Networks of (Dis)connection: Mobility practices, tertiary streets and sectarian divisions in north Belfast

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Abstract

Longstanding tensions between Protestant and Catholic communities in Northern Ireland have led to high levels of segregation. This paper explores the spaces within which residents of north Belfast move within everyday life and the extent to which these are influenced by segregation. We focus in particular on the role that interconnecting 'tertiary streets' have on patterns of mobility.

We adapt Grannis' (1998) concept to define T-communities from sets of interconnecting tertiary streets within north Belfast. These are combined with over 6000 GPS tracks collected from local residents in order to assess the amount of time spent within different spaces. Spaces are divided into areas of residents own community affiliation (ingroup), areas not clearly associated with either community (mixed), or areas of opposing community affiliation (outgroup). We further differentiate space as being either within a T-community or along a section of main road.

Our work extends research on T-communities by expanding their role beyond exploring residential preference, to explore instead, networks of (dis)connection through which social divisions are expressed via everyday mobility practices. We conclude that residents are significantly less likely to move within mixed and outgroup areas and that this was especially true within T-communities. It is also evident that residents were more likely to travel along outgroup sections of a main road if they were in a vehicle and that women showed no greater likelihood than men to move within outgroup space. Evidence from GPS tracks also provides insights into some areas where mixing appears to occur.

Key words

T-communities; post-conflict; Northern Ireland; GIS; segregation

Introduction

There have been longstanding tensions between Protestant and Catholic communities in Northern Ireland over whether the region should remain part of the United Kingdom or become part of a united Republic of Ireland (Brand 2009, Hughes et al. 2007). These tensions have frequently erupted into violence, including the three decades between 1969 and 1998, known as 'the troubles', which both

reinforced and extended patterns of residential, political and social segregation across the region. While the Good Friday peace agreement, in place since 1998, has helped bring a degree of peace to Northern Ireland, deep-seated notions of Britishness or Irishness are still strongly evident. Harassment, intimidation and occasional violence continue in cities such as Belfast, further fuelling mistrust between communities (Brand 2009). Decades of violence restricts the mobility of those living in highly segregated neighbourhoods, with residents rarely crossing sectarian boundaries, instead adjusting their movements and use of services in response to fear (Shirlow and Murtagh 2006, Lysaght and Basten 2003). Through the course of this paper, we will explore the extent to which evidence of this restricted mobility plays out in terms of movement through different types of group space in north Belfast.

Socio-spatial segregation in Belfast

Boal (1969) examined both residential and activity space segregation in the Shankhill and Falls communities (working class areas of Belfast). In these areas Protestants and Catholics are highly segregated, yet live in close proximity to one another. Boal found a strong correlation between residential and activity-space segregation, helping to explain ethno-sectarian immobility resulting from the presence of distinct territories. The layout of residential space through much of Belfast includes many cul-de-sacs and dead ends, which were intentionally used to segregate the two communities during the height of the region's conflict and which continue to create segregation leading to territorial concentration, preserving community identity and a strong sense of 'other' in relation to those beyond their community (Boal 1996). This attitude towards the 'other' community was also observed by Shirlow and McGovern (1998), working in the Ardoyne area of Belfast. They reiterated the understanding that residential segregation both expresses and regulates ethno-sectarian animosity. In further work in the Ardoyne, fear of the 'other' community was found to restrict mobility, impacting on job-seeking, leisure and consumption behaviour (Shirlow 2000). Shirlow (2003) found that people living in deeply segregated areas developed an instinctive awareness of 'safe' and 'unsafe' places.

Peace walls also remain a significant territorial feature in Belfast today. Initially constructed by the British Army in response to sectarian violence (Byrne, Heenan and Robinson 2012), these walls are material structures designed to reduce opportunities for conflict between opposing communities, providing some safety and security but also reinforcing sectarian segregation (Byrne et al. 2012, Donnan and Jarman 2016). Beyond physical barriers, varying forms of territorial marking both reinforce a sense of community identity within Belfast's neighbourhoods and act as boundary markers between communities (Shirlow 2006). These include tangible symbols such as wall murals, flags (Jarman 2007) and painted kerbs, as well as shared perceptions about who belongs where (Brand 2009, Hughes et al. 2007). The cumulative effect of these varying forms of socio-spatial division is that in many cases basic services such as schools, playgrounds, libraries, leisure centres and health services are used only by members of one community (Brand 2009) and residents have limited opportunity to interact across community divisions. Moreover, residents' free movement through the city's streets, and the routes and pathways they select or avoid is powerfully shaped by their understandings of the local sectarian geography (Huck et al. 2019, Lysaght and Basten 2003). In the present research, using a novel combination of GPS tracking and GIS data capture, we explore how Belfast residents' everyday movements are shaped by such understandings. As elaborated below, we focus particularly on the role of tertiary street networks or T-communities (Grannis, 1998) in the reproduction of segregated mobility practices over time. Indeed, we argue that such networks may represent a fundamental building block of the sectarian patterning of activity space use in cities such as Belfast.

There is limited literature that explores gender differences in mobility resulting from the segregation of urban street networks in Belfast, and this represents a second focus of the present research. Available evidence suggests , at least anecdotally, that women may feel more confident entering neighbourhoods of the opposing community (Lysaght and Basten 2003). A study into mobility and access to leisure facilities suggests, for example, that 62 percent of non-pensioners crossing the

community divide for leisure purposes were women (Bairner and Shirlow 2003). Research from interviews conducted during 'the troubles' also implies that, due to assumed political innocence and a mutual agreement women and children were not legitimate targets, some women felt a greater confidence crossing the peace line in West Belfast (Dowler 2001). Whilst there is some evidence here to suggest that women are potentially more willing to enter outgroup areas, this evidence has not explored concrete patterns of movement in and through everyday spaces. We will therefore explore this idea further to see if our evidence supports the idea that women move more freely than men within outgroup spaces.

Lysaght and Basten (2003) suggest that for those with access to a car it may be possible to overcome some of the spatial divisions that exist within a segregated city. The greater sense of safety and reduced opportunity for interaction derived when travelling in a vehicle, suggest a greater likelihood that people will enter outgroup or mixed spaces when travelling in a vehicle, than when travelling on foot. In other words, a vehicle may act as a kind of spatial 'bubble' that potentially insulates residents from forms of threat that are experienced more acutely when they travel as pedestrians, thus allowing them to cross sectarian boundaries. We will explore this hypothesis further during our analysis.

Segregation, T-Communities and everyday mobility practices: From pre-defined areal units to tertiary street networks

The present research aims to extend existing research on sectarian divisions in Belfast in two main ways. We extend Rick Grannis's (1998, 2005) work on the role of so-called T-communities in maintaining racial segregation in large American cities to the context of sectarian segregation in Belfast, Northern Ireland's capital city. As a novel contribution to the field, we show how such T-communities are central in shaping the everyday mobility practices of local Catholic and Protestant residents. In effect, they are central to maintaining networks of disconnection in this historically divided city.

Many segregation studies use pre-defined areas such as census boundaries to define neighbourhoods and measure the nature and extent of urban segregation (Li and Wang 2017, Lloyd 2010, Merrilees et al. 2017, Noonan 2005, Omer and Benenson 2002, Weaver 2015, Wong and Shaw 2011). Grannis (2009) stresses that while boundaries defined by census or other administrative agencies generate statistical units that are useful for summarising data, they do not delineate neighbourhoods in a socially meaningful way or account for the potential for residents to interact. Census boundaries seldom map onto residents' own perceptions or behaviours, which are important if the causes and consequences of segregation are to be determined (Deng 2016). For example, physical barriers such as open spaces, railways or major roads have been found to affect segregation (Noonan 2005); yet such barriers are often disregarded in the largely administrative definition of census boundaries. The geographic context relevant to individuals themselves may thus not necessarily relate to officially delineated geographic units (e.g. wards, districts or other census units) (Kwan 2012). In the context of the present study, the actual and perceived potential for interaction with specific group members is important for understanding both the nature of segregation and its consequences for the everyday mobility practices of individuals.

