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How might bicycle ownership/access and cycling expertise influence the design of cycling promotion interventions at the University of Johannesburg?

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Abstract

Objective: The present study examined potential barriers to cycle-based transport amongst undergraduate students, to inform the design of future cycling promotion interventions at the University of Johannesburg (UJ).

Participants: A total of 606 first, second and third year UJ undergraduates took part.

Methods: Sociodemographic and economic determinants of bicycle/car ownership, cycling competency and behaviour were evaluated using data derived from a 9-item questionnaire, before and after adjustment for measured confounders.

Results: While 70% of respondents knew how to cycle, only 26% owned/had access to a bicycle, and only 18% had last cycled for transport. Bicycle ownership and competency were far commoner amongst male and older participants, and those whose parents had the means to own a car.

Conclusions: Interventions to promote cycle-based transport must address the many (predominantly female) students who: have limited cycling competency; do not own/have access to a bicycle; or have little/no experience of cycling for transport.

Key words: bicycle, cycling, South Africa, University, student

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Introduction

The City of Johannesburg recently drew up a Strategic Integrated Transport Plan Framework[1,2] which outlined a number of strategies for enabling, facilitating and promoting non-motorised transport (NMT) across the City as part of a far-reaching initiative termed *Corridors of Freedom*.[3] These strategies include:

- the identification of suitable cycle routes and the construction of dedicated high-quality cycle lanes;
- the integration of cycling with public transport;
- NMT projects focusing on schools, university students, and the general public;
- increasing the availability of bicycles; and

- an ‘awareness and social marketing’ programme to make cycling “cool” and encourage more people to make use of NMT (City of Johannesburg, 2013).[1]

Amongst the cycle routes identified were those along the so-called “university corridor”, running from Johannesburg’s Park Station, via the University of the Witwatersrand in Braamfontein, past the University of Johannesburg’s Bunting Road campus, through Brixton to the University of Johannesburg’s Kingsway campus (see Figure 1). The construction of cycle lanes along these routes was intended to provide the infrastructure required for students at both Universities, as well as for residents and employers in neighbourhoods on either side of these routes (notably the South African Broadcasting Corporation).[2,3] Following the completion of the “university corridor” cycle lanes in 2016, the City of Johannesburg commissioned the University of Johannesburg to undertake a series of projects with students, residents and commuters to evaluate attitudes towards, and use of, the new cycle lanes; and to identify potential barriers to the uptake of cycling thereon. One such project involved designing cycling promotion interventions tailored to the specific needs of University students, of which the present study forms an integral part.

[Figure 1 near here]

The study was conducted against the backdrop of substantial research examining cycling (and cyclists) across a number of South African cities;[4-8] and a number of schemes intended to increase access to, and use of, bicycles amongst students at universities including: the University of Western Australia;[9] a “large Midwestern University” in the United States;[10] the University of California, Davis;[11] the University of Cambridge;[12] the University of Leeds;[13] and the ‘Matie Bike’ rental scheme introduced at Stellenbosch University in South Africa 2012.[14] These schemes embrace considerable heterogeneity amongst universities (and students) in terms of cycling-related attitudes, aspirations and behaviour.[15]. In South Africa, such heterogeneity is likely to reflect, in part, the very different histories of its higher education institutions, and the long shadow cast by differential access to education during apartheid.[16] Prior to 1994, legislation influenced both the funding for, and availability of, higher education amongst apartheid’s different ‘population groups’, and the legacy of these policies is still evident more than 20 years on.[16] Universities at which cycling has been, and remains, more prevalent are those formerly ‘reserved’ for students classified as ‘White’ – although primarily on campuses where the proximity of student accommodation and local amenities, and the limited traffic on surrounding streets, make cycling attractive and/or

feasible (cycling being more common, for example, at Stellenbosch and Potchefstroom Universities than at the University of the Witwatersrand in Johannesburg).

While cycle-based transport may have limited utility for students able to walk to/within campus and those travelling long distances to campus (particularly where the routes involved lack appropriate provision for cyclists), cycling nonetheless offers distinct advantages to students and universities. First and foremost, cycle-based transport is far cheaper than any motorised alternative – an important consideration given the financial pressures facing South African universities, many of whom provide shuttle buses within/between campuses.[17] Indeed, transport costs are also likely to contribute to the financial barriers undermining student enrolment, progression and completion.[18] Meanwhile, bicycles take up far less space than motorised vehicles, both in terms of the access routes they require, and storage/'parking' – an important consideration for universities where space is finite, limited and/or expensive. Cycling can also be safely integrated with existing pedestrian infrastructure,[19] and might therefore share space with other campus users. Finally, while cycling is considered an accessible form of 'active transport' that has benefits for the cyclist *and* the environment,[20] it is also likely that cycling constitutes a more equitable form of transport for students from a range of different socioeconomic circumstances, and might thereby contribute to other measures intended to support widening participation, student integration and equality.[21]

Nonetheless, each of these apparent advantages face a number of entrenched challenges, including: the long distances many students travel to university; the financial and opportunity costs of establishing suitable cycling infrastructure; concerns over safety and security (particularly in the absence of suitable infrastructure); substantial variation in cycling competency and bicycle ownership/access; attitudinal barriers to cycle-based transport (i.e. 'utility cycling'); and widespread aspirations for car ownership (particularly amongst many who currently cycle – so-called 'captive cyclists').[4]

In Johannesburg, the planned integration of cycling with public transport to facilitate "first or last mile" cycle-based commuting by "cycle-transit users"[22] should help to address the limitations of cycle-based transport for longer journeys to university campuses. As described earlier, these plans have already generated a network of dedicated cycle lanes (along the "university corridor", linked to Johannesburg's Park Station) which aim to improve the feasibility of cycling to, and between, university campuses. There nonetheless remain a

number of potential structural, experiential and attitudinal barriers to cycle-based transport for university students, not least amongst those who have not (yet) cycled to, within or between campuses. The present study aimed to assess the prevalence of such barriers amongst undergraduate students at the University of Johannesburg and, by examining the demographic and socioeconomic distribution of these barriers, generate the contextual evidence required to design cycling promotion interventions aimed at addressing these (including the possible introduction of subsidised bicycle loan, rental and/or purchase schemes – similar to the 'Matie Bike' rental scheme at Stellenbosch University[14] – none of which the University of Johannesburg has yet deployed).

