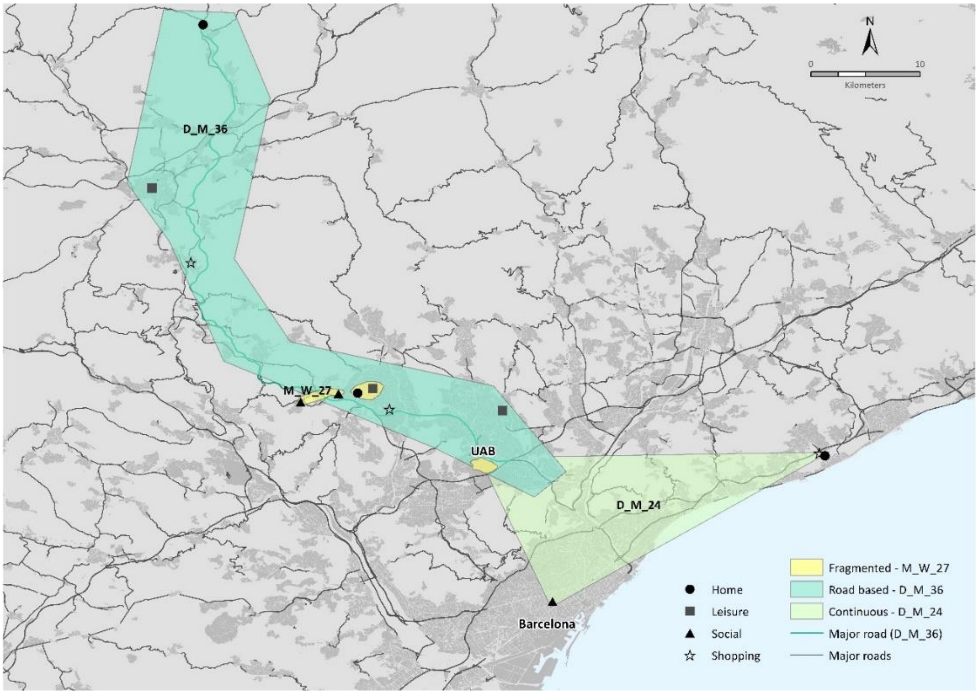
As **Table 3** shows, the sketch maps of participants drawing a single figure acquired two different shapes. This single figure was either identified as the generalisation of the everyday space utilised (see sketch from participant D_M_24 in **Figure 12**) or as a space following the road infrastructure used in their commute (see sketch from participant D_M_36 in **Figure 12**). Regarding the exact position of daily destinations from their activity's maps (UAB campus, home, shops, leisure, social and personal destinations), these were placed at the vertices of the drawings. Furthermore, the oral maps corroborated the same cognitive image of a territory perceived as a unit and including their daily activities across different parts of the Barcelona Metropolitan Region:

D_M_24: *My activities are all very scattered across the map, but for me it is a unit.*

This representation of the activity space at a metropolitan scale and drawn as a single territory is also related to explanatory factors such as the use of private transport, since obtained cognitive maps identified the daily routes utilised through roads and motorways, being more evident in a sketch from participant D_M_36 rather than from participant D_M_24. It is noteworthy that all of these residents lived in monofunctional residential areas, as seen in **Table 2**, in which there is a lack of many everyday services (shops, leisure, social activities, etc.) and residents are forced to drive a motorised vehicle in order to reach all of their daily destinations, hence, enlarging the boundaries of their daily perceived utilised space outside their residential areas:

J_M_48: *Our village is well located since we have the campus and all daily amenities within 20-30 minutes driving distance to the neighbouring towns.*

Figure 12. Perceived activity spaces at one single scale.



Source: Own production.

However, sketch maps and activities maps did not always coincide with the orally-described cognitive image, since a contradiction between the visual and the oral description was evidenced among some participants. Although their activity space is represented as a unit in the sketch map and their daily activities were located at the vertices of these figures spread across the territory, these individuals declared experiencing a distinction between the space around the UAB campus and the territory surrounding the rest of their activities:

D_M_36: *The UAB is far from home and even more so if I get into traffic jams. I see it as something separate. In my everyday life I distribute my activities around the county, but not in my own town.*

These cognitive maps, expressed as the sum of fragmented territories, were also detected in the sketch maps of other participants (see sketch from participant M_W_27 in **Figure 12**). In them, a group of drawn areas included the different daily destinations, evidencing a representation of the functional separation of the RMB. In this case, the locations of the activities maps were placed inside each of the multiple independent spaces. Their comments in their oral maps highlighted the perception of space surrounding their home and daily activities as more familiar and unconnected from the space surrounding the UAB campus:

M_M_44: *For me, home and work are two separate spaces. Between the campus and my home there is an empty space.*

This perception of the region as a fragmented territory can be explained by the increased distances due to expansive and functional segregation developments, since participants with this type of cognitive image live further away from the campus than other participants.

4.4.2. The perception of the activity space at two different scales

The cognitive image of activity spaces of residents in this metropolitan region showed other particularities. Some participants experienced the influence of another spatial dynamic within the overall utilised space at a metropolitan scale, which is spatial proximity. This resulted in the perception a duality of territorial scales including, simultaneously, distant (metropolitan) and close (neighbourhood) spaces from the place of residence. However, these different spatial dimensions of their everyday life could not be detected by all of the methodologies used in this study.

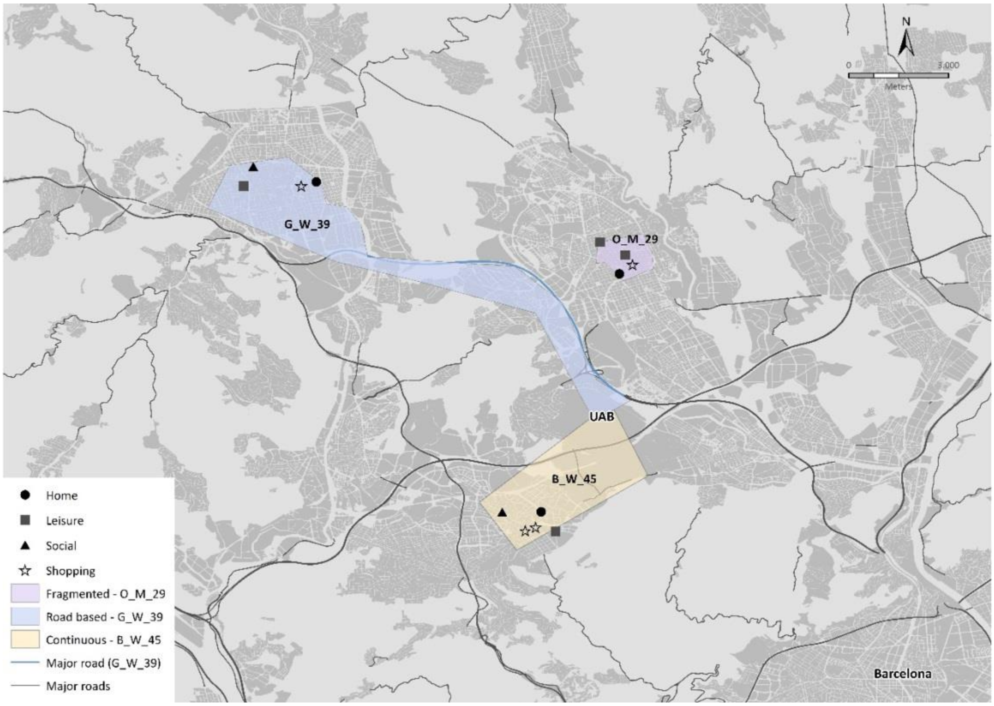
As **Figure 13** shows, while the obtained sketch maps highlight the shape of one single figure at a metropolitan scale, the activities maps and oral maps contradict the initial sketches, signalling a clear distribution of daily destinations at both metropolitan and neighbourhood levels. These locations were clustered around their place of residence, normally at a walkable distance, but also placed the location of the UAB at a further distance. See the sketch from participant B_W_45 in **Figure 13**:

B_W_45: *Apart from my workplace at the campus, I have most of my daily activities within walking distance. I really like it because I get very stressed when riding my motorbike to work every day.*

The transport infrastructure also proved to influence on the perception of the spatial scale of everyday activities on residents experiencing this duality of scales. In this case, the obtained sketch maps, represented as one single polygon, also imply the representation of both the utilised road and railways infrastructures. Moreover, in some cases, the areas surrounding the residence and the UAB campus are clearly identifiable, but are connected through the transport infrastructure (see the sketch from participant G_W_39 in **Figure 3**):

G_W_39: *My daily activity is characterised by my main trip to and from the UAB and the rest is spread locally around my hometown.*

Figura 13. Perceived activity space at two different scales.



Source: Own production.

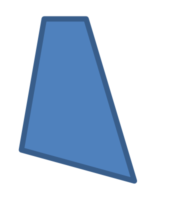
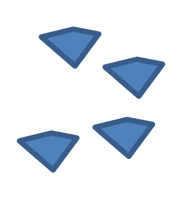
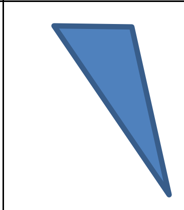
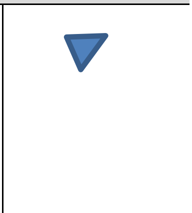
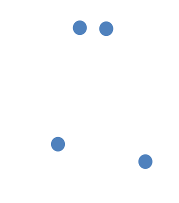
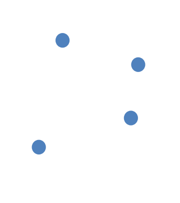
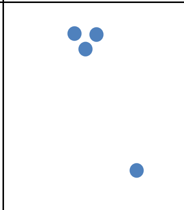
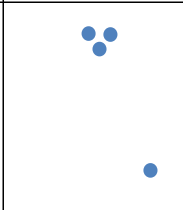
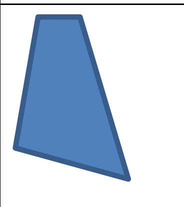
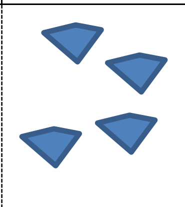
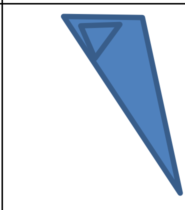
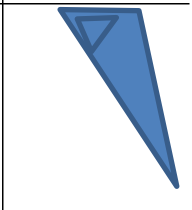
The distance between place of work and residence was also related to differences in the spatial perception among individuals when experiencing a duality of scales of everyday life. Among those living further away from the UAB campus, the space referring to the neighbourhood was highlighted as being more important for them to the detriment of the space implied by the commute to the UAB campus (see the sketch from participant O_M_29 in **Figure 13**). It was at a later stage, when locating daily destinations and the oral description of their cognitive image, that they admitted the perception of these two territorial scales:

O_M_29: *Yes, the campus is there, i.e. outside of Barcelona, but the most important part for me is my life in Barcelona.*

Finally, the perception of this duality of territorial scales in their activity spaces has been specifically detected among residents in urban areas that are characterised by a mixture of land uses. The morphology of these areas, allowing the access to most of their daily destinations on foot, has proven to be a determining factor of their cognitive image, implying a differentiation between the spaces surrounding residential areas from the spaces that include the UAB campus.

To summarise the results, they show how the everyday life of these participants fully occurs within the territory of the RMB, although the perception of this metropolitan space varies across participants and methods utilised to capture the cognitive image of activity spaces. As **Table 3** shows, the perception of the scale can be divided into two levels, one identified with the whole of the metropolis, and another that superimposes the neighbourhood scale onto the metropolis. The shapes of extracted cognitive maps relate to a territory that is understood as a unit, as a fragmentation or as multiple overlaid spaces. These particularities and nuances have been detected differently across the utilised methods to obtain the cognitive maps of participants: sketch maps, activities maps and oral maps. Finally, the characteristics of the residential area, the commuting distance and utilised transport mode of individuals have proven to influence on their cognitive maps.

Table 3. Different perceived scales and shapes of activity spaces, across three cognitive map methods.

Results	*Scale*	**Metropolitan**		**Metropolitan + Neighbourhood**	
	Shape	**Unit**	**Fragmented**	**Overlaid**	
Method	*Sketch map*				
	Activities map				
	Oral map				
Explanatory factor of cognitive differences		**Transport mode** **Land use mix**	**Distance between functions**	**Transport mode** **Land use mix**	**Distance between functions**

Source: Own production.

4.5. Discussion

The main finding of this study is the corroboration of relational geography and planning postulates by which spatial scales should not be understood as nested hierarchies, but rather as extensions in space (and time) connecting many discontinuous sites in different networks (Healey 2004; Massey 1994). Within this conceptualisation, social relationships can be shaped in spatial 'warps' and 'folds' (Amin y Thrift 2002) or 'bits' (Mitchell 1995), as was detected in the results of the study, with participants representing their cognitive maps at different scales (i.e.

metropolitan, proximity or dual) and shapes (i.e. single unit, overlaid spaces and fragmented territories). Moreover, this study adds to the body of research within behavioural geography and cognitive mapping by exploring the imagery and legibility of urban environments as initiated by Lynch (1960), proving that cognitive processes can allow specific groups of population, in this case urban commuters, to perceive the same geographic context in different ways (Marquet y Miralles-Guasch 2014; Matthews y Yang 2013).

The first evidence of the results shows that residents living in this region perceive the spatial distribution of activities at a metropolitan scale, since participants' activities are spread across the territory, as demonstrated by sketched and oral cognitive maps. A clear example of this can be seen in those cognitive maps which represent, in the terminology of Lynch, the boundaries of their territory as a single-scale spatial continuum which includes their place of residence, the UAB campus and the rest of their daily activities at the edges. This proves how the increasing the distance between activities in metropolitan contexts can be perceived and represented in cognitive maps as large extent territories. This coincides with studies that objective measure the scale of activity spaces in order to explore the effects of suburbanisation and urban expansion processes in everyday life (Buliung y Kanaroglou 2006; Vich et al. 2017). This type of perception, expressed as a spatial continuum, could represent cognitive images of the whole territory as an easily reachable space, especially through the use of private vehicles. In fact, previous research has proven how access to private vehicles is associated with perceiving job opportunities in less spatially constrained ways, since these can be searched for in larger geographical areas with respect to work (Holzer y Reaser 2000; Stoll 1999). The consequent spatial behaviour derived from this kind of perception often creates well known externalities such as traffic congestion, increased energy consumption or air pollution (Ewing et al. 2016).

Some cognitive images obtained in this study represent small-scale boundaries within or attached to the larger-scale activity space that include non-work daily destinations, forming what previous authors describe as 'folds' (Amin y Thrift 2002), which can be explained by the dual model of urban development of the RMB, characterised by multiple territorial scales (Marmolejo y Cerda Troncoso 2017; Miralles-Guasch y Tulla-Pujol 2012). This differentiation of regions within cognitive maps is also confirmed by other participants representing their activity spaces as a fragmented territory, not overlaid, in which different parts correspond to different daily destinations (residence, work, leisure, etc.), in other words, what relational geographers describe as 'bits' (Mitchell 1995). This functional regionalising of cognitive territories as overlaid or fragmented can also be linked with the concept of anchor points, previously introduced by behavioural geographers, by which nodes or reference points, such as workplaces or residences, anchor differentiated regions in the cognitive maps in any given environment (Couclelis et al. 1987). Recent studies confirm these findings from Robinson and Oreskovic (2013) with adolescents also perceiving their neighbourhood limits as multiple non-contiguous areas, and also from Minaei (2014) with the finding of an association between the cognitive regionalisation of the territory and the daily use of GPS navigation services in London.

Within regionalised cognitive images of territories, local environments have proven to acquire high relevance among many participants. This can be explained by a common attachment of residents in metropolitan areas to their neighbourhood and a preference for its environmental setting (Johnston 1972; Lovejoy, Handy, y Mokhtarian 2010). This preference for local environments might also have consequences for spatial behaviour, being potentially beneficial in terms of transport-related externalities, especially if the urban morphology of preferred residential areas allows the creation of urban proximity dynamics.

Another idea appearing in this study is the importance of the pathways connecting origins, nodes and destinations. Among many participants in this study, the utilised transport infrastructure (roads and railways) was made clearly identifiable in their perceived image of activity spaces. This is particularly relevant since this group of commuters uses the same pathway on a daily basis to reach the university campus and, therefore, it becomes an important structural part of their cognitive image of the real world that connects their everyday destinations. Lynch (1960) and Appleyard (1970) also found that some people represent cognitive maps as complete road systems, probably due to the recurrence of the journey and familiarity with the map of the city. More recently, Minaei (2014) also found a higher positive correlation between car usage and the structuring of cognitive maps via the roads of a city.

In terms of methodology, this study delves into the quest for optimal measurements of the geographical scale at which characteristics of built environment influence individuals (Gehrke y Clifton 2015; Matthews y Yang 2013). Cognitive maps prove to be more realistic representations of the utilised space compared to the administrative limits of neighbourhoods or census tracts, corroborating the previous literature which notes that everyday life also occurs in locations away from residential areas (Inagami, Cohen, y Finch 2007; Stewart et al. 2015; Vallée et al. 2014). Moreover, SoftGIS applications in combination with oral descriptions of cognitive maps have proven to describe the cognitive image of the real world more accurately, since the sole use of two-dimensional boundaries from cartographic maps would fail to represent multiple and overlaid spatial scales of cognitive maps.

4.6. Conclusions

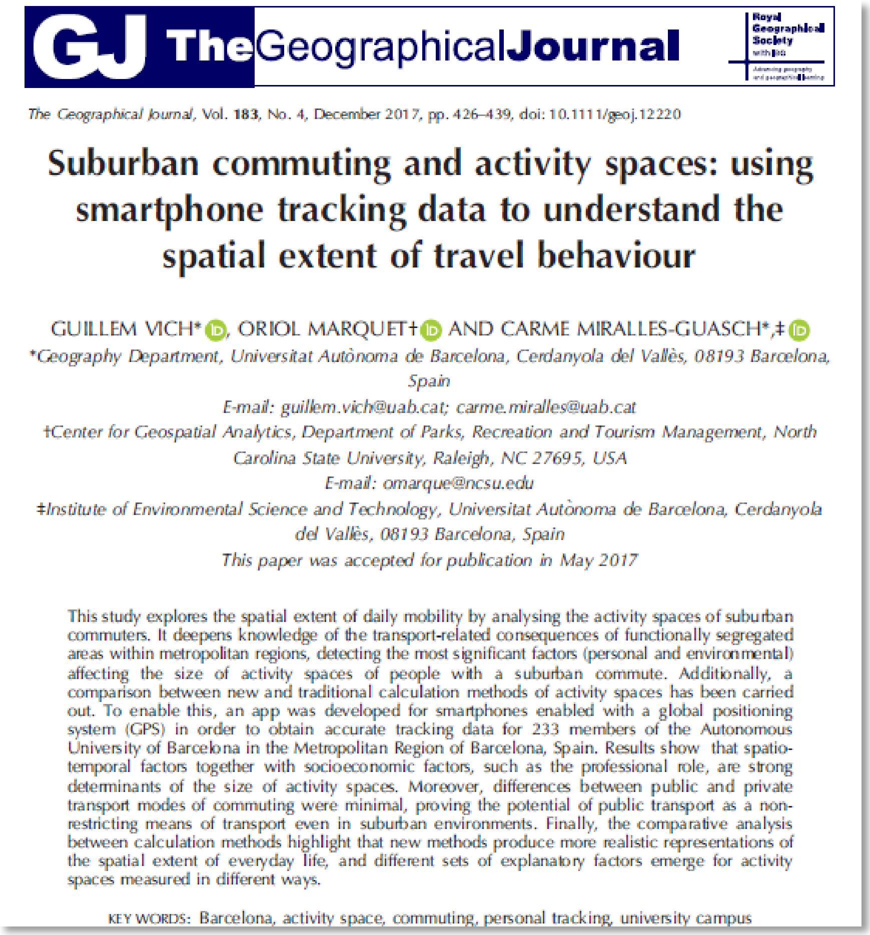
This study has explored the influence of the geographical scale on the cognitive images of the activity spaces of individuals residing in a large-scale territory that is characterised by multiple spatial dynamics. In order to achieve this, a sample of economically-active residents of the Barcelona Metropolitan Region with a constraining interurban commute to a suburban location was selected. The cognitive images of their activity space were obtained and analysed by using two SoftGIS map-sketching exercises and their oral descriptions from semi-structured interviews.

The present work has confirmed that a single territory can be perceived differently and that the diversity of functions and the mode of transport influence this perception. Our study finds that functional segregation leads to a perception of a metropolitan territory as broadly reachable by means of motorised transport, although residents experiencing proximity dynamics also perceive the smaller-scale local environment within larger spaces, which are usually preferred.

The utilisation of cognitive maps to explore the perception of large-scale environments adds to the re-born focus on cognitive-behavioural approaches in geography (Gold 2009). The use of three different techniques to capture the cognitive maps of participants has proven the importance of the election of method. In this case, SoftGIS tools have been useful to obtain the boundaries, location, shape or structure, size or scale of perceived activity space, but it has been the inclusion of oral representations of cognitive images that allow to obtain the perception of different urban spatial dynamics in play at a specific place, that the simple drawing of cognitive boundaries would not have been able to detect.

Finally, we have deepened knowledge of the cognitive image of the real world which provides insight for urban planning and transportation policies regarding urban accessibility challenges. The perception of a regionalised territory and preference for residential areas, as shown in this study, can encourage planners to enforce proximity dynamics while minimising transport-related externalities (Ewing et al. 2016). Moreover, since cognitive maps inform on how places, travelling distances or transport infrastructures are perceived; this knowledge provides a basic foundation for policymakers to understand spatial decisions, such as where to reside, where to look for job opportunities or leisure activities and how to travel between destinations (Delclòs-Alió y Miralles-Guasch 2017; Mondschein et al. 2010). Therefore, this study challenges the utility maximisation preconception of physical distance as the main determinant of spatial behaviour.

5. Suburban commuting and activity spaces: using smartphone tracking data to understand the spatial extent of travel behaviour



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Suburban commuting and activity spaces: using smartphone tracking data to understand the spatial extent of travel behaviour

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This study explores the spatial extent of daily mobility by analysing the activity spaces of suburban commuters. It deepens knowledge of the transport-related consequences of functionally segregated areas within metropolitan regions, detecting the most significant factors (personal and environmental) affecting the size of activity spaces of people with a suburban commute. Additionally, a comparison between new and traditional calculation methods of activity spaces has been carried out. To enable this, an app was developed for smartphones enabled with a global positioning system (GPS) in order to obtain accurate tracking data for 233 members of the Autonomous University of Barcelona in the Metropolitan Region of Barcelona, Spain. Results show that spatio-temporal factors together with socioeconomic factors, such as the professional role, are strong determinants of the size of activity spaces. Moreover, differences between public and private transport modes of commuting were minimal, proving the potential of public transport as a non-restricting means of transport even in suburban environments. Finally, the comparative analysis between calculation methods highlight that new methods produce more realistic representations of the spatial extent of everyday life, and different sets of explanatory factors emerge for activity spaces measured in different ways.

KEY WORDS: Barcelona, activity space, commuting, personal tracking, university campus

Vich, G., Marquet, O. y Miralles-Guasch, C. (2018) “The Scales of the Metropolis: Exploring Cognitive Maps Using a Qualitative Approach Based on SoftGIS Software.” Geoforum 88 (November 2017): 49–56. doi/abs/10.1111/geoj.12220

Factor de Impacto: 2,566 ; **Clasificación:** Primer cuartil en *Geografía* (Q1)

5.1. Introduction

Functional segregation and sprawling patterns of land development have long been acknowledged as major determinants of the character of everyday mobility in metropolitan regions, as a result of the increased trip lengths and frequencies that they generate (Banister 2008; Ewing et al. 2016). In consequence, transport-related externalities such as car dependence, traffic congestion, fuel consumption or air pollution, among others, represent a challenge for these regions and their inhabitants (Ewing 2008; Fernandez Milan y Creutzig 2016; Hennig et al. 2015). Therefore, understanding the spatial components of travel behaviour continues to be a priority for transport and urban policy-makers (Buliung y Kanaroglou 2006).

