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

3
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29 **Declaration of interest**

30 Declarations of interest none.

31
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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

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

68

69 **INTRODUCTION**

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

81

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

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

94

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

103

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

110

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

128

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

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

139

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

146

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

159

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

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

165

166 **Aim**

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

170

171 **METHODS**

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

176

177 **20mph speed limit intervention**

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

186

187 The new speed limits operate 24 hours per day, seven days per week, with intervention activities
188 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

205

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

215

216 **Topic Guide**

217 Questions were initially developed by the research team (CC, RH, GB and KT), guided by the published
 218 programme theory.¹³ This programme theory was developed by considering multiple facets of public
 219 qualitative opinion (i.e. semi-structured interviews and focus groups) and a review of the literature.
 220 The programme theory aimed to assist evaluations of 20mph speed limit interventions through
 221 outlining proposed mechanisms and pathways between intervention activities and outcomes.^{10,13} The
 222 topic guide consisted of nine overarching topics: 1) awareness; 2) engagement; 3) intervention
 223 rationale; 4) perceptions; 5) enforcement; 6) driver behaviour change following the implementation
 224 of the intervention; 7) change in other road users' behaviours; 8) liveability; and 9) other (Table 2).
 225 The topic guide was reviewed by the wider "is 20 plenty for health?" research team and piloted with
 226 colleagues within Queen's University Belfast who were external to the research team. During the focus
 227 groups, a flexible approach was taken to initiate conversations with and between participants and to
 228 cover as much of the topic guide as possible and relevant.
 229

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

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

	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?	Stop - start Smoother driving – more/less breaking, harsh or less harsh acceleration
	Has it changed your driving behaviour?	Traffic flow
	If yes in what way?	Less frequent stops and braking
	If no why not?	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	

230

231 **Study participants**

232 In total, nine focus groups were conducted involving 60 participants (mean age 43 years (*SD*17), 73%

233 (n=44) female, mostly with no disability or medical conditions that make mobility difficult (n=55, 92%)

234 and who mostly self-classified their ethnic group as white (n=57, 95%). The participants included older

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

239

240 **Data collection**

241 The focus groups were conducted approximately 29-34 months after the implementation of the
242 20mph speed limit intervention (July-Dec 2018). Therefore, the majority of participants had been
243 exposed to the reduced speed limits for over two years prior to participating in this study. Focus
244 groups were held in a convenient location for participants (e.g., community centre, place of work)
245 and lasted approximately one hour. On arrival participants were provided with the opportunity to ask
246 questions to gain further clarification, they provided informed written consent and completed a short
247 demographic questionnaire. Each focus group was conducted by one researcher (CC). CC is a Research
248 Fellow who holds a PhD in Public Health, has completed formal qualitative training and has over 10
249 years' experience of qualitative research methods and analysis. To ensure transparent reporting, CC
250 is a car owner, road user, walks as a method of active transport and uses public transport (i.e. bus and
251 rapid transport). CC is not a local resident of Belfast and has undertaken no prior research in this area,
252 reducing the risk of having any pre-conceptions or beliefs about the intervention. Each participant was
253 compensated for their time by receiving a £10 gift voucher. Recruitment stopped once the research
254 team were satisfied that no new themes were generated and each key sub-group had been
255 represented (where possible).

256

257 **Data management and analysis**

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

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

267

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

272

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

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

288

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

298

299 **RESULTS AND DISCUSSION**

300 The first stage of data analysis established three overarching themes: 1) reduced driving speed; 2) no
301 change in driving speed; and 3) driving behaviour. Subsequently, as a result of the retrospective
302 concept mapping approach a range of key mechanisms (n = 12), pathways (n = 15) and public health
303 outcomes (n = 10) were identified. In addition, it was also possible to categorise each mechanism,
304 pathway and public health outcome as 'intended' or 'unintended', with the majority of outcomes (n =
305 6 of 10) being categorised as unintended (Figure 1). The mixed findings that transpired within this
306 study reiterate the multi-faceted nature of 20mph speed limit interventions and reaffirm that whilst
307 interventions can result in purported intended outcomes, there is also the possibility that unintended
308 and potentially harmful impacts can arise, disrupting the wider complex system.^{16,25-27} For the
309 purposes of this discussion we have grouped and contextualised the findings within the broader
310 literature: Driving speed; Collisions and casualties; Improved cyclist safety and liveability; and Driving
311 behaviour.