Methods

Participant recruitment

Anonymised, institution-wide data on key demographic and socioeconomic variables (including gender, race/ethnicity and financial eligibility for a university bursary) indicated that undergraduate students registered in the Department of Anthropology and Development Studies were broadly representative of undergraduate students at the University of Johannesburg. Participants for the present study were therefore recruited during the Department's scheduled lectures for first, second and third year undergraduates. A brief verbal explanation of the survey's aims and objectives, and of the contribution students could make to these, was followed by an explicit statement regarding: the voluntary nature of participation; the right of participants to withdraw at any time; and the anonymisation procedures that would be used ensure that no participants could be identified during analysis, interpretation or dissemination. Students who consented to participate received a paper copy of the survey instrument to complete (see Online Supplementary Material 1), and all completed instruments were collected at the end of each lecture.

Survey instrument

To facilitate participation in the survey, minimise the risk of missing data (and its impact on the external validity of the study's sample of participants), and enhance the salience of the questions posed, the survey instrument focussed on just two demographic characteristics (gender and age), and selected a single measure of socioeconomic status (parental car

ownership) that was also intended to have substantial relevance to the topic of enquiry. The remaining six items all focused on cycling-related criteria, namely: cycling competency (i.e. whether or not the respondent knew how to ride a bicycle); participant bicycle ownership/access; participant car ownership; and, for those who knew how to cycle, details of 'when' (i.e. how recently), 'why; (e.g. whether for recreation, exercise or as a form of transport) and 'how far' (i.e. the distance involved) they had last ridden a bicycle. As such the survey instrument contained just 12 items, 6 of which were closed-ended with pre-specified answer categories (see Online Supplementary Information 1). This balance of brevity and prescription was considered optimal during pre-survey piloting of the study's questionnaire amongst the research team, since its design was intended to ensure sufficient data were consistently recorded for quantitative analysis while permitting some scope for respondents to provide additional detail on their recent cycling activities (if any).

Statistical analyses

Data collected using the paper-based survey instrument were captured by double data entry (to minimise transcription errors), and subjected to coding prior to descriptive analysis. Coding involved creating functional categories from continuous or ordinal variables to facilitate analysis and meaningful interpretation. These were further reduced to binary variables prior to multivariable analysis, to reduce the degrees of freedom required in models adjusting for multiple covariates, and thereby optimise their statistical power (albeit at the cost of reducing the information value of each of the re-categorised variables).

The covariate adjustment sets used in these analyses were determined using a theoretical causal path diagram (in the form of a directed acyclic graph or 'DAG'; drawn and interpreted using the online software www.dagitty.net; see Figure 2 and Online Supplementary Information 2).[23-25] In the present study it was assumed that the determination of age and gender (at birth) occurred before *current* parental car ownership (acting as a marker of familial socioeconomic position and/or socially heritable transport behaviours/aspirations). All three of these variables were then assumed to have preceded the development of cycling competency (i.e. when participants first learned to ride a bicycle), which in turn was assumed to have preceded their *current* ownership of/access to a bicycle and, thereafter, their ownership of a car (i.e. as reported in the survey). Meanwhile, for those participants who knew how to ride a bicycle, all of the preceding variables (i.e. from gender and age through to participant car ownership) were

assumed to have preceded 'when', 'why' and 'how far' participants had last ridden a bicycle, in that order.

These assumptions underpin the theoretical temporal relationships between each of the variables as summarised in the DAG (Figure 2). The adjustment sets required to reduce the effect of bias from measured covariates identified as potential confounders (i.e. any covariates that precede *both* the 'exposure' or 'cause' *and* the 'outcome' or 'consequence' of interest) could then be specified with reference to the DAG. Adjusting for potential confounders ensures that multivariable statistical analyses: minimise confounder bias (if only from those confounders for which measurements are available); and generate less biased estimates of the 'total causal effect' observed between each of the potential 'causes' and 'consequences' examined.[23] The chief benefits of this approach are that: it explicitly states the theoretical assumptions underlying any subsequent analyses; and helps to ensure that the adjustment sets specified therein include (only) those variables assumed to act as confounders (rather than those acting as likely mediators or as subsequent 'consequences' of the specified 'outcome/consequence of interest'). However, despite these benefits, this remains an approach that cannot determine whether the *theoretical* assumptions involved are *actually* correct.[25] Nonetheless, in this instance, the *predominant* temporal sequence in which parental car ownership precedes cycling competency and so on seems more likely than the reverse, if only because parental car ownership (in this context, and with these participants) is most likely to act as a measure of family socioeconomic trajectories and/or heritable transport aspirations that *preceded* learning to cycle.

The results of the descriptive statistical analyses were presented as frequencies with percentages in parentheses, while the results of the multivariable analyses were presented as odds ratios (ORs) with 95% confidence intervals (95%CI) in parentheses. All analyses were conducted in STATA-IC 13 (Stata Corp, USA).

Ethics

Ethical approval for the present study was obtained from the Faculty of Humanities Research Ethics Committee at the University of Johannesburg.

Results

Study participants

Table 1 provides a summary of the data provided by the n=606 students who completed the study's questionnaire, almost all of whom (n=576; 95%) provided responses to all of the items relevant to their cycling competency (demographic/socioeconomic: n=604/606, 99.7%; behaviour: n=408/427, 95.5%). As a group, these participants were predominantly young adults, the vast majority (98%) being 27yrs or younger with an average age of 21yrs. Two thirds were female (n=408; 67%), and over two thirds had parents with the means to own a car (n=426; 71%). A similar proportion knew how to ride a bicycle (n=427; 70%), yet only a quarter currently owned/had access to a bicycle (n=156; 26%); and only around a sixth owned a car (n=88; 15%; although half of these also owned/had access to a bicycle: n=47; 7.8%). Most of those participants who knew how to cycle had last cycled within the past 2 years (60%), though more than a quarter had not cycled for 4 or more years (27%). The vast majority of participants also reported that they had last cycled for recreation or exercise (81%), only 18% having last used cycling as a form of transport. Indeed, few participants reported cycling more than 5km when they had last ridden a bicycle (22%), and most had cycled either >1-5km (34%) or less (≤1km; 40%; see Table 1).