These transport-related challenges have been explored through theoretical conceptualisations from the 1970s, updated with new methodologies. This is the case for the concept of *activity space*, which was first considered by behavioural geographers (Horton y Reynolds 1971), and continue to be a useful tool for understanding the spatial extent of daily mobility, the modes of transport utilised and their consequences for everyday life in metropolitan regions (Kwan 1998; Patterson y Farber 2015; Ren 2016).

Exploration of characteristics of activity spaces of metropolitan residents is essential for understanding the consequences of functional segregation and sprawl. Accordingly, this study analyses the different factors (at the individual and environmental levels) influencing the extent of GPS-measured activity spaces of individuals with a long commute to a suburban location within the Barcelona Metropolitan Region. The recent introduction of GPS data in mobility and transport research reduces self-reporting bias, obtaining real-time tracking locations following the daily travelled routes by individuals and, hence, describing spatial behaviour more precisely than traditional sources of data (Zenk et al. 2011).

The effect of using different measurement methods for the activity space analysis will be explored through comparative analysis.

This article is structured as follows: the next section reviews recent research on activity spaces and the factors determining their sizes and is followed by a description of the research setting and the data sources and analytical methods. This is then followed by an outline of the results, using descriptive statistics and regression analysis. The penultimate section compares the main results with evidence from related studies, and the paper then ends with some conclusions and proposals for future research.

5.2. Background

Although its terminology is diverse, definitions of activity space all derive from the idea first introduced by Horton and Reynolds, understanding activity space as the space implied by *"the subset of all urban locations with which the individual has direct contact as the result of day-to-day activities"* (1971:37). Higgs (1975) referred to contact action spaces as the areas that are physically or visually experienced, Zahavi (1979) employed the term travel fields and Dijst (1999) used the term actual action spaces to describe the area within which individuals carry out activities. No matter which term is used, the idea of activity space becomes a useful concept for the study of the spatial extent of the travel behaviour of metropolitan residents, since its structure is formed by the locations where people undertake their daily activities (Ren 2016). Despite being conceptualised decades ago by behavioural geographers, the idea of activity space is now back in vogue (Patterson y Farber 2015).

Activity spaces serve as indicators of the degree of mobility of metropolitan residents at both individual and aggregate level, since they reflect the ability of people to reach daily destinations under various constraints (Gesler y Meade 1988), but are also measures of the accessibility to opportunities and environmental exposure (Sherman et al. 2005; Zenk et al. 2011). For instance, at the individual level, large activity spaces due to long commuting distances might decrease the chances to reach other destinations due to daily space-time limitations. This may, as a consequence, reduce the level of subjective well-being of metropolitan residents (Farber y Páez 2011; Susilo y Kitamura 2005). Although they are mainly a measure of individual spatial extent, activity spaces are also a very useful tool for assessing the aggregate cost of metropolitan trips. Large activity spaces, due to long trip lengths, usually imply the use of motorised transport modes (Banister 2008; Farber y Páez 2011), hence increase externalities such as traffic congestion, energy consumption, air pollution and the level of investment in transport infrastructure, and cause loss of agricultural land and open space (Ewing et al. 2016; Fernandez Milan y Creutzig 2016; Hennig et al. 2015; Soria-Lara et al. 2016).

In order to understand the spatial extent of the travel behaviour of metropolitan residents, an exploration of explanatory factors behind spatial choices is needed. Differences in the size of activity spaces are normally caused by constraints, needs, preferences or resources available (Sherman et al. 2005), that can be grouped depending on whether they relate to individual or environmental characteristics.

The first group of factors relates to the personal profile of the metropolitan resident, represented by their social and demographic characteristics. For instance, gender is believed to be a strong determinant of the size of activity spaces, with men being associated with larger activity spaces than women (Kwan y Kotsev 2015). Previous literature also considers age effects, as mature adults are understood to have larger activity spaces than both younger adults and seniors (Fan y Khattak 2008; Tana et al. 2015). In terms of income, wealthier households have been associated with larger activity spaces (Buliung y Kanaroglou 2006; Fan y Khattak 2008). Smaller activity spaces from women, young and older people and low-income individuals might lead to a reduced access to opportunities in metropolitan regions.

A less frequently explored factor in the configuration of activity spaces is time. A typical individual is faced with a limited time budget of 24 hours per day. Contributions from time geographers have shown that the allocation of limited time, time constraints and trade-offs between activities in space are basic to understanding human spatial behaviour (Hägerstrand 1970b). Because everyday life generally implies mandatory daily activities (eating, sleeping, working, etc.), travel time expenditure is generally limited to 1-2 hours (Ahmed y Stopher 2014; Mokhtarian y Chen 2004). With this stable time resource, individuals will decide on the locations of their daily activities (Mokhtarian y Chen 2004) and, hence, determine the characteristics of their individual spatial experience. People experiencing long working hours are forced to reduce the time spent – and may even choose not to participate – in other activities such as socialising, thereby reducing the size of their activity space (Farber y Páez 2011; Susilo y Kitamura 2005).

A second group of factors relate to the environmental setting – such as the distance to and density of allocation of services or the provision of a transport system – since these represent the main constraints for spatial behaviour, reflected in the structure of the activity spaces of individuals (Buliung y Kanaroglou 2006; Zahavi 1979). Thus, a key factor in activity spaces is the distance between usually fixed activity nodes in daily life, such as home and workplace (Horton y Reynolds 1971). Long commuting distances have been found to increase the sizes of activity spaces (Buliung y Kanaroglou 2006; Fan y Khattak 2008; Tana et al. 2015). Individuals experiencing long commutes are forced to use motorised transport modes and to prioritise the time invested in commuting relative to time invested in other activities (Banister 2008; Farber y Páez 2011). Nonetheless, short trips, due to proximity dynamics, are linked with small activity spaces (Hirsch, Winters, et al.

2014). Within small areas of space, access to opportunities by metropolitan residents can be maximised, encouraging the use of active transport modes (Frank et al. 2010; Marquet y Miralles-Guasch 2015a; Soria-Lara, Valenzuela-Montes, y Pinho 2015). Additionally, a less often considered mobility-related factor is the trip frequency to certain locations. Routine destinations, such as the workplace, are believed to influence the shape and orientation of activity spaces (Sherman et al. 2005).

Despite the science behind activity spaces having a long tradition, never before have researchers been able to locate activities in time in such a precise manner as is now possible using GPS technology. Given this resource, there has been a new interest in behavioural geography concepts and activity spaces (Gold 2009; Patterson y Farber 2015). Technologically speaking, the appearance of new technology has eased the collection of objective measures of both the built environment (e.g., via GIS) and mobility patterns (e.g., via GPS), facilitating more precise measures of spatial behaviour. Moreover, the increasing availability of GPS-enabled smartphones has widened the options for data collection in mobility and transportation studies (Birenboim y Shoval 2015; Cottrill et al. 2013). The possibilities of smartphone-based tracking data increase when these data are combined with the data from traditional mobility surveys, helping to identify explanatory factors behind travel behaviour. All these advances are helping to tackle issues such as the *uncertain geographic context problem*, which has been fundamental among behavioural geographers. This problem refers to the spatial uncertainty implied when measuring the influence of the environmental context on human behaviour. Traditional place-based exposure measures assume that individuals are exposed to the characteristics of areas such as their neighbourhood or census tract, but omit the effect of other areas outside these limits, hence, deviating from the true geographic context (Kwan 2012). Moreover, traditional people-based measures that overgeneralise spatial behaviour, such as the minimum convex hull polygon (MCP) or the Standard Deviation Ellipse (SDE), are being substituted by network-based approaches, such as the Daily Path Area (DPA) that calculates the activity space taking routes and transport infrastructures into account (Sherman et al. 2005; Zenk et al. 2011). Besides flaws in their reproducibility and transferability due to the high costs of collecting data, these new people-based methods are comparatively more precise than the MCP and SDE, and more theoretically valid than census tracts since they consider the actual travel processes of individuals (Farber et al. 2015; Kwan 2012). The research reported here is framed with those behavioural studies utilizing DPA to improve the understanding of metropolitan mobility, and specifically in this case, the consequences for the activity space of long commuters from a suburban area.

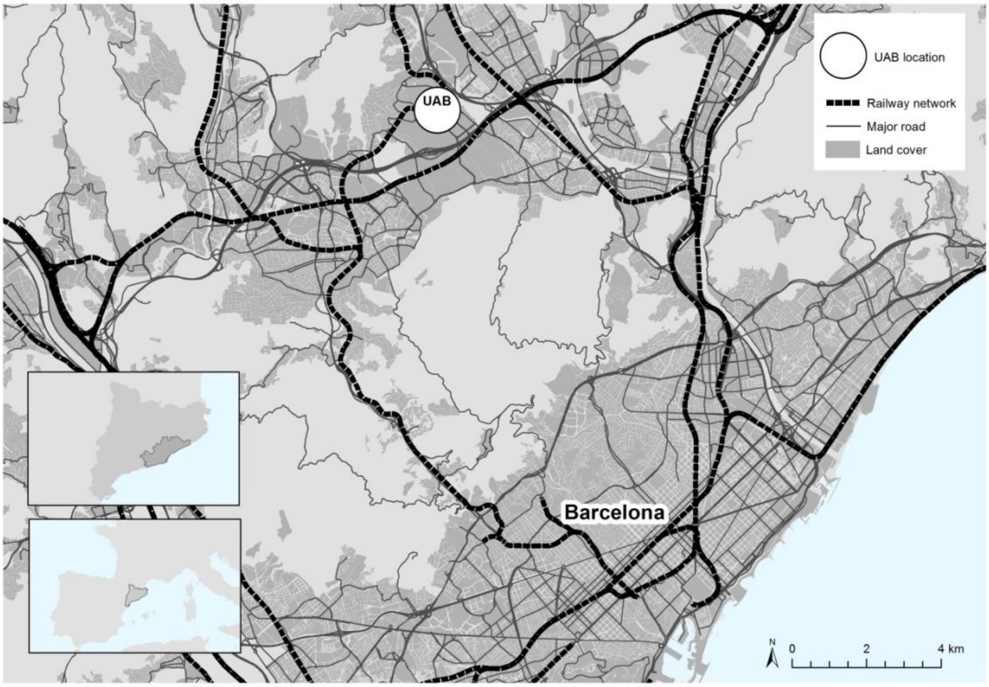
5.3. Materials and methods

5.3.1. Study area

In order to explore the factors affecting the characteristics of the activity spaces of suburban commuters in a metropolitan region such as the Barcelona Metropolitan Region (BMR), the present work focuses on the university community of the UAB, which is organised as a suburban campus in the BMR (**Figure 14**). University communities are very suitable for travel behaviour studies, being homogenous population groups, whose members share the same commuting destination as well as similar objectives, needs and preferences (Wedel and Kamakura 1998).

The university community accounted for 39,841 members in 2015, including students (undergraduate and postgraduate) and staff (faculty members and administrative personnel), making this university an important node in terms of daily mobility (Miralles-Guasch y Domene 2010). The approach of this study is consistent with previous research, basing the analysis on two data sources: a conventional daily mobility survey and a smartphone tracking application (app).

Figure 14. The UAB campus in the Barcelona Metropolitan Region (BMR).



Source: Own producion.

5.3.2. Data sources

The on-line University Community Mobility Habits Survey (UCMHS) of the UAB is a standard travel survey that measures the travel patterns and the personal profile of the members of the university community. This survey, conducted biennially since 2001, has already supported previous studies of travel behaviour and daily mobility (Miralles-Guasch y Domene 2010; Miralles-Guasch, Martínez-Melo, y Marquet 2014). The UAB held the 8th round of the UCMHS (GEMOTT 2015) during the period of April to June 2015, and it was complemented with a personal tracking experiment which was based on a free GPS-enabled smartphone app, called “Campus Mobility”.

Those survey respondents who were interested in the experiment were offered the possibility to download the app from Google Play Store © and were asked to have it running on their phones for several days. The app tracked the daily mobility of users through logging GPS positional data every 2 minutes and using mobile phone network signals when the former was not available. The locational error had a modal value of 15m, a median of 24m and a standard deviation of 18.87m with a 60% confidence level. The output database consisted of a set of georeferenced tracks containing information on geographic coordinates, date, time, user code and accuracy measures. The privacy and confidentiality of data were guaranteed at every stage in the experiment using different user codes for participants for the field work, data processing and analysis stages, as well as working in separate databases.

Smartphones were chosen as research tools for their widespread use in people's daily lives (Cottrill et al. 2013), especially in university campuses. GPS-based tracking experiments have used specialised GPS loggers used for outdoor sporting activities, allowing high resolution georeferenced locational data to be collected for small numbers of participants. Technological advances in the introduction of GPS-enabled smartphones and their widespread use, make this technology an excellent tool for obtaining large amounts of mobility data for behavioural and mobility-related studies (Birenboim y Shoval 2015; Cottrill et al. 2013; Ferrer y Ruiz 2014; Yip, Forrest, y Xian 2016). Compared to GPS loggers, smartphones impose minimal burdens for users, being frequently used in their everyday life. However, battery autonomy may compromise the frequency of georeferenced locations (Palmer et al. 2013; Patterson y Fitzsimmons 2016).

The "Campus Mobility" experiment was used to collect tracking data during 66 consecutive days, during which 233 participants downloaded and activated the application. Only participants with a minimum data potential of 12 hours per day, in a period of between 2 and 5 working days, were selected in order to represent more precisely everyday life behaviour (Hirsch, Winters, et al. 2014; Zenk et al. 2011). Only georeferenced points obtained on days that participants visited the Campus and points within the Barcelona Metropolitan Region were included in the study. Moreover, points with duplicate times (from the same user), those with accuracy worse than 50m, and those implying speeds greater than 140 km/h were all removed. Finally, the speeds between remaining records were recalculated and repeated until there were no more non-gap records implying more than 140 km/h (Palmer et al. 2013).

Regarding the measurement of activity spaces, it is important to highlight the methodological challenge involved. The assumptions inherent in traditional exposure or accessibility methods, such as administrative limits, have implied a biased image of the influence of the environment on individuals, leading to the so-called *uncertain geographic context problem*, since only the characteristics of, for instance, the neighbourhood are taken into account (Kwan 2012). Nonetheless, this bias was minimised through utilisation of people-based and network-based approaches, that calculate all the locations individuals visit on an daily basis, enabled by using Geographical Information Systems (GIS) and real-time tracking technologies provided by Global Positioning Systems (GPS) (Patterson y Farber 2015).

Activity spaces have been represented in multiple different ways, as seen in **Table 4** (Patterson y Farber 2015; Schönfelder y Axhausen 2003; Sherman et al. 2005). The range of possibilities is from traditional techniques, such as Minimum Convex Polygon (MCP), Standard Deviation Ellipse (SDE), to newer methodologies, such as kernel density maps or network-based approaches, and in this study, it was considered relevant to compare traditional with newer approaches. The MCP consists of the union of the furthest locations an individual visits and calculates the area inside this polygon, as in the home range characterisation of animal species applied by ecologists (Patterson y Farber 2015). The SDE summarises the overall dispersion and orientation of daily activities through an elliptical polygon, excluding the effect of outlying locations (Buliung y

Kanaroglou 2006). These traditional methods allow a straightforward calculation and representation of the areas of activity spaces (in km^2), but they overgeneralise the actual utilised space. On the other hand, the DPA method, inspired by Kwan's shortest path network, has emerged as a more realistic method representing activity space by buffering real-time tracking locations of recorded daily routes of individuals, providing higher accuracy than the former methods (Zenk et al. 2011), as seen in **Figure 15**. These three methodologies are obtained from the vector spatial analysis toolbox from ArcGIS 10.2, which allows the exploration of the differences between methods.

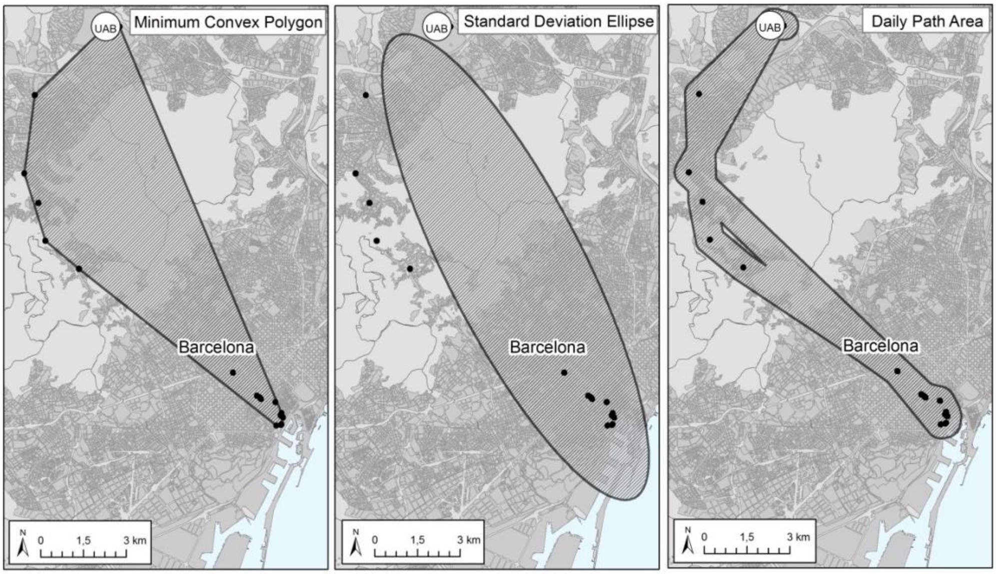
Table 4. Summary of calculation methods for activity spaces.

	Type of representation	Type and shape of measure	Data sources	Advantages	Disadvantages
MCP	-Descriptive -Abstract space	-Euclidean measure -Vector image -Geometrical shape	-Activity locations	-Describes the range of movement -Easy calculation -Captures all activity destinations	-Overgeneralises the space individuals are in contact with
SDE	-Statistical approximation -Abstract space	-Euclidean measure -Vector image -Ellipsoid shape	-Activity locations -Frequency-weighted	-Shows the orientation of activities -Possibility to weight by frequency	-Does not capture all activities -A minimum of three unique activities required -Overgeneralises the space individuals are in contact with
Kernel density map	-Descriptive -Actual access	-Density map -Raster image	-Activity locations -Frequency-weighted	-Captures all activity destinations -Shows the orientation of activities -Possibility to weight by frequency	-Not comparable with other methods -Does not capture the connections between activities
Shortest route	-Descriptive -Actual access	-Network-based measure -Vector image -Network-derived polygon	-Activity locations -Network Analysis (ArcGIS)	-Captures all activity destinations -Shows the orientation of activities -Approximation of routes followed	-May be too restricted for predictive purposes
DPA	-Descriptive -Actual access	-Network-based measure -Vector image -Network-derived polygon	Activity locations GPS and/or mobile phone tracks	-Captures all activity destinations -Shows the orientation of activities -Shows the actual routes followed	-The occasional loss of signal of navigation devices might misrepresent the actual route

Source: Own production, based on Sherman et al. (2005) and Schönfelder and Axhausen (2003).

In this study, the DPA was calculated by buffering at 500 m the line that connected all GPS points. This buffer size was chosen since 497m was the maximum accuracy error recorded by GPS network signals for the "Campus Mobility" participants, and also falls within the limits (200-1,000m) chosen for previous studies (Hirsch, Winters, et al. 2014; Sherman et al. 2005; Zenk et al. 2011). The final sample resulted in 411 polygons, corresponding to 103 participants and an average of 4 days of participation. DPA data were chosen for the regression analysis due to their more accurate representations of actual activity spaces, capturing 100% of people's locations through their mobility nodes and routes (Schönfelder y Axhausen 2003; Sherman et al. 2005).

Figure 15. Examples of Daily Path Area (DPA), Minimum Convex Polygon (MCP) and Standard Deviation Ellipse (SDE).[1]



Source: Own production.

In order to explain the characteristics of activity spaces, the information extracted from the UCMH Survey was divided into three groups of variables:

[1] In this and later figures, the dots within the mapped activity spaces are the GPS geolocations registered with Campus Mobility app.

spatial and time-related, travel-related and socio-demographic. The first group considered socio-demographic factors, for which *gender* and *university role* (staff or student) were chosen. *Gender* is included as a predicting factor, since males and females generally have different mobility patterns (Law 1999). *University role* was included as a proxy of social status since it reflects age and income differences in travel patterns observed between staff and students (Rybarczyk y Gallagher 2014).

In the second group, the Euclidean distances between the homes of participants and the UAB location were calculated using the address provided by the participants in the survey in order to obtain *residence location*. This variable was chosen because residence and place of work are usually the main mobility nodes in commuting travel (Horton y Reynolds 1971), and therefore influence the size of activity spaces. The suburban location of the university makes time-related factors, such as *time spent at the university*, determinant in the organisation of household schedules and in the accessibility to non-professional locations that can produce differences in the activity space areas (Schönfelder y Axhausen 2003). The *transport mode* to access the campus included physically active modes (walking or cycling) and motorised modes, a subgroup including both public (train or bus) and private transport (car or motorbike). Since motorised transport is the main mode given the suburban location of the university, analysis of differences between public and private modes was necessary. *The trip frequency* can imply differences in the spatial extent, since a high frequency of trips to the workplace is associated with influences on the shapes of activity spaces over time (Sherman et al. 2005).

5.3.3. Statistical analysis

The first part of the analysis includes a description of the statistics calculated for the 411 polygons for the three methods used: MCP, SDE and DPA. The differences in area are analysed using medians and interquartile ranges because of the skewed distribution of the data. Similarly, the Mann-Whitney U test (for two-category variables) and the Kruskal-Wallis test (for more than 3 categories) were used to measure significance levels (*p*) of the independent variables.

For the purpose of measuring associations between explanatory factors and the log-transformed areas of DPA, a hierarchical multiple regression analysis was built as **Model 1** (**Table 5**). This regression method was chosen to control the effect of the Euclidean distance between residences and the UAB Campus location, to enable a focus on the effects of the other variables. The predicting factors included in the model were *time spent at the university* (hours/day), *mode of transport*, *trip frequency* (journeys/week), *gender* and *university role*. Categorical variables (*mode of transport*, *gender* and *university role*) were transformed into dichotomous variables.

In order to deepen the analysis of travel behaviour, two further regression models were built. **Models 2** and **3** (**Table 6**) focus on the differences between motorised transport modes with **Model 2** analysing data for public transport users and **Model 3** those for private transport commuters. All statistical analyses employed IBM SPSS Statistics 21.0© software.

5.4. Results

The DPA generally produces lower area estimates of activity spaces resulting in a median of 2.68 km² for all participants; compared to 4.31 and 3.38 km² using the more traditional MCP and SDE measures (**Table 5**). The variability of areas is also lower for DPA than for MCP or SDE measures (IQR= 2.53; 6.45; 5.34, respectively). With regards to significance, the influence of the different factors on the area of activity spaces varies across the three different methods of activity space calculation. Kruskal-Wallis tests results indicate consistent significant differences in the size of activity spaces depending on the *transport mode* used [MCP ($p<0.001$); SDE ($p<0.001$); DPA ($p<0.001$)], the *residence location* [MCP ($p<0.001$);

SDE ($p<0.001$); DPA ($p<0.001$)] and the *trip frequency to the university* [MCP ($p<0.001$); SDE ($p<0.05$); DPA ($p<0.05$)]. However, *time spent at the university* is only found significant when activity spaces are measures with DPA ($p<0.01$), *gender* is significant only when using SDE ($p<0.05$) and the *university role* is only significant when measured with DPA ($p<0.01$). Differences in activity space area for the different variable categories will only be discussed below using DPA areas, since these are more appropriate and accurate estimates of activity spaces involving route-following and including 100% of all locations visited, thereby, minimising spatial overgeneralisation.

Table 5. Sample size differences and significance level of calculated areas of Campus Mobility, across three methods.

