



Combinations of factors contribute to young driver crashes

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ABSTRACT

Introduction: Motor-vehicle crashes are a leading cause of death in adolescence and young adults. A multitude of factors, including skill level, inexperience, and risk taking behaviors are associated with young drivers' crashes. This research investigated whether combinations of factors underlie crashes involving young drivers. **Method:** A retrospective longitudinal study was conducted on population-wide one- and two-car crashes in Great Britain during years 2005–2012 per driver age (17–20, 21–29, 30–39, 40–49) and sex. Reporting officers provided their assessment of the factors contributing to crashes. Principal components analysis was conducted to identify combinations of factors underlying young drivers' crashes. Factor combinations, including challenging driving conditions, risk taking behaviors, and inexperience were implicated in young drivers' crashes. **Results:** Combinations of factors reveal new insights into underlying causes of crashes involving young drivers. One combination revealed that slippery roads due to poor weather pose greater risk to young drivers who are inexperienced and likely to exceed the appropriate speed. The findings motivate new policy recommendations, such as educating young drivers about the importance of adjusting their speed to the road conditions.

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1. Introduction

A quarter of deaths among 16- to 20-year-olds in the United States are caused by motor vehicle crashes (CDCP, 2015). Crashes cause suffering for injury survivors and their families and in younger age burden society due to loss of productivity and costs of medical care and treatment (Donaldson, Brooke, & Faux, 2009) for people who otherwise are in good health (Dalal, Lin, Gifford, & Svanström, 2013; Donaldson et al., 2009). A multitude of factors contribute to young drivers' crashes. For example, skill level (McGwin & Brown, 1999), inexperience (McCartt, Shabanova, & Leaf, 2003), and risk-taking behaviors (Rolison, Hanoch, Wood, & Pi-Ju, 2014), including speeding (Gonzales, Dickinson, DiGuseppi, & Lowenstein, 2005; Rolison, Regev, Moutari, & Feeney, 2018), reckless driving (Lam, 2003), and drug and alcohol impairment (Bingham, Shope, & Zhu, 2008), have all been implicated in the crashes of young drivers.

The crash rate of young drivers is markedly higher than that of other drivers in the middle-age ranges (Chen, Baker, Braver, & Li, 2000; Masten, Foss, & Marshall, 2011; Rolison & Moutari, 2018; Rolison, Hewson, Hellier, & Hurst, 2013; Rolison, Moutari,

Hewson, & Hellier, 2014b; Williams, 2003), possibly due to factors associated with their crashes. Currey, Hafetz, Kallan, Winston, and Durbin (2011) found that recognition error (e.g., inadequate surveillance, attention) and decision error (e.g., following too closely, traveling too fast for the road conditions) were often the critical reasons for young drivers' crashes. To a lesser extent, performance error (e.g., loss of control) was also associated with young drivers' crashes (Curry et al., 2011; see also McDonald, Curry, Kandadai, Sommers, & Winston, 2014). These findings indicate that driver actions, namely recognition error and decision error, may partly underlie young drivers' crashes.

The crashes of young drivers may result from combinations of multiple co-occurring factors. That is, a crash may result not from a single driver fault, but from a combination of factors. For instance, poor weather conditions (e.g., slippery road due to rain) may increase risk for drivers who are traveling too fast for the conditions. As a multitude of factors (e.g., skill, inexperience, risk taking) have been associated with young drivers' crashes, their crashes may result from certain combinations of co-occurring driver actions and behaviors. For instance, a crash could result from a young driver failing to look properly whilst exceeding the speed limit. In such cases, multiple driver errors would underlie a driver's contribution to their crash, where each co-occurring factor contributes in some way to cause the crash. Age differences in the combinations of factors associated with drivers' crashes may pro-

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vide a richer account of age differences in crash causation by capturing multiple co-occurring factors that contribute to their crashes. In the current research, we investigated whether combinations of factors underlie crashes of young drivers and whether such combinations of factors are unique to young drivers' crashes, differing from those that underlie crashes of drivers in the middle age ranges.

