A qualitative exploration of the mechanisms, pathways and public health outcomes of a city centre 20mph speed limit intervention

TITLE: A qualitative exploration of the mechanisms, pathways and public health outcomes of a city centre 20mph speed limit intervention: the case of Belfast, United Kingdom.

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Declaration of interest

Declarations of interest none.

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CRediT STATEMENT

CC: conceptualization, methodology, acquisition of data, analysis, interpretation, writing (original draft, review & editing) and visualization. **GB:** conceptualization, methodology, analysis, interpretation and writing (review & editing). **KT:** conceptualization, methodology, acquisition of data, analysis, interpretation and writing (review & editing). **RJ:** conceptualization, interpretation and writing (review & editing). **FK:** conceptualization, interpretation and writing (review & editing). **KM:** conceptualization, interpretation and writing (review & editing). **MK:** conceptualization, interpretation and writing (review & editing). **GN:** conceptualization, interpretation and writing (review & editing). **RH:** conceptualization, methodology, analysis, interpretation, writing (review & editing), supervision and visualization.

ABSTRACT

Twenty miles per hour (mph) speed limits can impact the health of the public (e.g., road safety, active travel). However, a better understanding of how individuals experience 20mph limits is required, to ensure interventions are cognisant of perceptions and potential un/intended outcomes. Focus groups (n=9, 60 participants) to explore the Belfast 20mph intervention highlighted divergent perspectives and experiences including: 12 mechanisms (e.g., limited awareness), 15 pathways (e.g., reduced driving speed→improved liveability) and 10 public health outcomes (e.g., increased cyclist safety). Future interventions should consider un/intended outcomes and implement strategies to enhance effectiveness and mitigate harms (e.g., through training, enforcement).

INTRODUCTION

The transport system is one that is considered complex with many interacting (e.g., between cars, pedestrians, cyclists) and interlinking components (e.g., transport infrastructure, road safety interventions).[1] Modes of transport are determinants of health, with potential detrimental implications for physical health (e.g., road traffic casualties and collisions, physical inactivity) and mental health (e.g., stress, social isolation) and widening of health, social and environmental inequalities.[2-5] The transport system can exacerbate inequalities, for example, by the disproportionate negative impacts of noise and air pollution on socio-economically disadvantaged communities, due to their proximity to transport infrastructure, the inaccessibility of locations via public or active transport for those living in rural communities resulting in greater levels of car dependence, and the vulnerability of children and older adults as pedestrians which can lead to increased injury severity following a road traffic collision.[5]

Consequently, as the complex transport system has the potential to result in a range of detrimental health and environmental outcomes, researchers, policy makers and practitioners continuously work to design and implement a multitude of interventions, ultimately resulting in the urban mobility triad of “Avoid, Shift, Improve”.[2-6] “Avoid” strategies aim to make motorised transport unnecessary (e.g.,

walkable cities), “shift” policies encourage a change in mode of transport (e.g., transitioning to public and/or active transport) and “improve” efforts rely on technological advances to provide energy efficient modes.[6] Whilst, it is noted that each of these discrete strategies have the capacity to positively affect behaviour change at the individual level (e.g., modal shift, improve road safety); they ultimately interlink and interact, operating as part of the complex transport system to affect change and challenge the car-dominant paradigm at a population level.[6] Consequently, it is not only important to evaluate the transport system as a whole but it is also vital to take stock of the individual interventions and policies, and to evaluate their effectiveness.

In this regard, recent publications have noted the widespread implementation of 20 miles per hour (mph) speed limit interventions across the United Kingdom (UK) and continental Europe.[7-11] Reduced speed limits are commonly implemented with the intention of simply acting as a road safety intervention.[10] However, because when they operate through a range of specific intervention activities (i.e. signage, awareness/education, legislation and enforcement), within the complex transport system, alongside other transport initiatives (e.g., active and public transport) that are collectively seeking to affect behaviour change, 20mph speed limit interventions have the potential to become part of the fundamental reset of the way we choose our travel priorities.

The recent widespread implementation of 20mph speed limits may be due to their capacity to: 1) potentially result in a range of beneficial public health outcomes (i.e. less collisions and casualties and increased road safety); 2) offer policy makers a lower cost intervention in comparison to other transport initiatives (e.g., segregated cycle lanes) as minimal physical infrastructure changes are required (signage only with no chicanes or speed bumps); and 3) operate as population level public health interventions.[8,9,11,13]

As 20mph speed limit interventions are complex and multi-faceted, supplementing the evidence base is not straightforward. To date, 20mph speed limit evaluations have predominantly focused on quantifying the primary intended outcome of 'reduced driving speed' and the potential impacts on collisions and casualties.[8,9,11] The potential that 20mph speed limit interventions have to operate at a population level and to impact numerous public health outcomes in theory is vast; although, evidence of their effectiveness is currently inconclusive.[9-11,13] Specifically, a recent meta-narrative review identified two studies evaluating 20mph speed limit interventions and concluded the evidence was: 1) "insufficient" to draw conclusions on changes in collisions and casualties; and 2) "limited" in regards to their impact on liveability, pollution and inequalities, due to a lack of research.[7,8,10] Therefore, it is important that evaluations do not simply focus on whether the implementation of 20mph speed limits result in quantifiable changes in public health outcomes, but investigations should also provide more in-depth context specific investigations to help unravel some of the complexities that surround 20mph speed limit interventions.[14] Ways that this can be realised are by considering the general public's perceptions of the: 1) underlying mechanisms (i.e. the process through which intervention activities and the target population interact and operate); 2) pathways (i.e. the sequential process from intervention implementation through to intervention outcomes, that includes one or more mechanisms); and 3) public health outcomes.[13,15]

Noting this evidence gap, Turner and colleagues aimed to provide a theoretical understanding of the putative/potential mechanisms between 20mph speed limit intervention activities and outcomes.[13] They highlighted a range of proposed key mechanisms (e.g., increased awareness, self-enforcement, change in attitudes, increased perceptions of safety, improved perception of route choice, and changing driving behaviours/style) and outcomes (e.g., reduced traffic speed, change in collision rate/frequency, and reduced casualty severity). Their study instigated investigations, highlighting the potential impact and providing a starting point to inform future 20mph speed limit evaluations. We build on this work to further explore and understand the experiences and perceptions of those who

have been exposed to a 20mph speed limit intervention and as a consequence have received a 'dose' of the intervention on a regular or periodic basis and are considered 'experts by experience'.[13]

Those who experience the intervention are best placed to provide information relating to: the intervention message (e.g., delivery, acceptance and understanding); their experiences of the intervention that has been implemented; and their perceptions of its effectiveness (e.g., speed reduction, public health outcomes). In addition, by being 'experts by experience' they can provide detailed information, enabling us to consider the intervention complexities that are harder to predict through quantitative methods.