The challenges relating to use of census boundaries for neighbourhood delineation are evident in north Belfast. Here some census small areas (smallest reporting unit for the Northern Ireland census) appear to be highly mixed, yet as the example in Figure 1 shows, the area is in fact highly divided. On closer inspection of the small area shown as mixed in Figure 1a it can be seen that there is no route, pedestrian or otherwise, between one side of the census small area and the other without crossing the boundary of the census small area. In fact, divided by a peacewall, this small area falls straddles an interface between highly segregated neighbourhoods. This suggests that not only is community affiliation poorly defined, but also that the census boundaries do not form part of a cohesive neighbourhood definition.

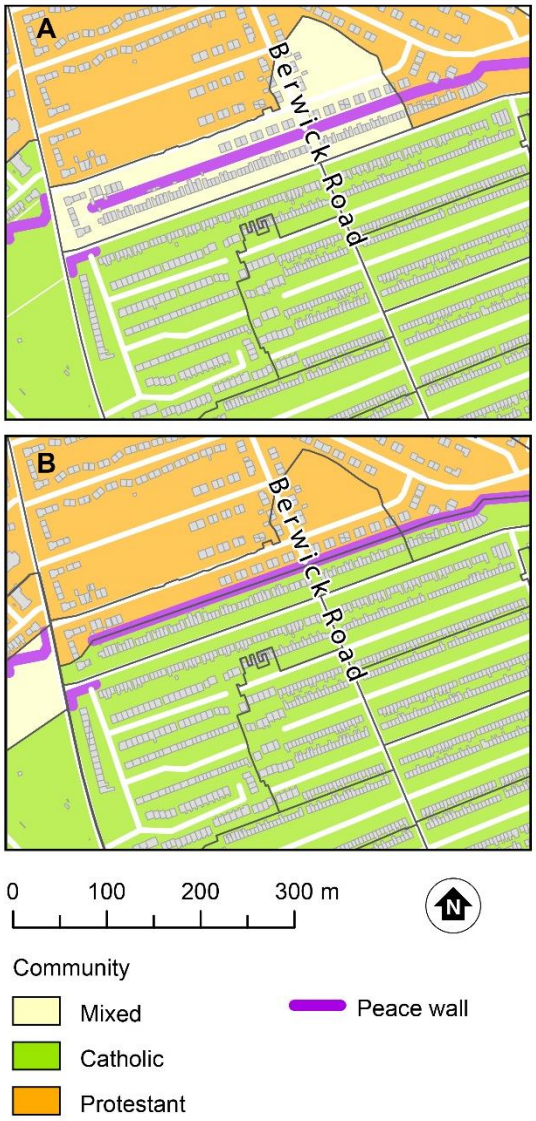

Figure 1. a) Community definitions based upon UK population census small area statistics for 2011. Areas defined based upon greater than 65% Catholic or Protestant. b) Adjusted community definition accounting for street layout, presence of peace walls and known community boundaries

The concept of T-communities was introduced by Grannis (1998), whose hypothesis was that relational connections via tertiary streets were a better predictor of the racial composition of neighbourhoods than either simple proximity or distribution across census units. By studying two cities with very different social and geographic backgrounds, Los Angeles and San Francisco, Grannis (1998) tested this hypothesis, finding that those residents connected via tertiary streets were much more similar than those not connected through a tertiary street network. He concluded that those 'down the street' - regardless of distance - are more similar to each other than those who may be closer by straight-line distance, but less connected. Grannis (1998) also highlighted that residents living within the same census area do not have the same opportunities for contact as those living within the same T-communities. This concurs with our own observations as demonstrated earlier in Figure 1, which indicates how interaction between residents who share a census tract may nonetheless be limited by territorial boundaries and the (dis)connection of existing street networks.

Grannis (2005) later went on to study variations within T-communities, this time studying the cities of Los Angeles, New York and Chicago. Here he concluded that T-communities and their role in social connectivity between residents who view themselves as similar, were a major factor in individuals'

decisions regarding where they choose to live. The T-community concept suggests that the geographic opportunities for everyday 'passive' contacts, which tertiary street networks facilitate, may lead to opportunities for active contact between residents and the building of a sense of community (Weaver 2015). For these reasons, individuals' residential preferences reflect not only simple relations of physical proximity, but also relations of real and imagined connection, a sense of who lives down the street and who is likely to be encountered in everyday life whilst engaging in such mundane activities as going to the shops, visiting a friend, walking the dog, or simply taking a stroll.

Grannis (1998) defined tertiary streets as pedestrian-orientated streets that are not used as throughways, but are designed to connect local residents with a socio-spatial network of seemingly 'trivial' streets. Where two or more tertiary streets interconnect, they are considered part of the same T-community, but once a tertiary street interconnects with a main road or other barrier, the outer limit of the T-community is defined (Figure 2). T-communities also account for other boundaries that may separate neighbourhoods including parks, shopping malls or physical barriers such as walls (Grannis 1998). Although there may always remain some uncertainty about the true geographic context affecting individuals (Kwan 2012), T-communities help to focus defined neighbourhoods around opportunities for interaction, which is particularly important when considering segregation and mobility. The interconnections and opportunities for interaction facilitated by T-communities, we would argue, thus provide a more meaningful definition of spatial units for segregation studies than more commonly applied census boundaries.

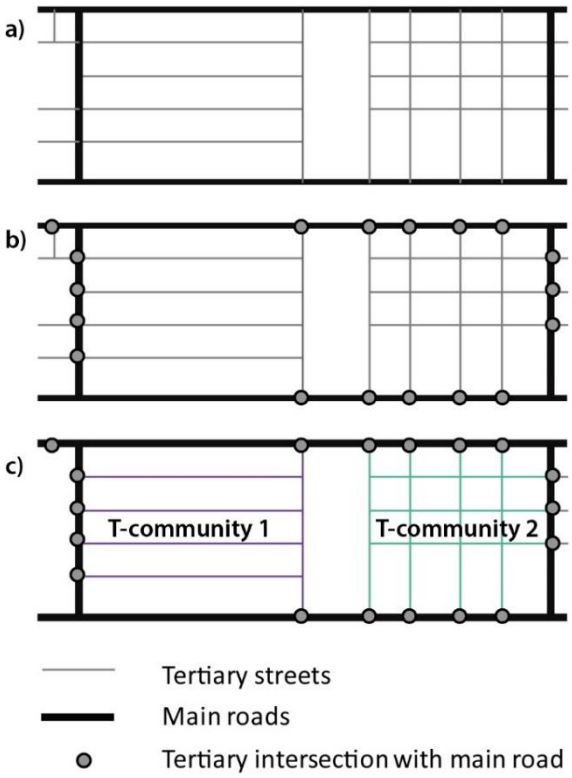

Figure 2: The T-community concept: a) distinguish main roads from tertiary streets, b) identify intersections between tertiary streets and main roads (or other barriers), c) group tertiary streets into T-communities, terminating the T-community when it reaches an intersection with a main road.

If, as Grannis suggests, T-communities influence opportunities for interaction, then we might predict higher levels of activity space segregation (and lower levels of mixing) within them, than within non-tertiary streets. As discussed further below, the present research thus aimed to explore the extent to which sectarian segregation of mobility practices varies between tertiary and non-tertiary streets, focusing on relations in the northern area of in the historically divided city of Belfast. Our main objective here was not to directly compare the analytic utility of standard census units with T-Communities as a foundational unit of analysis in residential segregation research, a comparison that

Grannis has already developed (e.g. Grannis, 1998). Rather, as we elaborate below, our objective was more novel, namely to explore the potential role of T-communities in shaping how residents use everyday pathways and activity space beyond their homes.