	Descriptive variables	n	%	Minimum Convex Polygon (km²)			Standard Deviation Ellipse (km²)			Daily Path Area (km²)		
				Median	*IQR*[a]	*p*[b]	*Median*	*IQR*[a]	*p*[b]	*Median*	*IQR*[a]	*p*[b]
	Total sample	411	100.0	4.31	6.45		3.38	5.34		2.68	2.53	
Sociodemog. characteristics	**Gender**					*0.161*			*0.039**			*0.107*
	Male	179	43.6	4.73	4.23		3.62	4.35		2.87	2.13	
	Female	232	56.4	3.79	8.71		2.66	6.54		2.48	2.78	
	University role					*0.094*			*0.162*			*0.009**
	Student	191	46.5	4.79	5.77		3.83	5.17		2.95	2.44	
	Staff	220	53.5	3.92	6.77		2.96	5.26		2.38	2.23	
Travel characteristics	**Trip frequency**					*0.009**			*0.021**			*0.031**
	3 days or less	35	8.6	5.10	3.64		3.90	3.21		3.10	1.65	
	4 days or more	366	90.1	3.92	6.39		2.87	5.55		2.42	2.42	
	Transport mode					*0.000**			*0.000**			*0.000**
	Active modes	29	7.1	1.03	2.68		0.72	1.52		1.55	1.85	
	Public transport	212	51.6	4.67	5.44		4.12	4.42		2.79	2.22	
	Private transport	170	41.4	3.88	8.10		2.52	7.84		2.71	2.69	
Time-spatial characteristics	**Residence location**					*0.000**			*0.000**			*0.000***
	<= 8.5 Km	143	34.8	0.97	2.37		0.65	1.75		1.26	1.40	
	8.501 Km-12 Km	111	27.0	4.11	2.26		3.35	2.91		2.58	1.06	
	+ 12.001 Km	157	38.2	7.84	17.31		6.23	13.98		4.16	3.94	
	Time spent					*0.056**			*0.264*			*0.007**
	1-5 hours	85	21.2	5.97	42.68		4.89	36.93		3.07	6.48	
	More than 5 hours	316	78.8	4.11	5.61		3.17	4.79		2.62	2.38	

[a] Interquartile range (IQR).

[b] p-value from Kruskal-Wallis non-parametric one-way Analysis of Variance (ANOVA) or Wilcoxon Rank Sum test across sociodemographic and travel-related characteristics.

* Significant p-value.

5.4.1. Descriptive analysis

Regarding sociodemographic factors, DPA polygons registered by male participants were larger (2.87) and with a lower variability (2.13), than those of female participants (median= 2.48; IQR= 2.78). In terms of *university role*, the median sizes of activity spaces are larger among students (2.95), with a larger variability (2.44), compared to staff who registered smaller areas (2.38) with lower variability (2.23).

Larger median areas are found for those participants living further away from the university (4.16), who also register greater variability (IQR=3.94) than for those living closer (median=1.26; IQR= 1.40). Those participants spending less daily time at the university also develop larger activity spaces (median=3.07; IQR=6.48) compared to those spending more *time at the university* (median= 2.62; IQR=2.38). Moreover, *residence location* ($p<0.000$) and time spent ($p<0.007$) are strongly associated with area size.

In the group of travel-related factors, larger median areas with higher variability occur for DPA polygons of participants travelling by motorised transport modes, compared to active modes. Activity spaces are slightly larger among participants travelling on public transport (2.79), compared to those using private modes (2.71). However, the highest variability of activity area size is shown for the polygons of participants using private motorised transport (2.69); those using public modes have lower variability (2.22). In addition, the areas for participants with lower trip frequency to the university are larger (3.10), with lower variability (1.65), than for those who travel more frequently, whose polygons show smaller areas (2.42) with higher variability (2.42). The *mode of transport* is a highly significant activity control ($p<0.000$) as is *trip frequency to the university* ($p<0.031$).

5.4.2. Correlation analysis

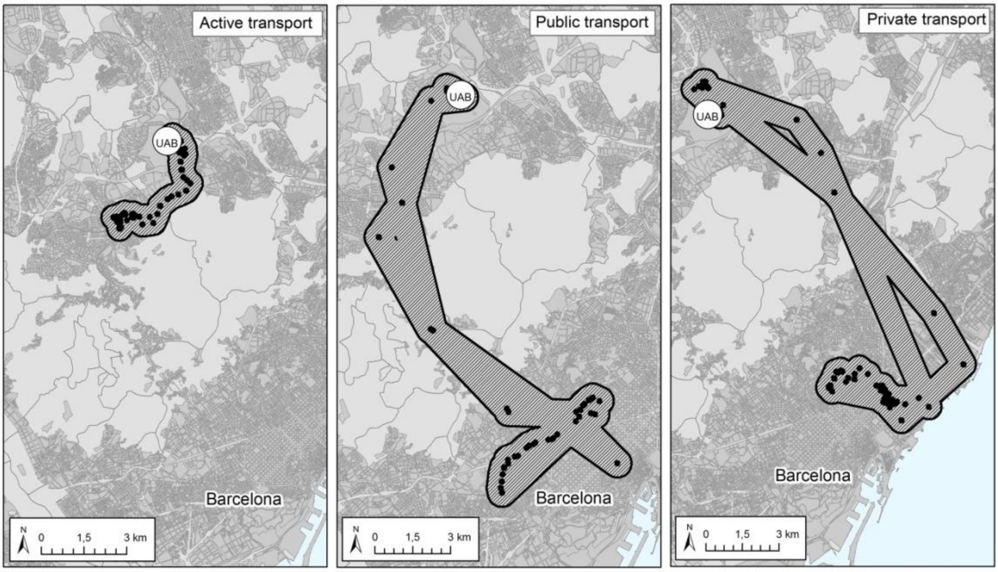
Table 6 presents the **Model 1** results for the statistically significant predictors of the log-transformed areas of activity spaces, based on an ANOVA test. Even with all variables taken together, there is low goodness of fit (R^2=45%) to the variability of area sizes. **Table 6** also shows how the independent variables make a statistically significant contribution towards predicting activity spaces. After controlling the effect of residence location, the independent variables account for 44% of the variability in activity space dimension, marginally decreasing the predictive power. Those variables that are statistically significant determinants of the size of activity space are those for travelling to the university using active modes ($p<0.000$), followed by the time spent at the university ($p<0.039$). This is because active travellers and people working fewer hours usually have smaller activity spaces (**Figures 16** and **17**).

Table 6. Association analysis of Daily Path Area and predicting factors of Campus Mobility.

Model 1: *Daily Path Area*		*n*	*Coefficient Estimate*	*St. Error*	*t*	*Sig.*
Constant	**Activity space area (km²)**	411		0.087	37.883	*0.000**
Control variable	**Residence location**	411	0.621	0.000	15.134	*0.000**
Independent Variables	**Gender**					
	Dummy female	411	-0.043	0.026	-1.098	*0.273*
	University role					
	Dummy staff	411	-0.059	0.028	-1.413	*0.159*
	Time spent					
	Hours/day (continuous)	401	-0.082	0.005	-2.066	*0.039**
	Transport mode					
	Dummy active modes	411	-0.159	0.052	-3.993	*0.000***
	Dummy private transport	411	0.029	0.028	0.696	*0.487*
	Trip frequency					
	Days/week (continuous)	401	0.007	0.017	0.181	*0.857*
Model 1:					*Significance (ANOVA)*	*0.000**
Independent variables:					*Sig. F change*	*0.000**
					R²	*0.45*
					Adjusted R²	*0.44*

* Significant p-value.

Figure 16. Examples of Daily Path Areas registered by participants travelling on different modes of transport.



Source: Own production.

Figure 17. Examples of Daily Path Areas registered by participants working part and full-time.

Source: Own production.

Table 7 shows the results for **Models 2** and **3** for activity spaces of participants using different motorised transport modes analysed separately. Public transport users' polygons are represented by **Model 2** which is also statistically significant ($p<0.000$) but with a higher goodness of fit than **Model 1** ($R^2=57\%$) and with slightly higher predictive power (adjusted $R^2=56\%$). In this model, the *university role* becomes the most statistically significant determinant of the size of activity spaces ($p<0.000$), showing staff tend to have smaller activity spaces, holding all other variables constant (**Figure 18**). *Gender* is not found to be a significant variable ($p>0.063$).

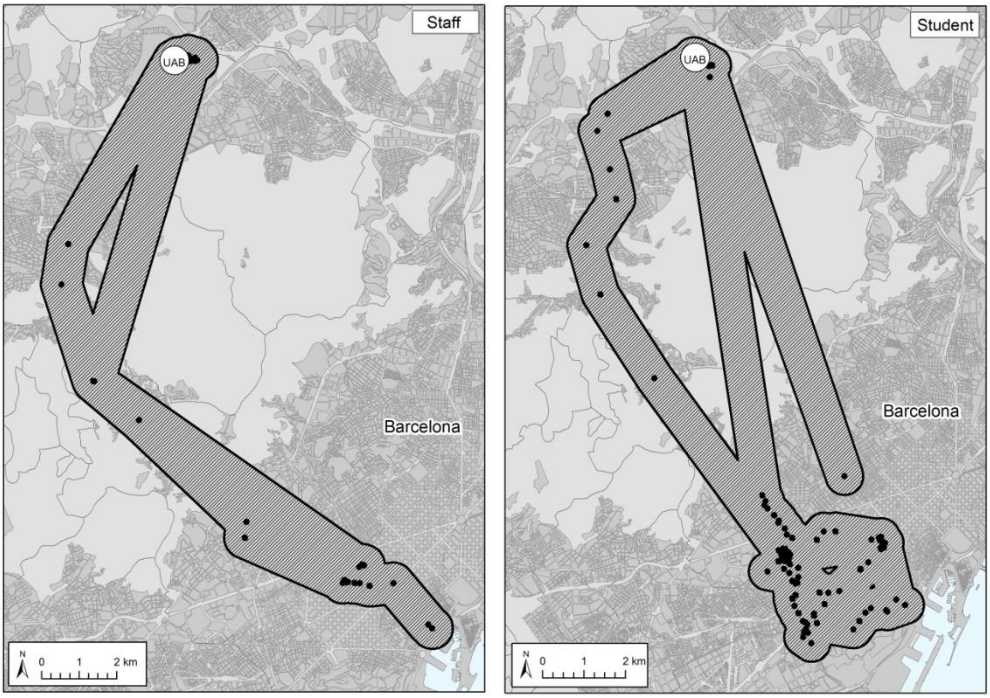
Model 3, which considers only polygons created by private motorised transport users, was also significant ($p<0.003$), but with a lower goodness of fit ($R^2=37\%$) and a lower predictive power (adjusted $R^2=35\%$). Again, the only significant variable included in **Model 3** is the *time spent at the university*; implying that among private transport users, spending more hours at the campus is correlated with smaller activity spaces. In this third model, *gender* and *trip frequency* were found not significant ($p>0.066$; $p>0.064$).

Table 7. Association analysis of Daily Path Area and predicting factors of motorised transport users of Campus Mobility.

Models 2 and 3: *Daily Path Area*		**Model 2. Public transport users**					**Model 3. Private transport users**				
		n	*Coefficient Estimate*	*St. error*	*t*	*Sig.*	*n*	*Coefficient Estimate*	*St. error*	*t*	*Sig.*
Constant	**Activity space area (km²)**	212		0.109	31.555	*0.000**	170		0.204	18.573	*0.000**
Control variable	**Residence location**	212	0.723	0.000	14.431	*0.000**	170	0.559	0.000	8.267	*0.000**
Predictive Variables	**Gender**										
	Dummy female	212	-0.094	0.030	-1.869	*0.063*	170	-0.119	0.044	-1.853	*0.066*
	University role										
	Dummy staff	212	-0.214	0.031	-4.172	*0.000**	170	0.084	0.055	1.154	*0.250*
	Trip frequency *Days/week (continuous)*	202	0.071	0.015	1.449	*0.149*	170	-0.135	0.038	-2.151	*0.064*
	Time spent *Hours/day (continuous)*	202	-0.061	0.005	-1.246	*0.214*	170	-0.151	0.014	-1.862	*0.033**
Models 2 and 3:					*Significance (ANOVA)*	*0.000**				*Significance (ANOVA)*	*0.000**
Independent variables					*Sig. F change*	*0.000**				*Sig. F change*	*0.030**
					R^2	*0.57*				R^2	*0.37*
					Adjusted R^2	*0.56*				*Adjusted* R^2	*0.35*

* Significant p-value.

Figure 18. Examples of Daily Path Areas registered by student and staff university UAB members.



Source: Own production

5.5. Discussion

This study has explored the spatial extent of daily mobility through the analysis of the activity spaces of suburban commuters. The analysis informs knowledge of the transport-related challenges faced by metropolitan regions, detecting the most significant factors affecting the size of activity spaces of their residents. Here, we have examined the activity spaces of individuals experiencing a long commute to a suburban location within the Barcelona Metropolitan Region, using data from GPS-enabled smartphones, combined with an on-line survey.

Results confirmed spatio-temporal factors and the university role as the strongest determinants of the size of activity space. The present study found that when both the origin and the destination of the commute were controlled, significant differences in variables involving a time-distance component were detected, such as the *time spent at the university*. Increasing the time devoted to work/study at the university tended to reduce the number of reachable activities and resulted in smaller activity spaces. This finding conforms with travel time-budget (TTB) theories and the idea of time as a finite everyday resource (Ahmed y Stopher 2014; Mokhtarian y Chen 2004). Regarding the *university role* variable, among those commuting on public transport, students registered larger activity spaces than staff, contradicting previous research that suggests that adults, with higher incomes and higher family burdens tend to have larger activity spaces (Buliung y Kanaroglou 2006; Fan y Khattak 2008; Tana et al. 2015). These findings could be explained either by a longer relationship of staff members with the university, which results in them residing closer to the campus (Miralles-Guasch et al. 2014), or by a greater schedule flexibility amongst students, that allows them to have a larger variability in their activity spaces. Results on activity spaces sizes are, thus, highly contextual to the characteristics of our sample and study settings, but it seems likely that other highly specialised suburban locations should develop similar dynamics with regards of activity spaces of its clients or employees.

The size of activity spaces helps us understand the use of different means of transport, notably between those who commute with active and motorised modes of transport. As expected, travelling in *active modes* (walking and cycling) is associated with smaller activity spaces, as *motorised transport* allows travelling longer distances in the same length of time (Rodrigue, Comtois, y Slack 2011), resulting in larger activity spaces (Hirsch, Winters, et al. 2014). Within the motorized group however, no differences were found in the size of activity spaces between those who commuted with private and public modes of transport. This is interesting since most studies comparing mobility patterns have found car users to develop larger activity spaces (Kwan y Kotsev 2015; Schönfelder y Axhausen 2003). Our study provides evidence that when well planned, public transport can provide the same opportunities and spatial reach as private transport, even in suburban locations. Commuting to the university by public transport neither created impairment, nor increased constraints on the spatial extent of participants' everyday lives.

Those factors with lower influence, such as *trip frequency* and *gender*, also revealed different features. *Trip frequency* shows that participants commuting to the campus less often generate larger activity spaces than those commuting more often. This contrasts with the constructivist view that links travel distance with frequency of visits to service points (Nemet y Bailey 2000). Additionally, the low influence of *gender* on the size of activity spaces in the present study enriches the open debate centred on gendered mobilities (Miralles-Guasch et al. 2016), questioning whether gender always is a strong determinant of the size of activity spaces (Buliung y Kanaroglou 2006; Schönfelder y Axhausen 2003).

Differences in the size of activity spaces have a direct impact on the set of externalities produced by everyday transportation. On the one hand, the suburban location of the university imposes large activity spaces as well as a motorized transport commute. These entail significant transport-related externalities such as traffic congestion, energy consumption or air pollution. On the other hand, the competitive supply of public transport accessing the university has produced similar mobility patterns among all motorised transport commuters, expressed in the minimal differences in the sizes of activity spaces between public and private users. This breaks the commonly assumed link between larger activity spaces and private transport use and leads to the conclusion that the impacts of transport in metropolitan areas can be reduced through the provision of public transport without having to downscale the size of individual spatial reach.

In terms of methodology, the activity spaces measured along the travelled routes have proven to be more realistic than the overgeneralising traditional methodologies, including 100% of all locations visited by individuals, providing smaller areas and, thus, minimising *the uncertain geographic context problem*. Therefore, Daily Path Area (DPA) becomes a precise measurement method profiting from the advantages of new data sources such as GPS, which is also consistent with previous research (Hirsch, Winters, et al. 2014; Zenk et al. 2011). Finally, this study has shown the importance of choosing the right method since each activity space measurement method may generate a specific set of explanatory factors.

5.6. Conclusions

Since externalities of functional segregation and sprawling patterns represent a challenge for metropolitan regions, this study has expanded the knowledge on their impact on transport using the concept of activity space. The present work has confirmed, by using GPS-based activity spaces, that the set of people's everyday locations is deeply determined by spatial settings and their own temporal constraints. The spatial location of residence and the time available for travel strongly determine the extent of each individual's activity space. Our results also suggest that given adequate planning, public transport can compete with private transport in suburban commuting situations, without prejudice to the spatial reach of activity spaces.

The use of activity spaces in travel behaviour studies contributes to the re-emerging interest in cognitive-behavioural geographies with new sophisticated and accurate quantitative methodologies (Gold 2009). The use of personal tracking data from GPS-enabled smartphones has added to this interest providing high precision activity measures without the need for significant financial investment in technology. Although the current performance of smartphones can be poor in certain circumstances (i.e. battery drainage), their wide-spread use (and future technical development) should make this technology a very helpful source of information in behavioural and transport research.

Finally, policy makers should also complement traditional data sources (i.e. surveys and Origin and Destination matrixes) with this new type of information when exploring mobility patterns of people for planning purposes. In terms of policies, these should avoid being over-invested into enlarging people's activity spaces and instead should focus on strategies that are oriented towards urban compactness and that can multiply the available potential destinations inside actual activity spaces. Furthermore, the importance of personal time when configuring people's everyday spatial patterns highlights the need to introduce time-use considerations when planning for accessibility and public service allocation.

6. Green exposure of walking routes and residential areas using smartphone tracking data and GIS in a Mediterranean city

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Green exposure of walking routes and residential areas using smartphone tracking data and GIS in a Mediterranean city

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ABSTRACT

The aim of this study was to explore the exposure to green elements of residents in a compact and dense Mediterranean city, with a main focus on the exposure to traditional green elements such as parks and gardens and also less-explored elements such as public squares, boulevards, and beaches. Differences between walking and residential environments between morphologically distinct residential areas are also analysed. To achieve this, both residential and GPS-based exposure measures were obtained with GIS and smartphone tracking data for 129 adult individuals from Barcelona, Spain. Results have shown how using smartphone tracking data allows obtaining a higher density of green elements and the different types of these elements that residential buffers are not able to detect. Furthermore, research findings highlight the importance of urban form in the provision of green spaces in cities and that alternative greenness can be found in other types of open spaces beyond public parks.

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6.1. Introduction

The increasing incidence of non-communicable diseases due to urban life-styles in relatively high-income countries has expanded the production of studies in urban planning and epidemiology, exploring the link between urban built environment and health (Hartig et al. 2014). During the past two decades, a relationship that has been increasingly studied has linked the contact with natural environments to several health outcomes, particularly in dedicated urban open spaces. This relationship has been commonly expressed through four major pathways (Markevych et al. 2017). The presence of vegetation in urban open spaces has proven to reduce exposure to air pollution, heat and noise (Baró et al. 2014; Basagaña et al. 2011; Pathak, Tripathi, y Mishra 2008), to provide safe, accessible and attractive areas where people can be physically active (Almanza et al. 2012; Schipperijn et al. 2013), allowing them to socialise with family and friends (De Vries et al. 2013). Thus, such urban open spaces become psychologically beneficial areas that facilitate relaxation, mental restoration and stress reduction (van Herzele y de Vries 2012). For these reasons, the provision of greenness has been noted as a key strategy in urban design for the achievement of urban sustainability and the improvement of health and well-being of residents (WHO 2016).

The most typical conception of an urban open space with vegetation usually relates to the public park. This type of space has received the most attention in the body of public health literature, which is reflected in most policy guidelines of international organisations which promote health-related benefits of greenness (European Commission 2001; WHO 2016). However, the availability and characteristics of green elements such as parks depends on the ecological conditions, political priorities and the historic urban planning legacies and also, very importantly, on the existing built environment of each urban context (Kabisch et al. 2016). In comparison with North European and especially with

North American cities, where sprawling patterns and functional segregation are highly present (Dempsey, Brown, y Bramley 2012; Ewing et al. 2016), Mediterranean cities tend to display a built environment that is characterised by compact urban forms, high-density levels and mixed-used functionality (Dura-Guimera 2003). On the other hand, these cities can also tend to suffer from low green space allocation (Fuller y Gaston 2009; Kabisch et al. 2016), but parks are not the only urban spaces where nature is present. This low allocation often leaves the interaction between residents and nature to depend on the landscape quality of other open spaces with similar urban functions than parks such as streets, squares or nearby forests (Ward Thompson 2002). Furthermore, ponds and coastal zones, commonly known as "blue spaces", have also been associated with health benefits and can also provide the same functions as parks (Hipp y Ogunseitan 2011; WHO 2016).

The available greenness in streets, avenues, boulevards and squares in the form of trees or parterres could partly compensate for the absence of nearby parks or gardens (Taylor et al. 2015). In particular, the provision of street trees in cities answers to a widespread and long tradition of landscape design in Europe, which was especially remarkable among Dutch and French landscapists, whereby trees were usually planted along streets, avenues and boulevards in order to improve the walking experience (Southworth 2005). In fact, street trees, which are understood to be a natural aesthetic attribute, have been found to incentivise walking and street life in the same way as other non-natural attributes such as street lamps, benches, or play areas (Handy y Boarnet 2002; Sarkar et al. 2015). Accordingly, when streets, avenues, boulevards and squares are provided with trees they become successful places within which people can be in contact with nature, they can socialise and they can even be physically active (Corraliza 2000; Sarkar et al. 2015). This study explores the availability of parks and gardens and also other little-studied types of green elements, which are characteristic of Mediterranean urban contexts.

Methodologically speaking, the appearance of new technologies that facilitate the objective measurement of the attributes of the built environment have refined the analysis of the health-related benefits of urban greenness (Troped et al. 2010; Vich et al. 2017). The traditional proxy for the measurement of exposure to greenness is *Proximity to green spaces*, and this is now being more accurately measured via the increased use of Geographical Information Systems (GIS) (Koohsari et al. 2015). However, these measures still usually omit the amount of vegetation that is available in other urban open spaces. Another improvement that is provided by GIS is the possibility to measure the *surrounding greenness* of urban areas in the form of vegetation indicators such as the Normalized Difference Vegetation Index (NDVI) and street tree density. On the one hand, NDVI assesses the overall level of vegetation in a specific territory through the processing of satellite images. This index, however, is still not able to differentiate between structured (e.g. parks) and unstructured (e.g. street trees, backyards) vegetation (Markevych et al. 2017), despite recent efforts to solve this problem (Shoshany 2012). On the other hand, street tree density and tree count usually allow the filtering of tree types even though they do not measure the size of tree canopy.

Moreover, methods that measure the contact of urban residents with the natural environment present several limitations. Among the most common are the inability to establish causality and the potential residential self-selection bias (Toftager et al. 2011), and also the *local trap* challenge (Vallée et al. 2014). Specifically, this latter challenge relates to the predefined scale of the exposure in a neighbourhood or census tract levels or by the buffering of commonly accepted distances from the place of residence, while omitting other visited territories by individuals and, as a consequence, deviating from the true geographic context (Kwan 2012). The quest for obtaining realistic environmental exposure measures has driven recent research towards adapting theoretical conceptualisations from other disciplines. The concept of *activity space* was first introduced in the 1970s and it has been increasingly used to explore the spatial behaviour of individuals, since its structure is formed by all of the visited locations where people undertake their daily activities, hence, the concept has become an optimal person-based measure of environmental influence (Horton y Reynolds 1971).