Public health interventions, such as 20mph speed limits, can be unpredictable and result in both intended (i.e. ones that were planned by those who developed and implemented the intervention) and unintended (i.e. ones that were not intended nor planned) outcomes or public perceptions regarding the intervention.[16,17] Research into speed restrictions has failed to provide in-depth detail specifically relating to unintended perceptions or outcomes and those which may have the potential to result in adverse consequences or potential harms. Turner et al only reported the proposed mechanism of 'more severe collision outcomes' through 'reduced driver attention' and 'less opportunity to slow down' – due to lack of attention.[13] Atkins noted 'driver frustration at 20mph' and the temptation to drive at higher speeds depending on the road environment (i.e. wide, straight) from their evaluations of implemented schemes.[8] Therefore, it is imperative that evaluations consider the potential unintended outcomes or beliefs to ensure that the experiences and perceptions of those exposed to 20mph speed limit interventions are explored and their voices heard.[16]

By doing so, this will ensure that those working to develop and implement reduced speed limit measures are cognisant of both the intended and unintended public health perceptions, beliefs and experiences, enabling strategies to be 'designed in' to not only enhance the overall intervention

effectiveness and mitigate any potential issues and/or harms but also to ensure that adequate approaches are implemented to dispel myths and misconceptions that may surround the intervention.

Aim

We aimed to explore qualitatively participant's experiences of the 20mph speed limit intervention in Belfast, and develop a concept map illustrating perceptions and experiences of the mechanisms, pathways and public health outcomes.

METHODS

Ethical approval was obtained from the Moray House School of Education Ethics Committee at the University of Edinburgh (no. 762, 29/03/17), as the principal investigator for the larger study was located here. Throughout this manuscript, we follow the Consolidated Criteria for Reporting Qualitative Research guidelines.[18]

20mph speed limit intervention

The three-year 20mph speed limit pilot was implemented in February 2016 by the Department for Infrastructure (Regional Government Department) within the core of Belfast city centre. The level of investment was £9,935 (budgeted for signage), with the intervention covering 76 streets (1-4 lanes , with on/off-street parking), and prior to the intervention, none had a speed limit less than 30mph. The intervention area would be considered predominantly commercial (i.e. shops, offices), with a limited number of student and residential properties. The intervention implementers intended that the 20mph speed limits would "reduce the number and severity of collisions in this area" and "improve conditions for pedestrians and cyclists".[19]

The new speed limits operate 24 hours per day, seven days per week, with intervention activities including: 1) a Traffic Limit Order (20mph); 2) 20mph traffic signs with small '20' repeater signs; 3)

189 warnings for drivers caught speeding (during the early implementation phase); and 4) issuing of
190 speeding tickets (for those caught speeding after one year).
191
192 **Sample selection and recruitment**
193 Focus groups were deemed the best method of data collection, as they provide the opportunity to
194 draw on individual's personal experiences and attitudes, whilst enabling group discussions and the
195 development of ideas.[20] It was also thought that the qualitative nature could help provide a deeper
196 understanding of the mechanisms and pathways as perceived and experienced by individuals living,
197 working, socialising and/or travelling to and through the 20mph speed limits in Belfast and receiving
198 a 'dose' of the intervention.
199
200 The research team developed a purposeful sampling strategy ensuring that, where possible, sampling
201 of specific population sub-groups was achieved where differential impacts on a range of outcomes
202 may be evident (Table 1). By developing the pragmatic justification matrix, a wide range of voices were
203 represented and narrow ideas and/or interests were avoided.
204

Table 1. Focus Group Pragmatic Justification Matrix

Characteristic sub-group		Justification	Number of participants
Cyclists	**Cyclists (FG1)**	The intervention looks to increase cycling: the opinions of cyclists are required relating to reduced speed and safety.	4
Demographic sub-groups	**Socio-economically disadvantaged parents (FG2)**	Likely that they/their children will be utilising 20mph streets. Young children and areas of high deprivation are disproportionately affected by road traffic collisions.	8
	Middle-to-older age adults (FG3)	Likely that they will be using 20mph streets when travelling to/ through Belfast city centre for work, leisure and/or socialising and may have family (due to caring responsibilities) who frequent the 20mph area with them.	7

	Older adults (FG4)	Likely to be utilising 20mph streets roads and are a group disproportionately impacted by road traffic collisions (as pedestrians and/or drivers).	3
Individuals frequenting the 20mph areas	**Multi-modal transport users (FG5)**	This mixed group (pedestrians, cyclists, drivers, active transport users etc.) are important as they will be using 20mph streets, footpaths and/or cycle lanes.	13
	Commuters travelling in to Belfast city centre (FG6)	Those who commute to Belfast city centre are likely to be or have been impacted by the 20mph limits.	7
	Commuters travelling through Belfast city centre (FG7)	Those who commute through Belfast city centre are likely to be or have been impacted by the 20mph limits.	5
Drivers	**Students/young car drivers (FG8)**	Road traffic injuries are the main cause of death for those aged 5-29.[40] Important to get the opinions of young drivers and/or those likely to socialise in Belfast city centre.	6
City centre businesses	**City centre workers (FG9)**	To determine the perceptions and opinions of those employees who have to travel to and are based for work within the 20mph area.	7

Participants were recruited who: were ≥17 years old; lived, worked, socialised and/or travelled through Belfast city centre; and due to travelling to/through the city centre were 'exposed' to the intervention. Recruitment strategies included: 1) the research team's established contacts and networks (e.g., a voluntary organisation and a government programme); 2) direct invitation to specific sub-groups (e.g., cyclists and city centre workers through workplaces); 3) a university email (i.e. an email inviting students to participate); and 4) snowball recruitment (i.e. participants were asked to identify other possible individuals). Individuals were invited to participate either directly or indirectly (via a third party e.g., centre manager of a government programme or a colleague) through an invitation letter or email and provided with a Participant Information Sheet.

Topic Guide

Questions were initially developed by the research team (CC, RH, GB and KT), guided by the published programme theory.[13] This programme theory was developed by considering multiple facets of public qualitative opinion (i.e. semi-structured interviews and focus groups) and a review of the literature. The programme theory aimed to assist evaluations of 20mph speed limit interventions through outlining proposed mechanisms and pathways between intervention activities and outcomes.[10,13] The topic guide consisted of nine overarching topics: 1) awareness; 2) engagement; 3) intervention rationale; 4) perceptions; 5) enforcement; 6) driver behaviour change following the implementation of the intervention; 7) change in other road users' behaviours; 8) liveability; and 9) other (Table 2). The topic guide was reviewed by the wider "is 20 plenty for health?" research team and piloted with colleagues within Queen's University Belfast who were external to the research team. During the focus groups, a flexible approach was taken to initiate conversations with and between participants and to cover as much of the topic guide as possible and relevant.

Table 2. Topic Guide.