2. Methods

2.1. Data sources

Data were collected on population-wide motor vehicle crashes per driver age (17–20, 21–29, 30–39, 40–49) and sex involving one- and two-vehicles occurring in Great Britain (England, Scotland, and Wales) during years 2005–2012. All crashes involved one or more road user (i.e., driver, passenger, pedestrian, cyclist) injuries. Local processing authorities (police, local authority, contractor) provided the casualty data to the UK Department for Transport (DfT) for public consumption and are referred to as STATS19 data (UK DfT, 2018b). In each event record, the reporting police officer provided a subjective assessment of the factors they believe contributed to the crash. The contributory factor data reflect opinions of the reporting officer and are intended to cast light on the underlying causes of road accidents (DfT, 2014). In this section of the report, the officer selected from seven categories up to six contributory factors per crash, including road environment (e.g., slippery road [due to weather]), vehicle defects (e.g., defective lights or indicators), injudicious actions (e.g., following too close), error or reaction (e.g., failure to look properly), impairment or distraction (e.g., impaired by alcohol), behavior or inexperience (e.g., careless, reckless, or in a hurry), and vision affected (e.g., dazzling sun; UK DfT, 2018a). Contributory factors were included only if in the crash record they were associated with the driver of the specified age and sex. As few factors accounted for the majority of crashes we focussed our investigation on the 15 most frequently reported factors.

2.2. Statistical analysis

Principal components analysis (PCA) with orthogonal varimax rotation was conducted on the 15 contributory factors to explore factor clusters contributing to 17- to 20-year-old male and female driver crashes. Orthogonal rotation was employed as we had no a priori expectations that the principal components would exhibit inter-correlations. The PCA was based on the tetrachoric correlation matrix for use with binary data (Kolenikov & Angeles, 2009). The scree plot of eigenvalues was used to determine the number of components for extraction, guided by a Kaiser's criterion of 1. R^2 values were calculated to estimate variance explained by each component. A rotated factor loading greater than 0.30 was used as the criterion for identifying factors clustering on each component. All analyses were conducted during years 2017–2018. Ethical approval for secondary analysis was not required as all data were made available by the UK Data Archive.

3. Results

3.1. One-car crashes

3.1.1. Factors contributing to young drivers' crashes

The heat map provided in Fig. 1 shows the frequency of each of the 15 most frequent factors per driver age and sex. The color coding indicates the most frequent (red) to the least frequent (green) factor in drivers' crashes. Loss of control was the most frequent

contributory factor in male and female drivers' one-car crashes, especially among youngest drivers as the occurrence of loss of control reduced sharply with driver age from age 17–20 years through 40–49 years (Fig. 1). Similarly, slippery road (due to weather) contributed to a large proportion of male and female drivers' crashes, and the occurrence of this factor reduced markedly with driver age. Traveling too fast for the conditions was a frequent contributor only among youngest drivers, and especially among youngest male drivers. Being a learner or inexperienced was also among the most frequent contributors to the one-car crashes of 17- to 20-year-old drivers.

3.1.2. Factor clusters contributing to young driver' crashes

Principal components analysis (PCA) on one-car crashes of 17- to 20-year-olds uncovered five clusters of factors for male drivers and four clusters for female drivers (Table 1). The first principal component, PCA1, explained the greatest proportion of variance in male and female driver crashes and reflects a combination of road environment (slippery road [due to weather], road layout [e.g., bend, hill, narrow carriageway]), driver behaviors (traveling too fast for conditions), inexperience, and loss of control. Inspection of the male and female tetrachoric correlation matrices (Table 2) confirmed positive associations between each factor in PCA1. The co-occurrence of these factors indicates that youngest drivers are at risk in challenging driving conditions due to traveling too fast for the conditions and inexperience. As such, traveling too fast for the conditions and inexperience raise the risk of losing control on slippery roads due to poor weather and on challenging road layouts.

Animal or object in carriageway, sudden braking, and swerving (and further loss of control for female drivers), clustered on PCA2. This component may reflect attempts to avoid an animal or object in the carriageway by braking suddenly or swerving, sometimes resulting in a crash due to loss of control (Table 1).

Injudicious and risk-taking behaviors, including exceeding the speed limit, impairment by alcohol, and being careless, reckless, or in a hurry clustered with loss of control on a third component (PCA3; Table 1). Inspection of the correlation matrices for male and female drivers (Table 2) revealed that impairment by alcohol and being careless, reckless, or in a hurry were positively associated with exceeding the speed limit, but not with each other. Further, exceeding the speed limit was associated with loss of control. This indicates that impairment by alcohol and being careless, reckless, or in a hurry may be two routes to excessive speed, raising young drivers' risk of losing control of their vehicle.

Fatigue and illness or disability clustered on PCA4 among male drivers, indicating a component related to driver fitness. Finally, poor turn or manoeuvre and failure to look properly clustered on PCA5 among male drivers and with inexperience on PCA4 among female drivers.

Our PCA indicated negative loadings of some contributory factors on the clusters (Table 1). Most notably, impairment by alcohol loaded negatively on PCA1, PCA2, and PCA5 among male drivers and on PCA4 among female drivers. Inspecting the correlation matrices (Table 2), impairment by alcohol was most strongly negatively associated with slippery road (due to weather) and failure to look properly within these clusters. The presence of these factors is associated with the absence of reports of alcohol impairment in the accident records, suggesting that alcohol impairment is less often involved or less often reported on when these factors are involved.