Technological advances, such as Global Positioning Systems (GPS), have also provided academics with precise objective data of mobility patterns, both temporally and spatially. A vast list of studies has already used GPS devices, together with actigraphy loggers, to detect the optimal spaces with green elements for being physically active (Almanza et al. 2012; Troped et al. 2010), and also to obtain precise measures of activity spaces (Hirsch et al. 2015; Vich et al. 2017; Zenk et al. 2011). Moreover, the increasing availability of GPS-enabled mobile phones (i.e. smartphones) has started to widen the options for data collection in transport-related studies (Delclòs-Alió y Miralles-Guasch 2017; Patterson y Fitzsimmons 2016) and in the body of environmental exposure literature. Tracking data from smartphones open the access to larger samples of study subjects, geographic ranges, and longer observation periods. Additionally, this technology provides information on human motivations, in helping to determine whether people are deliberately in contact with urban green elements or whether they are just passing by and when, however regularly and for however long, they visit these spaces (Marquet et al. 2018). However, due to its novelty, very few studies have utilised smartphones as a source of data to explore environmental exposure to greenness (Donaire-Gonzalez et al. 2016; Korpilo, Virtanen, y Lehvävirta 2017).

In order to overcome geographic and methodological limitations that are detected in reviewed green exposure studies, the aim of the present study was to measure the exposure to greenness in underexplored geographical contexts with specific types of green elements such as Mediterranean urban areas, using Barcelona as an example. Moreover, the potential exposure to green elements of residents in the city of Barcelona, that were calculated using placed-based

Residential Buffers (RBs), were compared to the total exposure resulting from their daily walking activity locations or Pedestrian Activity Space (PAS), which was measured through buffers obtained from smartphone tracking data.

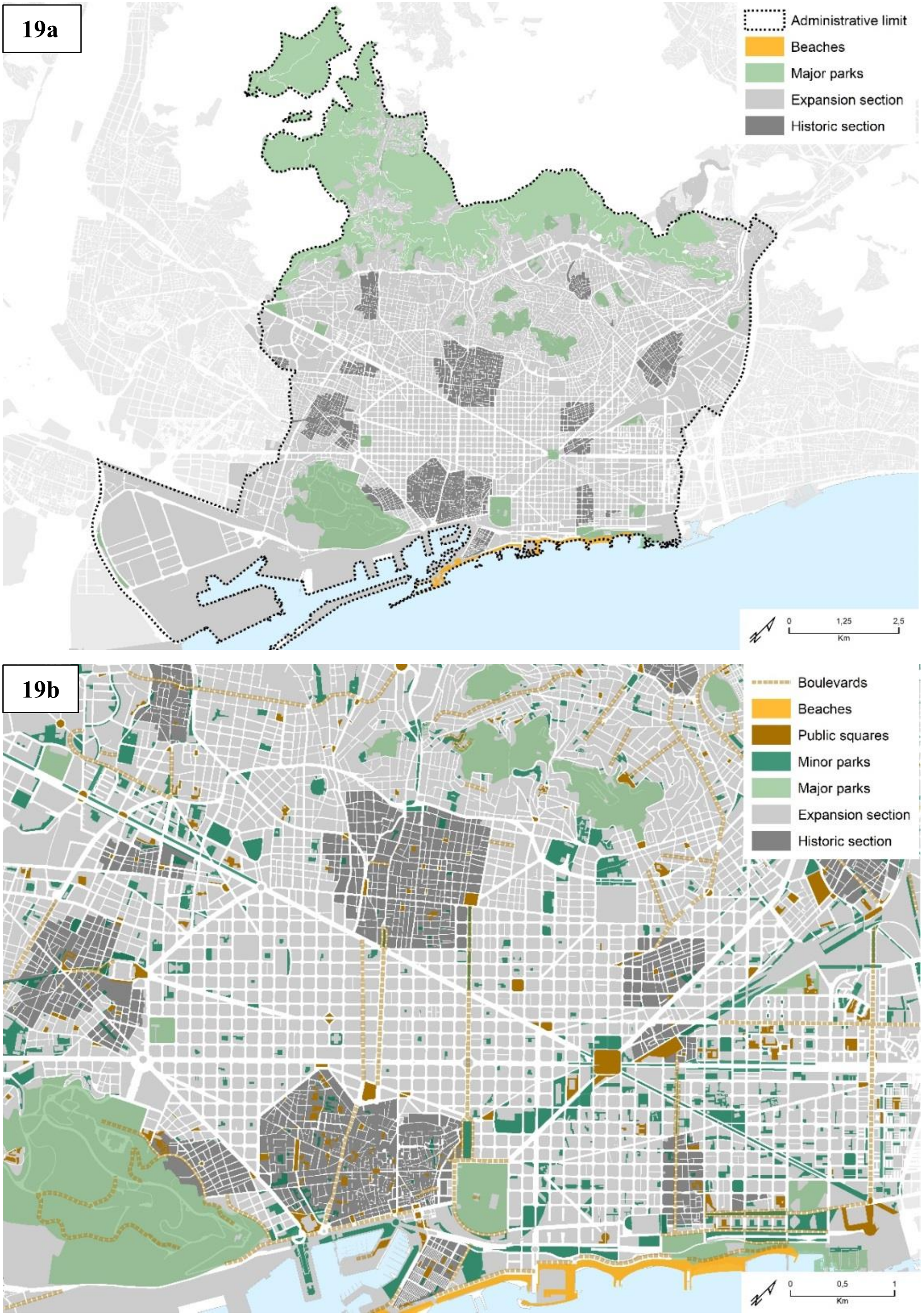
6.2. Methods

6.2.1. Study Area

The study area was the city of Barcelona (Spain), which accounted for 1.6 million inhabitants in 2016 that are distributed across a relatively small territory (102.2 km²), making a density of 15,740 inhabitants/km² (Ajuntament de Barcelona 2016a). Barcelona is administratively distributed across 73 neighbourhoods with an average density of 24,997 inhabitants/km² (Ajuntament de Barcelona 2016a). The physical form of Barcelona is compact and its functions are closely located and diverse which facilitate proximity urban dynamics (Dura-Guimera 2003; Marquet y Miralles-Guasch 2015a).

The city of Barcelona is an optimal example of a Mediterranean city with low provision of dedicated areas with greenness but with high levels of street vegetation. Besides the improvement undertaken in recent decades, the city of Barcelona still experiences a low density of public parks and gardens, with a considerable deficit in the central part of the city. In 2015 the inner city only counted for 11.25 km² of green areas, which accounts for only 11.01% of the territory, corresponding to 7.00 m² per inhabitant (Ajuntament de Barcelona 2016a). This is a low proportion compared to other European cities, especially in the north of the continent, where these spaces can be up to 300 m² per inhabitant (Fuller y Gaston 2009). Although Barcelona has several large green areas (see **Figure 19a)**, these correspond to the mountain range of Collserola, presenting accessibility issues due to its location on the north-western periphery of the city and with higher altitude than the rest of the city. On the other hand, these low levels of parks and gardens are compensated by the high levels of greenness in squares, streets, avenues, boulevards (locally known as *les rambles* in the Catalan language) that also offer infrastructure for resting, exercising, playing and socialising (see **Figure 19b, Figure 20a** and **Figure 20b**). In 2015, the city had 158,896 street trees, accounting for 98.36 trees per 1,000 inhabitants (Ajuntament de Barcelona 2016a), which is a high ratio compared to other urban areas in Europe that vary between 50 and 80 street trees per 1,000 inhabitants (Pauleit et al. 2002). It is noteworthy, however, that Barcelona's historical lack of public open space has been addressed since the 1980s with consecutive plans to build small, high-quality public spaces throughout the city, mainly public squares (or *plazas* in Spanish) but also public gardens (**Figure 19b)** at a smaller scale (Anguelovski et al. 2017; Garcia-Ramon, Ortiz, y Prats 2004). Finally, **Figure 19b** also displays the approximately 5 km of beaches along the coastline, which add large extensions of open space to the city of Barcelona.

Figure 19. Distribution of green elements in the city of Barcelona.



Source: Own production based on data from Barcelona City Council (BCN) (2016).

Figure 20. Image of typical urban square and boulevard from Barcelona: Plaça del Diamant (top) and Passeig de Fabra i Puig (bottom).

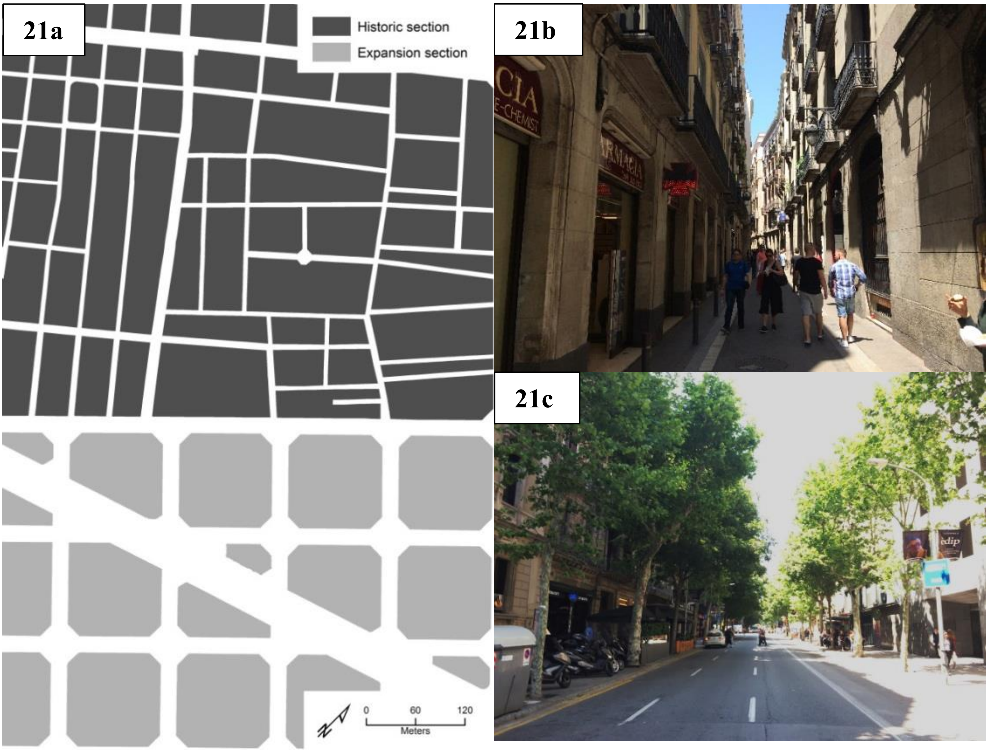
Source: author's own photos.

The urban form and planning traditions of cities limit the provision of green elements. The differentiated physical morphologies within Barcelona's current spatial continuum are explained by the historical periods of development and urban expansion: from its medieval historic city, with the surrounding villages dating from the 18th century, to Ildefons Cerdà's Urban Expansion Plan in the 19th century, followed by later developments during the 20th century (Pallares-Barbera et al. 2011). All of these planning and urban expansion traditions have treated access to green elements differently and they continue to shape their availability today.

The first type of urban morphology that can be detected in the city corresponds to the historic city of Barcelona and the surrounding villages that were later incorporated into the city with Cerda's Urban Plan[2]. The top part of **Figure 21a** and **Figure 21b** show a sample of the morphology of *historic quarters* evidencing a narrow and irregular street layout (average street width of 5 m) and high building density (Aibar y Bijker 1997). The bottom part of **Figure 21a** and **Figure 21c** show that the second type of morphology is related to newly-built areas of the city after Cerda's Urban Plan from mid-19th century until the present day. This Plan contemplated an orthogonally-distributed street network outside the limits of the Historic City of Barcelona with standard streets in *expansion quarters* that are 20 m wide and with a lower density of buildings (Pallares-Barbera et al. 2011). Although the Plan's guidelines were not fully complied with, due to increased building construction and loss of open space during the following 150 years, Cerdà's street layout has prevailed. Nevertheless, both morphologies provide a street pattern across most parts of the city that facilitates active transport mobility (Marquet y Miralles-Guasch 2015a).

[2] Illdefons Cerdà (1815-1876) was a Catalan civil/urban engineer responsible for Barcelona's Urban Expansion Plan (1859).

Figure 21. Morphological differences between Historic and Expansion Quarters.



Sources: Figure 3a: Own production based on data from Barcelona City Council (BCN) (2016); Figures 3b and 3c: Author's own photos.

6.2.2. Participants

Participants were recruited through a campaign that sought people who would be interested in participating in an academic research project regarding active mobility called "Campus Mobility 2017". The main source of participants pertained to respondents to the 2017's Autonomous University of Barcelona (UAB) Mobility Survey (n=263) who agreed to participate in this research. Those participants were added to other voluntary participants who were recruited through a snowball process (n=64), mailing lists (n=11), and advertising in social networks (n=9), making a final sample of 347 participants.

Participants were asked to download and install a freely available smartphone app called MOVES©. This app is available both for Android© and iOS© devices and it was used to track the daily walking patterns of the participants. MOVES© uses the smartphone-enabled GPS and accelerometer to provide a diary of individuals' mobility, recording variables such as distances, durations, steps, and even the daily burning of calories, and recognising routes, places and modes of transport used throughout the day (Evenson y Furberg 2017). Transport modes are automatically obtained by the app through the speed and acceleration detected by the smartphone's accelerometer, even though the utilised algorithm is not disclosed by the company (Protogeo 2016). By downloading, installing and using MOVES©, participants agreed to the terms and conditions of the private developer. The confidentiality of data was guaranteed in the experiment by using different user codes during the field work, data processing and analysis stages. The ethics committee of the Autonomous University of Barcelona approved the study (CEEAH-3657).

Participants were asked to keep the app activated for a week (5 weekdays, 2 weekend days) and they were also asked to answer an online survey with several sociodemographic questions. Only participants with a minimum of 5 and a maximum of 7 working days residing in Barcelona were selected (n=129) (Hirsch et al. 2015; Zenk et al. 2011). The profile of the final sample of participants (n=129) was balanced in relation to gender (male=54; female=75) and predominantly young (<29 y.o.= 88; 30-42 y.o.= 29; 42-64 y.o.= 11). The data-gathering phase of the study took place between April and June 2017. No incentive was offered or provided in relation to participation in this research.

6.2.3. Measurements

a) Tracking Data

MOVES© categorises those consecutive georeferenced points that are registered with a certain speed and acceleration as *move* tracks and assigns them a transport mode (*walking*, *running*, *cycling* or *motorised transport*). Those points with zero velocity and no acceleration are classified as *waiting* track. From the Application Programming Interface (API) library, a raw database of 204,292 tracking points (*move* and *waiting*) was downloaded at the end of the field work. From the raw database, 87,997 tracking points that MOVES© classified as *walking* and which were located within Barcelona via residents in the city were selected. From these, 85,112 tracks made the final sample after the data cleansing process and analysed as days of participation. Using the ArcGIS 10.3 Tracking Analyst tool, consecutive points were unified into trip segments in order to calculate speeds and durations between points. Following commonly accepted data cleansing thresholds (Cho, Rodríguez, y Evenson 2011), those points forming segments of speeds higher than 6 km/h and lasting over 3 minutes were excluded. The final sample of 129 individuals contributed to a total of 787 complete days of data (average of 6 days/person), which is in line with previous research (Hirsch et al. 2015; Zenk et al. 2011).

b) GIS Measures

We used publicly available shapefile layers to select the different categories of green elements to be analysed: *major parks*, *minor parks*, *public squares*, *boulevards*, *beaches* and *street trees*. First, traditional green elements such as parks and gardens were extracted from the city's Land Use Map (Ajuntament de Barcelona 2016b), which contains land-use classifications for the whole municipality. All areas with greenness over 2 hectares were classified as *major parks* (N=94), and all areas below

2 hectares were classified as *minor parks* (N=1,671) (Natural England 2010). All land uses identified as public squares and boulevards that had trees, were classified as *public squares* (N=359) and *boulevards* (N=91), respectively. All trees planted outside of *squares* and *boulevards* were classified under the category of *street trees* (N=111,651). Finally, those polygons implying *beaches* (N=12) were also extracted for the analysis. This same set of cartographic data was used to locate the residential addresses of all participants, classifying them as within *historic* and *expansion quarter* areas, and to detect differences between morphologically-distinct street layouts.

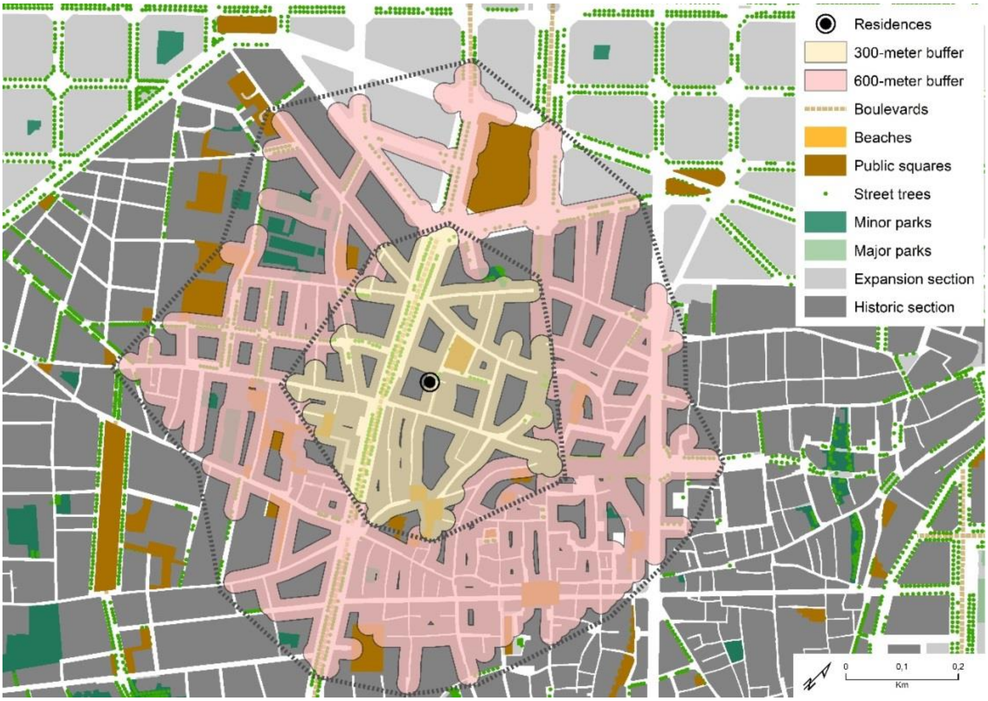
6.2.4. Measurement of the exposure to green elements

In order to measure the differences in capturing green exposure, two distinct methodologies were applied in this study. First, a traditional exposure analysis based on the participant's place of residence, *Residential Buffer* (RB), was calculated using a 300 m street-network buffer around the participant's address and a further 600 m street-network buffer as a sensitivity analysis. Second, the full green exposure during each day of participation was measured using a *Pedestrian Activity Space* (PAS) which consisted of a 20 m buffer around all the geocoded GPS locations that MOVES© identified as having been encountered while walking.

In order to obtain *Residential Buffers* (RBs), two buffers of 300 m and 600 m along the road network with widths of 20 m were created (see **Figure 22**). The first length measurement was based on Natural England's guideline of 300 m as the recommended distance threshold for access to a large park (Natural England 2010; Rojas et al. 2016). The 600 m buffer was produced as a sensitivity analysis but one that also corresponds approximately to the walkable distance in a 10 minute trip (Ryley 2006). The buffer width of 20 m is smaller than that used in similar studies, for example using 100 or 200 m buffers (Burgoine et al. 2015; Hirsch et al. 2015), since it has been adapted to the average street width of Barcelona.

Once these buffers were obtained, the Spatial Join tool from ArcGIS 10.3© was used to calculate the total number of green elements (counts) included within their buffer area: *parks* (*major* and *minor*), *public gardens*, *street trees*, *public squares*, *boulevards* and *beaches*. Moreover, each buffer was categorised as being located in "historic" and "expansion" quarters in order to detect differences in the exposure between morphologically distinct urban layouts.

Figure 22. Examples of residential buffers (RBs) (300 and 600 m).

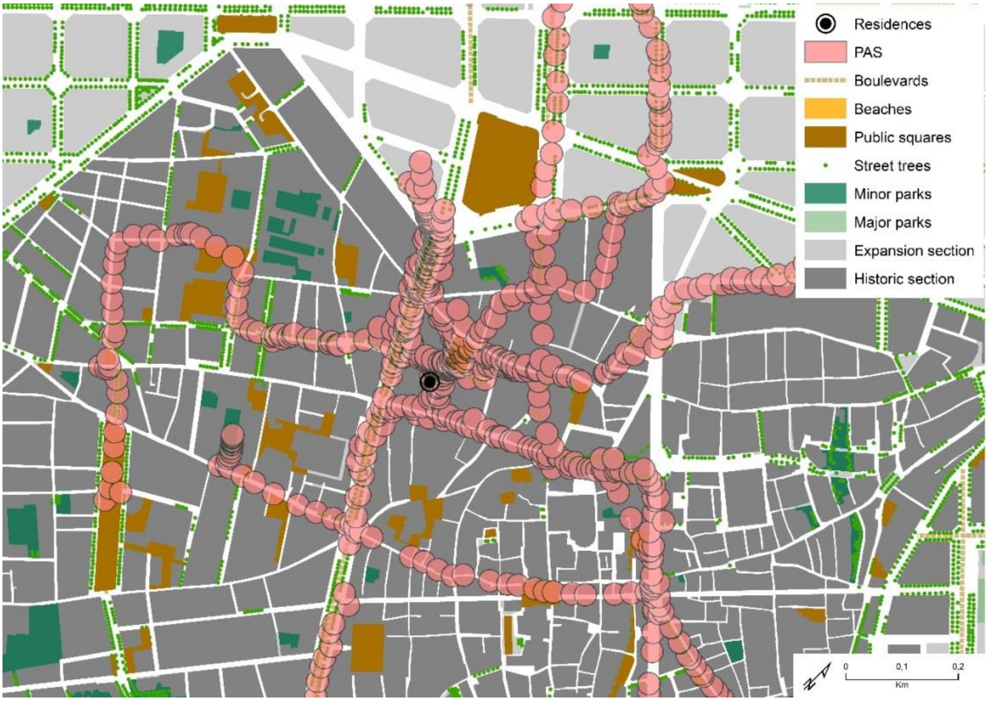


Source: Own production.

For the measurements of *Pedestrian Activity Spaces* (PASs), a 20 m radius buffer was calculated for each of the 85,112 walking tracks that are registered in Barcelona (see **Figure 23**). This buffer size has also been adapted to the average street width of Barcelona, allowing its comparison with RBs. The same GIS process was used to calculate the number of green elements that were included within the buffer area: *parks* (*major* and *minor*), *public gardens*, *street trees*, *public squares*, *boulevards* and *beaches*. Also, the place of residence of the participant was assigned to each 20 m buffer: "Historic" and "Expansion" quarters.

The density of elements (counts/km²) was calculated for each PAS and RB, obtaining two different measures of exposure to greenness. Because a single participant (N=129) could have more than one PAS per day (N=787), we used the mean density of all PASs that were accumulated per participant and per day. By doing so, not only were we approaching a referential temporal scale expressing everydayness, but we were also able to compare each participant PAS greenness exposure with its own RB exposure. At the same time, we were also able to make comparisons between participants with different numbers of participated days. In conclusion, *high mean density of elements per day* will mean that the participant, at the end of one day, will have walked along an environment with a high concentration of green elements. However, a low mean density of elements per day means that participants at the end of one day will have been in contact with a low concentration of these elements.

Figure 23. Example of a Pedestrian Activity Space (PAS).



Source: Own production.

6.2.5. Analysis

The first analysis compares the differences in green exposure between "Historic" and "Expansion" quarters, using the two measures of *Residential Buffer* (RB) (300 and 600 m). Then, the same analysis was undertaken for the exposure that was registered using *Pedestrian Activity Spaces* (PASs). Both mean and median densities were used, and their significance was statistically tested using the Student's *t*-test for normally distributed variables (*street trees*) and the Wilcoxon Rank-Sum non-parametric test for skewed variables (*major parks*, *minor parks*, *public squares*, *boulevards*, and *beaches*). Finally, the differences between exposures to greenness obtained using the 300m RB and the exposures obtained using PAS were also compared in order to test the two methodologies.