Theme	Question	Points for further investigations
Awareness	When did you first become aware that the Department for Infrastructure were implementing a citywide 20mph speed limit?	Encourage participants to think about pre-, during or post-implementation of the 20mph limits
	How did you find out that the city was implementing this limit?	Encourage participants to recall how they heard about the limits - media, social media, word of mouth, work place etc
	What were your thoughts when you first heard about the 20mph limits? Now that the 20mph limits are implemented, have your thoughts changed?	Encourage participants to be honest about their initial views of the 20mph limits
	When did you become aware that the particular area you live/work/socialise in or that you travel through was about to have or it was having a 20mph speed limit implemented?	Was it at the same time that they first heard about the city wide limits or was it at a different time?
	How did you find out that the 20mph limits would impact you directly?	Encourage participants to recall how they heard about the limits - media, social media, word of mouth, work place etc

	How did you feel when you realised that the 20mph limits would impact you directly? Now that the 20mph limits have are implemented, have your thoughts changed?	Encourage participants to be honest about their views of the 20mph limits directly impacting them – does this differ from their feelings when they heard about it being a city wide scheme?
Engagement	Do you recall seeing any campaigns or press releases about the 20mph limits? What were they? What did you think about them? Have you ever attended any event that aimed to deliver awareness or education of the 20mph limits?	Encourage participants to provide details
Rationale	What do you think the reason/s were behind the introduction of the limits?	Talking points - traffic calming, reduction in accidents, reduction in accident severity, safety, pedestrian safety, cyclists, public health, pleasant environments
Perceptions	What are your opinions of the 20mph limits?	Good, bad, worthwhile, causes problems, congestion, reduction in accidents
	Additional probing questions: Do you think that the 20mph limits will make people drive slower? Do you think the 20mph limits will reduce the number of collisions? Do you think the 20mph limits will reduce the number of pedestrian accidents? Would you or do you feel safer walking on a 20mph limit road? If so, why? If not why? Regarding other members of your family e.g., children, adolescents, older adults, those with a disability do you feel they are safe walking on a 20mph speed limit road? If so, why? If not why? Do you think there should be certain areas for implementation? Do you think they should be implemented 24 hours per day 7 days per week? Would you or do you feel safer driving or cycling on a 20mph limit road? If so, why? If not why? Regarding other members of your family e.g., adolescents, older adults, those with a disability do you feel they are safe driving and/or cycling on a 20mph speed limit? If so, why? If not why?	
Enforcement	Do you have any opinions regarding enforcement of the 20mph limits? Or how you feel it should be enforced? Who do you feel is/are responsible for this enforcement?	Fines, penalty points, speed cameras, policing, traffic wardens etc,
Behaviour Change	Has the introduction of the new 20mph speed limits caused you to change your behaviour? If so, how?	Car use, walking, cycling, commuting, driving efficiency/behaviour
	How do you travel to/out of Belfast? How do you travel within Belfast?	Walk, cycle, drive, taxi, bus, run, motorcycle etc. Have you always travelled this way? If not how did you travel before?

	Why did your behaviour change?	Traffic, 20mph, congestion, petrol prices, health, car sharing, bicycle scheme – explore reasons
	Are the 20mph limits where you live, work, travel to or travel through?	Explore which aspect of their life the limit may have changed
	If no, why do you feel your behaviour has not changed or the limits have not impacted you?	
	If it has not changed your behaviour has it changed anyone's behaviour that you know and in what way?	Car use, walking, cycling, commuting, driving efficiency/behaviour
	Have the limits impacted you in any way? If so, how?	Positively, negatively? Encourage participants to provide examples
	What behaviours do you think 20mph limits have the potential to change/impact? And how/why?	Car use, walking, cycling, commuting, driving efficiency/behaviour
Driving behaviour change	Do you think the implementation of the 20mph limits can change individuals driving behaviour? Has it changed your driving behaviour? If yes in what way? If no why not?	Stop - start Smoother driving – more/less breaking, harsh or less harsh acceleration Traffic flow Less frequent stops and braking Over braking
Other	Do you think there are any negative aspects of 20mph limits? In Belfast, the 20mph scheme is a 3 year pilot which is due to end in February 2019. Do you think it should remain in place after the pilot?	Congestion, pollution, noise, inconvenience, decrease fuel efficiency
Liveability	Regarding liveability do you think the 20mph limits have or will have an impact on any of the following components: - Noise - Aesthetics - Making a more pleasant environment - Ability to socialise - Protect the environment - Services: use of, access to, provision of - Pollution / air quality - Well-being - Safety - Public transport	

Study participants

In total, nine focus groups were conducted involving 60 participants (mean age 43 years (*SD*17), 73% (n=44) female, mostly with no disability or medical conditions that make mobility difficult (n=55, 92%) and who mostly self-classified their ethnic group as white (n=57, 95%)). The participants included older

adults (n = 3), socio-economically disadvantaged young mothers (n = 8), cyclists (n = 4), commuters (n =7), multi-modal transport users (i.e. drivers, pedestrians, users of public transport) (n = 13), Belfast City centre workers (n = 7), middle-aged adults (n = 7), students/young drivers (n = 6) and individuals commuting through the 20mph speed limits to get to work (n = 5) (Table 1).

Data collection

The focus groups were conducted approximately 29-34 months after the implementation of the 20mph speed limit intervention (July-Dec 2018). Therefore, the majority of participants had been exposed to the reduced speed limits for over two years prior to participating in this study. Focus groups where held in a convenient location for participants (e.g., community centre, place of work) and lasted approximately one hour. On arrival participants were provided with the opportunity to ask questions to gain further clarification, they provided informed written consent and completed a short demographic questionnaire. Each focus group was conducted by one researcher (CC). CC is a Research Fellow who holds a PhD in Public Health, has completed formal qualitative training and has over 10 years' experience of qualitative research methods and analysis. To ensure transparent reporting, CC is a car owner, road user, walks as a method of active transport and uses public transport (i.e. bus and rapid transport). CC is not a local resident of Belfast and has undertaken no prior research in this area, reducing the risk of having any pre-conceptions or beliefs about the intervention. Each participant was compensated for their time by receiving a £10 gift voucher. Recruitment stopped once the research team were satisfied that no new themes were generated and each key sub-group had been represented (where possible).

Data management and analysis

Each focus group was audio recorded (with participants' written consent), transcribed verbatim by a professional independent service and anonymised. The transcribed interview and audio files were stored securely on a password protected computer.

Data analysis was performed by three members of the research team independently (CC, RH and GB). CC and RH (Reader in Public Health) working in the field of public health, specifically on the design, development and implementation of complex interventions. GB is a lecturer in Physical Activity for Health, who primarily focuses on understanding and promoting walking and cycling. Data analysis followed a thematic analysis approach, providing a flexible approach to qualitative analysis and the generation of themes transpiring from the data.[21]

The first stage of analysis involved familiarisation with a sub-set of the data and coding of three transcripts independently by CC, RH and GB. The codes and themes were then discussed. Following the establishment of the coding protocol, two researchers (CC and RH) continued with analysis and further developed the theme review (i.e. naming and defining themes) and coding framework.