Research focus and questions

Regardless of how neighbourhoods are defined, many segregation studies focus exclusively on residential segregation, often using census data to define the ethnic mix of the residential population (Bruch 2014, Grannis 1998, Hughes et al. 2007, Lloyd and Shuttleworth 2012). While some studies have measured use of space through activity diaries (Farber et al. 2013, Li and Wang 2017, Wong and Shaw 2011) or from mobile phone usage (Järv et al. 2015, Silm and Ahas 2014), few studies have used GPS tracking for understanding the impact of segregation on mobility (Palmer et al. 2013, Roulston et al. 2017). GPS tracks potentially identify locations people go when not at home, as well as the routes people take to reach these locations. To date the T-community concept has only been used for studies of residential segregation in large grid plan cities (Grannis 1998, Grannis 2005). Meanwhile work using GPS tracks to measure time in neighbourhoods of differing characteristics has relied upon census units to define neighbourhood boundaries (Palmer et al. 2013). By combining T-community neighbourhood definitions with GPS tracks collected by residents, we gain new insights into the way in which people use different types of group space (ingroup, mixed and outgroup) and different neighbourhood types (T-communities, main roads). In order to explore the impact of segregation on residents' everyday movements, the study focuses entirely on time spent in transit, moving through open space and excludes time spent at destinations.

Fear of the opposing community, either real or perceived, leads to negative emotional responses towards outgroup areas (Shirlow 2003, Roulston et al. 2017), suggesting therefore that residents would be less likely to spend time moving within outgroup areas. This is the first assumption that we will seek to test. We then explore a second assumption that time spent in outgroup space is less likely to be within T-communities, and more likely to be along sections of main road which are more likely to be used as through routes or for access to services, including access to supermarkets and retail parks. Based on the suggestion that fear is reduced when travelling in a vehicle (Lysaght and Basten 2003), we will test whether mode of transport affects likelihood of entering outgroup or mixed spaces. Finally, based on suggestions in the literature that women may be more willing to enter outgroup space, we will explore this idea further using data from a sample of local residents to determine whether there is any greater likelihood that women will enter outgroup spaces than men.

Combining GPS tracking and T-community definitions we will answer the following research questions:

1. Do residents of north Belfast spend significantly more time moving within areas of their own community affiliation (ingroup areas) than within outgroup or mixed spaces?
2. Of time spent within outgroup space is this more likely to be along sections of main road than within outgroup T-communities?
3. Does mode of transport affect mobility, with people travelling in vehicles more likely to enter mixed or outgroup space?
4. Do women spend more time within outgroup areas than men?

Methods

In this section, we will outline the data inputs used and analysis undertaken, focusing on the challenge of studying how T-communities may shape everyday mobility practices in north Belfast and how this may be affected by factors such as mode of transport and gender. The key steps are summarised in the flow diagram in Figure 3.

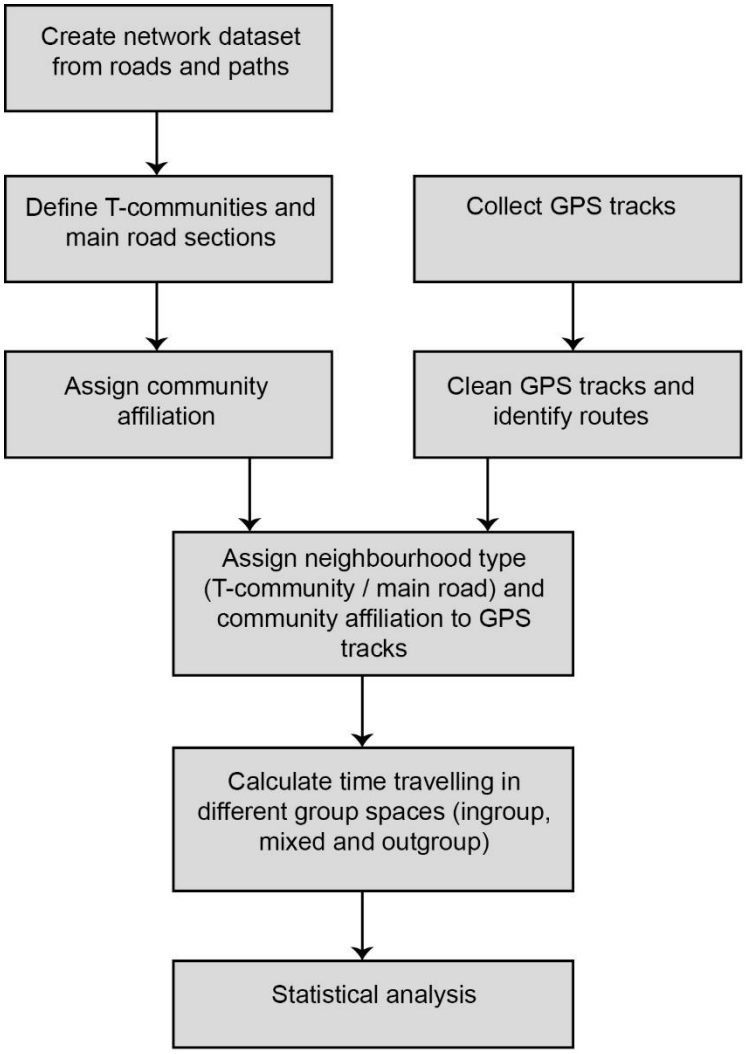

Figure 3: Summary of steps in the methodology

Study Area

This study focuses on the area of north Belfast. While east Belfast is predominately Protestant and west Belfast predominately Catholic, north Belfast has approximately even numbers of Catholics and Protestants living side by side in highly segregated communities, as illustrated in Figure 4. It is also within this part of the city that physical barriers to movement, in the form of peace walls, are most prevalent (Figure 4). Both the close proximity of opposing communities and the presence of peace walls in north Belfast potentially affect people's everyday mobility patterns, therefore making it an interesting focus for this study. Figure 5 illustrates the way in which peace walls divide tertiary streets that would once have connected communities. The example shown in Figure 5 is a section of a 650m long fence, which now divides a once joined T-community into two disconnected communities. Here it evident that the tertiary street, Berwick Road, once connecting the two communities has been truncated. Regardless of any preference for avoiding outgroup communities, it is obvious that the presence of peace walls themselves has affected the everyday mobility in Belfast.

North Belfast experiences high levels of deprivation, with half of the residents living in the top 20 percent of most deprived wards in Northern Ireland. Deprivation levels are very similar for both the Protestant and Catholic communities in this study. The research here is part of a wider study exploring mobility and segregation in north Belfast (Hocking et al. 2018, Huck et al. 2019). Of all participants taking part in the study, 73 percent had a household income of less than £20,000 per year, with very little variation between community groups. Variation in economic status or deprivation is therefore excluded from subsequent analysis.