3.2. Two-car crashes

3.2.1. Factors contributing to young drivers' crashes

Observing Fig. 2, failure to look properly was the most frequent factor contributing to male and female drivers' two-car crashes,

Factors per 100 male driver crashes (one-car)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
17-20	21.7	5.3	4.1	14.0	24.1	7.6	6.4	6.1	8.4	45.2	11.3	2.0	0.4	19.4	24.6
21-29	17.5	3.3	3.2	10.1	16.9	5.9	9.5	5.0	6.5	33.5	15.9	2.7	0.9	15.0	2.9
30-39	13.5	2.6	2.5	5.1	10.8	5.6	12.6	5.1	4.9	22.9	9.9	2.7	1.5	10.0	0.6
40-49	11.4	2.5	2.1	3.0	8.3	5.1	13.5	5.4	3.7	17.6	6.4	2.7	2.4	7.6	0.3

Factors per 100 female driver crashes (one-car)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
17-20	27.4	5.8	4.1	4.7	16.9	7.5	6.1	6.3	9.2	41.6	5.0	1.5	0.7	8.9	28.6
21-29	23.3	3.9	3.2	3.4	12.4	5.7	8.6	4.9	7.8	33.5	6.5	2.0	1.1	7.3	4.5
30-39	18.2	3.1	2.3	2.0	8.9	4.9	11.3	3.9	5.5	24.4	5.5	1.6	1.6	6.2	1.5
40-49	17.0	2.6	2.0	1.5	7.6	4.5	11.7	3.3	4.6	21.0	4.5	1.8	1.9	5.2	0.8

- (A) Slippery road (due to weather)
- (B) Road layout (bend, hill, narrow carriageway)
- (C) Animal or object in carriageway
- (D) Exceeding speed limit
- (E) Traveling too fast for conditions
- (F) Poor turn or manoeuvre
- (G) Failed to look properly
- (H) Sudden braking
- (I) Swerved
- (J) Loss of control
- (K) Impaired by alcohol
- (L) Fatigue
- (M) Illness or disability, mental or physical
- (N) Careless, reckless, or in a hurry
- (O) Learner or inexperienced

Fig. 1. Frequency of contributory factors per 100 two-car crashes per driver age and sex. Color coding of the contributory factors indicates the most frequent (red) to the least frequent (green) factors contributing male and female drivers' two-car crashes among the 15 most frequently contributing factors. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Principal components analysis on one-car crashes of male and female 17- to 20-year-old drivers in Great Britain, 2005–2012.

Factor	Male drivers				
	PCA 1	PCA 2	PCA 3	PCA 4	PCA 5
Slippery road (due to weather)	0.68	-0.08	-0.31	-0.26	-0.26
Road layout (e.g., bend, hill, narrow carriageway)	0.64	0.00	-0.09	0.02	0.05
Animal or object in carriageway	-0.23	0.72	-0.25	-0.18	-0.41
Exceeding speed limit	0.06	0.06	0.71	-0.04	-0.01
Travelling too fast for conditions	0.55	-0.13	0.17	-0.34	-0.09
Poor turn or manoeuvre	0.09	0.05	0.15	0.04	0.69
Failed to look properly	-0.47	-0.12	-0.17	-0.27	0.68
Sudden braking	0.26	0.61	0.05	-0.16	0.19
Swerved	-0.04	0.87	0.05	0.10	0.03
Loss of control	0.53	0.26	0.46	0.27	0.03
Impaired by alcohol	-0.31	-0.31	0.55	0.03	-0.45
Fatigue	-0.12	0.03	0.06	0.73	-0.07
Illness or disability, mental or physical	-0.14	-0.23	-0.29	0.74	0.02
Careless, reckless, or in a hurry	-0.04	-0.08	0.61	-0.20	0.28
Learner or inexperienced	0.47	0.12	0.09	-0.17	0.17
Eigenvalues	2.17	1.93	1.74	1.56	1.54
R ²	14%	13%	12%	10%	10%
Factor	Female drivers				
	PCA 1	PCA 2	PCA 3	PCA 4	
Slippery road (due to weather)	0.79	-0.08	-0.31	0.03	
Road layout (e.g., bend, hill, narrow carriageway)	0.59	-0.03	-0.08	0.12	
Animal or object in carriageway	-0.27	0.69	-0.43	-0.12	
Exceeding speed limit	0.09	0.23	0.70	0.07	
Travelling too fast for conditions	0.63	-0.09	0.25	0.11	
Poor turn or manoeuvre	0.00	-0.01	0.29	0.56	
Failed to look properly	-0.55	-0.28	0.06	0.58	
Sudden braking	0.29	0.56	0.06	0.15	
Swerved	-0.19	0.86	0.07	0.06	
Loss of control	0.44	0.43	0.37	-0.11	
Impaired by alcohol	-0.19	-0.20	0.59	-0.34	
Fatigue	-0.12	0.04	0.22	-0.65	
Illness or disability, mental or physical	-0.27	-0.30	-0.07	-0.63	
Careless, reckless, or in a hurry	-0.07	-0.08	0.71	0.16	
Learner or inexperienced	0.36	0.18	0.05	0.32	
Eigenvalues	2.31	2.02	1.97	1.80	
R ²	15%	13%	13%	12%	