6.3. Results

Results in **Tables 8** and **9** show the environmental exposure to different types of green elements that were measured using *Residential Buffer* (RB) and *Pedestrian Activity Space* (PAS) and were analysed according to the type of morphologically distinct areas of the city of Barcelona: *historic* and *expansion* areas.

The analysis of the residential exposure to greenness that was measured using the 300-m RB (see **Table 8**), shows different levels of potential environmental exposure depending on the type of area within which the participants reside. Participants residing in historic neighbourhoods were significantly ($p<0.001$) more exposed to more squares (22.22 vs. 8.56 squares/km², respectively) and to more boulevards (6.71 vs. 0.00 squares/km²) than those participants residing in expansion-type areas. The trend of the differences changed its direction when analysing exposure to minor parks, major parks and street trees. In historic quarters, participants proved to be significantly exposed ($p<0.002$) to nearly half of minor parks/km² (19.99 minor parks/km²) compared to residents of expansion-type quarters (39.32 minor parks/km²). The same differences were applicable to street trees, whereby living in expansion-type areas implied almost double the amount of residential exposure to street trees (3,626.14 trees/km²) compared to residents of historic quarters (2,290.18 trees/km²) ($p<0.001$). No significant differences were found in the exposure to major parks or beaches in either type of residential area. The same significant differences remained for the 600 m RB, (see **Table 8**). The only differences detected were the decreases in the densities of different green element types. The 600 m RB also showed a higher average density of boulevards among residents in expansion-type areas and neither of them included exposure to beaches and major parks.

When using *Pedestrian Activity Spaces* (PASs), the differences in exposure for residents in both types of areas were reduced in percentage points, in both the cases of street trees (-18.60) and squares (42.50). The results showed how residents in historic quarter-type areas were significantly exposed (p<0.001) to nearly two times more public squares (114.33/km² per day) on a daily basis compared to those residents in expansion-type areas (65.74/km²). The residents in both historic and expansion areas were exposed to a very similar density of street trees (2,334.46 and 2,768.63 trees/km², respectively), minor parks (96.5 and 102.8 minor parks/km², respectively) and boulevards (56.54 and 52.34 boulevards/km²) but these differences were only significant in the case of street trees (p<0.001). Participants from historic quarters were exposed to a higher density of major parks with 16.30 major parks/km² compared to expansion quarters that showed lower exposure to these elements. Finally, in the case of beaches, participants of both historic and expansion quarters were not to beaches on their daily walks.

Table 8. Median density of green elements across different methods and neighbourhood type[a].

	Residential buffer (RB)						Pedestrian Activity Space (PAS)		
	300 m			600 m			20 m buffer		
	Historic	**Expansion**	Diff. (%)	**Historic**	**Expansion**	Diff. (%)	**Historic**	**Expansion**	Diff. (%)
N	33	96		33	96		33	96	
Street trees[b]	2,290.18	3,626.14	-58.33*	2,466.93	3,392.37	-37.51*	2,334.46	2,768.63	-18.60*
Squares[c]	22.22	8.56	61.48*	11.96	6.61	44.73*	114.33	65.74	42.50*
Boulevards[c]	6.71	0.00	-	3.84	2.96	22.92	56.54	52.34	7.43
Minor parks[c]	19.99	39.32	96.70**	21.68	35.20	-62.36 **	96.5	102.8	-6.53
Major parks[c]	0.00	0.00	-	0.00	0.00	-	16.30	0.00	100.00*
Beaches[c]	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-

**Significant p-value (p<0.001).*
*** Significant p-value (p<0.005).*
[a] *Units: counts/km².*
[b] *Normally distributed sample: Mean values and p-value obtained from Student's t-test for independent samples.*
[c] *Skewed sample: Median values and p-value obtained from the Wilcoxon Rank-Sum non-parametric test.*
Source: Own production.

When comparing the results from both measures, in **Table 9** the densities of green elements are generally higher when measured using PAS except for street tree density in expansion quarters. The results for density of minor parks and squares were between three to five times higher when measured using PAS for residents of both historic (-79.28; -88.13 percentage points) and expansion quarters (-61.75; -86.98 percentage points). Boulevards were detected in PAS for residents of both historic and expansion quarters, producing higher median densities than residential buffers of 300 m. Densities of major parks were equally obtained using both methods in the case of expansion quarters, but in the case of historic quarters, obtaining exposure to these elements using PAS but not via RB. Finally, participants were not in contact with beaches in neither of the exposure methods.

Table 9. Difference between types of measures of green space exposure.

	Historic quarters			Expansion quarters		
	RB	**PAS**	Diff. (%)	**RB**	**PAS**	Diff. (%)
Street trees	2,290.18	2,334.46	-1.93	3,626.14	2,768.63	23.65
Squares	22.22	114.33	-88.13	8.56	65.74	-86.98
Boulevards	6.71	56.54	-80.56	0.00	52.34	-
Minor parks	19.99	96.5	-79.28	39.32	102.80	-61.75
Major parks	0.00	16.303	-	0.00	0.00	-
Beaches	0.00	0.00	-	0.00	0.00	-

Source: Own production.

6.4. Discussion

In this study, exposure to urban greenness in the context of a Mediterranean city like Barcelona was analysed. In this study, the role of public open spaces such as s and boulevards as alternative providers of greenness was explored. At the same time, two different methods that are used to define exposure were tested. The first method is based on buffers around residential locations and the second method uses activity spaces that are derived from GPS-based smartphone tracking data.

The methodology utilised in this study has shown how Pedestrian Activity Spaces (PASs) obtained higher green element exposure than generalising exposure measures such as Residential Buffers (RBs). This suggests that using only residential buffers in exposure studies might be overlooking a significant part of the exposures which people receive in their daily life. Higher densities of green elements using walking route-based activity spaces in comparison with traditional measures have also been found in previous environmental exposure studies (Hirsch et al. 2015; Zenk et al. 2011). Despite the fact that several authors have found activity space measures to be better predictors of exposure than residential buffers, part of the differences in the present study might have originated from overgeneralised surfaces from RB, that lower the density of elements in these measures. Additionally, the use of PAS has shown that some participants, even though they did not have access to green elements such as major parks at a walkable distance from their place of residence, did make the effort to reach these types of elements during their walks. These differences answer the call of some scholars for the need of further research in exploring environmental influences on human behaviour and health beyond residential areas and aiming to find the true geographic contexts (Kwan 2012; Matthews y Yang 2013). Although place of residence-based methodologies offer an opportunity to measure the exposure to large samples, the utilisation of GPS-based PASs provides valuable spatio-temporal information of real locations with which to explore health-related effects of the environment in terms of improving the performance of potential exposure measures based on the residential addresses of research participants. Therefore, the health effects of the surrounding environment can be analysed through the real behaviour of individuals and not solely through the potentiality.

This study has also shown how research in environmental exposure to greenness must adapt the analysed type of green elements in the specific urban context. In the case of Barcelona, the results of this study confirm that the lower exposure to traditional public parks is compensated by the green exposure in other open spaces such as streets, boulevards or public squares. Barcelona's relative lack of large parks together with the peripheral location of the beaches made it difficult for the participants to have such facilities within walkable distances from their place of residence and prohibited those participants from encountering such facilities during their walks around the city. For a public space to be successful, the optimal location, size, sense of containment, programming of activities and design should be addressed (Carmona, M., Tiesdell, S., Heath, T., & Oc 2010; Gehl 2010). In Barcelona, although there is a huge forest in the mountain range of Collserola, together with the mountain of Montjuïc and other hills, which provide the city with large extensions of greenness, these are located in the periphery of the city and at a high altitude with respect to the city plane, complicating their access either on public transport or on foot. However, since Barcelona is well provided with street trees (Baró et al. 2014; Pauleit et al. 2002) and incorporates high quality open spaces such as public squares and gardens (Garcia-Ramon et al. 2004), both methodologies used in this study show high levels of exposure to these elements.

Furthermore, the analysis of exposure using PAS provided some differences by type of morphology within the city which proved to have results that are not dissimilar in trend to those of RB. However, the intensity of these differences varied. These results could mean that even though the provision of green elements within walkable distance from places of residence is highly influential in the overall exposure of individuals, deficiencies in specific areas of cities due to urban form can be compensated for by walking in other areas. This could be explained by the high walkability levels that are available across most parts of the city of Barcelona (Marquet y Miralles-Guasch 2015a). Findings from this study have also demonstrated that residing in historic quarters can infer a higher level of exposure to public squares, due to the higher availability of these spaces. This can be explained by the central position of public squares in medieval city planning due to the intensive use of these spaces and streets in premodern cities (Madanipour 1999; Oktay 2002). During recent decades, the plans by the Barcelona City Council which are aimed at the rehabilitation of historic neighbourhoods have provided these areas with a broad offering of public squares (Garcia-Ramon et al. 2004). Besides the implementation of car lanes and densification processes during the 20th century, inner Barcelona city still enjoys the street layout that was designed by Cerdà for his Expansion Plan. That is, wide streets allowing the allocation of trees and wide pavements, a pattern that has been continued in later urban developments in the city (Dura-Guimera 2003; Pallares-Barbera et al. 2011). These developments resulted in a higher exposure to street trees for those who reside in expansion areas. Finally, no significant differences were detected regarding exposure to major parks and beaches by residents from these morphologically distinct areas because of their peripheral and hilly location within the city.

6.5. Limitations

Some limitations of the present study should be acknowledged, and specifically regarding the methodology that was used. First, a smartphone tracking app has been chosen as the main data source for the measurement of green exposure due to the integration of GPS and accelerometer technology into smartphone devices that are used daily, becoming potential tools for monitoring daily travel locations (Lee y M. P. Kwan 2018). However, the reliability of MOVES© and other tracking apps, to our knowledge, has only been analysed from the point of view of the quantification of physical activity, hence, as an alternative tool to pedometers. The step counting performance of MOVES© does not satisfy comparative analysis since its accuracy depends on the accelerometer of the mobile: depending on the position of the smartphone device, it does not detect some accelerations of individuals, therefore, some movements and steps are omitted (Case et al. 2015; Evenson y Furberg 2017; Washington et al. 2016). Notwithstanding, when used as a route and location detector, MOVES© improves the geolocation precision of GPS loggers with respect to other sources, such as cellular positioning, obtaining faster fixes and lower signal drop-out due to the street canyoning effect or indoor movement (Kerr et al. 2011). Furthermore, MOVES© and other tracking apps have become valid tools for detecting walking routes and locations in urban environments, and also useful sources of information for actual environmental exposure measures, such as for the purposes of the present study.

Second, it is noteworthy that in the same way that environmental exposure to green elements based on residential addresses of participants are affected by *residential self-selection bias* (Markevych et al. 2014), findings from tracking-based exposure studies are also inherently influenced by the commonly-known *selective daily mobility bias* (Chaix et al. 2013). This bias establishes that destinations and routes taken by individuals could be influenced by intrapersonal preferences. Therefore, in this study the resulting measurement of exposure to green elements could be due to the personal preferences of the research participants, especially in the cases of visiting major parks and beaches.

6.6. Conclusions

The main finding in this study is that exposure to green elements is highly dependent on the configuration of the built environment of a specific urban context. The research results have shown how the low accessibility to large parks in Barcelona is compensated with a wide network of streets, boulevards and public squares and gardens provided with vegetation. The research findings also suggest that this trend, together with the importance of alternative sources of nature, is sustained through the morphologically distinct areas of the city. Additionally, the use of *Pedestrian Activity Spaces*, based on smartphone tracking data, allowed us to obtain exposures to green elements that *Residential Buffers* were unable to detect, even though proximity dynamics in the city determined the results of this research to a large extent.

These findings suggest that neighbourhood environments are strong determinants of green exposure, and that there are alternative sources of greenness across other parts of the city that can be provided by city councils in locations that are outside of large parks. Future policies should be oriented towards improving accessibility to green elements through high quality parks and gardens, and to improving streetscape quality through greening programmes.

7. Green streetscape and walking: Exploring active mobility patterns in dense and compact cities

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Green streetscape and walking: Exploring active mobility patterns in dense and compact cities☆

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A B S T R A C T

Being physically active in natural environments has been linked with multiple mental and physical health benefits. However, not all urban contexts can provide their residents the same access to green areas for walking and sport activities. Mediterranean cities provide open spaces for physical activity that differ from those of Northern European cities. This study explores both conventional spaces in the form of public parks and urban green spaces, i.e. beaches, tree-lined streets, boulevards and public squares, in relation to the daily walking levels of residents in a Mediterranean city, such as Barcelona by presenting findings based on examining and assessing spatio-temporal exposure levels measured with the help of smartphones and publicly available GIS layers. To achieve this, both exposure and daily walking time were measured from GIS and GPS-based smartphone tracking data for 127 adult individuals from Barcelona, Spain. Based on these measurements, it was determined that the presence of large-scale open spaces for physical activity, such as beaches or large parks in the participants' daily walking routes, proved to have the highest association with daily walking time. Also, underexplored forms of nature, such as street trees were also positively correlated with individual walking levels. Additionally, small-scale public spaces, such as public squares and boulevards, indicated a considerably negative association with walking time. The findings from this study confirm existing evidence on the health benefits of urban greenness and broaden the analytical focus on the role and impact of green space provision on physical health. Altogether, street trees and the presence of both blue and traditional green spaces proved to be significant factors of increased walking levels.

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7.1. Background

Walking is considered to be one of the most common physical activities among the adult population due to its associated increments in individual energy expenditures (Brownson et al. 2000; Lachapelle y Pinto 2016). This becomes more relevant in view of the recent findings of the World Health Organization that identify physical inactivity as the fourth leading risk factor for global mortality, as it leads to coronary heart disease and chronic conditions including hypertension, non-insulin-dependent diabetes, colon cancer, osteoarthritis and osteoporosis (WHO 2010). To address these health concerns, public health officials and academics have identified active travel, i.e. walking or cycling, as a pathway towards minimising sedentary lifestyles and an acceptable source of exercise for achieving optimal health standards (Carlson et al. 2015; Sallis et al. 2004).

Apart from the various elements of urban planning and design that have been conducive to walking (Cervero y Kockelman 1997; Sallis et al. 2015), a growing body of literature has linked people's access to nature with multiple mental and physical health benefits (Hartig et al. 2014; Markevych et al. 2017; Tsai et al. 2018). In fact, available greenness in structured urban green spaces has proven to reduce stress (van Herzele y de Vries 2012; Sarkar, Webster, y Gallacher 2018), promote socialising with friends (De Vries et al. 2013), and diminish the levels of air pollution, heat and noise (Baró et al. 2014; Basagaña et al. 2011; Pathak et al. 2008). Moreover, these spaces have been linked with increased physical activity levels (Douglas et al. 2017; Markevych et al. 2017), since they provide a safe, accessible and attractive setting for walking and physical activity practices (Almanza et al. 2012; Schipperijn et al. 2013).

Public parks and gardens are the most widely researched forms of green space (Koohsari et al. 2015). However, the presence of nature is not only evident in public parks and gardens. Street trees and their canopies are common natural elements found in most urban areas in Europe. Apart from being a source of nature, research has found that they also increase street walkability (Cervero y Kockelman 1997; Southworth 2005; Talavera-Garcia y Soria-Lara 2015). Together with streets, boulevards, and avenues with trees, also public squares and pocket parks are underexplored forms of green space and facilitators of several health benefits (Abelt y McLafferty 2017), including increased physical activity. In Mediterranean cities, where the provision of public parks tends to be lower than in other urban areas (Akpinar 2016; Fuller y Gaston 2009), public squares and pocket parks could compensate for the absence of natural parks as a source of nature (Taylor et al. 2015). Urban residents can use these public spaces for resting, walking and socialising while enjoying access to urban greenness (Corraliza 2000; Ward Thompson 2002). Previous literature has linked the provision of street trees with several health benefits, such as improved general health perception (van Dillen et al. 2012), lower depression levels (Sarkar et al. 2018; Taylor et al. 2015) and positive birth outcomes (Abelt y McLafferty 2017). However, there are still few studies linking tree-lined streets as a mediator of physical health. In comparison to other green spaces, such as natural parks related to recreative walking, not only do green streets enable walking as a means of self-transportation along aesthetically pleasant routes (Sallis et al. 2012), but they could also become optimal places for recreational walking (Hahm et al. 2017; Lu et al. 2018). Some current studies provide evidences associating higher tree densities with increased walking levels among adults (Lu et al. 2018; Sarkar et al. 2015), or improved active travel and preventing obesity among children (Larsen et al. 2009; Lovasi et al. 2013). Nevertheless, more research is needed. Furthermore, many Mediterranean urban areas feature another distinct open space that provides people to have contact with nature, socialise and be physically active: the beach. This space, often considered as type of green space (WHO 2016), is also known as a coastal blue space and being exposed to it has been previously linked with similar health benefits as green spaces (Hipp y Ogunseitan 2011), particularly with increased physical activity levels (Galland y Hansen 2012; Gascon et al. 2017).

Another major topic in health-related green space studies is the objective measurement of urban greenness. Recently, the relationship between this environmental feature and health benefits has further examined and developed thanks to technologies, such as the Geographical Information Systems (GIS) (Rojas et al. 2016; Troped et al. 2010). Conventional exposure measurements, such as residential proximity to green spaces, are now accurately documented by means of street network distances thanks to GIS, which not only informs on the static potential access to greenness, but omits the available greenery in open spaces beyond conventional natural parks (Koohsari et al. 2015). Other utilised vegetation indicators also obtained by using GIS tools, such as the Normalized Difference Vegetation Index (NDVI) and the street tree density of an urban area, are helpful in examining the provision of greenness in different sorts of open spaces (Marquet et al. 2019). On the one hand, the NDVI indicates the overall vegetation level in a specific territory via satellite images; however, it still does not differentiate between the various types of greenness found in parks, street trees or private gardens (Markevych et al. 2017) despite recent efforts to improve the features of this tool (Shoshany 2012). On the other hand, the amount of street trees has become an increasingly used indicator of urban greenness, as it is a fine-grained measure for filtering the amounts and types of trees according to the area of analysis (Abelt y McLafferty 2017; Sarkar et al. 2015; Taylor et al. 2015).

New sources of information, such as Global Positioning Systems (GPS), have also provided individual data for detecting precise walking patterns and the consequent exposure to the surrounding environment. GPS data, especially when combined with GIS spatial analysis, has been widely used not only for detecting levels of physical activity in green spaces (Almanza et al. 2012; Andersen et al. 2015; James et al. 2017), but also measuring precise people-based exposure levels based on the mobility patterns of individuals in the surrounding environment, such as activity spaces(Hirsch et al. 2015; Holliday et al. 2017). GPS-based tracking measurements help minimise the challenges experienced with conventional place-based methods, such as the potential residential self-selection bias (Toftager et al. 2011), the Ecological Fallacy (Sarkar et al. 2015), and the so-called "Modifiable Area Unit Problem" or "local trap" (Vallée et al. 2014). These measurements predefine the scale of the environmental exposure at an administrative unit level (neighbourhood, census) or at buffered distances from residences, not including other visited locations by individuals (Kwan 2012; Vich et al. 2017). However, time-spatial measurements also include other challenges, such as the so-called "Selective Daily Mobility Bias", by which the resulting environmental exposures obtained from mobility patterns could be attributed to individual preferences, which lead to possible biased causal effects (Chaix et al. 2013).

Finally, the appearance of GPS-enabled smartphones and their widespread availability has widened the possibilities of collecting data for both urban and environmental exposure studies. Although data-loss situations may occur due to battery drainage (Birenboim y Shoval 2015), on-board accelerometers and GPS in smartphones can precisely monitor individual spatial and temporal behaviour while lowering the participation burden for users (i.e. carrying and charging a GPS device) (Hirsch, James, et al. 2014). Compared to GPS loggers, smartphone tracking data provides access to larger population samples and geographic ranges during longer observation periods, while posing relevant questions to study subjects on the go (Marquet et al. 2018) as well as promoting PA practices and sustainable mobility habits (Bopp et al. 2016). Apart from the available literature on urban planning and transportation, smartphone tracking data has concretely helped in tracking travel behaviour patterns, improving self-reported information and preventing common mobility survey biases (Birenboim y Shoval 2015; Delclòs-Alió et al. 2017; Patterson y Fitzsimmons 2016; Vich et al. 2017). From a health perspective, Hirsch et al. (2014) analysed the types of physical activities tracked by means of an app and the locations they occur in. More recently, Althoff et al. (2017) used smartphone tracking data to explore walking-derived physical activity patterns in 111 countries around the world, whereby they focused on the role of the built environment and people's incomes. Due to its novelty, only few studies have used smartphone tracking data to examine the relationship between exposure to green spaces (Vich, Marquet, y Miralles-Guasch 2018) and physical activity patterns (Donaire-Gonzalez et al. 2016; Hirsch, James, et al. 2014) or the influence of trees on the selection of specific walking routes (Hahm et al. 2017).

The aim of this study is to examine the association between different types of urban green spaces that have so far been overlooked or not sufficiently studied (parks and tree-lined streets, boulevards and public squares) and daily walking levels in a Mediterranean city, such as Barcelona. This research uses GPS-based smartphone tracking data to obtain exposure measurements from the mobility patterns of a group of individuals in order to analyse the relationship between green space exposure and daily walking time.

7.2. Methods

The city of Barcelona, which is the study area, had a population of 1.6 million in 2016 and an average population density of 15,740 inhabitants per km² (Ajuntament de Barcelona 2016a). Its density, morphology and street design make this city a highly walkable urban area (Dura-Guimera 2003; Marquet y Miralles-Guasch 2015a). Compared to other urban areas, its lower number of public nature parks (Fuller y Gaston 2009) is partly compensated by high quality open spaces, such as streets, boulevards and public squares (Garcia-Ramon et al. 2004), which are well provided with street trees (Pauleit et al. 2002). These spaces represent lively settings for walking or strolling as well as for social gathering (Corraliza 2000; Ward Thompson 2002). This provision of diverse green spaces makes Barcelona an ideal site for examining the relationship between walking levels and exposure to different sources of urban greenery.

7.2.1. Participants and data collection

We used a subsample of voluntary respondents to the 2017's Autonomous University of Barcelona (UAB) Mobility Survey (n=263). This was complemented with a snowball process (n=64), mailing lists (n=11) and ads placed in social networks (n=9). Altogether, we gathered a total of 347 participants. The recruiting campaign called for people interested in participating in an academic research on active mobility called "Campus Mobility 2017". To assess their daily walking patterns, participants were asked to download and install the MOVES© smartphone app, which is available for free on both Android and IOS). This GPS-based app provides users with a diary of personal mobility, in which they can record information on travelled distances, durations, steps, and burned calories. At the same time, the app recognise routes taken by the users, their visited location and transportation modes throughout the day (Evenson y Furberg 2017). Between April and June 2017, participants downloaded and kept MOVES© activated for seven days, and at the end of the tracking exercise, they took part in an online survey, in which they answered several profile questions (gender, age, commuting transport mode and residence address). This app was recently applied in a similar study on green space exposure (Vich et al. 2018). The downloading, installation and use of MOVES© by participants involved their explicit consent to the terms and conditions of the app developer, and the confidentiality of their data was ensured by implementing different user codes during data collection, data processing and data analysis stages. The study was approved by the Ethics Committee on Animal and Human Experimentation of the Autonomous University of Barcelona (code CEEAH-3657).

