Women's complex daily lives. A gendered look at trip chaining and activity pattern entropy in Germany

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Abstract: It has long been argued in feminist studies that women's daily lives are more complex than men's. This is largely due to the gendered division of work, according to which women juggle more varied obligations, including employment, household work and caregiving. Complex activity patterns in turn encourage women to organise their trips in a more efficient manner in trip chains. This paper studies the complexity of activity patterns (measured by Shannon entropy) and trip chaining patterns from a gender specific perspective. The data used is the German Mobility Panel (GMP) 1994 to 2012 which records respondents' trips over the period of a week. The outcome variables are regressed on sociodemographics, residential and workplace spatial context attributes, cohort and period effects. Gender differences in the effects of variables are tested using interaction terms. The results suggest that women's patterns are more complex than men's. Some effects differed distinctly between men and women, suggesting that men and women are differently affected by circumstances impacting the complexity of their lives, most notably by having children and by having a partner.

Keywords: activity pattern, gender, trip chain, tour complexity, travel behaviour, entropy

1 Introduction

A long-standing observation in feminist and gendered research on time use and travel is that women face more complex daily lives than men. Such complexity may be reflected in the variety of activities performed, the number of transitions between different activities, the number and spatio-temporal distribution of anchor points in an individual's activity space that need to be connected, the amount of multi-tasking undertaken in a day, the organisation of trips in complex trip chains, or even the tendency to use multiple travel modes rather than adhering to just one mode.

The main reason for this complexity is that women are typically responsible for more varied duties than men, including employment, housework, and caregiving for children, the elderly or other persons in need (MacDonald 1999). Many of these obligations require connections to be made between places, and this affects women's travel patterns in various respects. Firstly, on average, women travel shorter distances (and times) than men. This is a long-standing and consistent finding that refers primarily to commuting (Crane 2007; Sandow 2008; McQuaid and Chen 2012; Hjorthol and Vagane 2014) but also to shopping and leisure trips (Naess 2008; Scheiner 2010). It may be a result of the spatial ties imposed on women by household and caregiving duties. Secondly, women tend to organise their trips into more complex trip chains than men, thus achieving more efficient travelling (Strathman and Dueker 1995; Cao et al. 2008; Paleti et al. 2011). Thirdly, undertaking more varied activities suggests that women have more complex activity spaces than men, involving multiple 'anchor points' (the home, workplace, children's school(s) or nursery…) that are often fixed in space and/or time (Kwan 2000; Kwan et al. 2009). Fourthly, complex patterns may stimulate women to use flexible modes of transport such as the car to juggle all their duties, although it has been hypothesised that the effects on car use of gender differences in activity/travel needs may point in different directions (see Schwanen 2011, p. 153 for discussion).

This seemingly clear-cut picture varies between different segments of the population. The household division of labour is often organised in a strongly traditional way among couples with children, particularly those with infants (Grunow et al. 2012). 'Traditional' refers to a male-breadwinner-and-female-housewife model, where the husband is the primary wage-earner, while the wife is responsible for social and maintenance tasks. The hegemony of this model has tended to decline over time, but gender convergence in the aggregate population is accompanied by re-traditionalisation on the household level over the life course, as married couples tend to shift housework to the woman (Grunow et al. 2012) and employed work to the husband (Kanji and Schober 2014). This does not imply that convergence is limited to the younger generation. Rather, period effects (convergence) and life course related effects (re-traditionalisation) superimpose each other.

For couples without children the picture is different. They typically show more modern, sometimes close-to-equal patterns of worksharing (Grunow et al. 2012; Scheiner 2013). Single households do not of course exhibit any division of labour at all, but they are nonetheless known to have different activity and trip patterns depending on gender (Taylor and Mauch 1997; Sicks et al. 2014).

The focus of interest in this paper is the complexity of activity and travel patterns, studied from a gender perspective. Complexity is measured by two variables: the entropy of activity patterns and the number of trips per tour as a measure of trip chaining. Both variables are constructed from trip diaries completed for a whole week by a nationwide sample of respondents in Germany. The data span the period from 1994 to 2012. A companion paper (Scheiner 2014) focuses on changes in complexity over time.

The results should be seen against the background of the German gender policy context. Germany is commonly considered a conservative (or social capitalist/corporatist) regime in terms of gender relations, similar to France, Belgium, and The Netherlands (Kan et al. 2011; van der Lippe et al. 2011). This characterisation has to be understood in comparison with the Mediterranean regime on the one hand and the Nordic social democratic regime on the other hand. The former has less developed social security systems, stronger religious traditions and an even more conservative gender ideology, while in the latter both policy and society strongly promote gender equity. Germany has some notable incentives for couples to adopt a male-breadwinner-and-female-housewife type of work sharing, including a joint income tax system for couples and a limited provision of public childcare (Cooke 2006; Kan et al. 2011). Parental leave regulations are generous (36 months since 1992), but included little financial benefit until 2006

(Geisler and Kreyenfeld 2012). Female labour force participation has increased steadily over time, but with high proportions of part-time work (Statistisches Bundesamt 2014). In the past few years, Germany has undertaken considerable efforts to expand childcare facilities, and to encourage women into employment and fathers to take paternal leave (Geisler and Kreyenfeld 2012). Hence Germany has recently experienced a process of rapid change in gender relations.

The next section introduces the state of the research on the link between gender and complexity in activity and trip chaining patterns. This is followed by a description of the data, the modelling approach and the variables used. Subsequently the results are presented, starting with a descriptive analysis of complexity, followed by two regression models of activity pattern entropy and tour complexity. The paper closes with some conclusions for further research.

2 State of the research – gendered complexity of daily life

2.1 Activity patterns

Activity patterns have been studied from a gender perspective in countless studies, rendering it impossible to provide a detailed review here. The most common methods used are to either compare men and women in terms of mean values and proportions of time allocated to various activities (McGinnity and Russell 2008; Anxo et al. 2007), or else to use regression modelling or other multivariate techniques to isolate the marginal impact of gender from other impact factors. The strongest focus is on housework (Bianchi et al. 2000; Treas and Drobnic 2010; Grunow et al. 2012; Mencarini and Sironi 2012) but employed work is often considered simultaneously (Gershuny and Kan 2012; McGinnity and Russell 2008; van der Lippe et al. 2011). Leisure is included in relatively few studies (Anxo et al. 2007; Hilbrecht 2009).