Following stage one, it was decided that the analysis would benefit from a greater understanding of how the codes and themes interlinked, and how the reported personal experiences point to complexities in 20mph speed limit interventions that are less easily predicted. Therefore, a second stage of analysis involved retrospective concept mapping by CC and RH.[22] Concept mapping is a method commonly used to enhance evidence-based public health and has been defined as a "powerful utility for the demonstration of understanding" of complex topics.[23,24] Similar to Kinchin and colleagues, by implementing a concept mapping approach we were not attempting to measure change in behaviour but rather we were reducing our qualitative data to participant summaries of knowledge and understanding.[23] In addition, the approach enabled the data to be unpicked and disentangled (where possible), to make connections across emerging concepts.[19] We started by placing the 20mph speed limit intervention at the centre of the map with the themes arranged around the periphery. We then spent time reflecting and determining which themes were interconnected and formed chains, and in what sequence the chains were formed.[23] When the chains were structured,

this provided us with an overview of how the various mechanisms and pathways may operate between the intervention and potential resultant public health outcomes.

The focus group discussions included participants' reflections and perceptions, and their reported experiences relating to the intervention effects. Each of the participants' perceptions, experiences, and issues/concerns were considered and reviewed during data analysis as they provide an insight into a range of acceptable responses to the implementation of the intervention. Given the complexities in how participants spoke about their experiences it is not possible to disentangle perceptions versus actual behaviour change. However, we considered all elements of the discussion as part of the participants' experiences of the 20mph intervention. Each of the mechanisms and pathways were refined by the local research team to ensure the concept map was a true reflection of the data collected and the local context.

RESULTS AND DISCUSSION

The first stage of data analysis established three overarching themes: 1) reduced driving speed; 2) no change in driving speed; and 3) driving behaviour. Subsequently, as a result of the retrospective concept mapping approach a range of key mechanisms (n = 12), pathways (n = 15) and public health outcomes (n = 10) were identified. In addition, it was also possible to categorise each mechanism, pathway and public health outcome as 'intended' or 'unintended', with the majority of outcomes (n = 6 of 10) being categorised as unintended (Figure 1). The mixed findings that transpired within this study reiterate the multi-faceted nature of 20mph speed limit interventions and reaffirm that whilst interventions can result in purported intended outcomes, there is also the possibility that unintended and potentially harmful impacts can arise, disrupting the wider complex system.[16,25-27] For the purposes of this discussion we have grouped and contextaulised the findings within the broader literature: Driving speed; Collisions and casualties; Improved cyclist safety and liveability; and Driving behaviour.

Driving speed

It could be assumed that the implementation of 20mph speed limit interventions which include a Traffic Limit Order and 20mph signage, change driving behaviour and consequently reduce speeds to 20mph or below. However, this may not always be the case with findings presenting pathways that related to both reduced driving speeds (i.e. nine pathways) and no change in driving speeds (i.e. four pathways). For the participants in this study, a lack of awareness of the intervention was an issue. "*Really? The 20mph zone? We should have been doing 20mph for the last two years? (Laughter)" (a city centre worker FG9)".* Participants reported being unsighted about any awareness campaigns in the media or social media with an older adult stating *"no flyers, no posters. I used to be in advertising as well, so I do know a little bit about it, and as far as I'm concerned, as a punter, as a consumer, I've seen nothing. I would imagine, as a resident of Belfast, I would be a prime target market - it hasn't got to me. I don't think I'm particularly stupid, I would have seen it; I haven't, you know" (an older adult FG4)*. Participants also reported a lack of awareness of specific intervention details (e.g., implementation dates, scope, and signage location) *"At the minute I'm not even sure that everyone knows about the fact that it is 20mph in the city centre. When did it actually come into effect?" (a cyclist FG1).*

Awareness raising is an intervention strategy that should be established from the outset and maintained throughout. It should be achieved through adequate campaigns via various channels (e.g., media, social media, print), ensuring individuals who travel to and/or through 20mph speed limits are aware of both the interventions scope and implementation period. Our research emphasised that awareness should not be taken for granted, with the strong reoccurring mechanism of 'lack of awareness of the speed limit intervention', ultimately putting the potential success of the intervention in jeopardy. Toy and colleagues stressed that an adequate awareness strategy is vital to increase the likelihood of behaviour change, behaviour change maintenance and to encourage 'copycat' driving behaviours.[12] However, previous work also noted that although awareness is vital, it alone may not be

enough to instigate and maintain behaviour change, and supplementary strategies are required to enhance isolated interventions if there are to be any chances of success in changing behaviour.[12,28] Our work suggests that if awareness can be increased from the outset and 'soft measures' such as social marketing and personal relations are also implemented, this strategic approach may enable sustained and wider reaching awareness, ensuring reduced driving speeds are conceived to be the 'new normal'.[12] Adequate campaigns have the potential to play a role as the first step in raising awareness, but without an adequate intervention strategy (i.e. one that includes behaviour change techniques, education, enforcement and linkage with other interventions within the complex transport system) it may result in the 20mph speed limits being ineffective.

In relation to no change of driving speeds participants also described a perceived lack of enforcement of the 20mph speed limits. They reported that to their knowledge no statutory bodies were visibly enforcing the legislation and penalising those breaking the law by presenting them with a suitable penalty. Due to this perceived lack of enforcement, participants felt that there was no reason to adhere to the new limits nor change driving behaviour. However, interestingly they did note that if legislation was enforced strictly (e.g., penalty points, fines) by speed cameras for example and they witnessed it, they would be more inclined to adhere to the 20mph speed limits. *"I think it needs to be proven to work. We are going to have to see police actually patrolling the areas and saying "you did more than 20mph; there is a ticket", but nobody is doing that so people are just ignoring the 20mph zone. They're going as fast as they can" (a city centre worker FG9).* This viewpoint was also supported by a young mother who said: *"I think there needs to be speed cameras, as much as I hate to say it. I'm always the one that will get caught like, but…"(a socio-economically disadvantaged young mother FG2)* . Interestingly, participants noted that even though drivers are aware that they would be breaking the law by driving above the speed limit, they felt that some, still were not willing to change their behaviour. It was noted that for many it would take visible enforcement, publicising of this enforcement and the risk of being punished, for their behaviour to change.