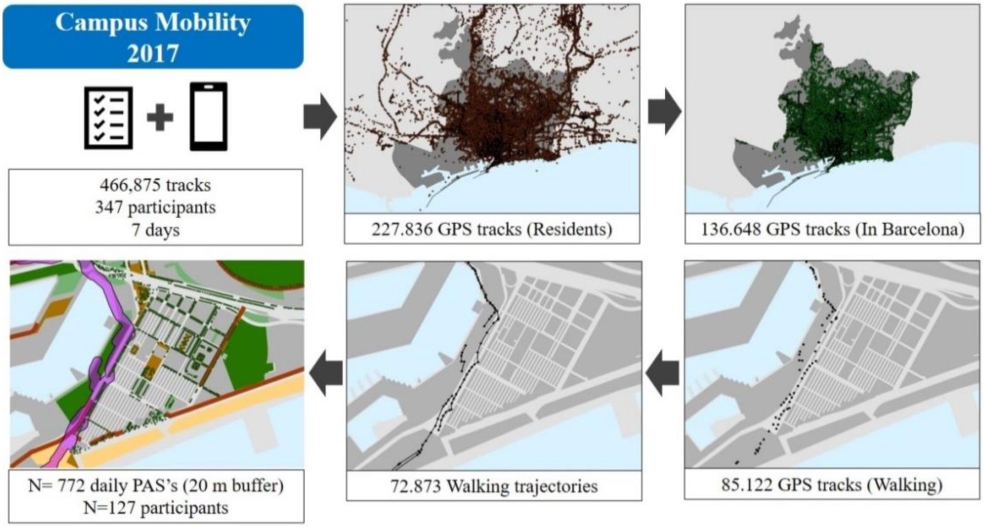
7.2.2. Measurements

At the end of the fieldwork, a total of 466,875 tracking points was registered using the MOVES© API. GPS points are georeferenced and transport modes assigned by this app when movement is detected by the smartphone's accelerometer (Protogeo 2016). The database required minimal cleansing, since trips and stops were detected by the app's algorithms. From the raw database, tracking points registered by residents in Barcelona (N=227,836) and registered within Barcelona's administrative limits (N=136,648) were selected. This app categorised georeferenced points either as a "waiting" or "moving" tracking point to differentiate whether these points were part of a trip or a stop. A "waiting" tracking point implied standing still, while one "moving" tracking point is defined by the app as comprising consecutive points , which exhibit a certain speed and acceleration and a transport mode that implies movement, i.e. walking, running, cycling or motorised transport, assigned by the smartphone's accelerometer (Protogeo 2016). Of the 136,648 tracking points registered by residents within the city limits of Barcelona, 85,112 "moving" tracking points categorised as "walking" made the final sample after the data cleansing process and accounting for days of participation.

The final 85,112 GPS tracking points obtained from MOVES© were utilised for measuring both the users' walking patterns and their environmental exposure to greenness. In order to examine the amount of physical activity generated by walking across the city, daily walking time was selected as the main outcome variable. This outcome was calculated by tallying the consecutive points assigned by MOVES© as "walking" points within Barcelona's boundaries into different trip segments using the Tracking Analyst function of the ArcGIS 10.3 toolbox. Trip segments or trajectories registered at a higher speed than 6 km/h and lasting over 3 minutes were excluded, and thus following commonly accepted data cleansing thresholds (Cho et al. 2011). A sample of the walking trajectories of three participants was extracted and visually checked to detect any incoherent transport mode assignments and erroneous multimodal trajectories. Of the total trajectories, 95% were correctly assigned. Days with remarkably low walking levels according to their Z-score were discarded (daily walking time under 1 min per day), thereby leaving the final sample at 127 individuals that contributed to a total of 772 complete days of data (average of 6.1 days/person), which concurs with previous research (Costa et al. 2015; Robinson y Oreskovic 2013). The participant sample (n=127) was fairly balanced according to gender (male=52; female=75) and predominantly young under 29 years = 87; 30-41 years = 29; 42-64 years = 11).

The methodological workflow followed is schematised in **Figure 24**.

Figure 24. Methodological scheme.



Source: Own production.

To capture the level of exposure to urban greenness, a GPS-based buffered trip segment called "Pedestrian Activity Space (PAS)" was calculated for each day of participation to measure the presence of greenness elements that individuals were exposed to. First, the calculation of all PAS's consisted of executing a 20-meter buffer around all the geocoded walking trip segments with ArcGIS 10.3©. 772 PAS's were generated, which corresponded to the 772 participated days from 127 individuals (See **Figure 25**). Although the buffer size of 20 meters was smaller than similar studies (Burgoine et al. 2015; Hirsch et al.

2015), this size was the average street width of Barcelona; thus, the buffer size was adapted to the spatial scale of the study.

Figure 25. Example of a Pedestrian Activity Space (PAS).

Source: Own production.

Publicly available spatial information on land uses in Barcelona, street intersections and geolocated trees planted in the city in shapefile formats were used to describe the surrounding green environment: public parks, street trees, boulevard, public squares and beaches (see also Fig. 1). The city's Land Use Map (Ajuntament de Barcelona 2016b) was utilised to identify "large parks". Only land use polygons categorised as *urban parks* (N=93), and *forestry parks* (N=1) by this map larger than 2 hectares were considered (Natural England 2010), whereas green areas under this threshold were identified as *small parks* (N=1,760) with sizes ranging between 20,020 and 1,640,000 m^2 and 16.88 and 19,340 m^2, respectively. *Beaches* (N=1), *public squares* (N=359) and *boulevards* (N=91) were identified by combining the land use map with the street category from the street network shapefile (BCC 2014). No pre-processing was required to identify *street trees* (N=153,414) included in the Street Tree Map in shape file (Ajuntament de Barcelona 2014). This only included those trees placed outside park borders.

We then used the Spatial Join tool of ArcGIS 10.3© to determine the presence of urban green elements included within each PAS. We calculated the proportion of these elements per PAS buffer, by dividing it by their total area (km^2 of green element/total km^2 of PAS). Proportions of these elements were applied for measuring and comparing concentrations of elements in PAS's with different areas to control for any size difference. For street trees, tree density (trees/total km^2 of PAS) was utilised to calculate the proportion of this element per PAS buffer. *Street intersection* density was also included in the analysis as a proxy of the different morphologies available in the city that can also influence walking patterns. (Christiansen et al. 2016) *Day type* of participation (week and weekend) was analysed to detect differences between utilitarian and recreational walking. Furthermore, the individual exposure to these environmental features was controlled by several profile and mobility variables, such as gender, age and commuting mode, which includes active (walking and cycling), public (train or bus) and private transport means (car or motorcycle), according to the data extracted from the profile questionnaire.

7.2.3. Statistical Analysis

Median differences were used to analyse variations in the amount of walking minutes between the categories of the selected independent variables (*gender, age, commuter type, day type, intersection density, tree density, proportion of boulevards, proportion of public squares, proportion of small parks, proportion of large parks, proportion of beaches*) and their significance levels were calculated using the Mann-Whitney U-test and the Kruskal-Wallis test due to the skewness of the sample of daily walking time. The descriptive statistics are followed by a mixed-effects multilevel regression analysis to test the association between the set of explanatory variables and the log-transformed outcome variable in which the 772 PAS's were set as level 1, at which explanatory factors were measured among 127 participants with individual-level data as level 2. The fixed effect analysis aimed at measuring differences in walking time between individuals after controlling for the independent variables. The random effect explored the variation of daily walking time corresponding to the different daily exposure measures and profile factors at the PAS level. No multicollinearity was detected between the explanatory variables exhibiting variance inflation factor (VIF) values ranging between 1.03 and 1.17.

7.3. Results

7.3.1. Descriptive statistics

Table 10 shows descriptive statistics for walking time across the different type of explanatory factors. Among the analysed variables, neither *gender* nor *age* proved to be significant explanatory factors of daily walking in the bivariate analysis. Male and female participants registered similar amounts of walking minutes, whereas individuals between 30 and 41 years old registered higher median values than people in their 20s or those over 42 years old. The *day type* also did not show any significant influence on walking time, although higher median values were registered during weekends than weekdays.

Variables, which describe the exposure to the surrounding environment (parks, beaches, squares, boulevards, trees and intersections) on participants' daily walks and the utilised *commuting mode*, showed significant results (also **Table 10**). The PAS's, which were registered by active commuters and public transport users, generated higher walking time than private transport commuters. In the same way, those individuals that incorporate large open spaces in their PAS, such as *large parks* and *beaches,* registered twice and four times as much daily walking minutes at the end of the day, respectively, than those who did not. Regarding smaller open spaces, those PAS's not indicating any presence of *small parks*, *public squares* and *boulevards* generated the lowest walking time per day. However, those with a low proportion of these elements generated higher walking time than those with intermediate and higher proportions. Regarding street trees, those individuals, who walked in higher *tree density* areas, registered more walking time than those who walked in the lower density areas. However, the highest median walking times were registered by participants exposed to intermediate tree densities, i.e. medium-low and medium-high, along their daily walks. The same pattern was detected when analysing the connectivity of the street pattern with the *intersection density*. PAS's with a higher density of intersections registered higher walking times than those with lower densities; the highest daily walking times were concentrated in areas of intermediate intersection density.

Table 10. Median daily walking time using explanatory factors at two levels.

Explanatory factors	Categories	N	Minutes [a]	IQR	p
	Total	772	25.13	37.58	
Gender	*Male*	331	25.03	42.47	0.623
	Female	441	25.23	34.72	
Age	*<= 29 y.o.*	521	23.72	34.83	0.080
	30 - 41 y.o.	182	28.84	42.27	
	>=42 y.o.	69	24.83	32.80	
Employment status	*Student*	411	23,70	34.68	0.641
	Employed	356	26.54	41.90	
	Unemployed	4	17.68	84.88	
Commuter type	*Active transport*	112	29.01	39.60	0.001*
	Public transport	556	26.58	38.66	
	Private transport	92	13.06	21.30	
Day type	*Week*	571	25.23	37.10	0.755
	Weekend	194	24.25	38.54	
Intersection density [b] (counts/km²)	*Low*	107	8.73	13.43	0.001*
	Medium-Low	334	30.98	39.06	
	Medium-High	230	33.73	39.35	
	High	101	19.02	36.33	
Tree density [c] (counts/km²)	*Low*	70	6.00	7.94	0.001*
	Medium-Low	457	24.72	34.53	
	Medium-High	179	35.08	37.32	
	High	66	38.93	37.90	
Boulevard proportion [d]	*No contact*	450	11.18	14.84	0.001*
	Low	793	40.80	38.97	
	Medium	371	28.15	28.10	
	High	100	9.61	11.78	
Public square proportion [e]	*No contact*	726	16.28	22.78	0.001*
	Low	820	39.26	36.47	
	Medium	126	28.82	35.76	
	High	42	14.31	32.53	
Small park proportion [f]	*No contact*	546	12.27	16.79	0.001*
	Low	677	39.62	36.08	
	Medium	310	35.94	33.81	
	High	181	25.80	28.66	
Large park proportion [g]	*No contact*	1,384	23.58	29.95	0.001*
	Low	93	45.12	44.85	
	Medium	117	53.43	41.82	
	High	120	33.09	36.65	
Beach proportion [h]	*No contact*	1,675	26.32	32.73	0.001*
	Medium	10	99.13	62.44	
	High	28	61.88	59.66	

**Significant p-value obtained from Kruskal-Wallis non-parametric one-way Analysis of Variance (ANOVA) or Wilcoxon Rank Sum test across individual and environmental factors.*

[a] *Median walking minutes per day.*

[b] *Categories obtained using 1 standard deviation: Low (<= 2004.73); Medium-Low (2004.74 – 3417.74); Medium-High (3417.75 – 4830.75); High (>4830.76).*

[c] *Categories obtained using 1 standard deviation: Low (<= 96.37); Medium-Low (96.38 – 228.33); Medium-High (228.34 – 360.29); High (>360.30).*

[d] *Categories obtained using 1 standard deviation: No contact (<= 0.00); Low (0.01 – 0.30); Medium (0.31 – 1.04); High (>1.05).*

[e] *Categories obtained using 1 standard deviation: No contact (<= 0.00); Low (0.01 – 0.02); Medium (0.02 – 0.03); High (>0.04).*

[f] *Categories obtained using 1 standard deviation: No contact (<= 0.00); Low (0.01 – 0.29); Medium (0.30 – 0.81); High (>0.82).*

[g] *Categories obtained using 1 standard deviation: No contact (<= 0.00); Low (0.01 – 0.10); Medium (0.11 – 0.47); High (>0.48).*

[h] *Categories obtained using 1 standard deviation: No contact (0.00 – 0.02); Medium (0.03 – 0.10); High (>0.11). The Low exposure category was excluded since there was only one case.*

Source: Own production.

Table 11 shows the multilevel regression analysis between walking time and the different explanatory factors at two levels: individual (level 2) and PAS (level 1). The intraclass correlation of daily walking time showed that 38% of the variation in registered walking minutes was attributable to differences between the participants. Environmental exposures measured along walking routes were all significantly associated with walking time at the individual level. The environmental factors with the highest association were *beach proportion* (B=2.298) and *large park proportion* (B=0.153), whereas *tree density* (B=0.001) also ended up being significant. Albeit showing negative association with the outcome variable, other significant environmental factors were, *public square proportion* (B=-1.420) and *boulevard proportion* (B=-0.108). The only non-significant exposure factor was *small park proportion*, which also showed a negative relationship with walking time. Furthermore, being a *private transport commuter* was also negatively associated with walking time and no significant influence was found for *day type* (reference weekend days), *gender* (reference female), employment status (reference student) and *age*. After controlling for the explanatory factors at the individual level, 34.16% of the variation in walking levels was still attributable to differences between participants. Of these differences, 29.32% corresponds to the different daily exposures to greenness at the PAS level. Therefore, the individual participants' different daily exposure to greenness can explain 10.01% (29.32% of 34.16%) of the total variance of walking time. Both variations among participants within their PAS were found to be significant.

Table 11. Mixed-effects linear regression coefficient for daily walking time (minutes) of exposure measures[ab].

Explanatory factors of daily walking time

Fixed effects	*B*	St. Err.	*t*	*p*	CI (95%)	
Intersect	1.437	0.261	5.506	0.001*	0.919	1.954
Profile factors						
Dummy male	0.047	0.056	0.846	0.399	-0.064	0.159
Age	0.007	0.003	1.950	0.054	0.000	0.013
Dummy student	0.009	0.032	0.271	0.787	-0.055	0.073
Dummy private transport	-0.296	0.087	-3.415	0.001*	-0.468	-0.124
Environmental factors						
Intersection density	0.008[c]	0.000	1.933	0.054	0.000	0.000
Tree density	0.001[c]	0.000	5.895	0.001*	0.000	0.000
Boulevard proportion	-0.108	0.016	-6.864	0.001*	-0.139	-0.077
Public square proportion	-1.420	0.430	-3.305	0.001*	-2.265	-0.576
Small park proportion	-0.033	0.036	-0.918	0.359	-0.105	0.038
Large park proportion	0.153	0.059	2.600	0.010*	0.037	0.268
Beach proportion	2.298	0.581	3.953	0.001*	1.156	3.440
Day characteristics						
Day type	0.034	0.032	1.069	0.286	-0.028	0.096
Random effects	***B***	**St. Err.**	***Wald Z***	***p***	**CI (95%)**	
Residual	0.111	0.007	16.071	0.001*	0.098	0.126
Participants	0.058	0.011	5.047	0.001*	0.039	0.085

B: Coefficient estimate; St. err.: Standard error; t: t-value; p: p-value; CI: Confidence interval; Wald Z: Wald test.
**Significant p-value.*
[a] *This model is based on the log-transformed dependant variable: MVPA.*
[b] *Intraclass coefficient (ICC): 0.387 (null model), 0.342(full model). Proportion of the variance at Level 1(0.293)*
[c] *Change in outcome per unit change in IQR.*
Source: Own production.

7.4. Discussion

The results showed a significant association of explanatory factors at both individual and Pedestrian Activity Space (PAS) levels in relation to walking time in Barcelona. Outcome variations at both interindividual (34.16%) and PAS (10.01%) levels indicated different walking levels among the 127 sampled participants.

The exposure to different green spaces and elements analysed in this paper has proven to be significantly associated with registered walking time at the end of the day. Of all the analysed factors, the strongest environmental factors were the presence of large open spaces, such as *beaches* and *large parks,* in the participants' PAS's, whereby being in contact with both blue and green large open spaces resulted in the highest association with daily walking time. These findings conform with conventional green space exposure academic studies, with which the presence of green areas and residential proximity thereto are related to increased walking levels (Kaczynski et al. 2009; Lachowycz y Jones 2011; Sugiyama et al. 2013).

Regarding less explored forms of green spaces, this study also significantly contributes to the growing number of studies examining the relationship of street trees and positive physical activity outcomes (Larsen et al. 2009; Lovasi et al. 2013; Sarkar et al. 2015) by showing a positive association between exposure to *tree density* and the daily walking time of individuals. However, for public squares and boulevards, a significant negative association with walking levels was detected. These differentiated associations for small-scale open spaces could be due to their design and preferential uses, which make them more attractive for rather sedentary forms of recreation (Carmona 2010; Gehl 2010; Madanipour 1999). Regarding profile-related factors, only those concerning mobility habits had an effect on daily walking time. Travelling to daily destinations by car has been long associated with a more sedentary lifestyle (Brownson, Boehmer, y Luke 2005), while using public transport has also been found to help meet physical activity recommendations (Lachapelle y Pinto 2016). In this study, those who used *public transport for commuting*, walked significantly more than those using private modes. Furthermore, no association was detected when examining how *gender*, *age, employment status* and *day type* affects daily walking time. The current literature highlights how women and young people are linked to healthier mobility patterns and increased walking times than men and older adults (Bauman et al. 2012; Rissel et al. 2012). Although findings in this study did show differences in *age* and *gender*, these did not reach statistical significance. The fact that the sample mostly comprised of young participants might have had an influence in the results.

The present research, which is one of the few studies examining the relationship between the built environment and daily walking levels using individual exposure measures based on smartphone tracking data, provides promising results for future health and planning studies. The detected differentiated walking time patterns within a highly dense urban area, such as the city of Barcelona, conform with state-of-the-art studies on physical activity and environmental exposure research (Althoff et al. 2017; Donaire-Gonzalez et al. 2016; Hirsch, James, et al. 2014). Moreover, the use of activity spaces for measuring the environmental exposure has proven to be a precise measurement, as only green spaces encountered along walking routes were registered. At the same time, this study addresses the need for examining environmental influences on human behaviour beyond residential areas while it aims to find true geographical contexts (Kwan 2012; Matthews y Yang 2013; Vallée et al. 2014).

The utilisation of smartphone technology for examining spatial behaviour provides methodological improvements due to their widespread daily use, which reduces possible utilisation bias, as they make users less aware of their mobility patterns. The tracking data derived from smartphones proves to be an accessible data source for both health and planning studies due to their easy collection and the ease of use by study subjects.

However, this study is not without limitations. The issue of *Selective Daily Mobility Bias* (Chaix et al. 2013), which is common among most tracking-based exposure research, continues to be a challenge. Individuals might choose certain destinations and routes according to intrapersonal preferences when travelling or during leisure time rather than for the mere purpose of gaining exposure to the environment. For instance, this is clear in the case of exposure to large parks and beaches. Moreover, a straight causality between exposure measures and walking time should not be drawn, since exposure to green spaces does not necessarily imply that these are being used (Koohsari et al. 2015; Markevych et al. 2017). At any rate, this study does provide valuable findings concerning the often unexamined urban spaces and green elements, where participants can have physical activity (James et al. 2017), in this case, through daily walking.

The present findings further supplement existing evidence on the health benefits of green spaces by casting a new light and perspective on a wider approach regarding greenness provision. Based on the results of the study, public health and planning policies working towards creating and developing healthy and vital environments could consider greening the streetscape of streets or public squares as a complementary solution to park planning. Indeed, the evidences in this study reaffirm the unexplored potential of providing street greenery in urban greening strategies and policies. Together with other design elements, such as benches or wide sidewalks, providing streets with different forms of greenness, has the potential of enhancing the urban dimensions and functions of simple paths and roads. Streets could become both walkable spaces and areas for social gathering and activities. In this specific context, greening strategies, such as the planning of urban green networks or green corridors, gain higher relevance, since providing these systems improves both the walkability of urban systems as well as the accessibility to specifically allocated green spaces, such as nature parks. This potential is particularly relevant not only for dense and compact urban areas, such as Barcelona, which does not have enough space to provide large monofunctional green areas, but also for less dense urban areas aiming to improve the walkability and vitality of their streets and neighbourhoods.

PARTE III

8. Discusión de los principales resultados

En el presente capítulo se ponen en común los principales resultados de los cuatro artículos científicos presentados con el propósito de responder a las preguntas de investigación y contrastar las hipótesis de la tesis doctoral.

- **Hipótesis principal.** En un contexto metropolitano, el espacio que utilizan sus residentes para la realización de las actividades cotidianas está condicionado tanto por las características del entorno construido como por los procesos cognitivos y las características individuales de las personas.

El objetivo general de esta tesis ha sido explorar los condicionantes de la dimensión espacial de la movilidad cotidiana en el contexto de la Región Metropolitana de Barcelona (RMB), a través de la utilización de nuevas fuentes de datos como el SoftGIS y el *tracking*. Los resultados obtenidos en los distintos casos de estudio realizados han confirmado la hipótesis principal de la tesis al demostrar el carácter multifactorial de los patrones de movilidad cotidiana de las personas, en el cual las características objetivas del territorio que los alberga, la imagen cognitiva que tienen sus residentes sobre él y el perfil sociodemográfico de éstos, ejercen un papel determinante. Asimismo, se ha demostrado que las características objetivas del territorio influencian tanto la información espacial almacenada en la mente de las personas, así como el comportamiento espacial relativo a la movilidad cotidiana.

- **Sub-Hipótesis 1.** La imagen cognitiva sobre el entorno urbano construido condiciona los patrones de movilidad de los residentes de una metrópolis.

El presente estudio ha confirmado que dentro de un grupo de población con características similares, en este caso miembros de una comunidad universitaria, pueden existir imágenes cognitivas distintas sobre un mismo contexto territorial, como es la Región Metropolitana de Barcelona (RMB).

La estructura espacial de un territorio, como la RMB, ha demostrado ejercer una influencia determinante en la configuración de los mapas cognitivos de las personas que residen en él. Por un lado, a través del ejercicio de mapeo cognitivo, los límites del espacio de actividad han sido representados como un continuo espacial a escala metropolitana, situando el lugar de residencia de la persona, el campus de la UAB y el resto de sus actividades diarias en los bordes de este continuo. Esta imagen cognitiva en la que se representa un territorio de gran extensión se debe a la amplia separación entre funciones urbanas en contextos metropolitanos (Golledge y Timmermans 1990). En consecuencia, este tipo concepción del espacio de actividad individual puede implicar el percibir un territorio, en este caso la RMB, como algo extenso y fácilmente accesible mediante la utilización de medios de transporte mecanizado. En este sentido, un uso generalizado del vehículo privado puede conllevar ciertas externalidades por su impacto en el medio ambiente (Ewing et al. 2016).

Por el otro, otra imagen extraída de los mapas cognitivos de los participantes diferencia distintas regiones separadas o superpuestas en un mismo espacio de actividad. En primer lugar, algunas personas han representado espacios de pequeño tamaño, en el que incluyen destinos cotidianos alrededor del lugar de residencia, dentro de un espacio de mayor tamaño donde se incluye mayoritariamente la localización del campus de la UAB. En segundo, otros mapas cognitivos regionalizados representan un territorio fragmentado con distintas partes no superpuestas (Mitchell 1995), en el que cada una de las partes corresponde a diferentes destinos cotidianos de las personas (lugar de residencia, trabajo, ocio, etc.). Esta representación de un espacio de actividad regionalizado confirma importancia de los puntos de anclaje espacial en el comportamiento espacial de las personas, resaltada por los geógrafos de la percepción y comportamiento, por la cual la localización de ciertas actividades estructura la vida cotidiana de los individuos en un territorio y desde las cuales pivotan las demás (Couclelis et al. 1987; Golledge y Stimson 1987). Esta tipo de representación puede estar influenciada por el modelo dual de desarrollo urbano de la RMB, caracterizado por una organización de las funciones urbanas a distintas escalas territoriales (Marmolejo y Cerda Troncoso 2017; Miralles-Guasch y Tulla-Pujol 2012). En estas imágenes cognitivas que implican territorios regionalizados, los entornos locales adquieren una gran relevancia debido a la fuerte vinculación y preferencia de los residentes metropolitanos por su barrio (Johnston 1972; Lovejoy et al. 2010). Esta preferencia y uso del entorno residencial, junto con una la morfología urbana y una disposición de usos del suelo favorables, pueden propiciar la creación de dinámicas de proximidad urbana y la reducción de la extensión espacial de la movilidad cotidiana de sus residentes, las cuales pueden tener repercusiones positivas para el medio ambiente.