The general finding is that men take on disproportionate shares of paid (employed, marketed) work and women disproportionate shares of unpaid (non-marketed, household/family/care) work. When total workload including paid and unpaid work is considered both genders carry similar loads (Gille and Marbach 2004 for Germany[1]; Sayer 2010 for nine countries).

While the gendered division of work still exists around the world, various studies from different countries have shown gender differences in activity patterns to converge over time (Fisher et al. 2007 for the USA, 1965-2003; Gershuny and Kan 2012 for 12 countries, ca. 1961-2004; Bianchi et al. 2000, for housework in the USA, 1965-1995; Gille and Marbach 2004, for Germany; 1991/92-2001/02; Sayer 2010 for nine countries, ca. 1965-2003).

Among households with children things seem to evolve differently. Mothers in Germany make a consistently above-average contribution to unpaid work (Gille and Marbach 2004). A re-traditionalisation of worksharing has been detected among married couples from a life course perspective, and having children has been identified as a key factor accelerating this process (Grunow et al. 2012). Mothers' family obligations increase with the number of children and decrease with the age of the youngest child (McGinnity and Russell 2008; Scheiner 2013). There may be some self-selection in this finding in that women and men who maintain more traditional norms may be more likely than others to found a family.

Measuring complexity in activity or trip patterns involves more than considering just the degree of participation in activities or trips. Complexity may be expected to result in various observable patterns, such as the fragmentation of activities in space and/or time, the variety of activities performed, or the number and/or distribution of spatially and/or temporally fixed anchor points in

[1] A new time use survey was carried out in Germany in 2012/13, but the data are not yet available.

daily life. Complexity may also be observed indirectly by looking at variables that are likely to reflect complexity, such as subjective or objective stress symptoms, or strategies to cope with complexity, such as organising trips into trip chains or multitasking. It should be noted that most time use and travel studies are limited to observed behaviour, and data often do not include information about people's subjective experience of behavioural patterns. However, complexity in behaviour is not necessarily associated with stress, burdens and a low quality of life. Simple patterns may rather be experienced as boring and monotonous.

There is some empirical evidence for several of these approaches. Bianchi et al. (2007) find that married mothers report more frequent multitasking than married fathers, reflecting a strategy of time-management to juggle multiple duties. This result is based on the respondents' subjective considerations of multitasking. However, time use diaries show similar evidence. Gille and Marbach (2004) simultaneously use the variety of activities undertaken during a day, the number of transitions between different activities, and multitasking (activities undertaken simultaneously) to construct a composite indicator of turbulence. They find that women's daily lives are considerably more turbulent than men's. Bittman and Wajcman (2000) provide evidence that women's leisure is more contaminated by interruptions and combined with unpaid work than men's, even though there may be little gender difference in leisure time in quantitative terms. Offer and Schneider (2011) add that mothers not only multitask more often than fathers, but that the types of multitasking differ in that mothers typically experience more negative effects and stress from multitasking than fathers.

Alexander et al. (2011) study the fragmentation of activity patterns in the Netherlands, i.e. "the disintegration of activities into smaller sets of acts that can then be performed at different times, different locations, or both" (ibid., 678). Fragmentation is likely to make activity patterns more burdensome and difficult to schedule. In various spatial and temporal measures of fragmentation they find only few significant gender differences. These suggest somewhat more fragmentation among men than women.

Spatial and temporal fixity is not only likely to contribute to complexity in the execution of activities, but also in their scheduling. Schwanen et al. (2008) undertake a study based on a time-geographic approach in the tradition of Cullen and Godson (1975). They find that women coordinate and deal with more space-time fixity constraints than men. Again this is because women engage in family and household obligations more than men.

Looking at trends over time, gender convergence has also been observed in the distribution of activities over the day and the week, i.e. women's temporal distribution of activities over the course of a day is becoming more similar to that of men (Fisher et al. 2007). This supports the idea that the complexity of activity patterns may be converging between the genders, which seems reasonable as the participation of men and women in different types of activities converges over time (see above).

Gender differences in complexity may be explained by a number of theoretical ideas. The most important single factor is probably the increase in women's employment in various countries (van der Lippe 2010). This trend does not necessarily result in more gender equity. Rather it may lead to a 'double burden' or 'second shift' for women (McGinnity and Russell 2008 for Ireland), as long as men do not contribute to filling the gap in caregiving and housework.

Besides the temporal constraints of worksharing, gender norms and preferences are likely to play a substantial role. The finding that even single women shop more often than single men (Taylor and Mauch 1997; Sicks et al. 2014) suggests that worksharing does not fully explain the picture. Rather, socialisation effects and norms may be at work. Alternatively, the difference may be an outcome of preferences for certain goods, such as healthy food which has to be purchased when fresh. Shopping for leisure purposes may also play a role. Based on a study of 25 OECD countries, Fortin (2005) finds evidence that women's labour market participation and earnings depend strongly on gender norms which in turn are shaped by socialisation. These norms include perceptions of women's homemaker role, attitudes towards gender equity, and inner conflicts between family values and egalitarian views ('mother's guilt').

2.2 Tour complexity

Individuals organise their daily trips in sequences that typically start and end at home (see Section 3.3 for a discussion of definitions). The complexity of trip chains and tours has been a topic of inquiry for decades in transport studies (see Thill and Thomas 1987 for an early review). Organising trips in complex chains is typically considered to serve efficiency in travel or, to put it another way, to minimise the disutility of travel (Chen 1996). By reducing total travel time, trip chaining contributes to increased accessibility (Chen 1996). Trip chaining has been found to increase considerably over time (McGuckin et al. 2005; review in Currie and Delbosc 2011), but part of the increase may be due to improved survey techniques that result in more accurate trip (chain) records.