312 **Driving speed**

313 It could be assumed that the implementation of 20mph speed limit interventions which include a
314 Traffic Limit Order and 20mph signage, change driving behaviour and consequently reduce speeds to
315 20mph or below. However, this may not always be the case with findings presenting pathways that
316 related to both reduced driving speeds (i.e. nine pathways) and no change in driving speeds (i.e. four
317 pathways). For the participants in this study, a lack of awareness of the intervention was an issue.
318 *“Really? The 20mph zone? We should have been doing 20mph for the last two years? (Laughter)” (a*
319 *city centre worker FG9)”. Participants reported being unsighted about any awareness campaigns in*
320 *the media or social media with an older adult stating “no flyers, no posters. I used to be in advertising*
321 *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*
322 *seen nothing. I would imagine, as a resident of Belfast, I would be a prime target market - it hasn’t got*
323 *to me. I don’t think I’m particularly stupid, I would have seen it; I haven’t, you know” (an older adult*
324 *FG4). Participants also reported a lack of awareness of specific intervention details (e.g.,*
325 *implementation dates, scope, and signage location) “At the minute I’m not even sure that everyone*
326 *knows about the fact that it is 20mph in the city centre. When did it actually come into effect?” (a*
327 *cyclist FG1).*

328

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

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

347

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

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

373

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

387

388 ***Collisions and casualties***

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

397

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

410

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

415 20mph speed limits FG7). Participants felt that this complacency has the potential to increase the rate
416 of collisions and casualties. Reduced driver attention through mobile phone use is worrying
417 considering 52% of drivers admitted to using their phone whilst driving.³² In addition, previous
418 research highlighted the compensatory belief that slowing down and self-regulating speed,
419 compensates for unlawful mobile phone use.^{33,34} Therefore, it could be purported that 20mph speed
420 limits may facilitate mobile phone use at an operational level, by removing the requirement for drivers
421 to self-impose/self-regulate speed, as the new legislation may provide drivers with the belief that this
422 has been done on their behalf. These findings further supports the need for an adequate enforcement
423 strategy not only of driving speed but also to include additional driving behaviours such as distracted
424 driving, use of mobiles phones and tailgating.

425

426 Furthermore, a shared reflection was that all road and pavement users should be responsible for their
427 behaviour, and not only motorised vehicle drivers. *"If you're going to put the onus on motorists to
428 behave, you need to get pedestrians to do the same thing, if the goal is safety"* (a worker commuting
429 through 20mph speed limits FG7). It was highlighted that safety responsibilities should be a concern
430 for pedestrians, cyclists and drivers (car, bus, lorry etc.) alike; and if legislation is being enforced for
431 motorised vehicle drivers there should also be legislation to regulate other road and pavement users.
432 *"I think it would have to be both sides. I don't think it can just be the motorist that should be punished
433 for things like that. So I think it's not fair to punish the driver and not the pedestrian. If they're going
434 to be in front of my car then that's their fault, not mine"* (a multi-modal transport user FG5). This theme
435 emerged due to the mechanism of reduced driving speed and pedestrians crossing in front of moving
436 vehicles and not using specific crossing points: *"I think as a pedestrian, like you said, you just think "I'm
437 going to run across the road here, because the traffic is slower." So, as a pedestrian, you are taking
438 more risks because the traffic's going slower"* (a worker commuting through 20mph speed limits FG7).
439 This finding is in contrast to anticipated findings which proposed reduced speeds would improve
440 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

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

468

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

475

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

485

486 ***Driving behaviour***

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

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

496

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

504

505 Furthermore, participants questioned the need for a reduced speed limit intervention within the city
506 centre, due to already slow travelling traffic, particularly during rush hour. *“I think as well though,*
507 *because in peak times, so like 9 am and 5 pm, generally it's a car park anyway, you're sitting and*
508 *stopped. So, in that respect, the 20mph becomes a bit futile at those times”* (a student FG8).

509 Discussions detailed the “futile” nature of the 20mph speed limits considering that due to the current
510 congestion levels, it was difficult to get to, or go above 20mph. *“You're going so slow you probably*
511 *don't infringe it anyway”* (a city centre worker FG9).