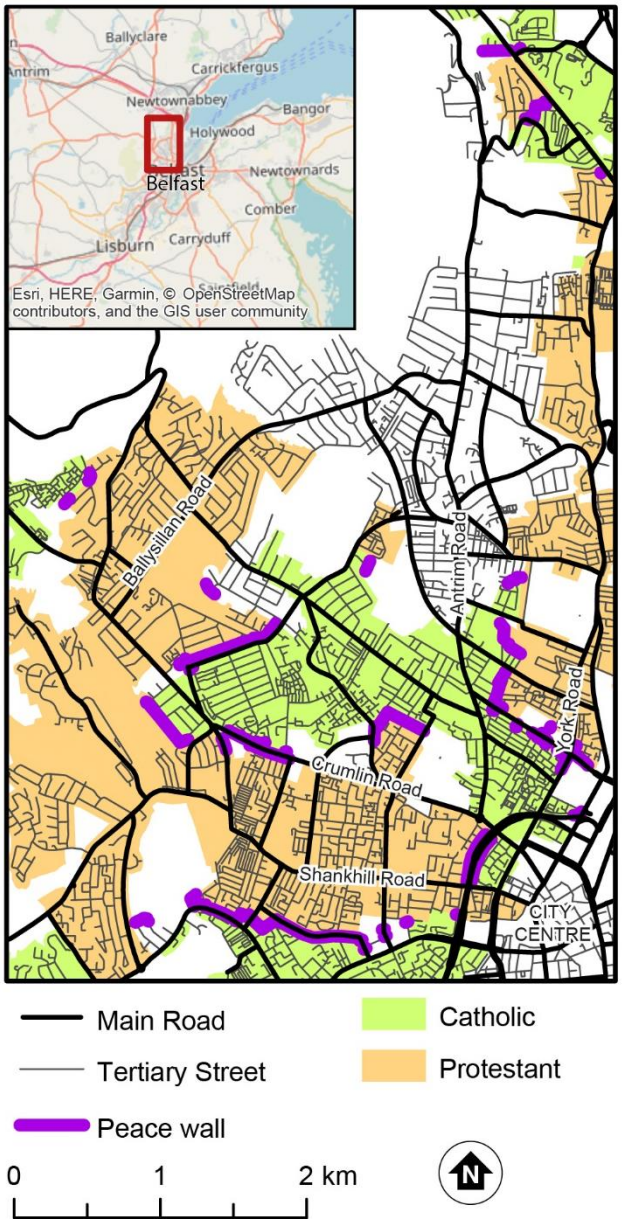

Figure 4. Study Area. Catholic and Protestant communities within study area of north Belfast, defined as census small areas with greater than 65 percent of residents identifying with this community during the 2011 Census of Population and where strong community identity is known to exist. Large non-residential spaces and mixed neighbourhoods are shown in white.

Figure 5: a) Aerial image showing the division of the tertiary street, Berwick Road, by a peace wall. b) Photo highlighting the impact of the barrier, on the Catholic side of the peace wall with evidence of painted murals c) Photo highlighting the impact of the barrier, on the Protestant side of the peace wall.

Defining T-communities

We began by creating a network dataset representing all roads and paths within north Belfast. This was derived from a road dataset supplied by the Ordnance Survey Northern Ireland (OSNI) into which we captured additional residential footpaths visible on either Google Maps or the OSNI 1:10,000 background maps. Tertiary streets and footpaths within residential areas were defined as traversable. Features such as main roads, peace walls, industrial areas, retail complexes and parks were defined as non-traversable and used as barriers within the network, thus defining boundaries for the T-communities. The T-communities were computed using ArcGIS Desktop 10.4 (ESRI 2015) network analysis tools to generate 'service areas' representing all sets of connected streets before a barrier is reached (See Figure 6a for examples of defined T-communities). A fuller description of the method for creating T-communities can be found in Supplementary Material 1.

One of the key distinctions between Grannis' original definition and our implementation of T-communities is the treatment of main roads. Using Grannis' definition only roads not suitable for pedestrians are defined as 'main roads' (Grannis 2005). By this definition, however, north Belfast would only form one T-community. Using our refined definition of main roads as those wide enough for two cars to pass and known as through routes, a more meaningful set of T-communities were created for studying segregation at a finer scale and in a context with a very different road structure. In Grannis' work the main roads are then of little interest to further analysis of segregation. In the context of north Belfast, however, the main roads used to delineate boundaries to T-communities are of interest themselves. These 'main roads' are well used as pedestrian routes and are often lined with residential properties, and they accordingly convey sectarian territorial meanings. In addition to defining distinct T-communities, main roads were also broken into sections at key junctions or known

community divides (Figure 6b) (See Supplementary Material 1 for more information). In total, there are 391 T-communities and 212 main road sections within the study area, compared to 411 census small areas.

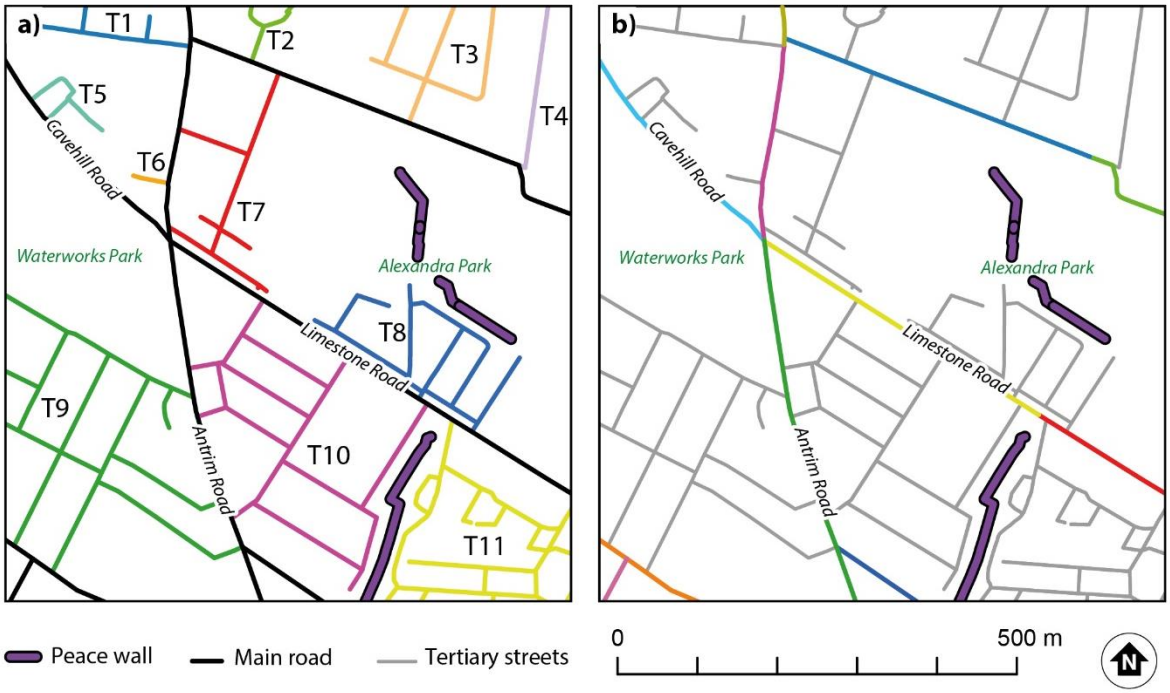

Figure 6. An illustrative section of north Belfast showing a) defined T-communities (labelled T1-T11), and b) sections of main roads.

Assigning community affiliation

While it is common to define the community affiliation of a neighbourhood using census data, this can in some instances be misleading. For example, in north Belfast some census zones (census small areas) that appear mixed based on even numbers of Catholics and Protestants can be some of the most divided, such as the established Protestant community of Greencastle (Huck et al. 2019). While census zones follow street patterns to some extent, they are often optimised to account for the number of households that they contain rather than aligned to community or neighbourhood divides. It is therefore possible for census zones to be constructed across a clear community divide. In some instances, the divide is not only a perceived one, but also a physical barrier with peace walls dividing census zones (as demonstrated earlier in Figure 1). Using extensive local knowledge of the research team, the location of barriers (Belfast Interface Project 2017), and existing census data, census zones straddling a community divide were split and community affiliation redefined accordingly. Areas were defined as either Catholic, Protestant or mixed where it was known that a clear sense of community identity existed, or mixing occurs, and was supported by census statistics. This definition was used to assign community affiliation to the T-communities. Unlike the census small area boundaries, no T-communities were found to straddle a known community divide. Community affiliation of sections of main road were defined, using the same community definition and with further refinement and advice from the Institute of Conflict Research, an NGO located on a sectarian interface in north Belfast that has conducted research on segregation for over 20 years.