Social circumstances, the spatial environment, and the transport system have been found to impact people's propensity to chain trips. Trip chaining is linked to mode choice, but the direction of causality is not clear (see Ellison and Greaves 2010 for discussion). Researchers typically assume that trip chain complexity impacts mode choice (Hensher and Reyes 2000; Krygsman et al. 2007) but the reverse causality may also be true. Public transport is considered less suitable to serve complex chains due to its limited flexibility (Currie and Delbosc 2011; Hensher and Reyes 2000; Strathman and Dueker 1995; Krygsman et al. 2007).

Women are consistently found to make more complex trip chains than men (Paleti et al. 2011), both with respect to job tours and non-job tours[2] (Strathman and Dueker 1995; Cao et al. 2008). As people typically connect different purposes in a chain, a large part of research is devoted specifically to links between employment and non-job trips.

Men and women also differ in terms of the types of trip chains they make. Krygsman et al. (2007) point out that women are much more likely than men to take responsibility for social functions such as including passengers on their commute (e.g. combining it with the school run). As such purposes are strongly fixed in space and time (e.g. by school or daycare start and end times), they shape and constrain women's travel patterns (Kwan 2000; Kwan et al. 2009).

Perhaps this complexity is the reason why women "tend to be more structured in terms of how the week is planned" (Lee and McNally 2006, p. 553). On the other hand, comparisons between activity scheduling and realised activities reveal that many trip chains are formed 'as opportunity knocks' while being out of the home (Lee and McNally 2006).

As for activity pattern complexity, the general explanation for women's more complex trip chaining is the household division of labour, specifically women's stronger responsibility for various duties. Consequently, trip chain complexity refers to mothers more than to women in general (McGuckin and Murakami 1999). Mothers also encounter higher levels of fixity constraints (Kwan 1999) and, hence, it seems more likely that they would seek efficiency. This may not be true for women in

[2] These two types are mostly named work and non-work trip chains in the literature. However, the term 'non-work' masks that this type of trip chain includes much unpaid work, such as shopping, errands, and escort trips.

general, as Schwanen et al. (2008) did not find a significant gender effect in fixity constraints, other variables held constant.

2.3 Conclusions

The literature suggests that women may exhibit more complex activity patterns and trip chains than men. Including more control variables that reflect gender roles in the analysis should result in a decrease of the main effect of gender. However, these control variables, notably employment status and household structure, should affect men and women differently. Having children may be expected to increase complexity among mothers, but less so among fathers. The same is true for employment. A job brings with it the risk of a double burden for women, but men may be expected to stick more with their breadwinning role, rather than taking equal responsibility for household and family work.

Some gender convergence in complexity may be expected over time. This could come as a period effect, in which gender differences decrease in the population as a whole, or as a cohort effect, in that gender convergence affects only some cohorts (possibly younger adults), or some combination of the two.

3 Methods

3.1 Data

Daily activity/travel patterns have been studied using various survey methods: retrospective (stylised) questionnaires, (time use or trip) diaries, and the experience sampling method (ESM) (see Juster et al., 2003, for discussion, but without reference to gender issues). Each of these methods has strengths and limitations. While ESM delivers relatively accurate means in activities, it does not provide a full picture of some observation periods. Retrospective questionnaires are considered the least accurate. Time use (or activity) diaries typically provide more detailed information about activities, but trip diaries are usually linked to more additional information about mobility and accessibility issues.

We use the German Mobility Panel (GMP) 1994 to 2012 for our research[3]. The GMP is a trip-diary based household survey with the sample organised in overlapping waves. Every household is surveyed three times over a period of three consecutive years (KIT 2012), e.g. from 1994-1996, before being excluded from the survey. Trips are recorded over a whole week from all household members aged ten years or over using a trip diary. Personal and household-related sociodemographic attributes are collected as well as accessibility and spatial context attributes at the residence and at the household members' places of work or education.

The GMP has a number of advantages over other data sources that suit our purpose. First, the seven-day record allows us to detect activity and trip patterns on the individual level, while this is not possible with the more common single- or two-day activity/trip diaries. This is because a week represents the typical temporal organisation of daily life. Second, the GMP allows us to include rich information about mobility and access, e.g. to detect associations between complexity in daily life and car use. Third, the GMP is a long-standing panel survey, thus allowing us to study cohort and period effects. Hence, although activity diaries are more accurate in recording activities, their use would have meant that some of the main results of this paper could not have been produced.

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[3] The GMP is conducted by the University of Karlsruhe on behalf of the Federal Ministry of Transport, Building and Urban Development (BMVBS). The data are provided for research use by the Clearingstelle Verkehr (www.clearingstelle-verkehr.de).

An important limitation of our study is that our data do not permit us to detect sub-sequences in stationary activities.

What is more, household income has only been recorded since 2002. Income is thus excluded from the analysis. Education level and employment status are used as rough proxies for income.

The data include a total of 30,631 individual weeks of report. For 25,748 weeks reported by 12,552 individuals complete information is available, and these are used in regression modelling.

3.2 Analysis approach

We use regression modelling to study the effects of sociodemographic as well as spatial and access variables on activity pattern and tour complexity. Descriptive analysis illustrates gender differences in a range of defined life situations. We use unweighted data for regression modelling and any tests of significance, but weighted data for the descriptive analysis.

We started the modelling process using interaction terms between gender and any other variable to account for gendered differences in the effects of life circumstances. This resulted in exorbitant multicollinearity in some cases, most pronouncedly between the variables cohort and cohort squared, and their respective gender interactions, with variance inflation factors (VIF) exceeding VIF=100. Multicollinearity may result in biased significance levels. In an extended, stepwise modelling process a large number of variables were excluded (see Section 3.3). In the resulting models, VIF values are < 8 in all but two cases, which is less than the usually accepted threshold (VIF<10, Schendera 2008, p. 105). The first exception is gender (VIF=13.2), which is naturally correlated to various interaction terms. We retain these interactions in the models, as gendered effects are our main interest. Significance was confirmed with separate models for men and women without interaction terms. The second exception is cohort (VIF=60.5) which is obviously correlated to cohort squared (VIF=65.5). The cohort variables are retained in the model due to the recent debate on gender specific trends in travel behaviour among young adults (Kuhnimhof et al. 2012).