Fleiter & Watson provided insight into speeding behaviour, reporting "punishment avoidance was a significant predictor of total frequency of speeding" and better enforcement and detection methods are required.[29] In addition, reports showed that when individuals regularly avoid punishment they perceive 'immunity', reiterating the need for speeding drivers to be punished and for enforcement to be publicised and witnessed.[29] Participants's reflections regarding enforcement and lack of behaviour change also went on to discuss the potential consequence of ineffectiveness of the 20mph speed limits and ultimately to question road safety: *"I would feel safer if I knew that it was enforced, it might give you a false sense of security thinking they're going at 20mph and someone might just be speeding" (a city centre worker FG9).*

When considering the participants' reflections and previous research it is evident that for behaviour change to occur, enforcement needs to be visible (e.g., speed cameras and a police presence) and strict (e.g., penalty points and fines). Taking this into consideration it would be recommended that enforcement should be added along with awareness to the suite of intervention strategies. However, there may be little hope of consistent enforcement as the Department for Transport stated that there was no additional enforcement expectation by the police in regards to 20mph speed limit interventions.[30] This highlights the need for a shift in the car dominant culture not only by the general public but also by statutory bodies; and further emphasises the importance of a suite of intervention strategies to affect change to behaviours, norms and attitudes. If 20mph speed limit interventions can be given their place to operate within the complex transport system along with other community interventions (e.g., speed watch, stationary speed cameras or radar speed signs) this may not only have the capacity to affect behaviour change, resulting in beneficial public health and environmental outcomes, but it will also help to reduce the burden of enforcement on police.

Collisions and casualties

Reduced speed limit interventions have the potential to positively impact road traffic collisions and casualties.[10,11] However, previous research, has noted that although the probability of death due to a collision may reduce following speed reductions, the probability of injury may remain unchanged, highlighting that collisions may still occur but not with the same detrimental impact.[31] This was also the belief held by some of our participants who noted the intended outcome of a reduction in collision and casualty severity: *"The severity of the crash; going in a 20mph car is going to be less of an impact than 40 (a multi-modal transport user FG5)",* but the perception that rates could increase, *"The number might increase but the severity would probably decrease (a city centre worker FG9)".*

Regarding the perceptions that 20mph speed limits could lead to an increased rate of collisions and casualties, three mechanisms were reported: 1) irate/frustrated drivers; 2) reduced driver attention (e.g., using mobile phones); and 3) pedestrians walking in front of moving cars (Figure 1). Specifically, participants reflected on the fact that not only could slower driving speeds cause drivers to become irate/frustrated but they perceived this mechanism had the potential to result in drivers making errors, and ultimately increasing the number of collisions and casualties: *"More accidents are going to happen because lots of people are swapping and changing and getting annoyed" (a socio-economically disadvantaged young mother FG2). "Yes, they're pushing you on, beeping the horn or getting road rage or speeding past you" (a multi-modal transport user FG5). "Frustration in other drivers and that might actually increase or cause some accidents, because you can have a driver coming up behind and if someone is adhering to the 20mph they might try and do an overtake or something in frustration and it might cause problems there" (a student FG8).*

In addition, participants discussed 'reduced driver attention' at lower speeds. *"With being a low speed area, they're just going to get complacent, they'll start fiddling with their phones or fiddling with the radio, so they'll not like happy until they're at the back of someone" (a commuter FG6)*; and "*You sometimes play on your phone and stuff if you're driving a bit slower" (a worker commuting through*

20mph speed limits FG7). Participants felt that this complacency has the potential to increase the rate of collisions and casualties. Reduced driver attention through mobile phone use is worrying considering 52% of drivers admitted to using their phone whilst driving.[32] In addition, previous research highlighted the compensatory belief that slowing down and self-regulating speed, compensates for unlawful mobile phone use.[33,34] Therefore, it could be purported that 20mph speed limits may facilitate mobile phone use at an operational level, by removing the requirement for drivers to self-impose/self-regulate speed, as the new legislation may provide drivers with the belief that this has been done on their behalf. These findings further supports the need for an adequate enforcement strategy not only of driving speed but also to include additional driving behaviours such as distracted driving, use of mobiles phones and tailgating.

Furthermore, a shared reflection was that all road and pavement users should be responsible for their behaviour, and not only motorised vehicle drivers. *"If you're going to put the onus on motorists to behave, you need to get pedestrians to do the same thing, if the goal is safety" (a worker commuting through 20mph speed limits FG7).* It was highlighted that safety responsibilities should be a concern for pedestrians, cyclists and drivers (car, bus, lorry etc.) alike; and if legislation is being enforced for motorised vehicle drivers there should also be legislation to regulate other road and pavement users. *"I think it would have to be both sides. I don't think it can just be the motorist that should be punished for things like that. So I think it's not fair to punish the driver and not the pedestrian. If they're going to be in front of my car then that's their fault, not mine" (a multi-modal transport user FG5).* This theme emerged due to the mechanism of reduced driving speed and pedestrians crossing in front of moving vehicles and not using specific crossing points: *"I think as a pedestrian, like you said, you just think "I'm going to run across the road here, because the traffic is slower." So, as a pedestrian, you are taking more risks because the traffic's going slower" (a worker commuting through 20mph speed limits FG7).* This finding is in contrast to anticipated findings which proposed reduced speeds would improve street-crossing conditions.[13] When considering the findings from the current study and those of

441 previous research it could be argued that the mechanism of road crossing due to slower traffic speeds
442 may be considered unintended when it results in an increased rate of road traffic collisions and
443 casualties. However, if viewed from the perspective of a pedestrian it could be considered desirable,
444 as it improves road crossing conditions.
445
446 This raises the question of whether unintended pathways always result in undesirable outcomes or if
447 they have the potential to be considered as desirable. Such deliberations emphasise the need for
448 researchers to take a systems-thinking approach and to develop not only a logic model but also a 'dark'
449 logic model that accounts for potential risk, harms and adverse outcomes, including for who.[16] In
450 addition, policy makers should also critically consider the behaviours of each of the multiple agents in
451 this complex system including but not limited to, the driver, if the purported benefits are to be
452 realised. We recommend that a more in-depth behavioural approach be taken by considering both
453 the driver and other road and pavement user's beliefs and behaviours, and incorporating these into
454 intervention logic models (intended and unintended outcomes). For instance, techniques reported by
455 Michie could be incorporated within the intervention strategy.[35] This could include practices such as:
456 1) the provision of behavioural information through social marketing to "provide information about
457 antecedents or consequences of the behaviour, or connections between them"; and/or 2)
458 punishment, "contingent aversive consequence, i.e. if and only if behaviour is not performed".[35]
459
460 ***Improved cyclist safety and liveability***
461 Findings that related to the potential reduction in traffic speed were linked to the perceived
462 improvement in cyclist safety *"For cycling it's definitely a benefit. Definitely, for me, less scared if I was*
463 *to cycle round there" (a student FG8)*; and liveability *"I think it would improve liveability. As a*
464 *pedestrian, if you're wanting to go out for dinner or whatever, or out to the shops and walk your dog*
465 *or whatever, it would probably improve your lifestyle" (a cyclist FG1).* This was further supported by a

student: *"So if the traffic's slower then parents more likely to let their kids out onto the streets to play, which will have a positive impact on liveability" (a student FG8).*

Taking into consideration that participants perceived reduced speed limits could lead to improved cyclist safety and/or liveability, as a consequence this may have the capacity to result in individuals being more inclined to: cycle or walk for travel or leisure; socialise outside; and/or let their child/ren play outdoors.[36,37] However, for these improvements to transpire and social norms to be expected and take shape, it is important to ensure that traffic speed is in fact reducing through the suite of strategies.