GPS tracking

Participants for GPS-tracking were recruited to the project during a one year field campaign, in which two project researchers went door to door throughout north Belfast asking all householders who answered the door to participate by installing a custom application on an GPS-enabled Android Smartphone and collect data for a period up to fourteen days (See Hocking et al. 2018 for more details of the process of recruiting particpants). From this field campaign, 233 recruits agreed to install the

tracking application and registered some data. The application automatically captured points every four seconds and uploaded the data to a remote server once connected to Wi-Fi (Whyatt et al. 2016). Locational accuracy of GPS track points varies depending on a number of features including alignment of satellites, the quality of the receiver, and presence of blocking features such as building and trees. Signal indoors is usually poor. The GPS data was cleaned to remove points with poor positional accuracy. The continuous sequence of points for each participant was also divided into separate tracks and stop locations. Details of the data cleaning process and method used to separate tracks can be found in Davies et al. (2017). A total of 184 (86 Catholic, 87 Protestant, and 11 other) users recorded at least one valid track, where a route between two locations could be distinguished, were used in subsequent analysis. The number of tracks varied from one to 200 per participant, with a mean of thirty three per participant. 6158 separate tracks and stops were defined. The average age of participants was thirty nine (this was the same for both Catholic and Protestant participant groups). Of the participants whose data was used for this study, 62 percent were female and 38 percent male. There was a slight variation in gender split between community groups, with the 57 percent females in the Catholic group and 70 percent female in the Protestant group.

Travel mode has a potentially significant influence on an individual's willingness to move within outgroup areas (Lysaght and Basten 2003). Since the mobile app did not capture travel mode, mode was inferred based on the work of Bohte and Maat (2009). Participants were assumed to be 'on foot' if the average track speed was less than 10km/h and the maximum track speed was less than 14km/h; 'in vehicle' if average track speed was greater than 25km/h or maximum track speed was greater than 45km/h; and 'indeterminate' for all other speeds which may represent bicycle, slow moving traffic or a mixed mode journey.

GPS track points were assigned T-communities or main road sections by first snapping all points within 20m of a main road to those roads. This ensured that track points near junctions with tertiary streets remained associated with main roads. All remaining points within 40m of a road were snapped to the nearest road section, assuming that all points further than 40m from a road were associated with movement through open spaces such as parks. At this stage attributes from the assigned T-community or main road were joined to the GPS track points, including the community affiliation of the T-community. From this is was possible to ascertain whether the track points where 'in group' (same community affiliation as the participant), 'mixed' (either participant affiliation was 'other' or neighbourhood was mixed), or 'outgroup' (community affiliation was opposite to the participant). User ID, track ID, time, travel mode, participant's community affiliation and gender, and type of group space (ingroup, mixed, outgroup) were associated with each track point prior to the statistical analysis.

Statistical Approach

In order to address the research questions specified earlier, taking into account the structure of our data, which involved repeated measurement of participants from different groups, genders, and T-communities, we used mixed linear modelling with random intercepts for participants, implemented in the statistical programming language R (Team 2018) and the package NLME (Pinheiro et al. 2018).

Modelling our data with mixed linear methods allowed us to test the hypothesis that residents would spend more time moving within ingroup areas (a main effect), and when moving through outgroup or mixed areas would be more likely to do so along main roads (an interaction of type of group space and type of road). It also allowed us to test the hypothesis that residents would be more likely to move through mixed or outgroup spaces in a vehicle rather than on foot (an interaction of mode of transport and type of group space), as well as the hypothesis that women would spend more time within non-ingroup areas than men. To control for variable amounts of GPS tracking data captured from participants, which resulted in positively skewed distributions, time estimates were first aggregated per person, and then log-transformed.

Factors for analysis included type of Group Space (ingroup, mixed, outgroup), Community membership (Catholic/Protestant), Travel Mode (by vehicle, or on foot), and Neighbourhood Type

(Main road vs T-community). A further covariate was added into the analysis to control for opportunity for road usage across group space and neighbourhood type. This covariate represented the proportion of main roads and tertiary streets within 1km of a participant's home that was within ingroup, mixed or outgroup space. The dependent variable was the log-transformed, summed amount of time in minutes that each individual spent in different types of spaces using different modes of travel. This measure was used to generate, among other things, aggregate scores of the time spent by different community groups across different spaces. The mixed linear model fitted to the data had fixed effects for Group Space, Community membership (Catholic/Protestant), Travel Mode, Neighbourhood Type, and the road usage covariate, as well as a random intercept effect for participants. Modelling was carried out "top-down", as recommended by Zuur, Ieno, Walker, Saveliev and Smith (2009): that is, non-significant higher order model classes were removed iteratively, and non-significant individual terms removed from the highest remaining order of model class.

Results

We present results for each of the research questions in the order specified earlier and repeat the research questions for sake of clarity of presentation.

(1) Do residents of north Belfast spend significantly more time moving within areas of their own community affiliation (ingroup areas) than within outgroup or mixed spaces?
(2) Of time spent within outgroup space is this more likely to be along sections of main road than within outgroup T-communities?

Overall, participants spent considerably more time moving within ingroup areas, than mixed or outgroup areas. Figure 7 suggests that for sections of main road there is an ordinal pattern for time spent in types of group space (ingroup > mixed > outgroup). While the pattern of preference for ingroup space holds for both main roads and T-communities, the pattern is much more striking for time spent within T-communities, where very little time is spent within mixed or outgroup areas. This is borne out by the significant interaction for Group Space and Neighbourhood Type in the mixed linear model, as shown in Table 1. Our results therefore confirm not only the preference for moving within ingroup space, but also clearly demonstrate that time spent within outgroup space is more likely to be along sections of main road.

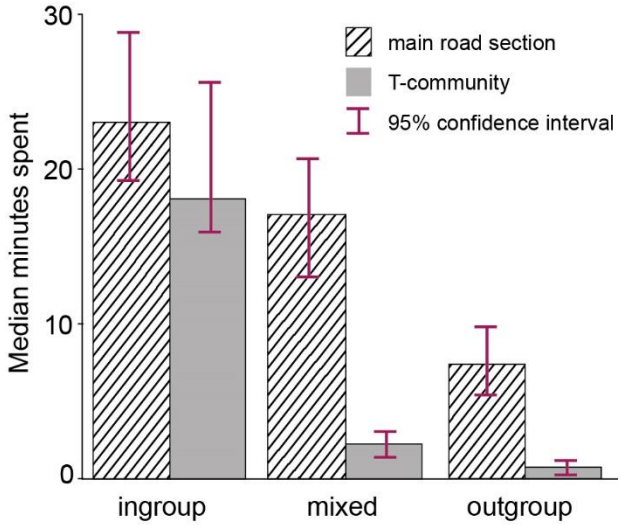

Figure 7. Median minutes spent along main roads or within T-communities, across types of group space. Note: the confidence intervals were estimated by bootstrap (1000 replicates).

Figure 8 further illustrates the finding that participants were significantly less likely to move within outgroup T-community space. This shows that along main roads there is movement within ingroup,

mixed and outgroup spaces, with a slight preference toward movement within ingroup spaces. For the majority of T-communities, however, it is evident that most movement occurs within ingroup space. While the majority of mixing between ingroup and outgroup usage occurs along main roads, pockets of outgroup movements within tertiary streets occur across the map, usually relating to a single trip by one participant (for example location C, Figure 8). In some areas where a greater amount of mixing appears present within tertiary streets, there are possible explanatory factors. For example, location A on the map shows the location of Holy Cross Girls Primary School. This is a Catholic primary school situated within a Protestant neighbourhood. Tracks within this area, recorded as movement within outgroup space, are all timed at the start or end of the school day, suggesting that taking children to or from the Holy Cross School offers a clear explanation of the use of this outgroup space. There is also strong evidence of movement within outgroup space around Location B. This is a predominately-Catholic area, which includes the location of the Belfast Royal Academy (a mixed grammar school). The timing of outgroup movement in this area is more varied, typically being at the start and end of the working day and at lunchtime.