[Table 1 near here]

All participants providing complete data on cycling competency and bicycle/car ownership were included in multivariable analyses examining their relationship with gender, age and parental car ownership (both before and after adjusting for confounding; Table 2). However, only those participants who knew how to ride a bicycle and provided complete data on 'when', 'why' and 'how far' they had last cycled were included in unadjusted and confounder-adjusted analyses of each of these three variables (Table 3).

[Figure 2 and Table 2 near here]

Potential determinants of cycling competency and participant bicycle/car ownership

From the first of these multivariable analyses it is clear that self-reported cycling competency was very strongly associated with gender, though somewhat less so with age and parental car

ownership (see Table 2). Male participants had eight times the odds of knowing how to ride a bicycle, while participants who were older than average (≥21yrs), and those whose parents owned cars, also had a modestly higher odds of cycling competency. While the associations for gender and age were somewhat attenuated following adjustment for confounding (male vs. female - OR:7.79; 95%CI:4.43,13.7); <21yrs vs. ≥21yrs - OR:1.42; 95%CI:0.97,2.08), that for age lost precision while that for parental car ownership strengthened somewhat to an OR of 1.64 (95%CI:1.09,2.46).

Gender had a far weaker association with bicycle ownership/access, and there was no evidence that age was associated with owning/having access to a bicycle (see Table 2); suggesting that a disproportionate number of the older, male respondents who knew how to cycle did not actually own/have access to a bicycle. Instead, parental car ownership and cycling competency were most strongly associated with current bicycle ownership/access, and these associations were largely unaffected following adjustment for confounding. As such, these analyses indicate that: male participants were somewhat more likely to own/have access to a bicycle (OR:1.33; 95%CI:0.91,1.95); those with car-owning parents had more than twice the odds of owning/having access to a bicycle (OR:2.20; 95%CI: 1.40,3.46); while those who knew how to ride a bicycle were, perhaps unsurprisingly, almost five times as likely to currently own/have access to a bicycle (OR:5.28; 95%CI: 2.94,9.49).

Nonetheless, very similar patterns were evident for the ownership of cars by participants, both before and after adjustment for confounding. Car ownership was modestly more common amongst male vs. female participants (OR:1.23; 95%CI:0.77,1.99), and slightly more so amongst older vs. younger participants (OR:1.89; 95%CI:1.19,3.01) – but was substantially more common amongst those: with car-owning parents (OR:8.82; 95%CI:3.50,22.26); who knew how to cycle (OR:5.07; 95%CI:2.23,11.50); and who owned/had access to a bicycle (OR:3.10; 95%CI:1.88,5.13). These associations indicate that parental car ownership was the most important determinant of participants owning cars, reflecting perhaps the wealthier socioeconomic position of car-owning parents and/or familial expectations/aspirations for car ownership. Indeed, knowing how to ride a bicycle and owning/having access to a bicycle – both of which were assumed to have preceded participant car ownership in the theoretical causal path diagram presented in Figure 2 – were both *positively* associated with participant car ownership. This suggests that learning to ride a bicycle and/or owning/having access to a bicycle did not satisfy the aspirations or needs of participants to own a car. Instead, the

positive associations between cycling competency, bicycle ownership/access and car ownership seem likely to reflect greater opportunities for, and interest in, cycling and bicycle ownership amongst those participants who were wealthy enough to *also* own cars. This interpretation is supported by the far smaller proportion (of those participants who knew how to cycle) who last used a bicycle as a form of transport (18%), than those who last cycled for recreational purposes or for exercise (81%; see Table 1).

[Table 3 near here]

Potential determinants of cycling behaviour amongst participants with cycling competency

To further explore 'when', 'why' and 'how far' participants had last ridden a bicycle, Table 3 summarises the results of multivariable statistical analyses exploring these three cycling-related behaviours amongst those participants who knew how to cycle (and were therefore able to answer the questions relating to the last time they had cycled). Even after adjustment for potential confounding, these analyses indicate that male participants were far more likely to have last cycled: recently (i.e. at some time in the past two years rather than longer ago; OR:1.83; 95%CI:1.22,2.75); for transport (than for recreation or exercise; OR:2.27; 95%CI:1.37,3.77); and further than 1km (than ≤1km; OR:2.31; 95%CI:1.53,3.50). In contrast, younger participants (<21yrs) tended to be less likely to have cycled in the past two years (OR: 0.71; 95%CI:0.48,1.06), but tended to be more likely to have cycled for transport (OR:1.45; 95%CI:0.87,2.40). While both of these associations had limited precision – suggesting substantial heterogeneity amongst younger and older participants in terms of the 'when' and 'why' they last rode a bicycle – there was a clearer relationship between age and the distance last cycled, which suggested that older participants were more likely to have last cycled for >1km (OR:1.67; 95%CI:1.11,2.51).

Interestingly, participants whose parents owned cars appeared *less* likely to have cycled: more recently; for transport (rather than recreation/exercise); and/or for >1km. Although these trends lacked precision, they were evident both before and after adjustment for gender and age. As such, they suggest that despite the importance of parental car ownership (and thereby socioeconomic position) as a strong determinant of participants' cycling competency and bicycle ownership/access (see Table 2), this may have actually *reduced* the: frequency of cycling; use of cycling for transport, and distances involved. This interpretation is supported

by the less recent use of cycling and lower rates of cycling for transport amongst those participants who themselves owned a car, even after adjustment for bicycle ownership/access (≤2ys vs. >2yrs OR:0.70; 0.39,1.27; transport vs. recreation/exercise OR:0.64; 95%CI:0.31,1.34). However, participants who owned cars also tended to have most recently cycled >1km (OR:1.72; 95%CI:0.96,3.08) suggesting, albeit somewhat speculatively, that the longer cycle trips they had made in the past might have encouraged these participants to own a car.