The data include non-independent (clustered) observations due to the panel survey design used, which violates a basic assumption of statistical analysis. The use of OLS regression may thus result in underestimated standard errors and, hence, overestimated parameter significance (Hedeker et al. 1994).

Thus, we employ a cluster-robust estimation based on pooled data. This model controls for autocorrelation within subjects emerging from the temporal order of records. The correlation matrix of within-subject dependencies is thus estimated as part of the model. Similar to OLS, the standard errors may be too small when the number of clusters is finite (Wooldridge 2003; Nichols and Schaffer 2007). However, the cluster-robust estimator converges to the true standard error as the number of clusters (not the number of observations) approaches infinity (Kézdi 2004; Nichols and Schaffer 2007). Given the large sample and number of clusters, this issue should not raise serious concern. The SPSS procedure GEE (generalised estimating equations) is used for the analysis. The coefficients reported may simply be interpreted as population average estimates, as in ordinary regression. The exponentiated coefficients (Exp(B)) are to be interpreted as percentage changes in the dependent variable for a one-unit change in the explanatory variable, i.e. negative regression coefficients result in values smaller than 1.

Concerning model specification (see Garson 2010 for details), the autoregressive correlation type is used due to the temporal order of within-subject measurements. This means that values at a given point in time are a function of prior values plus error term. The dependent variables used are continuous in nature, and normal distribution is assumed. A graphical inspection reveals that this assumption holds true for entropy. The distribution of tour complexity is strongly right-skewed (skewness=14.6). Therefore, the natural logarithm is used here, which reduces skewness to 2.8.

There is no determination coefficient available for cluster-robust regression. SPSS reports a quasi likelihood under independence criterion (QIC) which is an extension of the Akaike Information Criterion (AIC) for repeated measures (Garson 2010). It is available in a corrected form (QICC) that penalises model complexity and small sample size. QICC works in a 'the smaller the better' form. It is reported for the final models as well as for the intercept models. However, there is no formal test of significance in model improvement available.

For comparison, OLS regressions with a random subsample of one observation per individual are estimated. The results are available upon request from the authors. A comparison of the cluster-robust regressions with the OLS regressions yields very similar results with respect to both the coefficient magnitudes and signs, supporting the robustness of the findings. The R^2 values from the OLS regressions are reported in the results table for readers' convenience.

3.3 Variable definitions

Target variables

People organise their trips in trip chains that form tours. There are various definitions of trip chains in the literature. Some authors use the terms tour and trip chain interchangeably (Frank et al. 2008, p. 39). However, a tour is typically defined as a sequence of trips that starts and ends at a person's home (Paleti et al. 2011) or workplace (see Schmöcker et al. 2010 for discussion), while some authors consider trip chains to be parts of tours that link two 'anchors' (typically home and workplace). Seen this way, tours may be composed of more than one trip chain (McGuckin and Nakamoto 2005, p. 50; Vande Walle and Steenberghen 2006). Alternatively, a trip chain may be defined as a sequence of trips interrupted by dwell times of not more than, say, 30 minutes (Schmöcker et al. 2010; McGuckin and Nakamoto 2005). It could, e.g., start at the workplace and end at a shopping centre.

The complexity of a tour refers to the number of trips (Timmermans et al. 2003) or stops (Paleti et al. 2011) involved, with the number of trips being one more than the number of intermediate stops. Typically, multiple stop tours involving at least three trips are considered complex tours, while tours including two trips (outbound plus inbound trip) are considered simple tours. The same definition of complex versus simple is typically used for trip chains (Schmöcker et al. 2010, Paleti et al. 2011, p. 5; Frank et al. 2008; Strathman and Dueker 1995).

For the purpose of this paper, tour complexity is defined as the number of trips per home-to-home tour. The analysis is conducted at the level of the individual, and the target variable is a person's mean tour complexity over a whole week.

Likewise, activity pattern complexity is studied on the individual level. Activity is a nominal-scaled variable and measuring complexity in its patterns requires a qualitative measure of variance (Coulter 1989). From a detailed discussion of three key measures (variation ratio, index of diversity, Shannon's entropy) in Wagner and Franzmann (2000), it is concluded that Shannon entropy fits the purpose of this paper particularly well. The variation ratio measures the share of cases (here: duration of activity) that does not fall into the modal category. Hence, it does not address the distribution of cases over other categories. The index of diversity differs from Shannon's entropy in that it is based on squared values and hence emphasises strong categories, whereas the entropy emphasises weakly represented categories as it is based on logarithm. One may assume that side activities 'in-between' considerably affect the overall complexity of daily patterns and, hence, such side activities should rather be over- than underrepresented in a measure of complexity.

Activity pattern complexity is therefore measured using Shannon's entropy. Entropy describes the amount of heterogeneity in the distribution of certain categories (here: activities). Entropy simultaneously considers the number of different activities and the relative amount of time devoted to each activity, which resembles the merging of the two measures of activity fragmentation used by Alexander et al. (2011), i.e. the number of fragments and the distribution of fragment sizes. The reasoning behind the latter measure is that "a plate broken into 10 pieces of equal size is more fragmented than a plate broken into 10 pieces, one of which is 90% of the original plate" (Rutledge 2003, quoted from Alexander et al. 2011, p. 682). This idea reflects the basic reasoning in feminist claims that women's activity patterns are more complex than men's. Men tend to devote most of their work time to employed work, while women typically spread their limited time budgets more evenly over different types of work.

Mathematically, entropy is defined as $-\sum (p_i * \ln(p_i))$ (Coulter 1989). In this study the p_i are the shares of time spent on an activity plus associated trips in the week of report. Six activity classes are available for analysis, including employment, business, education, shopping/private errands, escort, and leisure. Trip times are added to the activity at the destination. Zero entropy means that a person conducts only one type of activity over the week of report, while the maximum value (here: 1.67) means that the time spent out of home is equally distributed over all activity types.

Note that our analysis refers to out-of-home stationary activities separated by a trip rather than sequences of episodes within a 'station'. This masks variation in activity sequences undertaken at one place. For instance, being interrupted at the workplace by a private phone call is not considered in the analysis as a caregiving or leisure activity. However, time spent at home, which is most likely to be affected by caregiving or other interruptions, does not enter our entropy measure. Note also that we do not take into account secondary activities performed at a given point in time (multitasking).