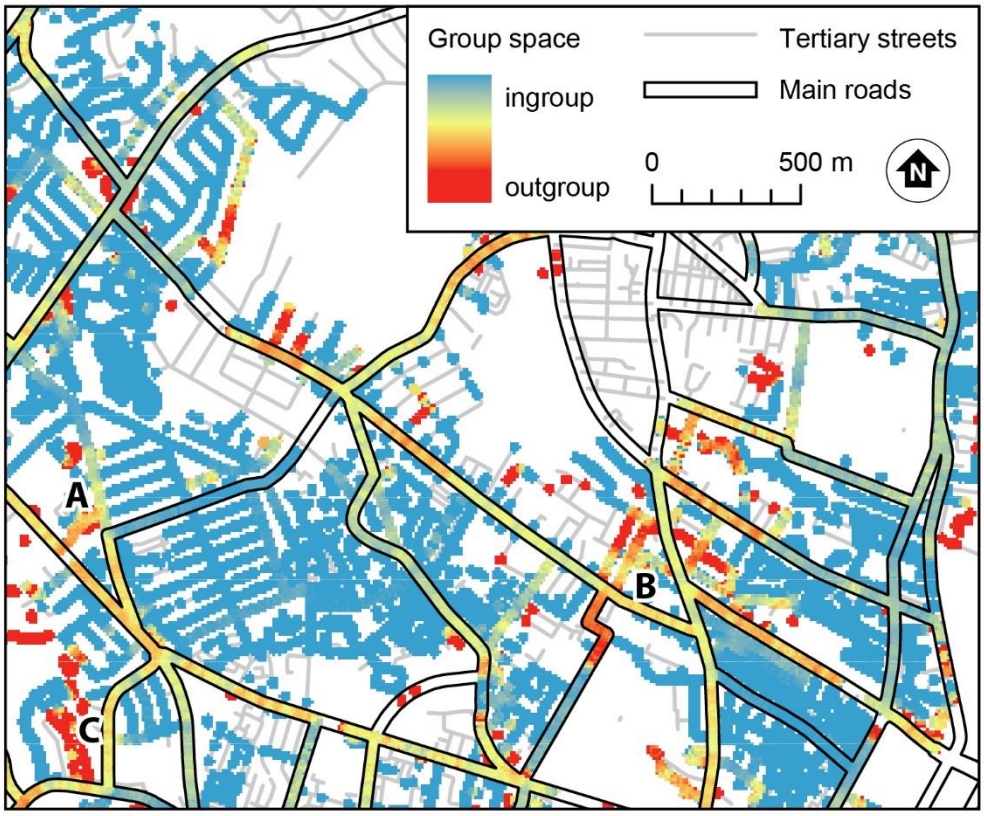

Figure 8. Movements captured from participants GPS tracks within north Belfast. Shading ranges from blue (track points show participants moving within ingroup areas), to red (track points show participant movement within outgroup spaces). Blended colours show mixed patterns of movement within ingroup and outgroup areas.

Although the non-overlapping confidence intervals in Figure 7 suggest clear differences in the patterns of time spent within sections of main road or T-communities across different group spaces (ingroup, mixed, outgroup), this may be an artefact of participants' home location rather than preference for ingroup space. We therefore introduced a covariate into the analysis to control for the opportunity of road usage across group space and neighbourhood type (main road section, T-community). Having carried out secondary analysis to account for the types of roads and group spaces within close proximity of a participant's home location, results showed that while the control for home location was significant in explaining use of group space, preference for ingroup space remained significant. Table 1 shows the modified analysis of variance table, which confirms that even

controlling for home location people were significantly less likely to spend time within outgroup space. The table shows that home location had a significant overall effect on time spent across different kinds of spaces ($F = 17.86$, $df = 1, 1641.6$, $p < 0.001$); however, above and beyond this effect, type of group space, neighbourhood type and crucially, the group space by neighbourhood type interaction all remained statistically significant. Examination of the residuals from the model suggested possible heteroscedasticity (an important assumption underlying the calculation of probability values), and we therefore computed bootstrap 95% confidence intervals (1000 replications) for model parameter estimates as an alternate, distribution-independent check on model effects. All effects reported as significant in Table 1 also had confidence intervals that were either entirely positive or entirely negative, supporting the findings in Table 1. Model parameters, with confidence intervals, are shown in Table 2.

Table 1. Analysis of variance table for mixed linear model containing two-way interaction of Group Space and Neighbourhood type, controlling for home location

	SS	MS	df_1	df_2	F	p <
Group space	292.55	146.28	2	1580.8	77.742	0.001
Neighbourhood type	382.67	382.67	1	1545.4	203.379	0.001
Control for home location	33.61	33.61	1	1641.6	17.862	0.001
Group space × Neighbourhood type	115.08	57.54	2	1507.5	30.582	0.001

SS = sums of squares; MS = mean square; df = degrees of freedom; F = value of F distribution statistic; p = probability

Table 2. Model coefficients (fixed effects, with bootstrapped 95% confidence intervals, 1000 repetitions)

	b	SE(B)	B	Lower CI	Upper CI
(Intercept)	2.14	0.10		1.94	2.33
Group space: outgroup vs ingroup	-0.47	0.12	-0.11973	-0.72	-0.24
Group space: shared vs ingroup	-0.29	0.11	-0.07992	-0.51	-0.08
Neighbourhood type: T comm vs Main Rd	-0.52	0.13	-0.15243	-0.77	-0.29
Control for home location	0.01	0.00	0.1237	0.01	0.02
Group space: outgroup vs ingroup × Road type: T community vs main	-1.40	0.18	-0.25982	-1.71	-1.02
Group space: shared vs ingroup × Neighbourhood type: Tcomm vs Main Rd	-0.60	0.17	-0.12447	-0.89	-0.25

b = unstandardized coefficient; SE = standard error; B = standardized coefficient; CI = confidence interval

For the statistical analysis all zero values were removed, meaning only participants who spent at least sometime within an outgroup area were included in the analysis. This removed from the analysis 21 percent of participants, who never recorded any movement within outgroup space. In the light of this, the clear preference found for use of ingroup rather than outgroup space is a conservative estimate of the impact of segregation on movement. The overall use of outgroup T-communities is particularly low, constituting less than 2 percent of the overall movements captured within the GPS tracks.

In summary our results show that residents of north Belfast spend significantly more time moving within areas of their own community affiliation (ingroup areas) and that time spent within outgroup space is more likely to be along sections of main road than within T-communities. The overall implication is that segregation is widespread within north Belfast, and that it is expressed most starkly via everyday patterns of movement within networks of tertiary streets (T-communities).

(3) Does mode of transport affect mobility, with people travelling in vehicles more likely to enter mixed or outgroup space?

Initial examination of the two-way interaction between group space and travel mode, shown as part of Table 3, suggested that there was no significant interaction between travel mode and group space ($p \leq 0.202$) in predicting time spent. Further exploration of the three-way interactions between group space, neighbourhood type and travel mode, shown in Figure 9 revealed that movement along outgroup or mixed sections of main roads was significantly more likely to occur within a vehicle than on foot. In contrast, we found no significant differences for travel mode within mixed or outgroup T communities. Model parameters, with confidence intervals, are shown in Table 4.

Table 3. Analysis of variance table for mixed linear modelling of time spent within ingroup spaces by travel mode, community, and neighbourhood type.