512

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

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

522

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

532

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

539

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

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

552

553 **Implications for future research, policy and practice**

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

562

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

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

571

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

578

579 **Strengths and limitations**

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

589

590 In addition, it was not possible to disentangle whether participants were reporting
591 reflections/perceptions, accurate behaviours or carefully assessed predictions about the effects of the
592 20mph speed limits. Each of the participant’s perceptions, behaviours, and issues/concerns were
593 considered and reviewed during analysis as they provide an insight into a range of acceptable
594 responses relating to the interventions implementation. Throughout, we have been cognisant that the

595 20mph speed limit intervention in Belfast does not operate as a standalone intervention but sits within
596 a complex transport system consisting of several interlinking and interacting initiatives. Consequently,
597 this context needs to be accounted for, when considering the transferability of our findings, and their
598 impacts on our described pathways, mechanisms and public health outcomes. However, it should be
599 noted that the views presented by our sample, largely align with the views of the ‘experts by
600 experience’ of the Edinburgh 20mph speed limit intervention, furthering emphasising that public
601 perceptions and experiences of 20mph speed limit interventions need to be highlighted and
602 considered.

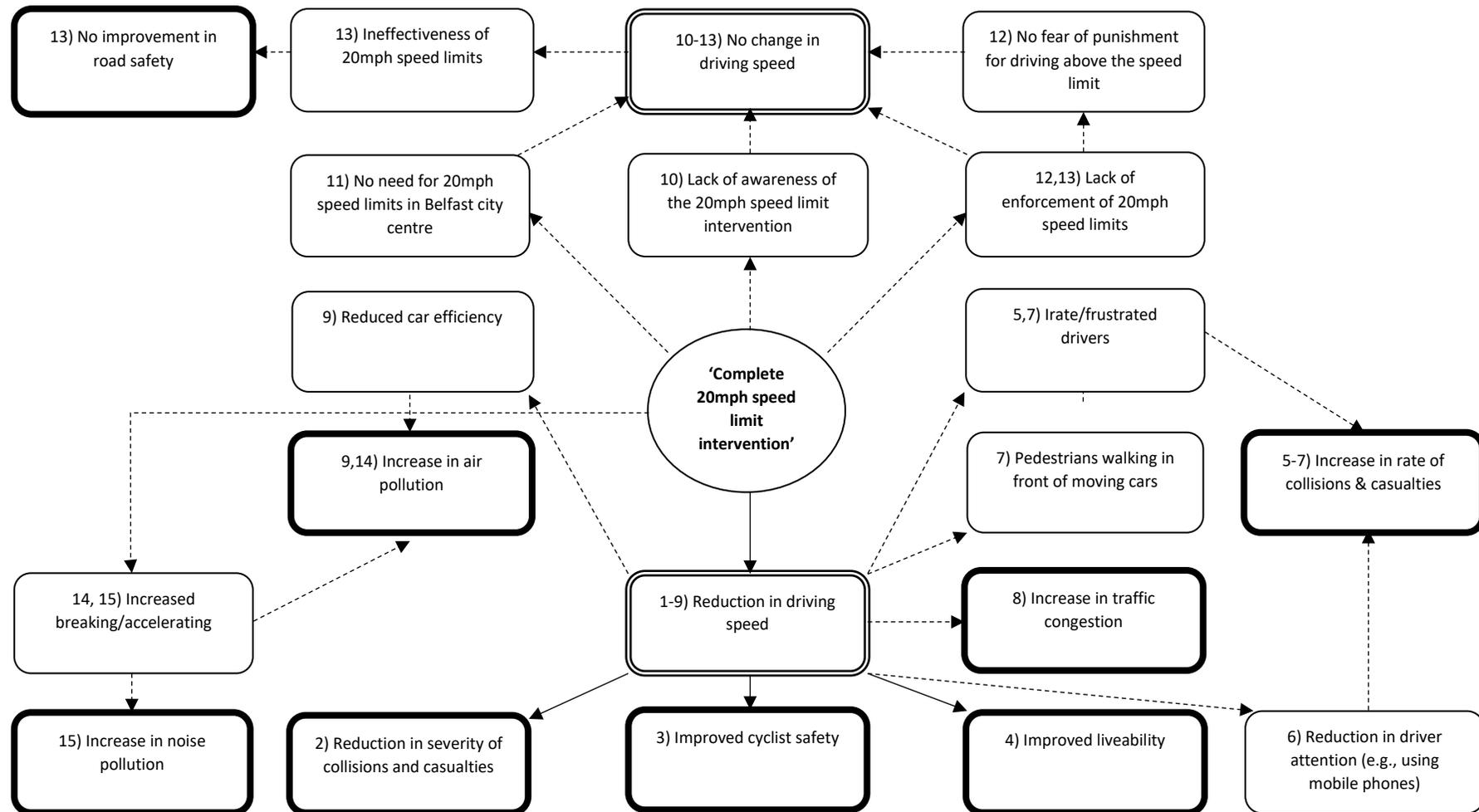
603

604 **CONCLUSIONS**

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

614

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

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