Indeed, by far the most important determinant of cycle-related behaviour was bicycle ownership/access. Those participants who owned/had access to a bicycle had over six times the adjusted odds of having last cycled within the past two years (OR:6.20; 95%CI:3.65,10.52) and almost twice the adjusted odds of having then cycled for >1km (OR: 1.89; 95%CI:1.20,2.96). In contrast, bicycle ownership/access appeared unrelated to cycling for transport vs. recreation/exercise (OR:0.96; 95%CI:0.56,1.66), presumably because so many bicycle owning participants also owned a car (n=47/88, 53.4%). It is not at all surprising that participants who currently owned/had access to a bicycle were more likely to have recently cycled given that owning/having access to a bicycle would have meant they had the means required to cycle. Likewise, the longer (more recent) cycle journeys taken by participants who owned/had access to a bicycle may also simply reflect the fact that these participants were older and, perhaps, had greater confidence to cycle further than those participants who had last cycled >2yrs earlier (many of whom would have only been in their mid- to late-teens, or younger still, at the time). Meanwhile, the fact that bicycle ownership/access was essentially unrelated to its use as a form of transport (rather than as a source of recreation or exercise), implies that bicycle ownership/access *in and of itself* was not sufficient to increase the use of cycle-based transport in the presence of alternative forms of transport (be that a private car or public transport).

Discussion

While the present study generated useful insights into the prevalence, and potential determinants, of cycling competency and bicycle ownership amongst undergraduates at the University of Johannesburg, these findings remain somewhat speculative as a result of: potential sampling bias; limited statistical power; the need to categories variables; residual and unmeasured confounding; and the observational nature of the study's design. Indeed,

although the sampling frame used will have addressed many of the underlying structural factors likely to affect cycling competency and bicycle ownership (given this comprised undergraduates attending classes in an academic Department whose demographic and socioeconomic characteristics were broadly representative of the University's student body), it was not possible to assess whether these undergraduates were broadly representative in other important respects (such as participation in exercise or sport). Likewise, although the very brief questionnaire developed for use in the present study helped to optimise participation and minimise missingness, the sample size attained was modest and required the categorisation of variables to maintain sufficient statistical power for multivariable statistical analysis. In some instances, categorisation required cut-offs that had questionable relevance to the analyses concerned (e.g. <21yrs vs. ≥21yrs). In others categorisation is likely to have reduced the information available in the original data (e.g. ≤1km vs. 1-5km vs.>5km) and will have increased the risk of measurement imprecision and residual confounding. Thus, despite the evident operational benefits of a brief, prescriptive survey instrument, these were offset by the limited number of variables available for analysis which reduced the scope of the analyses and increased the risk of unadjusted confounding (as illustrated by the large number of potential latent confounders included, somewhat speculatively, in Figure 2) – an issue that is likely to be a serious limitation of the current cross-sectional study. Indeed, this is the reason why many analysts continue to question the utility of observational study designs for causal inference;[26] and although the present study explicitly *sought* evidence of causality using recent innovations in analytical modelling (notably the use of a theoretical causal path diagram to identify appropriate confounder adjustment sets), its estimates of 'total causal effects' remain susceptible to bias from unmeasured and residual confounding.

Notwithstanding these limitations, the present study revealed a number of complex inter-relationships between demographic and socioeconomic factors, and the cycling competency, bicycle ownership/access and cycling behaviour of undergraduate students at the University of Johannesburg. Most conspicuous amongst these was the finding that cycling competency and behaviour were both highly gendered (male participants being far more likely to know how to cycle and more likely to have last cycled recently, further and for transport). Gender-specific differences aside, participants who knew how to cycle were also far more likely to currently own/have access to a bicycle. This association seems likely to reflect not only the impact of cycling competency on the potential utility of bicycle ownership/access; but also the necessity of owning (or at least having access to) a bicycle in order to have learned how to

cycle. Yet neither of these possibilities explain why participants who knew how to cycle *and* those who currently owned/had access to a bicycle were both much more likely to own a car. Instead, these relationships seem likely to reflect socioeconomic factors influencing not only whether participants had been able to learn how to ride a bicycle, but also whether they had been able to own/have ready access to a bicycle (and/or, indeed, a car).

The important role that such socioeconomic factors might play is evidenced by the much higher rates of cycling competency and bicycle/car ownership amongst those participants whose parents owned a car.[26] Yet this, essentially structural/financial, relationship between the ownership of transport-related assets by parents and their student-aged children, may also reflect the socioeconomic patterning of cycling as a more desirable lifestyle choice of wealthier individuals.[27] As such, these findings indicate that both gender and socioeconomic position strongly influence the uptake of, and access to, cycling amongst students at the University of Johannesburg.

While gender was also strongly associated with cycling behaviour (amongst participants who knew how to cycle), two of the variables acting as proxies for socioeconomic position (parental and participant car ownership) appeared far less precise determinants of cycling behaviour *per se*. Indeed, those participants whose parents owned a car, or who owned a car themselves, were modestly *less* likely to have last cycled: recently; for transport; and further than 1km. In effect, whilst parental car ownership was a strong determinant of cycling competency, bicycle ownership/access *and* car ownership amongst participants, it tended to be associated with what might be considered less 'committed' cycling behaviour. The role of a more favourable (parental) socioeconomic background is therefore somewhat paradoxical – it facilitates both the knowledge and means required to ride a bicycle, yet attenuates the use of bicycles (not least since it also appears to facilitate access to an alternative form of transport, namely a car). Indeed, participants who *themselves* owned cars were modestly less likely to have last ridden a bicycle in the past 2 years, or to have done so for transport (as opposed to recreation/exercise). However, these participants were also modestly more likely to have last ridden for >1km – an association that would be consistent with an increased incentive to own a car amongst those who had been required to cycle long(er) distances in the past.

Conclusions

Any interventions aiming to promote cycle-based transport amongst students at the University of Johannesburg will need to deal with the: substantial number of students (n=176/606; 30%) who do not know how to ride a bicycle; the large number of those who know how to cycle but do not own/have access to a bicycle (n=287/427; 67%); and the relatively small number of students who appeared to have recent experience of cycling for transport (rather than for recreation or exercise). If interventions to promote cycling are to be inclusive, they will need to cater for students with very different cycling competencies and experience, and for those who do not own their own bicycle or do not have access to a bicycle. They will also need to address the disproportionately higher numbers of female students who do not know how to cycle, and have less recent experience of cycling, and particularly of cycling as a form of transport. These gender-related disparities may make female students particularly challenging to interest or include in interventions to promote cycle-based transport. Addressing this may warrant the involvement of experienced female cyclists as intervention staff members to dispel the impression that cycling (particularly for transport) is/should be a predominantly male pursuit.