	SS	**MS**	**df_1**	**df_2**	**F**	**p <**
Group space	174.99	87.49	2	899.96	63.64	0.001
Travel mode	18.73	18.73	1	953.82	13.63	0.001
Neighbourhood type	140.27	140.27	1	886.45	102.04	0.001
Control for home location	7.03	7.03	1	906.94	5.12	0.024
Community	0.00	0.00	1	164.15	0.00	0.993
Group space x Travel mode	4.41	2.21	2	896.90	1.60	0.202
Group space x Neighbourhood type	35.57	17.79	2	876.96	12.94	0.001
Neighbourhood type × Travel mode	51.30	51.30	1	869.85	37.32	0.001
Group space x Travel mode × Neighbourhood type	10.55	5.27	2	871.21	3.84	0.022

Table 4. Model coefficients (fixed effects, with bootstrapped 95% confidence intervals, 1000 repetitions)

	b	se	B	CI Lower	CI Upper
(Intercept)	2.73	0.15		2.43	3.04
Group space : ingroup vs outgroup (1)	-0.52	0.14	-0.14	-0.80	-0.24
Group space : ingroup vs shared (2)	-0.28	0.14	-0.07	-0.57	0.01
Travel mode	-0.68	0.16	-0.19	-0.98	-0.39
Neighbourhood type	-0.76	0.17	-0.23	-1.11	-0.42
Control for home location	0.01	0.00	0.08	0.00	0.01
Community	0.00	0.17	0.00	-0.34	0.33
Group space: (1) × Travel mode	-0.50	0.31	-0.07	-1.08	0.03
Group space: (2) × Travel mode	-0.14	0.26	-0.02	-0.67	0.41
Group space: (1) × Neighbourhood type	-1.52	0.22	-0.29	-1.98	-1.12
Group space: (2) × Neighbourhood type	-1.07	0.23	-0.20	-1.54	-0.64
Travel mode x Neighbourhood type	0.48	0.22	0.11	0.03	0.90
Group space: (1) × Travel mode × Neighbourhood type	0.89	0.43	0.08	0.07	1.74
Group space: (2) × Travel mode × Neighbourhood type	0.90	0.38	0.10	0.10	1.66

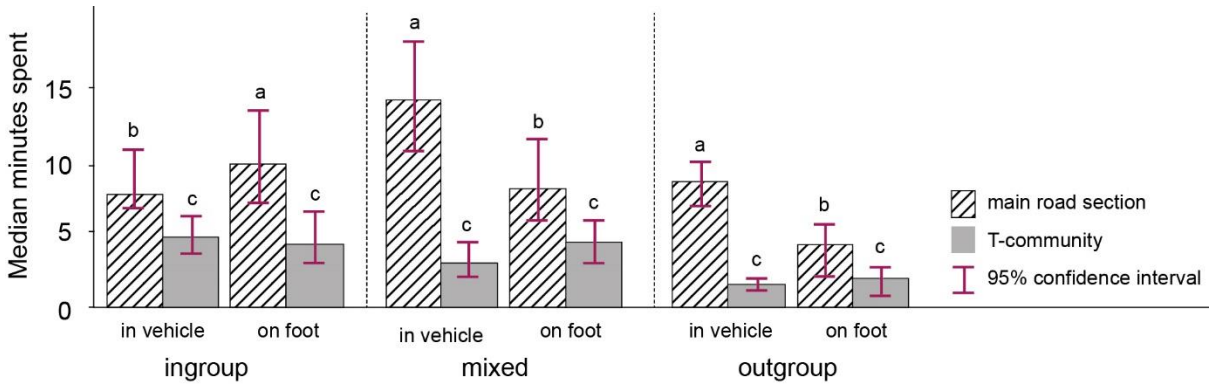

Figure 9. Median minutes spent in different group spaces by transport mode. Letters above bars indicate significantly different post hoc contrasts (Tukey) (different letters indicate a significant difference, at $p < .05$, Thus, in the far right panel a > b > c = c, indicating that participants spent significantly more time in outgroup main road sections when in a vehicle than when walking on such sections or either walking or driving in T-Communities).

We found that the combination of mode of transport and type of road had little influence on the use of ingroup space. However, several effects emerged for mixed and outgroup spaces when considering the same combination. Notably, along main roads residents were more likely to move within mixed or outgroup spaces when in a vehicle, rather than on foot. However, mode of transport had no effect on the time spent in mixed or outgroup spaces when those spaces were part of the T-communities. Thus, travelling in a vehicle may enable residents to spend more time on main roads outside their own community spaces, but it has no effect on the use of mixed or outgroup spaces that are within T-communities.

(4) Do women spend more time within outgroup areas than men?

We tested whether men or women spent different amounts of time in different group spaces, but we did not find a significant effect. The only notable effect we found for gender in all of our analyses was a marginally significant interaction between gender and mode of transport in a four way mixed linear model (extending the three way model reported in Table 5 by adding mode of transport). This showed that there was a significant likelihood that men would travel within a vehicle and that women would walk. But in general, our results do not support the hypothesis that women would spend more time in mixed or outgroup spaces, whether located along main roads or within T-communities.

Table 5. Analysis of variance table for mixed linear modelling of time spent ingroup spaces by Gender, neighbourhood type, and group space

	SS	MS	df_1	df_2	F	p
Group space	241.70	241.70	1	944.10	136.38	<.001
Gender	2.74	2.74	1	168.50	1.55	0.215
Neighbourhood type	144.53	144.53	1	971.28	81.55	<.001
Control	8.84	8.84	1	1034.35	4.99	0.026
Group space × Gender	0.19	0.19	1	954.74	0.11	0.745
Group space × Neighbourhood type	98.69	98.69	1	921.49	55.68	<.001
Gender × Neighbourhood type	1.06	1.06	1	908.16	0.60	0.441
Group space × Gender × Neighbourhood type	0.37	0.37	1	909.63	0.21	0.649

Discussion

In reflecting on the methodology applied and results obtained, we firstly examine the findings in relation to the hypothesis set, which explore the impact of segregation on people's mobility, particularly in the context of movement within defined T-community spaces. We then discuss challenges of adapting the T-community concept to a very different setting than its original implementation, examining the extent to which this is useful for further segregation studies.

Perhaps unsurprisingly, given the history of conflict within north Belfast and the continued presence of sectarian markers in the landscape, including physical barriers such as peace walls, our results show that residents of north Belfast spend significantly more time moving within ingroup spaces than within either mixed or outgroup areas. What is more interesting is that this pattern is significantly stronger within T-communities than along main roads, suggesting that it is within networks of tertiary streets (T-communities) that segregation remains at its strongest. Given Grannis' premise that opportunities for interaction between residents creates identity within T-communities, and thereby shapes residents' choices about where and with whom they want live (Grannis 1998), it is perhaps unsurprising that no T-communities straddle a community divide and that very little movement occurs within outgroup T-community space. Where use is made of outgroup T-community space this is often for specific reasons, such as access to Holy Cross Primary School, a Catholic school, situated within a predominately Protestant T-community (shown earlier on Figure 8, location A). At the same time, past tensions around areas such as Holy Cross serve to highlight tensions and fear related to entering outgroup neighbourhoods (Gilligan 2009, Young 2017).

Along main roads there is still a preference for use of ingroup space, however, this effect is less pronounced than within T-communities. One explanation for this is that journeys along main roads beyond ingroup space are necessary to access other parts of the city, as well as key services and facilities within north Belfast that may be located along main roads in or beyond outgroup spaces. Travel along main roads, typically in vehicles between an individual's home T-community and a neutral non-place such as a supermarket, limits interactions with people or symbols of sectarianism such as flags or graffiti (Huck et al. 2019). Although there is significantly more use of outgroup sections of main roads compared to T-communities, evidence from walking interviews (see Hocking et al. 2018 for details) conducted as part of the wider project, of which this study is one part, suggests that there remains a clear sense of defined community territories along main roads. In some cases, community members know which side of the road they need to walk on to feel safe. During his walking interview one participant (a male protestant) has a clear notion of where he did and did not feel safe, and the best route through an opposing outgroup area. Reference here to 'the Shankhill' relates to an area of shops along Shankhill Road. Both Shankhill Road and Crumlin Road are main roads that lead into the city centre.