Note. Values are rotated factor loadings based on principal components analyses conducted on contributory factors in Great Britain during years 2005–2012. Values in bold identify factors clustering on each principal component as per the criteria of a rotated factor loading greater than 0.30.

Table 2
Tetrachoric inter-correlations across factors for one-car crashes of male and female 17- to 20-year old drivers.

		Male drivers														
		F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15
F1	1															
F2	0.29	1														
F3	-0.09	-0.06	1													
F4	-0.11	0.04	-0.11	1												
F5	0.29	0.22	-0.14	0.12	1											
F6	-0.14	0.05	-0.25	0.03	-0.01	1										
F7	-0.38	-0.21	-0.23	-0.08	-0.18	0.17	1									
F8	0.15	0.12	0.16	0.08	0.07	0.11	-0.04	1								
F9	-0.08	0.00	0.51	0.06	-0.09	0.08	-0.06	0.38	1							
F10	0.10	0.19	-0.10	0.24	0.24	0.10	-0.32	0.18	0.22	1						
F11	-0.27	-0.17	-0.20	0.20	-0.08	-0.10	-0.26	-0.21	-0.17	-0.04	1					
F12	-0.23	-0.13	-0.10	-0.04	-0.19	-0.08	-0.13	-0.11	0.07	0.04	0.07	1				
F13	-0.23	-0.06	-0.19	-0.13	-0.31	-0.12	-0.08	-0.26	-0.10	-0.10	-0.11	0.28	1			
F14	-0.16	-0.03	-0.23	0.29	0.08	0.11	0.09	0.03	-0.04	0.14	0.08	-0.09	-0.21	1		
F15	0.14	0.18	-0.07	0.09	0.16	0.07	-0.14	0.16	0.03	0.18	-0.20	-0.12	-0.27	0.05	1	

		Female drivers														
		F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15
F1	1															
F2	0.29	1														
F3	-0.16	-0.15	1													
F4	-0.10	0.01	-0.07	1												
F5	0.34	0.20	-0.21	0.18	1											
F6	-0.13	0.05	-0.28	0.10	0.02	1										
F7	-0.42	-0.21	-0.22	-0.02	-0.17	0.07	1									
F8	0.20	0.09	0.10	0.15	0.13	0.07	-0.15	1								
F9	-0.21	-0.06	0.49	0.14	-0.13	0.08	-0.09	0.35	1							
F10	0.14	0.17	-0.06	0.23	0.22	0.12	-0.30	0.25	0.30	1						
F11	-0.32	-0.20	-0.23	0.24	0.00	0.00	-0.10	-0.18	-0.11	-0.03	1					
F12	-0.22	-0.08	-0.05	0.03	-0.12	-0.28	-0.15	-0.08	0.03	0.06	0.23	1				
F13	-0.29	-0.21	-0.15	-0.19	-0.27	-0.25	-0.21	-0.23	-0.21	-0.10	0.05	0.21	1			
F14	-0.17	-0.06	-0.28	0.39	0.13	0.13	0.19	0.02	0.02	0.12	0.20	0.02	-0.03	1		
F15	0.13	0.18	-0.04	0.08	0.15	0.10	-0.10	0.12	0.04	0.17	-0.18	-0.07	-0.34	0.04	1	

Values are tetrachoric correlations between contributory factors in Great Britain during years 2005–2012. F1 = slippery road (due to weather); F2 = road layout (bend, hill, narrow carriageway); F3 = animal or object in carriageway; F4 = exceeding speed limit; F5 = travelling too fast for conditions; F6 = poor turn or manoeuvre; F7 = failed to look properly; F8 = sudden braking; F9 = swerved; F10 = loss of control; F11 = impaired by alcohol; F12 = fatigue; F13 = illness or disability, mental or physical; F14 = careless, reckless, or in a hurry; F15 = Learner or inexperienced.