It should be noted, that although participants advocated for the presence of 20mph speed limits in relation to outcomes such as cyclist safety and liveability, they emphasised that the limits are only one element of the complex transport system and many more are required to instigate a modal and lifestyle change. They took the time to reflect on interventions that should be included within the suite of actions and that would operate alongside the reduced speed limits to have the greatest possibility of eliciting behaviour change and ultimately positive public health returns. Examples of interventions included: better public transport (e.g., cheaper, more frequent and better connections); improved quantity and quality of segregated bicycle lanes; community campaigns (e.g., safe street play); and safety initiatives (e.g., speed watch).

Driving behaviour

Participants described perceptions of car inefficiency, increased breaking/accelerating and increased air pollution as a result of 20mph limits: *"I think with stopping and starting your car, aren't you putting out more omissions when you're doing that than if your car is driving along at a certain speed. All that stopping and starting isn't going to do you any good" (a middle to older age adult FG3). "I thought if you were driving in a very low gear and a slow speed that you actually produce more emissions? You*

might get people revving more, because it's quite hard to drive at 20mph" (a worker commuting through 20mph speed limits FG7). "That's not good for air pollution either, if you're driving at a slow speed you're producing more gases and it's worse for the people walking around" (a city centre worker FG9).

In addition, discussions involved the potential outcome of increased noise pollution *"If you're going at 20mph there's still going to be the same amount of noise" (a worker commuting through the 20mph speed limits FG7)* and worsening traffic congestion *"If you've got traffic lights and you're waiting and then you're only going at 20mph, it's not clearing so many through" (a city centre worker FG9). "I think the traffic is heavier. I think the traffic has got heavier, because sometimes you think when they put things in place, suddenly you think, "why did you do that?"" (a socio-economically disadvantaged young mother FG2).*

Furthermore, participants questioned the need for a reduced speed limit intervention within the city centre, due to already slow travelling traffic, particularly during rush hour. *"I think as well though, because in peak times, so like 9 am and 5 pm, generally it's a car park anyway, you're sitting and stopped. So, in that respect, the 20mph becomes a bit futile at those times" (a student FG8)*. Discussions detailed the "futile" nature of the 20mph speed limits considering that due to the current congestion levels, it was difficult to get to, or go above 20mph. *"You're going so slow you probably don't infringe it anyway" (a city centre worker FG9).*

These participant reflections indicate the need for better driver training and education to be included within the suite of intervention strategies. Driver training could encourage fuel-efficient, smoother and free-flowing driving (e.g., reducing unnecessary breaking and accelerating and appropriate gear choice) which would help reduce harmful vehicle emissions and noise pollution.[38] In addition, driver education would provide all relevant information relating to the intervention rationale, the potential

outcomes/impacts and dispel any inaccurate public perceptions (i.e. car inefficiency, pollution).[39] An education campaign could be delivered through various media and/or social media channels, informing not only those who travel to and/or through speed limit areas but to all drivers in order to avoid the ripple effects of misconceptions or beliefs.

Both education and training are important considering the existing evidence presented by the National Institute for Health and Care Excellence.[38] Their guidelines recommend that a smoother, free-flowing driving style can help to reduce air pollution, with specific recommendations for the implementation of 20mph speed limit interventions to encourage this style of driving.[38] They also indicate that 20mph speed limit interventions are beneficial in areas with already low speed limits to avoid unnecessary breaking and accelerating.[38] This is interesting to note, as our participants felt there was in fact no need for the intervention when speeds were already low. However, if adequate training and education were in place the general public may understand the rationale for 20mph speed limit interventions and appreciate its implementation within their town/city.

It may also be beneficial to consider the dissemination of findings relating to the implementation of transport initatives. Findings could be disseminated in a variety of acceptable formats (e.g., social media, newsletters, briefing reports or seminars) providing interested parties with the opportunity to review the outcomes. Evaluation statistics (e.g., enforcement, road safety), research findings and future directions could all be included and provide individuals with the evidence they require to make changes to their travel and/or lifestyle behaviours.

Finally, regarding to the perception of congestion, this may not be solely due to the implementation of the 20mph speed limit intervention. With congestion already being an issue within the city centre, due to the volume of motorised vehicles travelling to/through and the numerous urban environmental factors (e.g., traffic lights, intersections, obstacles) this may hinder free flowing traffic. It may be

purported that the implementation of 20mph speed limits as standalone interventions may not result in the intended outcomes of reducing congestion or instigating a modal shift.[38,40] Therefore, it may be plausible to suggest that in addition to the 20mph speed limit intervention strategies and the interaction with other interventions, researchers, policy makers and practitioners should also consider a further integrated multi-sector approach. An approach like this has the capacity to make necessary urban environmental changes (i.e. reducing the number of obstacles (e.g., pinch points, traffic lights) and to go beyond the scope of 20mph speed limit intervention by implementing change to the urban environment, ultimately increasing the likelihood of a shift to the car-dominant paradigm.

Implications for future research, policy and practice

We feel it is vital that those designing, developing and implementing future 20mph speed limit interventions recognise that they are not standalone interventions solely implemented with the purpose of improving road safety. They should be: 1) viewed as one element of the wider complex transport system; 2) supported with a suite of behaviour change strategies (e.g., enforcement, penalties, training); and 3) have better linkage to other transport interventions (e.g., segregated bicycle lanes, improved public transport). By doing so, this may instigate changes to our car dependent society and strengthen the possibility of achieving an ambitious culture change to the car dominant paradigm.

With that being said it is still important that 20mph speed limit interventions are designed and developed by taking into consideration the factors highlighted within this study. Alongside the standard intervention activities (i.e. legislation and signage) it is plausible to recommend an additional five pronged intervention strategic approach. This includes: 1) awareness; 2) enforcement (including penalties); 3) education; 4) driver training; and 5) community and statutory engagement and involvement. In addition, this proposed approach should also be linked to and work cooperatively with

other transport interventions to “Avoid” (e.g., changes to the urban environment), “Shift" (e.g., better opportunities for public and active transport) and “Improve” (e.g., in-car interventions).[6]

Future research should aim to evaluate 20mph speed limit interventions by focusing on a range of public health outcomes beyond the impact on road traffic speed and collisions and casualties. In addition, unintended outcomes should be investigated and reported to determine the impact on health, social and environmental inequalities. Finally, more in-depth qualitative research is required to unpack the health equity impacts of the complex transport system and to investigate behaviour change.

Strengths and limitations

Strengths included the diverse sample, and data analysis performed by two trained independent researchers. Whilst we have presented and discussed the mechanisms, pathways and public health outcomes as understood by our participants, it should be noted that not all of the pathways are supported by the scientific evidence base, largely due to limited research.[10] For instance, participants described the mechanism of reduced driving speed, leading to reduced car efficiency and having the potential to result in increased air pollution. However, as there is a lack of research evaluating 20mph speed limit interventions, not all key public health outcomes have been adequately investigated and reported, meaning perceptions can neither be confirmed or refuted.[8,10] Consequently, this may be considered a limitation of the study.