The use of tour complexity and activity pattern entropy is not meant to indicate that these two measures reflect the same dimension of daily life. In fact, there is hardly any correlation between the two (r=0.03) even though the correlation is significant (p=0.01). Rather, tour complexity reflects the efficiency of trip organisation, although this may not always be a conscious strategy. On the other hand, activity pattern entropy reflects a need to juggle multiple activities of a similar level of importance (in terms of time spent on any one activity), while a low level of entropy means that an individual's daily life tends to be devoted to only one activity.

Explanatory variables

Initially a large range of variables including sociodemographics, travel behaviour and spatial context at the residence and at the place of work or education (for the sake of brevity: workplace) were included in the modelling as explanatory variables. Specifically, a set of 78 variables were tested. Of these variables, 31 were retained in the final analysis. Those that did not pass a very moderate significance level of p=0.10 in any model were excluded in a stepwise process together with their interaction terms with gender, respectively, except for categories logically related to other categories. The following variables were excluded:

- Age (three categories),
- Walking distance from PT stop to workplace,
- PT connection to work (from various categories, as reported by respondents),
- Central versus remote location of residence (subjective report),

- Urbanity (calculated from self-reported walking access in the neighbourhood to various facilities),
- Parking situation at the workplace (subjective report),
- Equivalent household income (recorded only since 2002; regression models that included equivalent income as a control variable revealed no significant income effects).

Following the same reasoning, some interaction terms were also excluded, although their main effects were retained in the models. This refers to interactions between gender and:

- Education level
- Possession of a driving license
- Car availability
- City size category
- PT quality in the neighbourhood (diversity of systems, calculated from the number of different systems accessible on foot)
- Cohort and cohort squared.

A measure of car use is considered to account for the interaction between travel/activity pattern complexity and mode choice. It should be born in mind that both activity pattern entropy and tour complexity are logically, although not deterministically, associated with the number of trips a person makes. Hence, the mode choice measure used should not be inherently related to trip frequency so as to avoid any tautology. Four measures of car use were tested and compared in terms of improvement in model fit: the duration of trips made as a car driver, the proportion of trips made as a car driver among all trips, and the same two measures, but including trips made as a car passenger. Of these four variables, the duration of trips made as a car driver or passenger performed best and, hence, was used in the final models. It is acknowledged that this variable does not necessarily have a unidirectional cause-impact relationship with complexity. Complexity may well contribute to using the car.

The effects of cohort plus cohort squared are considered simultaneously in order to capture non-linear effects. Cohort effects often reflect long-term societal trends for which the assumption of a linear relationship appears very restrictive. What is more, cohort is correlated with age here, as the data span a limited period of time, and age is known to have non-linear relationships with travel behaviour (Kroesen 2014). Those born in 1900 were coded as cohort zero while those born in 1901 were coded as cohort one and so forth[4].

Period effects are captured by the year of survey (1994 equals zero). They were also tested in two alternative, yet finally abandoned, model specifications. Firstly, a quadratic function was used. This variant was not significant, and it performed clearly worse than the version presented here in terms of improvement in QICC. Secondly, an interaction term between year of survey and a dummy taking the value one for the years from 2000 and zero for the years to 1999 was included, because travel behaviour trends in the aggregate tended to change from this year. This model specification performed slightly better than that presented here in the trip chain model, but still was insignificant. For the entropy model the straightforward linear specification performed best. Hence, for the sake of clarity, the linear specification was used for both models.

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[4] Models including age plus age squared, but excluding cohort, were run for comparison. These models turned out to be virtually identical to those including cohort.

	Male				Female				Total			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
Entropy in activity pattern	0	1.67	0.71	0.30	0	1.61	0.74	0.31	0	1.67	0.72	0.30
No. of trips per tour (ln, mean over report week)	0	3.78	0.90	0.26	0	3.71	0.90	0.24	0	3.78	0.90	0.25
No. of children in household (< 10 yrs)	0	5	0.27	0.63	0	5	0.28	0.63	0	5	0.28	0.63
No. of children in household (10-13 yrs)	0	3	0.15	0.42	0	3	0.15	0.42	0	3	0.15	0.42
No. of children in household (14-17 yrs)	0	3	0.17	0.43	0	3	0.18	0.44	0	3	0.17	0.44
PT quality (diversity of systems) in neighbourhood	0	6	2.45	1.08	0	6	2.45	1.08	0	6	2.45	1.08
Duration of car use (mean hours per day over report week)	0	10.3	0.86	0.73	0	7.40	0.66	0.55	0	10.3	0.76	0.65
Cohort (94 yrs in 1994 = 0)	4	96	56.3	18.1	5	96	56.8	17.7	4	96	56.5	17.9
Cohort, squared, div. by 100	0.16	92.2	34.9	21.0	0.25	92.2	35.4	20.6	0.16	92.2	35.2	20.8
Year of survey (1994 = 0)	0	18	9.41	5.00	0	18	9.33	4.89	0	18	9.37	4.94
n	12,349				13,399				25,748			

Table 1: Continuous variables used in regression: descriptive statistics

	Male	Female	Total
	Per cent 'yes'		
Gender female			52.0%
Living with a partner	77.6%	69.5%	73.4%
Full-time employed (reference)	50.2%	21.7%	35.4%
Part-time employed	4.2%	24.9%	15.0%
Apprenticeship, trainee, education	13.9%	12.9%	13.4%
Not employed	31.4%	40.1%	36.0%
Elementary school qualification without apprenticeship or no qualification	10.8%	13.6%	12.3%
Elementary school qualification plus apprenticeship	25.9%	21.5%	23.6%
Secondary school qualification level I	23.6%	33.8%	28.9%
University entrance qualification or higher (reference)	39.7%	31.1%	35.2%
Driving license ownership	86.8%	78.5%	82.5%
Car not available (reference)	22.2%	32.3%	27.4%
Car occasionally available / after agreement	11.5%	13.3%	12.4%
Car regularly available	66.3%	54.5%	60.2%
Municipality size category < 20,000 inh (reference)	42.4%	41.3%	41.9%
20-100,000 inh	27.2%	26.2%	26.6%
100-500,000 inh	16.3%	17.2%	16.8%
> 500,000 inh	14.1%	15.3%	14.7%
n	12,349	13,399	25,748

Table 2: Dummy variables used in regression: descriptive statistics

All variables are coded as yes=1, no=0.