While it is likely that some interventions might be tempted to focus initially on those individuals who already have the competence and the means to adopt cycle-based transport – and thereby increase both the volume and visibility of cycle-based transport as part and parcel of increasing awareness, interest and perceived utility – such interventions should bear in mind that focussing (first) on those who know how to cycle, who own/have access to a bicycle, and have substantial recent experience of travelling by bicycle (a disproportionate number of whom are male and from wealthier car-owning families) may ultimately strengthen the impression that cycling is only appropriate for wealthier (and predominantly male) students.[28,29]

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References

1. City of Johannesburg. *Strategic Integrated Transport Plan Framework for the City of Johannesburg: Draft for Discussion, 2013.* Available at: https://www.joburg.org.za/Campaigns/Documents/2014%20Documents/CoJ%20SITPF%20Draft%2013%20May%202013%20(1).pdf. Accessed November 19, 2019.

2. Mokitimi MM, Vanderschuren M. The Significance of non-motorised transport interventions in South Africa–A rural and local municipality focus. *Trans Res Proc* 2017;25:4798-821. doi: 10.1016/j.trpro.2017.05.491

3. Harrison P, Rubin M, Appelbaum A, Dittgen R. Corridors of Freedom: Analyzing Johannesburg's ambitious inclusionary transit-oriented development. *J Plan Ed Res*. 2019;8:456-68. doi: 10.1177/0739456X19870312

4. Bechstein E. Cycling as a supplementary mode to public transport: a case study of low income commuters in South Africa. *Proc S Afr Trans Conf*. 2010;29:33-41.

5. Gordge R, Laing G, Wentzel E. The development of a comprehensive cycle plan for Stellenbosch. *Proc S Afr Trans Conf*. 2015;34:531-541.

6. Jennings G. A bicycling renaissance in South Africa? Policies, programmes and trends in Cape Town. *Proc S Afr Trans Conf*. 2015;34:486-498.

7. Petzer B. 2015. Why cycling should matter when planning the future of South African cities. Available at: http://futurecapetown.com/2016/08/how-do-we-resolve-some-of-our-transport-issues-by-cycling-future-cape-town/. Accessed November 19, 2019.

8. Petzer B. A Contextual Analysis of Cycling Environment Assessment Tools in a Cape Town Mobility Corridor; 2016. Unpublished Master of City and Regional Planning, University of Cape Town. Available at:

https://open.uct.ac.za/bitstream/handle/11427/22895/thesis_ebe_2016_petzer_brett.pdf?sequence=1. Accessed November 19, 2019.

9. Shannon T, Giles-Corti B, Pikora T, Bulsara M, Shilton T, Bull F. Active commuting in a university setting: Assessing commuting habits and potential for modal change. *Trans Pol.* 2006;13:240-253. doi: 10.1016/j.tranpol.2005.11.002.

10. Bopp M, Kaczynski A, Wittman P. Active commuting patterns at a large, midwestern college campus. *J Am Coll Health.* 2011;59:605–611. doi: 10.1080/07448481.2010.518327.

11. University of California, Davis (UCD). UC Davis Bicycle Plan; 2011. Available at: http://taps.ucdavis.edu/sites/taps.ucdavis.edu/files/attachments/BikePlanUCDCampus2011.pdf. Accessed November 19, 2019.

12. Laker L. What makes Cambridge a model cycling city? Available at: https://www.theguardian.com/environment/bike-blog/2011/aug/17/cambridge-model-cycling-city. Accessed November 19, 2019.

13. University of Leeds (UoL). Bike Hub; 2019. Available at: https://sustainability.leeds.ac.uk/sustainable-transport/bike-hub/. Accessed November 19, 2019.

14. University of Stellenbosch (UoS). Bicycle Rental Procedures; 2019. Available at: https://www0.sun.ac.za/sustainability/pages/services/transport/bicycles/what-is-a-matie-bike.php. Accessed November 19, 2019.

15. University of Edinburgh (UoE). How do we Get Students Cycling More at Universities and Colleges in Edinburgh? University of Edinburgh Cycling Report, PPP; 2015. Available at: https://www.ed.ac.uk/files/atoms/files/ppp_cycling_report_march_2015_0.pdf. Accessed November 19, 2019.

16. Mdepa W, Tshiwula L. Student diversity in South African higher education. *Widening Partic Lifelong Learn.* 2012;13:19-33. doi: 10.1023/B:HIGH.0000

17. Malatji EM. The development of a smart campus. African universities point of view. *Proc IEEE Int Renew Ener Congr*. 2017;8: 1-5.

18. Kerr A. Tax(i)ing the poor? Commuting costs in South African cities. *S Afr J Econ*. 2017;85:321-340. doi: 10.1111/saje.12161

19. Grzebieta RH, McIntosh AM, Chong S. Pedestrian-cyclist collisions: issues and risk. *Proc Aus Coll Road Safety Nat Conf*. 2011;2011:1-12.

20. Woodcock J, Abbas A, Ullrich A, Tainio M, Lovelace R, Sa TH, Westgate K, Goodman A. Development of the Impacts of Cycling Tool (ICT): A modelling study and web tool for evaluating health and environmental impacts of cycling uptake. *PLoS Med.* 2018;15:e1002622. doi: 10.1371/journal.pmed.1002622

21. Wangenge-Ouma G. Widening participation in South African higher education. Bristol: Higher Education Funding Council for England; 2013. Available at: https://www.voced.edu.au/content/ngv%3A59466. Accessed November 19, 2019.

22. Flamm B, Rivasplata C. Perceptions of bicycle-friendly policy impacts on accessibility to transit services: the first and last mile bridge; 2014. Mineta Transportation Institute, San José State University, San José, CA. Available at: https://transweb.sjsu.edu/sites/default/files/1104-bicycle-policy-transit-accessibility-first-last-mile.pdf. Accessed November 19, 2019.

23. Textor J. Drawing and analyzing causal DAGs with DAGitty; 2015. Available at: http://www.dagitty.net/manual-2.x.pdf. Accessed November 19, 2019.