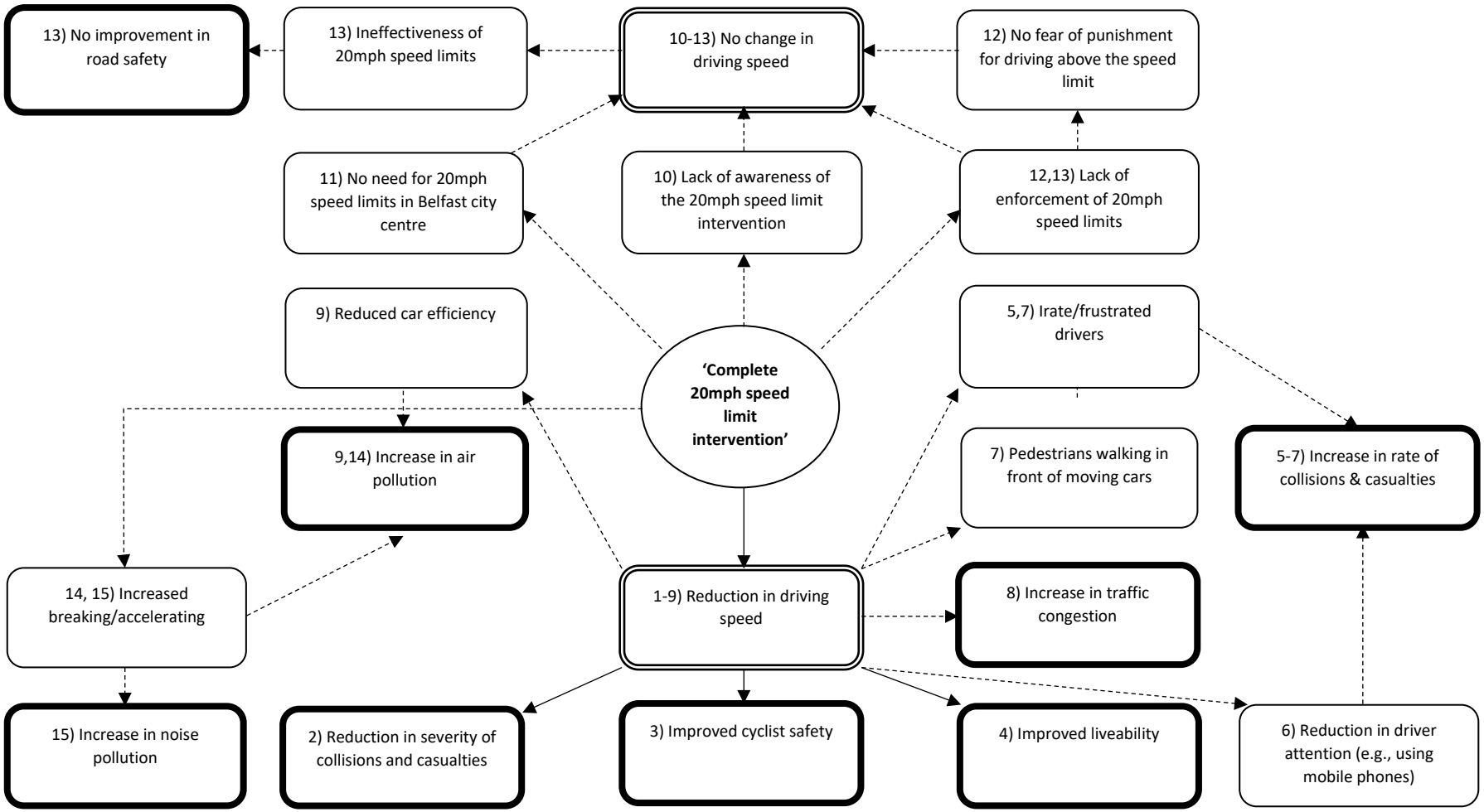
In addition, it was not possible to disentangle whether participants were reporting reflections/perceptions, accurate behaviours or carefully assessed predictions about the effects of the 20mph speed limits. Each of the participant’s perceptions, behaviours, and issues/concerns were considered and reviewed during analysis as they provide an insight into a range of acceptable responses relating to the interventions implementation. Throughout, we have been cognisant that the

20mph speed limit intervention in Belfast does not operate as a standalone intervention but sits within a complex transport system consisting of several interlinking and interacting initiatives. Consequently, this context needs to be accounted for, when considering the transferability of our findings, and their impacts on our described pathways, mechanisms and public health outcomes. However, it should be noted that the views presented by our sample, largely align with the views of the 'experts by experience' of the Edinburgh 20mph speed limit intervention, furthering emphasising that public perceptions and experiences of 20mph speed limit interventions need to be highlighted and considered.

CONCLUSIONS

We identified the pathways, mechanisms and public health outcomes (intended and unintended) that participants described following the implementation of 20mph speed limits in Belfast. Our findings illustrate the complex nature (i.e. positive and negative) of the way people understand 20mph speed limit interventions and the numerous interacting mechanisms and pathways that resulted in mixed experiences. The pathways align with those proposed by Turner and further enriches our understanding of the mechanisms and pathways operating within 20mph speed limit interventions. Future 20mph speed limit interventions should consider a wide range of possible public health outcomes, but be cognisant of potential unintended outcomes and harms, 'designing in' strategies to enhance effectiveness and mitigate challenges.

Figure 1. Concept map detailing the perceived intended and unintended public health outcomes of the Belfast city centre 20mph speed limit intervention



- - - > unintended public health outcome; ⟶ intended public health outcome; a bold outlined box represents a public health outcome; a double lined box represents a mechanism and a public health outcome; and a non-bold box represents a mechanism

REFERENCES

1. Gershenson, C. Improving urban mobility by understanding its complexity. [Internet]. 2016. Available from: https://arxiv.org/ftp/arxiv/papers/1603/1603.04267.pdf
2. Marmot M, Bell R. Fair society, healthy lives. Public Health. 2012;126(1):4–10.
3. Braveman P, Egerter S, Williams DR. The Social Determinants of Health: Coming of Age. Annu Rev Public Health. 2011;42(4):768–72.
4. The Health Foundation. What makes us healthy? An introduction to the social determinants of health [Internet]. 2018. Available from: https://www.health.org.uk/sites/default/files/What-makes-us-healthy-quick-guide.pdf
5. Cohen JM, Boniface S, Watkins S. Health implications of transport planning, development and operations. J. Transp. Health. 2014;1(1):63-72.
6. International Transport Forum. A new paradigm for urban mobility. [Internet]. 2015. Available from: https://www.itf-oecd.org/sites/default/files/docs/cop-pdf-03.pdf
7. Gaca S, Kiec M, Budzynski M. Evaluating the Effectiveness of Non-Physical Speed Management Measures. International Conf Traffic Transp. 2016;9:627–33.
8. Atkins, AECOM, Maher, M. Process and Impact Evaluation Headline Report. Atkins Global, London. [Internet]. 2018. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/757307/20mph-headline-report.pdf
9. Bornioli A, Bray I, Pilkington P, Bird EL. The effectiveness of a 20mph speed limit intervention on vehicle speeds in Bristol, UK: a non-randomised stepped wedge design. Journal of Transport and Health. 2018;11:47-55.
10. Cleland CL, McComb K, Kee F, Jepson R, Kelly M, Milton K, Nightingale G, Kelly P, Baker G, Craig N, Williams AJ, Hunter R. A systematic review to examine the effects of 20mph speed limits and 20mph zones on a range of public health outcomes using the meta-narrative method. Journal of Transport & Health. 2019.