Tables 1 and 2 present an overview of the full set of variables used along with their descriptive statistics. Note that the maximum of the natural log mean number of trips per tour is 3.78. This means that the actual maximum of the mean number of trips per tour is no less than 44. Five respondents reported 35 or more trips per tour, and these respondents' data were manually inspected to find out more about the circumstances. All of them were on holiday in the week of report. Some attempts were made to increase model fit by excluding cases with extreme values, but as model fit was in the same order for all attempts, all cases were finally included in the analysis, as there was no reason to doubt data validity here.

4 Results

4.1 Gender differences – descriptive mean value comparisons

We start by comparing men's and women's entropy and tour complexity in typical life situations. These situations are constructed from household type and employment, which are well-known to affect activity and travel patterns and which also turned out significant in the regression analysis (see next section). In addition, in households without children (couples and singles) we roughly distinguish between two age groups (Table 3).

In some life situations women exhibit higher entropy levels in activity patterns than men. This refers particularly to employed singles, employed individuals living in a couple with smaller or adolescent children, employees in 'other' (non-family) households with three or more adults, and lone parents no matter whether employed or not. Differences in magnitude are particularly striking among employees living in couples with small children and among lone parents. This finding supports the familiar notion that mothers rather than women in general are particularly affected by marked complexity in daily life due to their multiple duties. Conversely, men exhibit a slightly, significantly, higher level of entropy than women among elderly couples without children.

Few of these gender differences are reflected in tour complexity. Employed lone mothers make more complex tours than employed lone fathers. This is the only life situation studied that exhibits a significant gender difference both in entropy and tour complexity.

What is more, non-employed women living in a couple with adult children make considerably more complex tours than their male counterparts. This finding is based on a small subsample, and there is no supporting evidence among couples with younger children. Non-employed women living in a young to mid-aged couple without children make more complex tours than their male counterparts. The reason may be that this life situation includes more housewives than househusbands, but more unemployed men than unemployed women. Housewives are likely to have various obligations while the jobless have relatively low out-of-home activity and mobility levels (Scheiner et al., 2012).

Perhaps most notably, the differences between life situations, as defined by employment status and household type, are far more striking than the gender differences. Employed individuals exhibit considerably higher levels of entropy than those who are not employed. This is true for all life situations identified, although in households with children even those without a job show relatively high entropy levels. Again, the pattern for tour complexity is different. One may assume that employed individuals with children have more reason to seek efficiency in trip-making than those without a job and/or without children. Indeed, employed individuals make more complex tours than those who are not employed in all sub-groups. However, in households with children the level of tour complexity is by no means systematically higher than in those without.

Even though the age categories used are very rough, the results suggest that age plays a certain role. In couples without children and singles the elderly exhibit both lower levels of activity entropy and tour complexity.

Employed	Sex	Entropy	Trips per tour	n	Employed	Sex	Entropy	Trips per tour	n
	Single, 18-59 years				Couple with children, youngest child 10-17 yrs				
yes	M	*0.78*	2.75	1,035	yes	M	*0.73*	2.44	1,765
	F	*0.81*	2.77	985		F	*0.79*	2.45	1,629
	all	0.79	2.76	2,020		all	0.76	2.44	3,394
no	M	0.61	2.52	221	no	M	0.71	2.43	109
	F	0.62	2.55	211		F	0.70	2.36	220
	all	0.61	2.53	432		all	0.70	2.39	329
all	M	*0.75*	2.71	1,256	all	M	*0.73*	2.44	1,874
	F	*0.78*	2.73	1,196		F	*0.78*	2.44	1,849
	all	0.76	2.72	2,452		all	0.75	2.44	3,723
	Single, 60+ years				Couple with children, youngest child 18+ yrs				
yes	M	0.75	2.65	96	yes	M	0.76	2.68	937
	F	0.79	2.45	190		F	0.76	2.60	724
	all	0.78	2.51	286		all	0.76	2.65	1,661
no	M	0.55	2.43	770	no	M	0.65	*2.33*	141
	F	0.55	2.37	1,473		F	0.60	*2.88*	169
	all	0.55	2.38	2,243		all	0.63	2.62	310
all	M	0.57	2.45	866	all	M	0.74	2.64	1,078
	F	0.57	2.37	1,663		F	0.74	2.65	893

	all	0.57	2.39	2,529		all	0.74	2.64	1,971
Couple, no children, younger partner < 60 yrs					Other household with 3+ adults				
yes	M	0.79	2.75	1,367	yes	M	*0.73*	2.58	820
	F	0.79	2.70	1,350		F	*0.80*	2.61	844
	all	0.79	2.73	2,717		all	0.76	2.59	1,664
no	M	0.58	*2.44*	576	no	M	0.62	2.40	271
	F	0.57	*2.74*	573		F	0.57	2.38	358
	all	0.57	2.59	1,149		all	0.59	2.39	629
all	M	0.74	2.67	1,943	all	M	0.71	2.55	1,091
	F	0.72	2.71	1,923		F	0.73	2.54	1,202
	all	0.73	2.69	3,866		all	0.72	2.54	2,293
Couple; no children, younger partner 60+ yrs					Lone Parent				
yes	M	0.77	2.60	162	yes	M	*0.73*	*2.42*	830
	F	0.74	2.60	135		F	*0.84*	*2.52*	1,314
	all	0.76	2.60	297		all	0.80	2.48	2,144
no	M	*0.54*	2.43	1,813	no	M	*0.63*	2.38	35
	F	*0.51*	2.42	1,654		F	*0.75*	2.45	232
	all	0.52	2.42	3,467		all	0.74	2.44	267
all	M	*0.55*	2.45	1,975	all	M	*0.72*	*2.42*	865
	F	*0.52*	2.43	1,789		F	*0.83*	*2.51*	1,546
	all	0.54	2.44	3,764		all	0.79	2.48	2,411
Couple with children, youngest child < 10 yrs					All household types				
yes	M	*0.76*	2.61	2,161	yes	M	*0.75*	2.61	9,173
	F	*0.90*	2.60	1,532		F	*0.82*	2.60	8,703
	all	0.81	2.60	3,693		all	0.78	2.60	17,876
no	M	0.72	2.37	86	no	M	0.57	2.43	4,022
	F	0.74	2.47	755		F	0.58	2.44	5,645
	all	0.73	2.46	841		all	0.58	2.44	9,667
all	M	*0.75*	2.60	2,247	all	M	*0.70*	2.56	13,195
	F	*0.85*	2.55	2,287		F	*0.72*	2.53	14,348
	all	0.80	2.58	4,534		all	0.71	2.55	27,543