"I know that's Catholic, so therefore that would stop me from going in that direction. If I could avoid going in the direction of a Catholic area, hence, this is why I would go this way because I would feel very vulnerable going down through Alliance Avenue. Be very vulnerable down Ardoyne Road. But on this road, it runs straight down, straight down to Twaddell Avenue, Woodvale, Crumlin Road. And if I was going to the Shankill for instance to go to a shop, I'd walk on that side of the road [right hand if headed in the direction of town], and right down to that corner."

In exploring the impact of mode of transport on mobility, it is clear that participants are more likely to travel along outgroup sections of main roads, if they are in a vehicle. This is interesting because it qualifies the supposed 'bubble' effects of being enclosed within a motor vehicle. Being within a vehicle may cause residents to feel safer (Lysaght and Basten 2003), minimising opportunities for interaction with members of the other community. Residents may travel through outgroup areas in a vehicle to reach neutral spaces such as retail parks or supermarkets, sometimes referred to as non-spaces, which have no past history of ownership or conflict (Huck et al. 2019). The bubble effect of a vehicle, does not however, appear to extend into T-communities. This is perhaps to be expected, as T-communities are rarely used as thoroughfares, and therefore unlikely to be passed through in a vehicle on route to other destinations. It should also be remembered that very little movement was recorded within outgroup T-communities and limited conclusions can therefore be made in relation to travel mode within outgroup T-communities.

Despite anecdotal evidence from earlier literature (Bairner and Shirlow 2003, Dowler 2001, Lysaght and Basten 2003) suggesting that women may experience greater mobility within outgroup areas, evidence from the tracking data both along main roads and within T-communities in north Belfast

suggests that this is not the case, with no significant difference found in the amount of time that men and women spend moving within outgroup areas. Anecdotal evidence within the literature is now dated and mobility patterns may have since changed in 'post-conflict' Belfast. It is also possible that while women may be more prepared to enter outgroup areas, for example, to access certain shops, services or activities, these visits may be infrequent and hence not fully captured within the limited time frame of the tracking data collected. An alternative explanation may be that while women typically feel less afraid of entering outgroup area, both women and men will equally prefer ingroup areas, unless there is a particular need to cross a sectarian boundary.

Grannis' definition of T-communities was designed to work for large cities in the US and thus needed scaling, through redefining the interpretation of main roads, in order to be applicable in the present research context. This re-scaling was effective in delineating boundaries that fit well with existing understanding of community divides within north Belfast, and shows potential as a means of neighbourhood delineation for other studies and geographic contexts. While in some cases our T-communities extended over an area known locally to be defined by name as more than one neighbourhood, these were neighbourhoods of the same community affiliation and evidence from the tracking data in this area suggest that residents move throughout the whole that T-community, not only the locally named area in which they live. While this may suggest that T-communities do not necessarily delineate neighbourhoods as recognised locally, they do represent opportunities for interaction, as originally intended by Grannis. Kwan (2012) has previously commented that an individual's perceived neighbourhood may differ both from administratively defined neighbourhoods and from people's activity spaces. In this context, our T-communities not only appear appropriate for the context studied, but also offer a more meaningful fit to known community boundaries than census zones that are often used in segregation studies (Lloyd and Shuttleworth 2012, Palmer et al. 2013).

The other key adaptation to Grannis' original T-community concept was the treatment of main roads. In an area such as north Belfast, where the main roads are walkable and fronted by many residential properties these cannot simply be excluded from the analysis. The ability to compare patterns of segregation and mobility between main road sections and T-communities proved highly beneficial, leading to a greater understanding of the types of space in which the greatest impact of segregation on mobility occurs. As T-communities are based on real world geographies, they provide a useful unit of assessment for real world interventions to encourage greater mixing.

One of the key elements to understanding the impact of segregation on mobility is the GPS tracking data available for this study. This is a unique dataset, obtained from a year-long field campaign (Hocking et al. 2018) representing up to two weeks of movements for 184 residents. While the GPS tracks only represent a sample of the population for a limited time, they provide a rich source of understanding in terms of the types of spaces within which residents regularly move. However, the GPS data can only tell us where people do go, and does not offer conclusive evidence of where people do not go. Grannis' analysis of segregation was limited to residential data for census blocks, with no available information on time spent in different T-communities. The GPS track data collected for this study, however, gave us the opportunity to explore in more depth the extent to which individuals move with different types of T-communities or main roads and thus the extent to which segregation impacts on movement. Importantly it also helps identify the type of spaces where opposing communities may interact. The GPS tracking data offers opportunity to identify specific areas where greater mixing appears to occur. The most striking example of this is evident on Figure 8, location B. One reason for this mixing may be the location of the Belfast Royal Academy grammar school, although timing within the track data suggest that this cannot be the only explanation. Another explanation may be the lack of alternative options for local convenience shops within the neighbouring Protestant community. While the tracking data cannot confirm the full extent of, or reasons for mixing occurring in this area, it does suggest that this area warrants further exploration to ascertain the extent of this mixing and what factors may be encouraging this to occur. Further examination of this mixing may enhance opportunities to encourage further interaction between the communities both here and elsewhere.

The methods developed here are not only useful to the understanding of segregation in the context of north Belfast, but show the usefulness and adaptability of the T-community concept for understanding segregation and mobility in other geographic contexts.

Conclusion

This paper explores the impact of segregation in new ways. A rich set of GPS tracks obtained through an extensive, yearlong, field study (Hocking et al. 2018), enabled us to shift analytic focus away from residential segregation, which is already relatively well understood within Northern Ireland, and towards an understanding of the impact of segregation on individuals' everyday movements. More specifically, we have argued that shifting focus away from use of administrative geographies (e.g. census boundaries) towards use of defined T-communities, provides a more meaningful set of boundaries in relation to the geography that residents encounter when making day-to-day mobility choices in the city. Analysis using T-communities also enabled us to develop a clearer understanding of the different impact segregation has within networks of residential tertiary streets, more easily avoidable by members of the outgroup community, compared to main roads, sometimes unavoidably used to access facilities elsewhere.

We have shown Grannis' T-community to be scaleable and applicable within north Belfast. First, although the T-communities we generated were smaller in geographic area than Grannis' original work in larger cities such as Los Angeles, they are equally useful and appropriate for the street and neighbourhood configuration found in Belfast. In adapting the T-community definition to fit a new geographic context, we demonstrate its flexibility to be adapted and applied in future studies elsewhere. Future work may incorporate participatory approaches (Huck et al. 2019) to defining community affiliation of T-communities. Second, within north Belfast it is clear not only that segregation occurs and affects mobility, but also that the impact of segregation on mobility appears to be greatest within tertiary street networks, where movement within outgroup communities is minimal. Even along main roads where greater mixing occurs, evidence suggests that most of these movements are within vehicles, thus providing rare opportunities for face to face interactions between members of different community groups.

In summary, it is clear that the two main communities in North Belfast remain largely disconnected from each other, almost never entering residential T-communities associated with the other community. While there is some evidence to suggest potential connections along main roads, even here this is mostly within a vehicle, thus limiting opportunities for interaction and leaving the communities disconnected from each other. More positively, however, results from our GPS tracking highlight some areas where greater mixing appears to occur, and these areas warrant further investigation. Understanding why mixing occurs in particular areas may lead to greater understanding that can in turn influence policy and planning elsewhere in the city.

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