11. Cairns J, Warren J, Garthwaite K, Greig G, Bambra C. Go slow: an umbrella review of the effects of 20 mph zones and limits on health and health inequalities. J. Public Health. 2015;37(3):515-520.
12. Toy S, Tapp A, Musselwhite C, Davis A. Can social marketing make 20mph the new norm? J Transp Heal. 2014;1(3):165-173.
13. Turner K, Jepson R, MacDonald B, Kelly P, Biggs H, Baker G. Developing and refining a programme theory for understanding how twenty mile per hour speed limits impact health. Journal of Transport & Health. 2018:92-110.
14. Moore GF, Audrey S, Barker M, Bond L, Bonell C, Hardeman W, et al. Process evaluation of complex interventions: Medical Research Council guidance. BMJ. 2015.
15. Lewis CC, Klasnja P, Powell BJ, Lyon AR, Tuzzio L, Jones S, et al. From classification to causality: advancing understanding of mechanisms of change in implementation science. Front Public Health. 2018;6:136.
16. Bonell C, Jamal F, Melendez-Torress GJ, Cummins S. 'Dark logic': theorising the harmful consequences of public health interventions. Journal of Epidemiology and Community Health. 2015;69(1):95–98.
17. Oliver K, Lorenc T, Tinkler J, Bonell C. Understanding the unintended consequences of public health policies: The views of policymakers and evaluators. BMC Public Health 2019;19:1057.
18. Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. Int. J. Qual. Health Care. 2007;19:349– 357.
19. Department for Infrastructure. Map and schedule of streets for the Belfast City centre 20 mph speed limit zone. [Internet]. 2016. Available from: https://www.infrastructure-ni.gov.uk/publications/map-and-schedule-streets-belfast-city-centre-20-mph-speed-limit-zone

20. Nyumba TO, Wilson KA, Derrick C, Mukherjee N. The use of focus group discussion methodology: Insights from two decades of application in conservation. Methods in Ecology and Evolution. 2017.
21. Braun V, Clarke V. Using thematic analysis in psychology. Qual. Res.Psych.2006;3:77–101.
22. Daley BJ. Using concept maps in qualitative research. In A. J. Caňas, J. D. Novak, & F. M. Gonzales (Eds.), Concept maps: Theory, methodology and technology (Proceedings of the First International Conference on Concept Mapping). 2004:1;191-197.
23. Kinchin IM, Streatfield D, Hay DB. Using concept mapping to enhance the research interview. International Journal of Qualitative Methods. 2010;9(1):52-68.
24. Novak JD, Cañas AJ. The Theory Underlying Concept Maps and How to Construct and Use Them. Technical Report. Institute for Human and Machine Cognition, Florida. [Internet]. 2008. Available from: http://cmap.ihmc.us/docs/theory-of-concept-maps.php
25. Dishion TJ, McCord J, Poulin F. When interventions harm. Am Psychol 1999;54:755–64
26. Hawe P, Shiell A, Riley T. Theorising interventions as events in systems. Am J Community Psychol 2009;43:267–6.
27. Rutter H, Savona N, Glonti K, Bibby J, Cummins S, Finegood DT, Greaves F, Harper L, Hawe P, Moore L, et al. The need for a complex systems model of evidence for public health. Lancet. 2017;390(10112):2602–4.
28. Kelly MP, Barker M. Why is changing health-related behaviour so difficult? Public Health. 2016;136:109-116.
29. Fleiter JJ, Watson B. The speed paradox: the misalignment between driver attitudes and speeding behaviour. Journal of the Australasian College of Road Safety. 2006;17(2):2330.
30. Department for Transport. Setting Local Speed Limits. Circular. DfT 01/2013 London: Department for Transport. [Internet]. 2013. Available from: https://www.gov.uk/government/publications/setting-local-speed-limits/setting-local-speed-limits

31. Mohit B, Rosen Z, Muennig PA. The impact of urban speed reduction programs on health system cost and utilities. Injury Prevention. 2017.
32. Department for Infrastructure. Publication of road safety issues in Northern Ireland 2017/2018. Department for Infrastructure. [Internet]. 2019. Available from: https://www.infrastructure-ni.gov.uk/news/publication-road-safety-issues-northern-ireland-20172018
33. Zhou R, Yu M, Wang X. Why Do Drivers Use Mobile Phones While Driving? The Contribution of Compensatory Beliefs. PloS one. 2016;11(8).
34. King M, Legge M, Oviedo-Trespalacios O, Regan M, Rakotonirainy A. Scoping study of mobile phone use while driving: Final Report. Centre for Accident Research and Road Safety - Queensland, Australia [Internet]. 2017. Available from: https://eprints.qut.edu.au/121618/
35. Michie S, Johnston M, Francis J, Hardeman W, Eccles M. From theory to intervention: Mapping theoretically derived behavioral determinants to behavior change techniques. Appl Psychol. 2008;57:660–680.
36. Mertens L, Compernolle S, Gheysen F et al. Perceived environmental correlates of cycling for transport among adults in five regions of Europe. Obes Rev. 2016;17(1):53–61.
37. Götschi T, de Nazelle A, Brand C, Gerike R. Towards a comprehensive conceptual framework of active travel behavior: A review and synthesis of published frameworks. Curr. Environ. Health Rep. 2017;4:286–295.
38. National Institute for Health and Care Excellence. Air pollution: outdoor air quality and health NICE guidelines [NG70]. National Institute for Health and Care Excellence. [Internet]. 2017. Available from: https://www.nice.org.uk/guidance/ng70
39. Tapp A, Nancarrow C, Davis A. Support and compliance with 20mph speed limits in Great Britain. Transp Res Part F Traffic Psychol Behav. 2015;31:36–53.
40. The World Health Organization. Road Traffic Injuries [Internet]. 2020. Available from: https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries

41. Jepson R, Baker G, Cleland C, Cope A, Craig N, Hunter R, Foster C, Kee F, Kelly M, Kelly P, Milton K, Nightingale G, Turner K, Williams AJ, Woodcock J. Evaluation of the 20mph Speed Limit Networks in Edinburgh and Belfast on a Range of Public Health Outcomes: A Mixed Methods Approach. National Institute of Health Research. 2021.