- **Sub-Hipótesis 2.** Existen diferencias en el espacio metropolitano utilizado para realizar las actividades cotidianas según las características sociodemográficas y las preferencias de movilidad cotidiana.

La localización de lugares de trabajo y lugares de residencia es un elemento clave en la estructura espacial de un territorio metropolitano como la RMB. En el presente estudio se ha demostrado como esta estructura influye en la configuración del espacio de actividad de sus residentes. Sin embargo, las características individuales de cada persona también tienen un efecto determinante en la extensión espacial utilizada diariamente para realizar las actividades cotidianas de las personas.

La idea del tiempo como recurso finito (Ahmed y Stopher 2014; Mokhtarian y Chen 2004) y su estrecha relación con el espacio utilizable introducida por los geógrafos del tiempo (Hägerstrand 1970a) se ha evidenciado en este trabajo. En este sentido, la cantidad de tiempo trascurrido diariamente en el lugar de trabajo (o estudio) por los participantes de este estudio –en este caso el campus de la UAB– ha demostrado condicionar el tamaño de su espacio de actividad. Un mayor tiempo de estancia en el campus ha implicado una reducción del número de actividades alcanzables, dando lugar a espacios de actividad más pequeños, hecho que puede tener repercusiones negativas en su acceso a oportunidades.

Cabe destacar también el mayor tamaño del espacio de actividad obtenido por los estudiantes que los individuos del colectivo de personal administrativo e investigador. Este mayor tamaño por parte de un grupo de individuos, con un estatus social más elevado, contradice estudios previos en los cuales la población adulta, normalmente con mayor índice de incorporación al mercado laboral, mayor uso de vehículo privado y mayores cargas familiares tiende a registrar espacios de actividad más grandes (Buliung y Kanaroglou 2006; Fan y Khattak 2008). No obstante, este hallazgo podría explicarse por el contexto del estudio y por las características de la muestra. El menor tamaño de los espacios de actividad de investigadores y personal administrativo puede deberse a una relación de larga duración de estas personas con la universidad, lo cual implica que tiendan a residir más cerca del campus (Miralles-Guasch et al. 2014) y, de esta manera, recorran diariamente una menor extensión territorial.

Otro resultado destacable tiene que ver con el modo de transporte utilizado para acceder al campus de la UAB. La oferta competitiva de transporte público para acceder a éste ha producido mínimas diferencias en el tamaño de los espacios de actividad entre los usuarios de medios públicos y privados. Esto rompe la comúnmente asumida relación entre el uso del transporte privado y la obtención de espacios de actividad de mayor tamaño, señalando así la provisión de transporte público como estrategia para reducir los impactos del transporte en las áreas metropolitanas (Silveira y Giraldi Cocco 2013).

- **Sub-Hipótesis 3.** Las características morfológicas de un territorio pueden influir en accesibilidad y utilización de determinados espacios urbanos como los espacios verdes.

En esta investigación se ha comprobado el efecto de la estructura y forma urbana de un territorio, en este caso la ciudad Barcelona, en la provisión de espacios verdes y en la exposición a ellos por parte de sus residentes.

La ubicación periférica y montañosa de grandes espacios abiertos en la ciudad, como parques y playas, ha resultado en unos bajos niveles de exposición por parte de los participantes en el estudio, resaltando así la importancia de la accesibilidad para la utilización de los espacios públicos urbanos (Carmona, M., Tiesdell, S., Heath, T., & Oc 2010). Por otro lado, los bajos niveles de exposición a este tipo de espacios han sido compensados con una mayor exposición a otros tipos de espacios abiertos de calidad de menor tamaño pero mejor distribuidos por toda la ciudad -como calles, paseos o plazas públicas- por los que sus residentes pueden donde desplazarse, pasear o estar presentes y en los cuales es posible estar expuesto a gran cantidad de árboles (Baró et al. 2014; Pauleit 2003).

Los distintos tipos de formas urbanas presentes en la ciudad han resaltado diferencias en la exposición potencial a los diferentes tipos de espacios verdes. Entre los participantes residentes en los barrios históricos se ha detectado un mayor nivel de exposición potencial a plazas públicas por la mayor disponibilidad de estos espacios en los barrios históricos con pasado preindustrial (Madanipour 1999). Por otro lado, la mayor anchura de las calles en la zona central de la ciudad, correspondiente al Ensanche, con aceras anchas y arbolado viario ha resultado en una mayor exposición potencial a árboles por parte de los participantes residentes en esa zona.

Los niveles de exposición analizados a través de las rutas registradas por los participantes según el barrio de residencia han sido muy similares, pero obteniendo diferentes intensidades. En este sentido, los residentes en los barrios históricos estuvieron expuestos a una densidad más alta de árboles a través de sus rutas en comparación a las medias potenciales desde su lugar de residenciales. Debido a que Barcelona, es una ciudad altamente caminable (Marquet y Miralles-Guasch 2015a), las deficiencias de provisión de verde urbano en ciertas áreas de la ciudad pueden ser compensadas caminando en otras áreas.

- **Sub-Hipótesis 4.** La provisión de espacios verdes influye en el comportamiento espacial de las personas favoreciendo el caminar como modo de transporte activo.

La presencia de espacios verdes ha demostrado tener un efecto en el comportamiento espacial de un grupo residentes de la ciudad de Barcelona, concretamente, en sus hábitos de movilidad activa. Sin embargo, los distintos espacios verdes presentes en la ciudad han condicionado estos patrones de distinta manera.

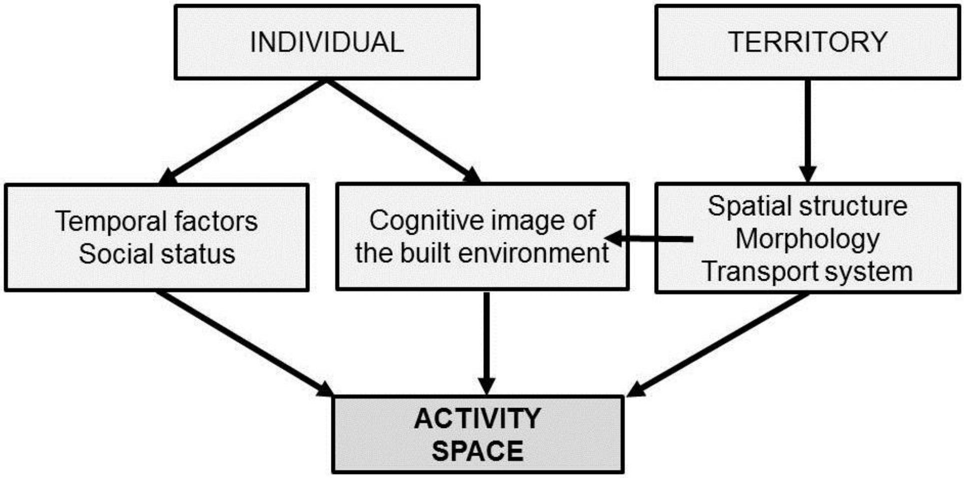
Este estudio contribuye significativamente al creciente número de análisis que examinan los beneficios para la salud del arbolado viario (Larsen et al. 2009; Sarkar et al. 2015), al detectarse una asociación positiva entre la exposición a árboles de las calles de Barcelona y el tiempo caminado diario por los participantes. No obstante, de todos los tipos de espacios verdes analizados, la exposición a grandes espacios abiertos, como playas y grandes parques, resultó tener la mayor influencia en tiempo caminado al final del día, confirmando así la literatura previa que relaciona la provisión de estos espacios, con mayores índices de actividad física de la población (Kaczynski et al. 2009; Lachowycz y Jones 2011; Sugiyama et al. 2013). Por el contrario, la exposición a espacios abiertos más pequeños como pequeños parques, plazas públicas y paseos estuvo asociada con un menor tiempo caminado al día. Este resultado puede explicarse por el diseño y usos de estos espacios, los cuales pueden atraer actividades de carácter más sedentario como, por ejemplo, estar sentado en bancos o terrazas (Carmona 2010; Gehl 2010).

9. Conclusions

This doctoral thesis has deepened the knowledge of the explanatory factors of the spatial behavior of individuals living in a metropolitan context. To do so, new data sources such as SoftGIS and tracking data have been used to analyse the spatial dimension of the daily mobility patterns of a group of individuals living in the Metropolitan Region of Barcelona (RMB).

This thesis joins the body of scientific research that have recovered the contributions of the Behavioural Geography to understand this current human phenomena by using new methodologies and focusing the analysis on the conditioning factors of spatial behaviour of specific population groups (Argent 2017; Gold 2009; Matthews y Yang 2013). The results of this thesis, which is summarized in **Figure 26**, have shown how the territorial structure and morphologies characterizing the RMB influence both the cognitive image and the spatial behaviour of the residents in this context. Likewise, the role of the individual characteristics of each person, such as the sociodemographic profile, the daily organization of time or mobility habits, has also been taken into account in the analysis. The approach of the thesis has allowed us to explore the influence of explanatory factors that influence spatial behaviour at different spatial scales, whether it is the Metropolitan Region or the city of Barcelona.

Figure 26. Determinants of the size of the activity space.



Source: Own production.

Through the exploration of the cognitive maps of a group of people who travel daily to a suburban university campus, it has been proven as a spatial structure of this territory is reflected in the cognitive maps of its residents and, at the same time, it determines their daily mobility patterns. In this sense, it has been proven how a single territory can be perceived differently due to the influence of the spatial scales in which its urban functions are distributed as per the transport infrastructures used daily by its residents.

The influence of the mode of transport has also been confirmed by obtaining similar patterns of spatial behaviour among regular users of public and private transport, demonstrating that, with proper planning, public transport can compete with private transport in situations of interurban transport (Domènech y Gutiérrez 2017; Silveira y Giraldi Cocco 2010, 2013).

The characteristic urban morphology of a territory, in particular of the city of Barcelona, has been shown to influence both the quantity and typology of open spaces, but also its access. Also, the exposure to different types of spaces has been shown to have an effect on active mobility patterns of participants in the study, such as walking. In this sense, being in contact with large parks, beaches and tree-lined streets has been associated with more time spent walking while other spaces, such as squares and small parks, have influenced a more sedentary spatial behaviour.

In addition to the characteristics of the built environment, this thesis has highlighted the importance of the individual characteristics of each person. The time available to travel through the territory or the socioeconomic status has proven to be other characteristics of the individuals that determine to a great extent the extension of their space of activity.

Beyond the scientific knowledge provided by the results obtained, this doctoral thesis can also contribute to the formulation and design of public policies in the field of urban planning and transport, but also in the field of public health. This knowledge provides a theoretical basis of knowledge so that those responsible for the development of public policies understand the relationship between the environment and humans. In particular, it is important to take into account the relationship between the built urban environment and daily spatial decisions such as where to reside, where to look for work opportunities or recreational activities and how to travel between destinations.

Through the obtained results, future urban planning strategies at the metropolitan scale should be aimed at promoting urban compactness and proximity in order to reduce the size of the activity space of its residents, to increase the accessibility to opportunities of a territory, to encourage the use of active modes of transport and, thus, minimising the impacts of transport on the environment (Galland y Elinbaum 2015; Marquet y Miralles-Guasch 2015b). In addition, the results obtained have highlighted the importance of the individual temporal organisation in the configuration of spatial patterns, highlighting the need to introduce considerations on the temporal limitation of people with different profiles when planning the location and access of public services (Queirós y Marques de Costa 2012).

This research has also indicated the benefits of certain characteristics of the built urban environment, such as the presence of green spaces, for the general health and well-being of people. A fact that should encourage joint policy-making between urban and public health planners to design sustainable and healthy urban environments (Maneja-Zaragoza, Linde, y Juncà 2013). Specifically, strategies that incorporate vegetation in open spaces such as streets or squares can enhance the walkability of the urban environment but also the access to other spaces such as urban parks through the formation of green corridors, as well as fostering social interaction in them. The potential to improve the accessibility and walkability of streets and neighbourhoods can be useful not only for dense and compact urban areas, which can be found in the RMB, but can be especially useful for less dense urban environments around the world.

10. Reflexiones finales

Los resultados obtenidos en esta tesis doctoral son el resultado de un conjunto de análisis de los cuales se destacan unas fortalezas y unas limitaciones a modo de evaluación final y que pueden dar luz a futuras líneas de investigación.

10.1. Fortalezas de la tesis

La mayor fortaleza de esta tesis doctoral es el hecho de afrontar la comprensión del comportamiento espacial que implica la movilidad cotidiana en un entorno metropolitano desde un enfoque multifactorial. Esta tesis reúne en un mismo trabajo los dos principales objetos de estudio de la Geografía del Comportamiento Analítica, históricamente explorados por separado, como son la exploración de la configuración de la estructura y geometría de los mapas cognitivos de las personas y el estudio de los factores determinantes del comportamiento espacial. De esta manera, además de la influencia de los mapas cognitivos en el comportamiento espacial se ha tenido en cuenta también la influencia en este comportamiento de las características objetivas del entorno urbano construido, el perfil sociodemográfico y los hábitos de movilidad de las personas analizadas.

La utilización de un grupo de población específico, como una comunidad universitaria, con un perfil individual y patrones de movilidad cotidiana muy homogéneos es otro aspecto de la tesis a resaltar ya que ha permitido poner el foco en ciertos aspectos del análisis. El hecho que su perfil socioeconómico y demográfico sea similar y que el viaje principal de estas personas tenga como destino el mismo lugar en la Región Metropolitana de Barcelona ha posibilitado controlar que las diferencias en los procesos cognitivos y el comportamiento espacial de los individuos analizados se deban a las características diferentes de los destinos o a perfiles de personas muy distintas. Este control ha permitido resaltar la importancia de los factores temporales, el estatus social y la provisión del sistema de transporte público en los procesos cognición y percepción del entorno y el comportamiento espacial de las personas.

La elección de la Región Metropolitana de Barcelona como ámbito de estudio ha permitido detectar matices específicos sobre la imagen cognitiva de las personas y su comportamiento espacial. La particularidad de este territorio, el cual ha sido muy poco estudiado desde el enfoque de la Geografía de la Percepción y del Comportamiento, ha permitido explorar la influencia de las distintas escalas espaciales que estructuran este territorio en los mapas cognitivos de un grupo de residentes. Asimismo, el particular entorno urbano construido de Barcelona ha permitido también detectar diferencias en la provisión de distintos tipos de espacios verdes según las morfologías urbanas de la ciudad y, en consecuencia, diferencias en el comportamiento espacial relativo al caminar de estas personas.

Es de destacar también la aproximación metodológica innovadora elegida para el estudio del comportamiento espacial y los patrones de movilidad cotidiana, mediante el uso de nuevas fuentes de datos provenientes de la Tecnologías de la Información y Comunicación en combinación con fuentes de datos tradicionales.

En primer lugar, se han utilizado tres técnicas diferentes para capturar los mapas cognitivos de personas residentes en la RMB. La herramienta de SoftGIS han sido de gran ayuda para obtener los límites, ubicación, forma o estructura, tamaño del espacio de actividad percibido, pero al complementar esta información con descripciones orales ha sido posible detectar la influencia de las distintas escalas territoriales de este territorio en las imágenes cognitivas de las personas. De este modo, la combinación de las aplicaciones de SoftGIS con descripciones orales ha demostrado ser metodologías eficaces para detectar la imagen cognitiva del mundo real, mejorando la bidimensionalidad y planaridad de los mapas cartográficos.

En segundo lugar, la utilización de datos de posicionamiento, como el *tracking*, ha facilitado la recopilación de medidas objetivas y precisas sobre comportamiento espacial de las personas. En comparación con las fuentes tradicionales como encuestas, entrevistas o diarios de viajes, se ha podido obtener las rutas cotidianas geolocalizadas de entre 100 y 200 personas y durante 7 días. Además, la pérdida de señal que pueden sufrir algunos dispositivos de GPS especializados se ha reducido mediante la combinación de localizaciones provenientes de GPS, Wi-Fi y torres de comunicación telefónicas disponible que permiten los teléfonos inteligentes o *smartphones*. Sin embargo y como se ha realizado en la presente investigación, la utilidad de los datos de *tracking* se ha visto aumentada al combinarlos con la información proveniente de las encuestas de movilidad tradicionales. Esta tesis confirma el potencial del *smartphone* como fuente de información espaciotemporal accesible y altamente precisa para estudios de distintas disciplinas.

Finalmente, en esta tesis se ha resaltado también la importancia del método de cálculo del espacio de actividad de las personas, al obtener resultados distintos según el enfoque utilizado. En concreto, el uso del *tracking* para obtener *área de ruta diaria* de las personas en comparación a métodos de cálculo tradicionales ha dado lugar a diferencias relativas al tamaño y al contenido de estas áreas.

Por un lado, los espacios de actividad medidos a lo largo de las rutas del segundo caso de estudio han proporcionado áreas más pequeñas y han obtenido asociaciones distintas con las variables independientes elegidas, resaltando así la importancia de la elección del método de cálculo, ya que cada método de medición del espacio de actividad puede generar un conjunto específico de factores explicativos. Por el otro, los espacios de actividad a través de las rutas realizadas a pie del tercer caso de estudio obtuvieron una mayor exposición a los espacios verdes analizados que la medida de exposición tradicional, en este caso, el buffer residencial a través de la red de calles. Esto sugiere que el uso exclusivo de búferes residenciales en estudios de exposición podría pasar por alto una parte significativa de las exposiciones que las personas reciben en su vida diaria. Además, algunos participantes, a pesar de no tener acceso algunos espacios verdes a una distancia caminable desde su lugar de residencia, se demostró que sí estuvieron en contacto con éstos durante sus caminatas. De este modo, estas nuevas metodologías permiten estudiar los efectos del entrono en la salud de las personas pueden analizarse a través del comportamiento real de los individuos y no únicamente el potencial, ayudando así a encontrar el verdadero contexto geográfico del comportamiento espacial de las personas (Kwan 2012; Kwan y Schwanen 2018; Matthews y Yang 2013; Vallée et al. 2014).

10.2. Limitaciones de la tesis

Una vez resaltadas las fortalezas de la tesis, es necesario repasar sus limitaciones para poder informar futuras investigaciones.

Una de las principales limitaciones ha sido no haber podido relacionar los tipos de imagen cognitiva sobre el territorio utilizado por los participantes con el consiguiente comportamiento espacial. Por el contrario, se ha analizado la influencia de las distintas escalas territoriales que caracterizan la RMB en los mapas cognitivos de las personas residentes en este territorio. Esta limitación puede abordarse en futuras investigaciones.

La influencia de las desigualdades socioeconómicas en el comportamiento espacial de las personas es otro de los aspectos que no se ha podido abordar en plenitud en esta tesis. Aunque se ha utilizado el rol en la universidad como una aproximación al nivel de estatus social, distinguiendo el comportamiento de estudiantes y personal contractado (administrativo e investigador), las diferencias según nivel de ingresos concretos no han podido ser exploradas. El principal motivo es la falta de información sobre el ingreso individual o familiar en las principales fuentes de datos utilizadas para describir el perfil de los participantes en los distintos casos de estudio, las ediciones de 2015 y 2017 de la Encuesta de Hábitos de Movilidad de la Comunidad Universitaria de la UAB (EHMCU).

La elección de la Región Metropolitana de Barcelona como ámbito de estudio y la comunidad universitaria de la UAB, además de fortalezas también puede limitar el análisis. En este sentido, los resultados obtenidos en esta tesis pueden no ser completamente aplicables en otros contextos geográficos. Por un lado, la provisión de oferta de transporte público o las dinámicas de proximidad presentes de ciertas zonas del territorio analizado no corresponden con la realidad de la mayoría de las áreas urbanas de Norteamérica, Latinoamérica o Asia. Por el otro, la elección de la comunidad de la UAB como grupo de población específico de análisis, aun siendo beneficioso por los motivos anteriormente comentados, no permite aplicar las conclusiones del estudio actual en otros grupos de población o destinos cotidianos.

La utilización de nuevas fuentes de datos como el *tracking* implica tener en cuenta también ciertas limitaciones. Primero, el tamaño reducido de la muestra, con cifras comprendidas entre los 100 y 200 individuos, se debe a la voluntariedad de la participación de las personas en los trabajos de campo realizados en esta investigación. Además, el hecho que se demande los datos de múltiples días hace bastante complicado obtener muestras representativas de una población como la RMB. Segundo, el *smartphone tracking* se nutre de distintos fuentes de información (GPS, Wi-Fi y torres de comunicación telefónicas), pueden producirse también episodios de pérdida de señal y errores de localización, por ejemplo, debido a la densidad y altitud elevada de edificios en entorno urbanos (Lee y M.-P. Kwan 2018).

El denominado *sesgo de movilidad selectiva* (Chaix et al. 2013), inherente en la mayoría de los trabajos basados en datos de *tracking*, es presente en el tercer y cuarto caso de estudio al explorar la exposición a distintos tipos de espacios verdes. Según este tipo de sesgo metodológico, la elección de ciertos destinos y rutas puede deberse a preferencias individuales intrapersonales y no solo por el mero propósito de exponerse a un entorno con ciertas características. Este sesgo puede explicar los niveles de exposición a grandes parques y playas. Asimismo, dado que la exposición a espacios verdes no implica necesariamente que estén siendo utilizados, no debe de establecerse una causalidad directa entre las medidas de exposición y el tiempo caminado diariamente (Markevych et al. 2017). En cualquier caso, este estudio sí que obtiene resultados valiosos sobre qué espacios urbanos dotados de vegetación permiten a las personas poder caminar y realizar actividades físicamente activas (James et al. 2017).

Finalmente, y en relación a los resultados obtenidos, otra limitación a tener en cuenta es la baja bondad de ajuste de los modelos estadísticos en los análisis presentados en esta tesis. Uno de los principales motivos del bajo nivel explicativo puede deberse a la cantidad de covariables seleccionadas para realizar análisis de regresión, debido a limitada información relativa al perfil individual de las personas. No obstante, este estudio cumple con el objetivo principal de los distintos casos de estudio y que es intrínseco al modelado estadístico en ciencias sociales, es decir, explorar la relación de asociación significativa y la dirección de ésta entre las variables dependientes que describen el comportamiento espacial y variables independientes que describen los factores explicativos (Goldberger 1991).

10.3. Futuras líneas de investigación

Una vez revisado los principales hallazgos de la tesis, resaltado sus fortalezas y limitaciones, es necesario detallar finalmente futuras líneas de investigación que emanan de la tesis en relación a los factores que configuran el comportamiento espacial de las personas residentes en contextos metropolitanos:

1. Estudiar el efecto de la forma y estructura del mapa cognitivo de las personas en su comportamiento espacial a través del análisis de sus patrones de movilidad cotidiana. En esta línea, podría ser explorado el nivel de coincidencia entre la extensión espacial percibida subjetivamente del espacio de actividad obtenido a través de los mapas cognitivos de estas personas en comparación con la extensión resultante de la movilidad cotidiana mediante el uso de datos de *tracking*.

2. Analizar los motivos, preferencias, hábitos o creencias que influencian cada uno de los desplazamientos de movilidad cotidiana que componen el comportamiento espacial final de una persona.

3. Explorar los factores explicativos del comportamiento espacial en movilidad cotidiana de otros grupos específicos de población como, por ejemplo, grupos sociales en riesgo de exclusión social por nivel de renda, etnia, género o edad.

4. Analizar la idoneidad de los límites administrativos como medidas de exposición o acceso a oportunidades en comparación al espacio de actividad en un entorno metropolitano.

5. Indagar en el efecto de otros elementos del entorno construido que pueden condicionar el comportamiento espacial de las personas como la mixtura de funciones urbanas, la densidad y diversidad comercial, otros

elementos específicos del diseño –aceras, bancos, iluminación, etc.– en espacios abiertos como calles, paseos, plazas, etc.

6. Analizar el comportamiento espacial relativo a la movilidad en otros contextos geográficos con distintas características urbanas y culturales a las de la RMB como, por ejemplo, las áreas metropolitanas en Latinoamérica o Asia.