24. Textor J, Hardt J, Knüppel S. DAGitty: a graphical tool for analyzing causal diagrams. *Epidemiol*. 2011;22:745. doi: 10.1097/EDE.0b013e318225c2be

25. Textor J, van der Zander B, Gilthorpe MS, Liskiewicz M, Ellison GTH. Robust causal inference using directed acyclic graphs: the R package 'dagitty'. *Int J Epidemiol.* 2016;45:1887-94. doi: 10.1093/ije/dyw341

26. Hernán MA. The C-word: scientific euphemisms do not improve causal inference from observational data. *Am J Publ Health*. 2018;108:616-9. doi: 10.2105/AJPH.2018.304337

27. Lam TF. Hackney: a cycling borough for whom? *Appl Mob*. 2018;3:115-32. doi: 10.1080/23800127.2017.1305151.

28/8. Madibogo J. There won't be bicycle lanes in Sandton, says Malema. Available at: http://www.timeslive.co.za/politics/2016/06/10/There-won't-be-bicycle-lanes-in-Sandton,-says-Malema. Accessed November 19, 2019.

29/9. Morgan N. Johannesburg's bike lanes are not well used. Here's why. Available at: https://theconversation.com/johannesburgs-bike-lanes-are-not-well-used-heres-why-75068. Accessed November 19, 2019.

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Table 1. The distribution of questionnaire responses provided by n=606 survey participants, disaggregated by those who responded that they knew how to ride a bicycle and those who did not.

	Do not know how to ride a bicycle (n=179) n (%)	Know how to ride a bicycle (n=427) n (%)
Demographic		
Respondent age		
Under 21yrs	113 (63%)	221 (52%)
21yrs and older	65 (37%)	205 (48%)
Missing	1 (<1%)	1 (<1%)
Respondent gender		
Female	164 (92%)	244 (57%)
Male	15 (8%)	183 (43%)
Missing	0 (0%)	0 (0%)
Socioeconomic		
Parental car ownership		
Do not own a car	62 (35%)	116 (27%)
Own a car	116 (65%)	310 (73%)
Missing	1 (<1%)	1 (<1%)
Respondent car ownership		
Do not own a car	171 (96%)	347 (81%)
Own a car	8 (4%)	80 (19%)
Missing	0 (0%)	0 (0%)
Respondent bicycle ownership/access		
Do not own/have access to a bicycle	162 (91%)	287 (67%)
Own/have access to a bicycle	16 (9%)	140 (33%)
Missing	1 (<1%)	0 (0%)
Cycling competency		
Know how to ride a bicycle		
Do not know	179 (100%)	0 (0%)
Know	-	427 (100%)
Missing	-	0 (0%)
Behavioural		
When last rode a bicycle		
During the past year	-	132 (31%)
1>2 years ago	-	122 (29%)
2>4 years ago	-	52 (12%)
>4 years ago	-	114 (27%)
Missing	179 (100%)	7 (2%)
Why last rode a bicycle		
Recreation	-	269 (63%)
Exercise	-	77 (18%)
Transport	-	77 (18%)
Missing	179 (100%)	4 (1%)
How far last rode a bicycle		
≤1km	-	171 (40%)
>1-5km	-	144 (34%)
>5km	-	93 (22%)
Missing	179 (100%)	19 (4%)

Table 2. Demographic and socioeconomic determinants of car and bicycle ownership, and of knowing how to ride a bicycle; before and after adjustment for potential confounders.

Outcome: (referent)	Participant cycling competency (Do not know how to cycle)		Participant bicycle ownership/access (Do not own)		Participant car ownership (Do not own)	
Model:	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Characteristic (referent)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
Respondent sex (Female)						
Male:	8.01 (4.56,14.1)	7.79 (4.43,13.7)	1.33 (0.91,1.96)	1.33 (0.91,1.95)	1.32 (0.82,2.11)	1.23 (0.77,1.99)
Respondent age (Under 21yrs)						
21yrs and over:	1.59 (1.11,2.28)	1.42 (0.97,2.08)	1.03 (0.71,1.49)	1.00 (0.69,1.45)	1.93 (1.22,3.06)	1.89 (1.19,3.01)
Parent car ownership (Do not own)						
Car:	1.40 (0.96,2.04)	1.64 (1.09,2.46)	2.16 (1.38,3.38)	2.20 (1.40,3.46)	8.22 (3.27,20.66)	8.82 (3.50,22.26)
Participant cycling competency (Do not know how to cycle)						
Know how:	-	-	5.27 (2.99,9.29)	5.28 (2.94,9.49)	5.63 (2.55,12.46)	5.07 (2.23,11.50)
Participant bicycle ownership/access (Do not own/have access)						
Bicycle:	-	-	-	-	5.27 (2.99,9.29)	3.10 (1.88,5.13)

Table 3. Demographic and socioeconomic determinants of when, why and how far those respondents who knew how to ride a bicycle had last ridden a bicycle; before and after adjustment for potential confounders.

Outcome (referent)	When last rode a bicycle (>2 years ago)		Why last rode a bicycle (Recreation or Exercise)		Distance last cycled (≤1km)	
	≤2yrs	≤2yrs	Transport	Transport	>1km	>1km
Model	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Characteristic (referent):	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
Respondent sex (Female)						
Male:	1.78 (1.19,2.66)	1.83 (1.22,2.75)	2.32 (1.40,3.84)	2.27 (1.37,3.77)	2.42 (1.60,3.65)	2.31 (1.53,3.50)
Respondent age (Under 21yrs)						
21yrs and over:	0.76 (0.51,1.12)	0.71 (0.48,1.06)	1.54 (0.94,2.54)	1.45 (0.87,2.40)	1.77 (1.19,2.64)	1.67 (1.11,2.51)
Parent car ownership (Do not own)						
Car:	0.78 (0.50,1.22)	0.82 (0.52,1.29)	0.80 (0.47,1.38)	0.90 (0.52,1.56)	0.78 (0.50,1.22)	0.85 (0.54,1.36)
Participant bicycle ownership/access (Do not own/have access)						
Bicycle:	5.42 (3.24,9.04)	6.20 (3.65,10.52)	0.92 (0.54,1.57)	0.96 (0.56,1.66)	1.70 (1.11,2.63)	1.89 (1.20,2.96)
Participant car ownership (Do not own)						
Car:	1.01 (0.61,1.67)	0.70 (0.39,1.27)	0.67 (0.34,1.33)	0.64 (0.31,1.34)	1.85 (1.09,3.17)	1.72 (0.96,3.08)
When last rode a bicycle (≤2 years ago)						
>2 years ago	-	-	0.86 (0.51,1.43)	0.93 (0.53,1.64)	0.69 (0.46,1.04)	0.90 (0.57,1.43)
Why last rode a bicycle (Recreation or Exercise)						
Transport	-	-	-	-	1.30 (0.78,2.18)	1.06 (0.61,1.82)