Table 3: Mean entropy and tour complexity in various life situations, categorised by gender

M: Male, F: Female
Entropy: activity plus trip time, without housing
Trips per tour: mean value in week of report
Employed respondents include students and those in apprenticeship
Italics: gender difference significant (p=0.05, two-tailed t-test)

4.2 Factors affecting complexity – multiple regression analysis

Table 4 presents the results of the two regression models. The fit values (taken from OLS models) are reasonable for individual level models of activity/travel behaviour. At the same time, the fit values show that much variance remains unexplained and, hence, complexity of behaviour seems to be strongly affected by unobserved variables, e.g. specific individual or couple-level arrangements for caregiving and other responsibilities, leisure preferences etc.

We start by discussing the entropy model that exhibits a considerably higher proportion of explained variance. The positive and significant effect of gender on entropy suggests that women have more complex activity patterns than men. Part-time employees and – less so – those still in education have higher levels of entropy than full-time employees, while the opposite is true for the unemployed. Women are more likely to be part-time employed, while men are more often in full-time employment. Hence, the effect of part-time employment suggests that real-world gender differences – without controlling for employment status – may be even more pronounced than those found in the models.

Having children has significant positive effects on women's activity pattern entropy, but less so on men's. This is particularly true of young children, who exhibit a stronger effect on women's entropy than elder children. Men's entropy is only affected significantly and positively by children aged 14 or older. Living with a partner decreases women's activity pattern entropy, but not men's, which is likely to result from gendered intra-household worksharing.

Education level positively affects entropy. Being licensed, having a car available, and making much use of the car are also associated with higher entropy levels. It should be noted that the cause-impact structure of these associations is not clear. They suggest either that driving allows the juggling of more varied responsibilities and activities, or – vice versa – that the mobility of respondents who perform multiple activities in a week is more strongly linked to the car. Interestingly, the duration of car use is less strongly linked to entropy among women than among men (significant interaction term). Perhaps this link is related to the observation that men tend to have first choice of car use in Germany in couple households with only one car (Scheiner and Holz-Rau 2012); entropy may be an argument for men in negotiating car use.

The spatial environment is also associated with complexity. Entropy tends to increase with municipality size, and – on the intra-municipal level – with the quality of public transport supply in a neighbourhood.

Last, but not least, activity pattern entropy increases from one cohort to the next, but the trend reverses and entropy tends to decrease in younger cohorts born after 1970. At the same time, a negative period effect suggests that entropy tends to decrease for the whole population over time.

Turning to tour complexity, the positive effect of gender echoes the entropy model. It suggests that women make more complex tours than men, but the effect just fails to reach significance. Those not employed exhibit lower levels of tour complexity than full-time employees, which may result from less time constraints and, accordingly, less need to efficiently organise trips. What is more, part-time employed women, but not men, make less complex tours than full-time employees.

Women's tour complexity is negatively affected by having children aged 10 or older, and the same is true, to a lesser extent, for fathers with children aged 10-13 years. This supports the idea that mothers are more affected by having children than fathers, but contradicts previous research suggesting that mothers tend to organise their tours in complex chains more than other women. Living with a partner reduces tour complexity for both genders, which again may point towards more worksharing in the household and, accordingly, less need to combine multiple purposes in a tour.

Education level positively affects tour complexity, and the same is true for duration of car use, municipality size, and public transport supply quality. These effects again echo the entropy model.

The cohort effects suggest that tour complexity increases from one cohort to the next and reaches a maximum among those born in 1987, while younger cohorts decrease their complexity. The period effect is insignificant. This result fits with earlier research that found increasingly complex trip chains over time, but adds that this increase may result from cohort effects and may be negative in younger cohorts.