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12. Anexos

12.1. Declaración de los coautores

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- Vich, G., Marquet, O. & Miralles-Guasch, C. (2018) "The Scales of the Metropolis: Exploring Cognitive Maps Using a Qualitative Approach Based on SoftGIS Software." *Geoforum* (September) 88: 49–56.
- Vich, G., Marquet, O. y Miralles-Guasch, C. (2018) "Green exposure of walking routes and residential areas using smartphone tracking data and GIS in a Mediterranean city." Urban Forestry and Urban Greening (August 2018): 1-11.
- Vich, G., Marquet, O. & Miralles-Guasch, C. (2017) "Suburban Commuting and Activity Spaces: Using Smartphone Tracking Data to Understand the Spatial Extent of Travel Behaviour." *The Geographical Journal* 183(4): 426–39.

no han format part anteriorment de cap altra tesi doctoral, i RENUNCIA a presentar-los com a tal en el futur.

Bellaterra, 10 de gener de 2019

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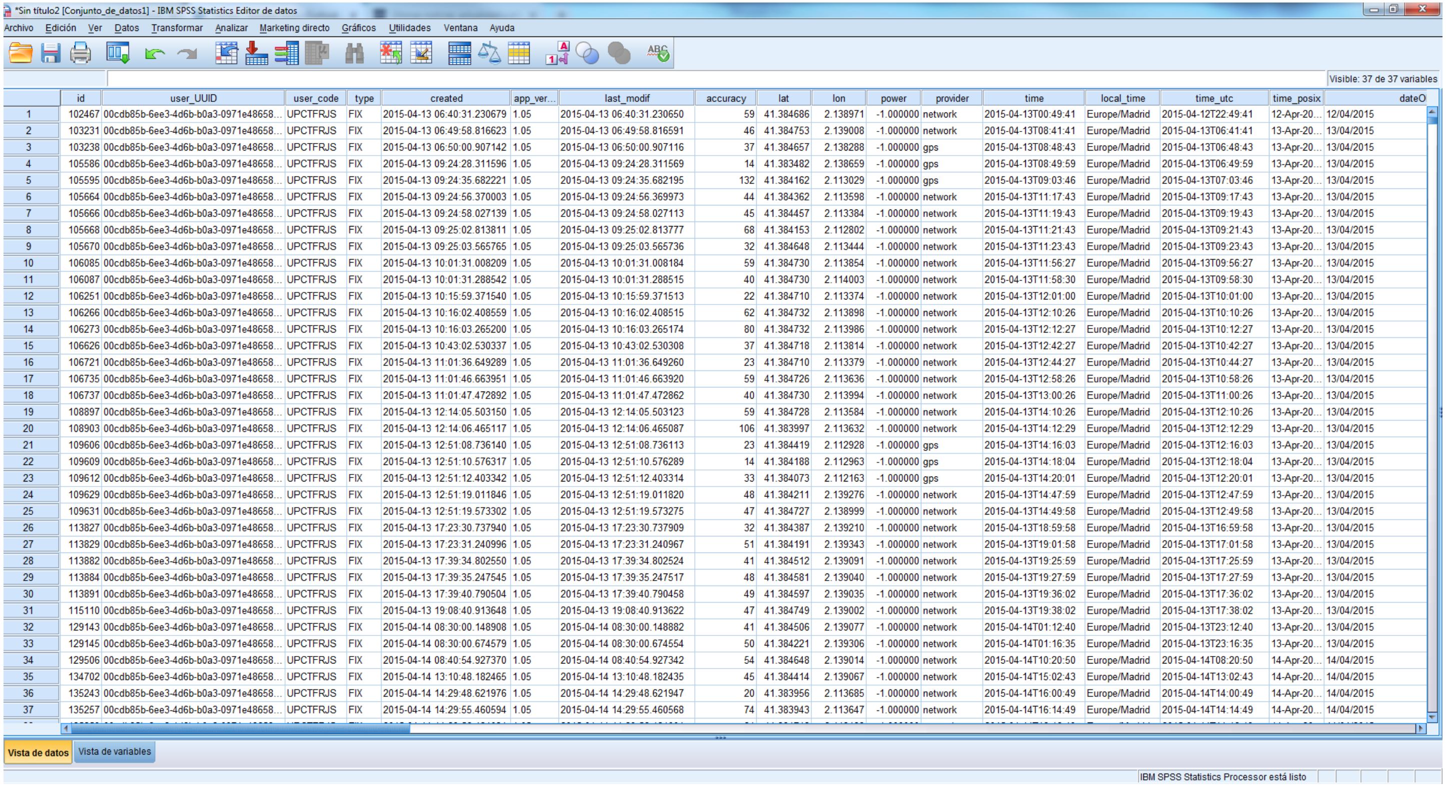
- Vich, G., Marquet, O. & Miralles-Guasch, C. (2019) "Green Streetscape and Walking: Exploring Active Mobility Patterns in Dense and Compact Cities." *Journal of Transport & Health* 12(June 2018):
- Vich, G., Marquet, O. & Miralles-Guasch, C. (2018) "The Scales of the Metropolis: Exploring Cognitive Maps Using a Qualitative Approach Based on SoftGIS Software." *Geoforum* 88: 49–56.
- Vich, G., Marquet, O. y Miralles-Guasch, C. (2018) "Green exposure of walking routes and residential areas using smartphone tracking data and GIS in a Mediterranean city." Urban Forestry and Urban Greening (August 2018): 1-11.
- Vich, G., Marquet, O. & Miralles-Guasch, C. (2017) "Suburban Commuting and Activity Spaces: Using Smartphone Tracking Data to Understand the Spatial Extent of Travel Behaviour." *The Geographical Journal* 183(4): 426–39.

no han format part anteriorment de cap altra tesi doctoral, i RENUNCIA a presentar-los com a tal en el futur.

Barcelona, 6 de febrer de 2019

12.2. Ejemplo de base de datos de *tracking* sin depurar



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2	103231	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 06:49:58.816623	1.05	2015-04-13 06:49:58.816591	46	41.384753	2.139008	-1.000000	network	2015-04-13T08:41:41	Europe/Madrid	2015-04-13T06:41:41	13-Apr-20...	13/04/2015
3	103238	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 06:50:00.907142	1.05	2015-04-13 06:50:00.907116	37	41.384657	2.138288	-1.000000	gps	2015-04-13T08:48:43	Europe/Madrid	2015-04-13T06:48:43	13-Apr-20...	13/04/2015
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5	105595	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 09:24:35.682221	1.05	2015-04-13 09:24:35.682195	132	41.384162	2.113029	-1.000000	gps	2015-04-13T09:03:46	Europe/Madrid	2015-04-13T07:03:46	13-Apr-20...	13/04/2015
6	105664	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 09:24:56.370003	1.05	2015-04-13 09:24:56.369973	44	41.384362	2.113598	-1.000000	network	2015-04-13T11:17:43	Europe/Madrid	2015-04-13T09:17:43	13-Apr-20...	13/04/2015
7	105666	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 09:24:58.027139	1.05	2015-04-13 09:24:58.027113	45	41.384457	2.113384	-1.000000	network	2015-04-13T11:19:43	Europe/Madrid	2015-04-13T09:19:43	13-Apr-20...	13/04/2015
8	105668	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 09:25:02.813811	1.05	2015-04-13 09:25:02.813777	68	41.384153	2.112802	-1.000000	network	2015-04-13T11:21:43	Europe/Madrid	2015-04-13T09:21:43	13-Apr-20...	13/04/2015
9	105670	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 09:25:03.565765	1.05	2015-04-13 09:25:03.565736	32	41.384648	2.113444	-1.000000	network	2015-04-13T11:23:43	Europe/Madrid	2015-04-13T09:23:43	13-Apr-20...	13/04/2015
10	106085	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 10:01:31.008209	1.05	2015-04-13 10:01:31.008184	59	41.384730	2.113854	-1.000000	network	2015-04-13T11:56:27	Europe/Madrid	2015-04-13T09:56:27	13-Apr-20...	13/04/2015
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18	106737	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 11:01:47.472892	1.05	2015-04-13 11:01:47.472862	40	41.384730	2.113994	-1.000000	network	2015-04-13T13:00:26	Europe/Madrid	2015-04-13T11:00:26	13-Apr-20...	13/04/2015
19	108897	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 12:14:05.503150	1.05	2015-04-13 12:14:05.503123	59	41.384728	2.113584	-1.000000	network	2015-04-13T14:10:26	Europe/Madrid	2015-04-13T12:10:26	13-Apr-20...	13/04/2015
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22	109609	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 12:51:10.576317	1.05	2015-04-13 12:51:10.576289	14	41.384188	2.112963	-1.000000	gps	2015-04-13T14:18:04	Europe/Madrid	2015-04-13T12:18:04	13-Apr-20...	13/04/2015
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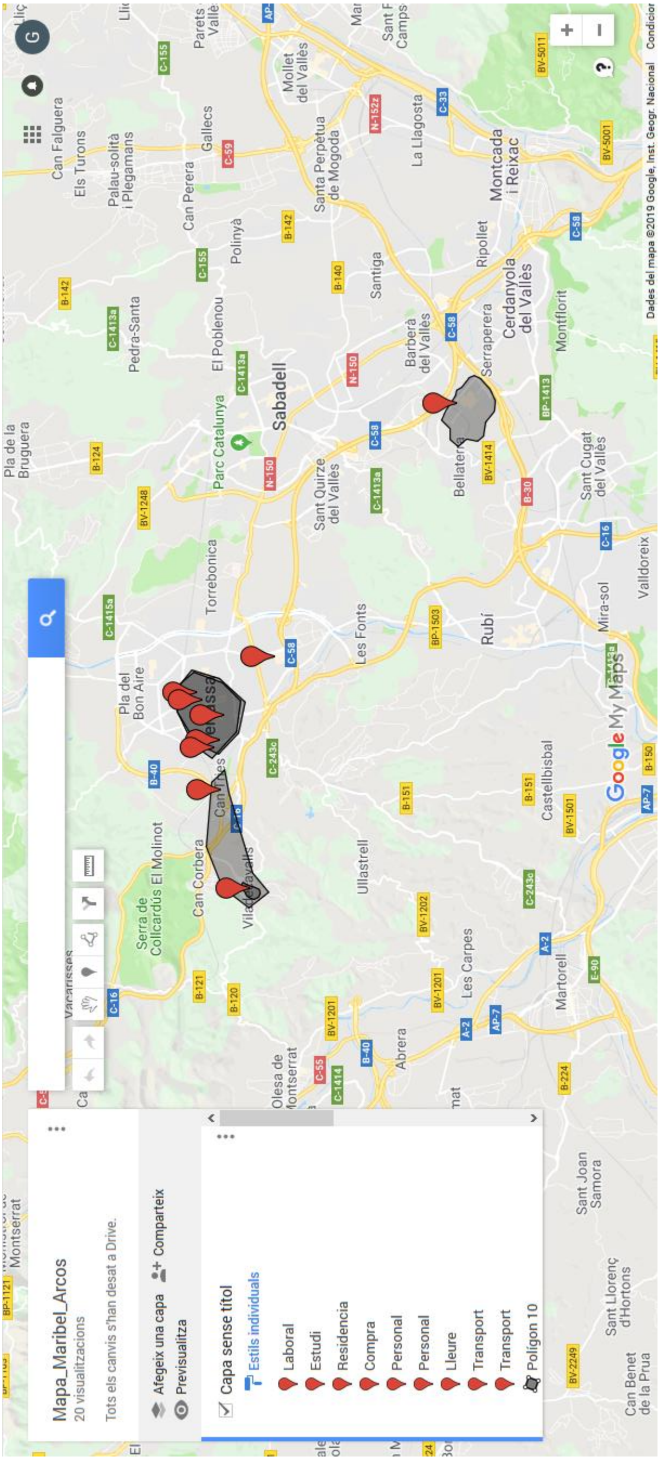
26	113827	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 17:23:30.737940	1.05	2015-04-13 17:23:30.737909	32	41.384387	2.139210	-1.000000	network	2015-04-13T18:59:58	Europe/Madrid	2015-04-13T16:59:58	13-Apr-20...	13/04/2015
27	113829	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 17:23:31.240996	1.05	2015-04-13 17:23:31.240967	51	41.384191	2.139343	-1.000000	network	2015-04-13T19:01:58	Europe/Madrid	2015-04-13T17:01:58	13-Apr-20...	13/04/2015
28	113882	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 17:39:34.802550	1.05	2015-04-13 17:39:34.802524	41	41.384512	2.139091	-1.000000	network	2015-04-13T19:25:59	Europe/Madrid	2015-04-13T17:25:59	13-Apr-20...	13/04/2015
29	113884	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 17:39:35.247545	1.05	2015-04-13 17:39:35.247517	48	41.384581	2.139040	-1.000000	network	2015-04-13T19:27:59	Europe/Madrid	2015-04-13T17:27:59	13-Apr-20...	13/04/2015
30	113891	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 17:39:40.790504	1.05	2015-04-13 17:39:40.790458	49	41.384597	2.139035	-1.000000	network	2015-04-13T19:36:02	Europe/Madrid	2015-04-13T17:36:02	13-Apr-20...	13/04/2015
31	115110	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-13 19:08:40.913648	1.05	2015-04-13 19:08:40.913622	47	41.384749	2.139002	-1.000000	network	2015-04-13T19:38:02	Europe/Madrid	2015-04-13T17:38:02	13-Apr-20...	13/04/2015
32	129143	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-14 08:30:00.148908	1.05	2015-04-14 08:30:00.148882	41	41.384506	2.139077	-1.000000	network	2015-04-14T01:12:40	Europe/Madrid	2015-04-13T23:12:40	13-Apr-20...	13/04/2015
33	129145	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-14 08:30:00.674579	1.05	2015-04-14 08:30:00.674554	50	41.384221	2.139306	-1.000000	network	2015-04-14T01:16:35	Europe/Madrid	2015-04-13T23:16:35	13-Apr-20...	13/04/2015
34	129506	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-14 08:40:54.927370	1.05	2015-04-14 08:40:54.927342	54	41.384648	2.139014	-1.000000	network	2015-04-14T10:20:50	Europe/Madrid	2015-04-14T08:20:50	14-Apr-20...	14/04/2015
35	134702	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-14 13:10:48.182465	1.05	2015-04-14 13:10:48.182435	45	41.384414	2.139067	-1.000000	network	2015-04-14T15:02:43	Europe/Madrid	2015-04-14T13:02:43	14-Apr-20...	14/04/2015
36	135243	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-14 14:29:48.621976	1.05	2015-04-14 14:29:48.621947	20	41.383956	2.113685	-1.000000	network	2015-04-14T16:00:49	Europe/Madrid	2015-04-14T14:00:49	14-Apr-20...	14/04/2015
37	135257	00cdb85b-6ee3-4d6b-b0a3-0971e48658...	UPCTFRJS	FIX	2015-04-14 14:29:55.460594	1.05	2015-04-14 14:29:55.460568	74	41.383943	2.113647	-1.000000	network	2015-04-14T16:14:49	Europe/Madrid	2015-04-14T14:14:49	14-Apr-20...	14/04/2015

12.3. Ejemplo de esbozo realizado con Google Maps©



12.4. Guión de la entrevista

Estudio sobre el impacto de las escalas territoriales en el mapa cognitivo de personas residentes de la RMB

1. Recuerda durante unos segundos dónde realizas tus actividades del día y las rutas realizadas diariamente.
2. ¿Cómo lo presentarías?
3. Haz clic en "Añadir una capa" en esta aplicación de mapas en línea. Llámala "CAPA 1". Dibuja el espacio que utilizas en un día tipo, es decir, por donde te desplazas normalmente de lunes a viernes (el campus de la UAB incluido). *NOTA: no decir la palabra "barrio".*
4. ¿Qué condiciona su tamaño?
5. ¿Cambiarías de residencia o de trabajo para estar más cerca o más lejos? ¿Has trabajado en otros lugares? ¿Era mejor? ¿Por qué?
6. ¿Para qué servicios tienes que desplazarte más lejos? ¿Qué es lejos por ti? (Tiempo, intermodalidad…)
7. Haz clic otra vez en "Añadir una capa". Esta vez llámala "CAPA 2". Señala las localizaciones más frecuentes de un día tipo con la opción de "chincheta" de esta aplicación. Cada chincheta es un clic y debes añadir los motivos siguientes (mínimo uno de cada) en el recuadro de observaciones:
    a) Localización de la residencia.
    b) Motivo de estudio o laboral (también de otros centros de trabajo o estudio diferentes al campus de la UAB si es pertinente).
    c) Motivos por compras cotidianas.
    d) Motivos personales (médico, visitas a amigos o familiares, recados, etc.).
    e) Motivos ocio (actividades sociales, culturales, asociativas, etc.).
    f) Motivo de transporte (estación más utilizada o aparcamiento)
    g) ¿Por qué motivos los eliges?
8. ¿Cómo de satisfactorio es este espacio? (Forma y tamaño) Escala Likert del 0 al
9. ¿Cómo te orientas cuando no conoces un sitio? ¿Utilizas Google Maps?

12.5. Difusión de los resultados de la tesis

En este anexo se describe la participación en conferencias nacionales e internacionales, conferencias y charlas en la que se ha difundido el contenido de la tesis.

a) Congresos y conferencias

- **Vich**, G.; Delclòs-Alió, X.; Miralles-Guach, C.; (2018) "Green Streetscape and Health: Exploring the Physical Activity Benefits of Walking in Dense and Compact Cities". *Urban Transitions 2018: Integrating urban and transport planning, environment and health for healthier urban living*, Sitges (España), 25-27 de noviembre de 2018.

- **Vich**, G.; Montané, D.; Miralles-Guasch, C. (2017) "La extensión espacial de la vida cotidiana en la Región Metropolitana de Barcelona a través del estudio de mapas cognitivos". *XXV Congreso de la Asociación de Geógrafos Españoles*. Universidad Autónoma de Madrid, Madrid (España), 25-27 de octubre de 2017.

- **Vich**, G.; Delclòs-Alió, X.; Miralles-Guach, C.; Maciejewska, M. (2017). "Can public squares compensate for the lack of urban greenness? Using smartphone tracking data to explore the link between open spaces and exposure when walking". *6th EUGEO Congress on the Geography of Europe*. Brussels (Bélgica), 4-6 de septiembre de 2017.

- **Vich**, G.; & Delclòs, X. (2017). "New approaches to the study of daily mobility at Universitat Autònoma de Barcelona". *I European Conference on Sustainable Mobility at Universities*. Universitat Autònoma de Barcelona, Cerdanyola del Vallès (España), 8-10 de marzo de 2017.

- Delclòs, X., **Vich**, G., Marquet, O., Montané, D. & Miralles-Guasch, C. (2016). La dimensión temporal de la movilidad cotidiana: ¿Cuánto tiempo

dedicamos diariamente a desplazarnos? *XV Coloquio Ibérico de Geografía. Foro de desarrollo y discusión de diversos aspectos de la Geografía*. Asociación de Geógrafos Españoles, Asociaçao Portuguesa de Geógrafos. Murcia (España), 7-9 de noviembre de 2016.

- **Vich**, G.; Delclòs, X.; Marquet, O. & Miralles-Guasch, C. (2016): "Activity spaces when commuting to the university. An example from tracking data". *RGS-IBG Annual International Conference 2016*. London (Reino Unido), 30 de agosto–3 de septiembre de 2016.

- **Vich**, G., Marquet, O, Delclòs, X., Maciejewska, M. & Miralles-Guasch, C. (2016). Gender differences in active transport among commuters to a university campus. *International Conference on Feminist Geographies and Intersectionality: places, identities and knowledges*. Grup de Recerca de Geografia i Gènere (UAB). Cerdanyola del Vallès (España), 14-16 de julio de 2016.

- **Vich**, G., Delclòs, X., Marquet, O. & Miralles-Guasch, C.; (2016) Los espacios de actividad, una medida de la movilidad cotidiana en época de crisis. La UAB como ejemplo. *XIII Coloquio gel Grupo de Geografía Urbana de la Asociación de Geógrafos Españoles: Nuevos escenarios urbanos: nuevos conflictos y nuevas políticas*. Asociación de Geógrafos Españoles. Girona (España), 15-18 de junio de 2016.

- **Vich**, G., Gil-Alonso, F. & Pujadas, I. (2016) Residential mobility and urban deconcentration in the region of Camp de Tarragona: the impact of the economic crisis. *XI Congreso Asociación de Demografía Histórica*. Cádiz (España) 21-24 de junio de 2016.

- Miralles-Guasch, C., Delclòs, X. & **Vich**, G. (2015). Nuevas fuentes de información para el análisis de la movilidad cotidiana: de las encuestas de movilidad a las aplicaciones para móviles. *XXIV Congreso de la Asociación de Geógrafos Españoles: Análisis espacial y representación geográfica: innovación y*

aplicación. Universidad de Zaragoza-AGE. Zaragoza (España), 28-30 de octubre de 2015.

b) Charlas y presentaciones

- Presentación titulada "Proximitat i llunyania: Una exploració de la dimensió espacial de la vida quotidiana en un context metropolità", realizada el 21 de marzo de 2018 a los alumnos del Màster Oficial en Estudis Interdisciplinaris en Sostenibilitat Ambiental, Econòmica i Social (ICTA-UAB).
- Presentación titulada "Proximitat i llunyania: Una exploració de la dimensió espacial de la vida quotidiana en un context metropolità", realizada el 18 de febrero de 2018 a los alumnos Màster Oficial en Estudis Territorials i de la Població (Departament de Geografia, UAB).
- Presentación titulada "Espacios de actividad y las nuevas fuentes de información para el análisis de la movilidad cotidiana" el 12 de diciembre de 2016 a los alumnos del Màster Oficial en Estudis Interdisciplinaris en Sostenibilitat Ambiental, Econòmica i Social (Institut de Ciència i Tecnologia Ambientals, ICTA-UAB).
- Presentación titulada "Nuevas fuentes de información para el análisis de la movilidad cotidiana" realizada el 22 de febrero de 2017 a los alumnos del Màster Oficial en Estudis Territorials i de la Població (Departament de Geografia, Universitat Autònoma de Barcelona).
- Presentación titulada "Espacios de actividad y las nuevas fuentes de información para el análisis de la movilidad cotidiana" realizada el 27 de marzo de 2017 a los alumnos del Màster Oficial en Estudis Interdisciplinaris en Sostenibilitat Ambiental, Econòmica i Social (Institut de Ciència i Tecnologia Ambientals, ICTA-UAB).
- Presentación titulada "Nuevas fuentes de información para el análisis de la movilidad cotidiana", realizada el 7 de octubre de 2015 a los alumnos del

Màster Oficial en Estudis Interdisciplinaris en Sostenibilitat Ambiental, Econòmica i Social (Institut de Ciència i Tecnologia Ambientals, ICTA-UAB).

- Presentación titulada "Espacios de actividad y las nuevas fuentes de información para el análisis de la movilidad cotidiana", realizada el 25 de febrero de 2015 a los alumnos del Màster Oficial en Estudis Territorials i de la Població (Departament de Geografia – UAB).
- Presentación titulada "Nuevas fuentes de información para el análisis de la movilidad cotidiana", realizada el 23 de marzo de 2015 a los alumnos del Màster Oficial en Estudis Interdisciplinaris en Sostenibilitat Ambiental, Econòmica i Social (Institut de Ciència i Tecnologia Ambientals, ICTA-UAB).
- Presentación titulada "Nuevas fuentes de información para el análisis de la movilidad cotidiana", realizada el 28 de abril de 2015 a los alumnos del Màster Oficial en Estudis Territorials i de la Població (Departament de Geografia – UAB).
- Presentación titulada "New approaches to the study of daily mobiliy: from travel surveys to smartphone apps", realizada el 5 de mayo de 2015 a alumnos del Departamento de Desarrollo y Planeamiento de la Universidad de Aalborg en la Universitat Pompeu Fabra (Campus Ciutadella de Barcelona).
- Sesión de trabajo conjunta con miembros del Centre de política del Sòl i Valoracions – CPSV – Universitat Politècnica de Catalunya y con miembros de la Facultad de Arquitectura de la Universidad Autónoma de Nuevo León (México).

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