Figure 1. Street map of central Johannesburg showing the location of the "university corridor" cycle lanes running from Park Station via the University of the Witwatersrand in Braamfontein to the two campuses of the University of Johannesburg (Bunting Road and Kingsway) in Auckland Park. Source: Google Maps

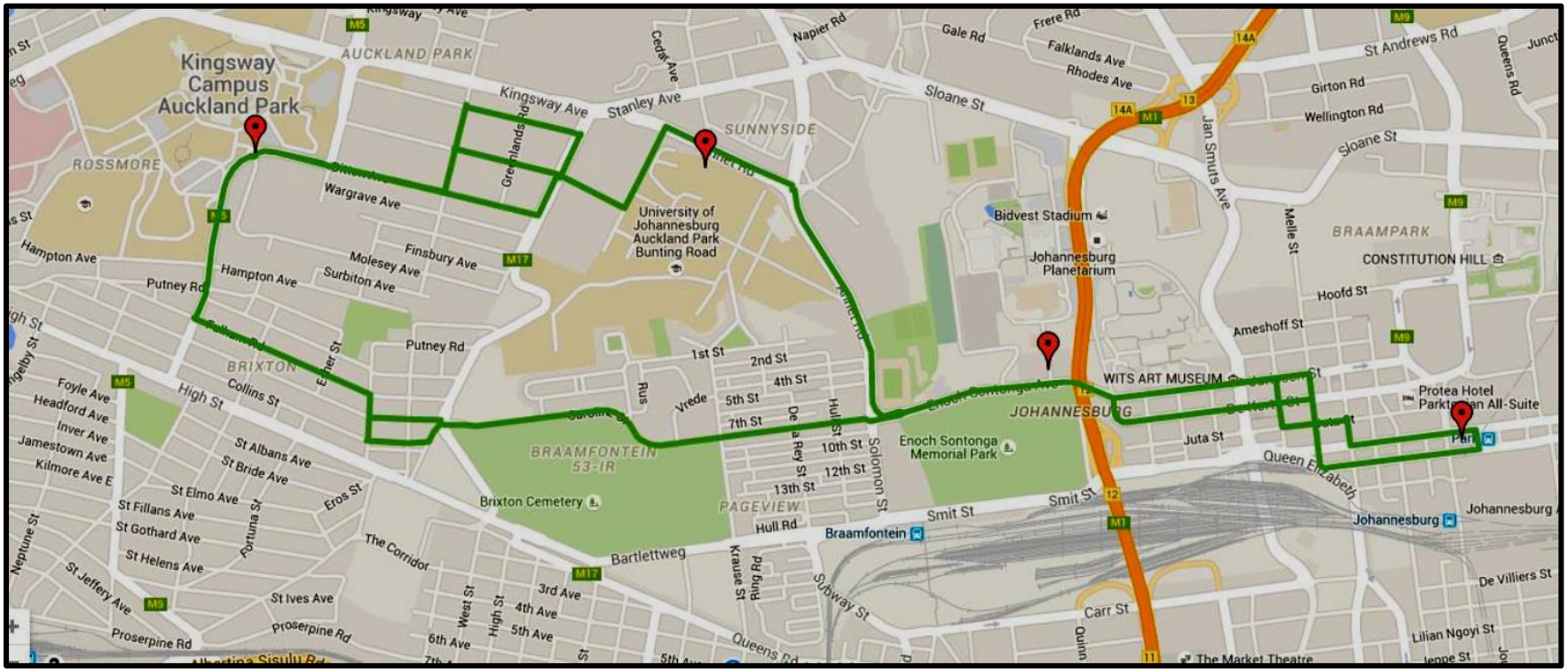
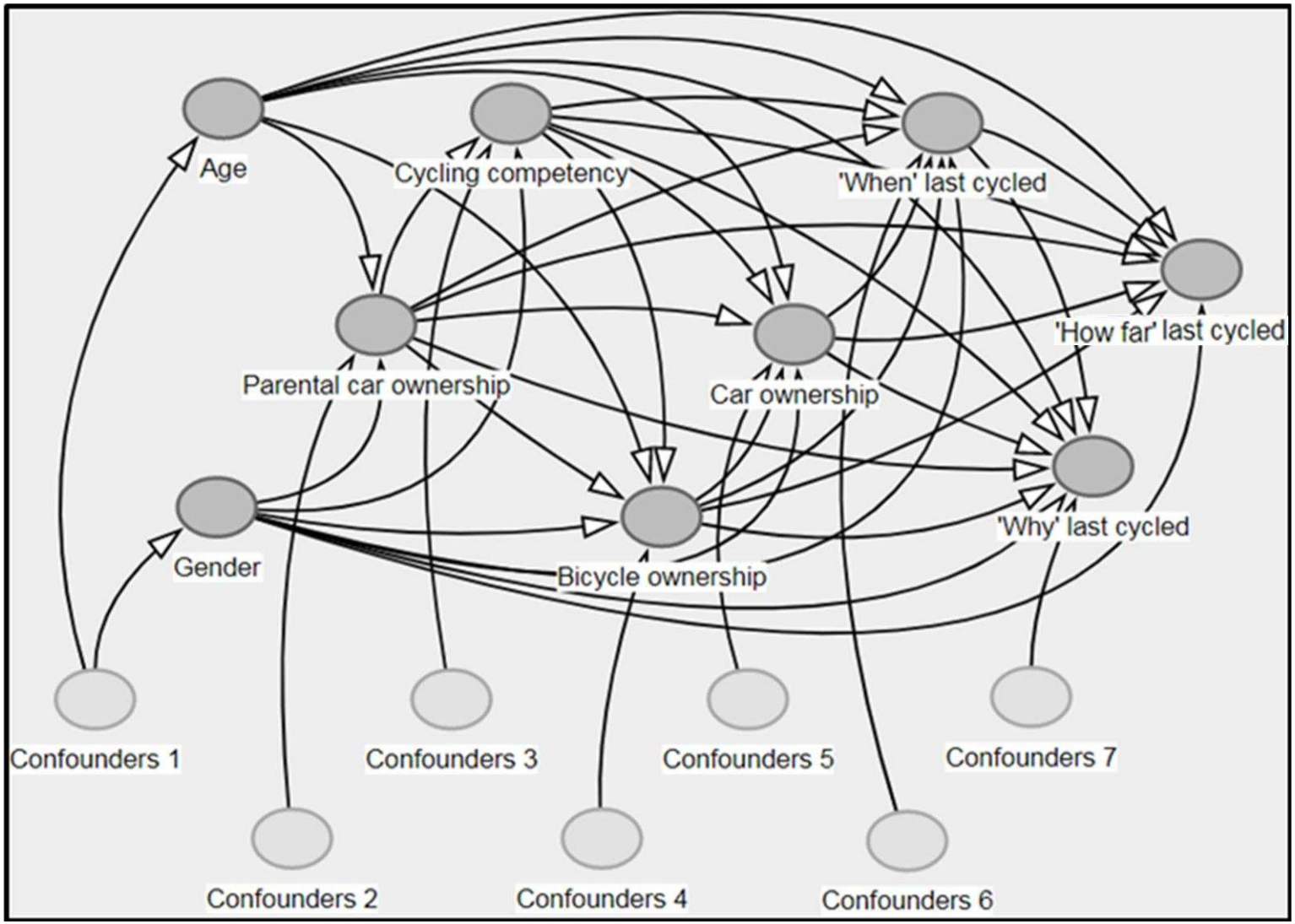