	Entropy			No. of trips per tour		
	B	Exp(B)	Sig.	B	Exp(B)	Sig.
Intercept	0.385	1.470	0.000	0.768	2.155	0.000
Gender and household						
Gender female	0.056	1.057	0.000	0.025	1.025	0.066
No. of children in household (< 10 yrs)	0.007	1.007	0.170	0.000	1.000	0.934
No. of children in household (10-13 yrs)	0.001	1.001	0.876	-0.017	0.984	0.003
No. of children in household (14-17 yrs)	0.016	1.016	0.011	-0.008	0.992	0.155
No. of children in household (< 10 yrs) * female	0.050	1.051	0.000	0.004	1.004	0.459
No. of children in household (10-13 yrs) * female	0.025	1.026	0.004	-0.018	0.983	0.015
No. of children in household (14-17 yrs) * female	0.025	1.025	0.004	-0.016	0.984	0.025
Living with partner	-0.009	0.991	0.206	-0.015	0.986	0.017
Living with partner * female	-0.032	0.969	0.000	-0.005	0.995	0.496
Employment and education						
Employment (reference: full-time)						
Part-time employed	0.102	1.107	0.000	0.006	1.006	0.657
Apprenticeship, trainee, education	0.057	1.059	0.000	0.000	1.000	0.971
Not employed	-0.088	0.916	0.000	-0.019	0.981	0.007
Part-time employed * female	0.025	1.026	0.144	-0.042	0.959	0.007
Apprenticeship, trainee, education * female	-0.022	0.978	0.098	0.007	1.007	0.619
Not employed * female	-0.004	0.997	0.740	-0.007	0.993	0.454
Education level (reference: university entrance qualification or higher)						
Elementary school qualification without apprenticeship or no qualification	-0.064	0.938	0.000	-0.080	0.923	0.000
Elementary school qualification plus apprenticeship	-0.058	0.943	0.000	-0.070	0.932	0.000
Secondary school qualification level I	-0.041	0.959	0.000	-0.047	0.954	0.000
License holding and car availability						
Driving license holding	0.042	1.043	0.000	0.001	1.001	0.852
Car availability (reference: not available)						
Occasionally / after agreement	0.031	1.031	0.000	0.003	1.003	0.596
Regularly	0.024	1.024	0.000	-0.003	0.997	0.505
Spatial context at residence						
Municipality size category (reference: < 20,000 inh)						
20,000-100,000 inh	0.014	1.014	0.004	0.015	1.015	0.001
100,000-500,000 inh	0.035	1.036	0.000	0.022	1.023	0.000
> 500,000 inh	0.030	1.030	0.000	0.016	1.016	0.006
PT quality in neighbourhood	0.012	1.012	0.000	0.004	1.005	0.009
Travel						
Duration of car use (hours per day, mean)	0.098	1.103	0.000	0.088	1.092	0.000
Duration of car use (hours per day, mean) * female	-0.020	0.980	0.011	0.014	1.014	0.094
Cohort and period						
Cohort (94 yrs in 1994 = 0)	0.007	1.007	0.000	0.003	1.003	0.000
Cohort, squared, div. by 100	-0.005	0.995	0.000	-0.001	0.999	0.022
Year of survey (1994 = 0)	-0.003	0.997	0.000	0.001	1.001	0.207
Year of survey (1994 = 0) * female	0.000	1.000	0.751	0.001	1.001	0.322
(Scale)	0.072			0.054		
QICC	1,928			1,455		
QICC (intercept model)	2,393			1,567		

R² (adjusted, from OLS models)	20.7	11.1
n (observations)	25,748	25,748
n (individuals)	12,552	12,552

Table 4: Cluster-robust regression models of entropy and tour complexity

5 Conclusions

This paper has studied complexity in activity and travel patterns from a gender perspective. Activity pattern entropy and tour complexity were used as the variables of interest. The main findings can be summarised in five points.

1. Women were found to have significantly higher levels of entropy even though control variables have been used. The same was true for tour complexity, but the effect just failed to reach significance.

2. As expected, having children has significant positive effects on women's activity pattern entropy, but less so on men's. This is particularly true of young children, while the effects of children aged 10 or older are weaker. The findings strongly support the well-known notion that having children mainly affects mothers' rather than fathers' activity patterns.

3. Living with one's partner in a household also exhibits gendered effects on complexity in daily life. Living with a partner decreases women's activity pattern entropy, but not men's. Living with a partner also reduces tour complexity for both genders. Both findings suggest that intra-household worksharing may be at play in couples. Intra-household worksharing may reduce women's entropy as a result of women taking on household and family caring roles while giving up employment, which effectively results in reduced entropy. At the same time, these more traditional worksharing arrangements may reduce tour complexity for both partners. On the one hand, such arrangements tend to reproduce traditional gender role 'traps'. On the other hand, they may provide relief from double roles that are linked to more complex daily organisation and, hence, may increase subjective quality of life (see Hilbrecht 2009 and Mencarini and Sironi 2012 for nuanced discussions on the association between gender equality and quality of life).

4. From a geographical perspective it is interesting that urbanity is positively associated with both complexity measures used. Those living in cities appear to have more complex behavioural patterns than rural dwellers, and this is even more true for inner-city residents than for those living in the outskirts.

5. Neither cohort nor period effects seem to be gendered. Both entropy and tour complexity increase from one cohort to the next, but the slope flattens over time and turns negative among younger cohorts. An additional period effect in entropy suggests that entropy tends to decrease for the whole population over time.

The gender structures found may be seen in the German policy context which has been characterised as a conservative gender regime compared to other Western welfare states. As this regime has recently undergone a process of rapid change, future research may well find gender convergence and different patterns in complexity. As gender equity is likely to continue to further develop in the future, complexity will probably increase as well.

Traditional worksharing arrangements in couples that reproduce traditional gender role 'traps' impede trends towards more equity, but on the other hand they may alleviate the burden of taking on multiple roles linked to more complex daily organisation and stress. Of course this is not to say that we should return to these clear-cut roles and associated hierarchies. Rather it indicates the need to develop policies to better cope with complexity, i.e. to reduce associated stress (which was not studied in this paper). This can be achieved by better synchronising land-use and transport systems on a spatial and/or temporal level, but also by de-synchronising activities via telecommunication (van Wee et al. 2014). Better synchronisation of land-use and transport systems favours the idea of mixed land-use and compact development, which would allow activities to be linked and an efficient, highly developed public transport system to be provided. This may not sound particularly novel, but in practice there is still much to be done to achieve it.

The results presented in this paper suggest a number of directions for future research.

Firstly, travel behaviour surveys typically allow only limited conclusions on the reasons for observed behaviour. They rarely include information on preferences and attitudes which may affect behaviour, on the subjective experience of behaviour, and on freedom versus choice in behavioural outcome. They typically also do not include personal income which may serve as a proxy for the distribution of economic power within a household, which in turn is likely to shape the gendered distribution of work.

Secondly, the structure of daily activity and travel patterns may affect satisfaction levels and quality of life in multiple and unexpected ways. It is by no means clear that more complex patterns of activities are necessarily associated with more stress and less quality of life. Simple patterns may in fact be pretty boring and frustrating for many people.

Thirdly, this paper is basically cross-sectional in nature, even though period and cohort effects are taken into account. A true longitudinal, life-course oriented perspective including pattern changes may shed more light on the cause-impact structures behind the associations found. For instance, preferences and attitudes may not only affect behaviour, but daily behaviour and the experiences people make are likely to shape their preferences and attitudes as well.

Fourthly, complexity has been measured on a rather abstract and perhaps crude level in this paper. The analysis does not allow conclusions about which activities actually constitute complexity in certain life situations. A more detailed and illustrative record of in-home and out-of-home activities that better reflects the multiple facets of daily life may shed more light on this issue.

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