Figure 2. Hypothesised temporal and causal relationships between measurements of demographic and socioeconomic characteristics, cycling competency, bicycle and car ownership, and (for respondents who knew how to ride a bicycle) 'when', 'why' and 'how far' respondents had last ridden a bicycle (represented as filled circles/nodes in a Directed Acyclic Graph published at: http://dagitty.net/maSvX5s;[23-24] see also Online Supplementary Information 2). The clear circles/nodes represent speculative groups of *unmeasured* or *latent* variables that would be capable of acting as potential confounders in any relationship involving the next *measured* variable or any subsequent *measured* variable (if specified as the 'exposure' or 'cause of interest') and any *measured* variable thereafter (if specified as the 'outcome' or 'consequence of interest'). For brevity, arcs from each speculative group of latent variables have only been drawn to the first of the measured variable(s) these *could* affect as potential confounder.



Online Supplementary Information 1. The custom item set included in the brief survey instrument designed to reduce missingness and enhance the external validity of responses generated from undergraduate students at the University of Johannesburg.

1. Do you know how to ride a bicycle?

☐ Yes

☐ No

If you answered yes, please answer the following questions about the last time you rode a bicycle:

a. When last did you ride a bicycle? _____ month _____ year

b. What was the purpose of the journey? _____

c. Approximately how far did you cycle? _____

2. Do you currently own a bicycle or have access to a bicycle?

☐ Yes

☐ No

If you answered yes:

Where is this bicycle? _____

3. Do you own a car?

☐ Yes

☐ No

4. Do your parents own a car?

☐ Yes

☐ No

5. Are you male or female?

☐ Male

☐ Female

6. How old are you? _____

7. What year of study are you in?

☐ First Year

☐ Second Year

☐ Third Year

8. Where do you live? _____

Online Supplementary Information 2. Dagitty 'model code' for reproducing Figure 2 using www.dagitty.net (Textor et al., 2011; Textor, 2015).

```
'When'%20last%20cycled 'How%20far'%20last%20cycled @0.529,0.437 'Why'%20last%20cycled @0.548,0.493
Age 'How%20far'%20last%20cycled @0.474,0.309 'When'%20last%20cycled @0.382,0.357 'Why'%20last%20cycled
@0.450,0.341 Bicycle%20ownership @0.329,0.464 Car%20ownership @0.402,0.364 Parental%20car%20ownership
@0.237,0.445
Bicycle%20ownership 'How%20far'%20last%20cycled @0.481,0.594 'When'%20last%20cycled @0.487,0.573
'Why'%20last%20cycled @0.474,0.640 Car%20ownership @0.409,0.592
Car%20ownership 'How%20far'%20last%20cycled @0.493,0.538 'When'%20last%20cycled @0.472,0.499
'Why'%20last%20cycled @0.471,0.562
Confounders%201 Age @0.079,0.558 Gender @0.120,0.655
Confounders%202 Parental%20car%20ownership @0.192,0.615
Confounders%203 Cycling%20competency @0.248,0.530
Confounders%204 Bicycle%20ownership @0.338,0.707
Confounders%205 Car%20ownership @0.378,0.608
Confounders%206 'When'%20last%20cycled @0.417,0.570
Confounders%207 'Why'%20last%20cycled @0.529,0.658
Cycling%20competency 'How%20far'%20last%20cycled @0.455,0.437 'When'%20last%20cycled @0.392,0.409
'Why'%20last%20cycled @0.451,0.475 Bicycle%20ownership @0.373,0.479 Car%20ownership @0.391,0.465
Gender 'How%20far'%20last%20cycled @0.604,0.765 'When'%20last%20cycled @0.540,0.723 'Why'%20last%20cycled
@0.467,0.709 Bicycle%20ownership @0.269,0.632 Car%20ownership @0.437,0.695 Cycling%20competency
@0.327,0.624 Parental%20car%20ownership @0.249,0.601
Parental%20car%20ownership 'How%20far'%20last%20cycled @0.402,0.450 'When'%20last%20cycled @0.368,0.449
'Why'%20last%20cycled @0.411,0.600 Bicycle%20ownership @0.307,0.580 Car%20ownership @0.361,0.510
Cycling%20competency @0.248,0.475
```

Textor J, Hardt J, Knüppel S. DAGitty: a graphical tool for analyzing causal diagrams. *Epidemiol*. 2011;22:745. doi: 10.1097/EDE.0b013e318225c2be

Textor J. Drawing and analyzing causal DAGs with DAGitty; 2015. Available at: http://www.dagitty.net/manual-2.x.pdf. Accessed November 19, 2019.