Factors per 100 male driver crashes (two-car)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
17-20	11.4	2.3	5.0	9.8	14.3	7.3	3.5	16.2	40.9	24.8	8.5	14.6	3.9	23.3	18.6
21-29	9.5	2.9	5.3	7.0	10.8	8.3	3.4	17.8	47.6	26.9	7.6	10.0	5.8	21.3	3.2
30-39	8.0	2.9	5.3	4.7	8.4	9.1	3.0	18.8	51.0	27.9	7.5	7.6	5.0	19.6	1.9
40-49	7.6	2.8	5.2	3.7	7.4	8.4	3.0	19.2	52.4	28.0	7.3	6.9	4.2	17.8	1.7

Factors per 100 female driver crashes (two-car)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
17-20	11.2	2.3	6.0	4.2	8.7	7.9	3.4	16.3	47.1	29.2	8.4	9.5	2.0	14.4	22.9
21-29	10.3	2.7	5.8	3.7	7.6	9.1	3.1	16.8	51.6	29.4	7.7	8.1	2.6	15.6	4.6
30-39	8.7	2.6	5.6	3.1	6.9	8.6	3.0	17.6	54.6	28.8	7.0	6.6	2.7	15.8	2.6
40-49	8.5	2.6	6.1	3.0	6.6	8.3	3.2	17.6	55.6	28.9	6.8	6.3	2.7	15.8	2.1

- | | | |
|--|--|--|
| (A) Slippery road (due to weather) | (B) Disobeyed automatic traffic signal | (C) Disobeyed give way or stop sign or marking |
| (D) Exceeding speed limit | (E) Traveling too fast for conditions | (F) Following too close |
| (G) Junction overshoot | (H) Poor turn or manoeuvre | (I) Failed to look properly |
| (J) Failed to judge another person's path or speed | (K) Sudden braking | (L) Loss of control |
| (M) Impaired by alcohol | (N) Careless, reckless, or in a hurry | (O) Learner or inexperienced |

Fig. 2. Frequency of contributory factors per 100 two-car crashes per driver age and sex. Color coding of the contributory factors indicates the most frequent (red) to the least frequent (green) factors contributing male and female drivers' two-car crashes among the 15 most frequently contributing factors. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

followed by failure to judge another person's path or speed, poor turn or manoeuvre, and among male drivers, being careless, reckless, or in a hurry. Regarding age differences, travelling too fast for the road conditions and being careless, reckless, or in a hurry reduced markedly with age among male drivers. Being a learner or inexperienced was a frequent contributor only to the two-car crashes of 17- to 20-year-olds.

3.2.2. Factor clusters contributing to young drivers' crashes

Principal components analysis (PCA) on two-car crashes revealed three clusters of factors contributing to 17- to 20-year-old male and female driver crashes (Table 3). The first principal component, PCA1, explained the greatest proportion of variance and has similarities with PCA1 for one-car crashes, reflecting a combination of road environment (slippery road [due to weather]), risk taking behaviors (traveling too fast for conditions), injudicious actions among male drivers (exceeding the speed limit, impaired by alcohol), and loss of control. Inspection of the male and female driver correlation matrices (Table 4) indicated positive association between loss of control and each other PCA1 factor, indicating that risk-taking and injudicious behaviors raise the risk of 17- to 20-year-old drivers losing control on slippery roads in poor weather conditions and colliding with another vehicle.

Table 3
Principal components analysis on two-car crashes of male and female 17- to 20-year-old drivers in Great Britain, 2005–2012.

Factor	Male drivers		
	PCA 1	PCA 2	PCA 3
Slippery road (due to weather)	0.48	-0.09	0.53
Disobeyed automatic traffic signal	-0.01	0.04	-0.64
Disobeyed give way, stop sign, or markings	-0.27	0.77	0.14
Exceeding speed limit	0.44	0.08	-0.22
Travelling too fast for conditions	0.56	-0.03	0.35
Following too close	-0.14	-0.74	0.25
Junction overshoot	-0.01	0.71	0.17
Poor turn or manoeuvre	-0.34	0.10	-0.12
Failed to look properly	-0.75	0.17	-0.02
Failed to judge other person's path or speed	-0.58	-0.26	0.14
Sudden braking	0.19	-0.48	0.51
Loss of control	0.77	-0.04	0.11
Impaired by alcohol	0.43	0.07	-0.61
Careless, reckless, or in a hurry	0.15	0.17	-0.15
Learner or inexperienced	0.09	0.13	0.38
Eigenvalues	2.70	2.06	1.82
R ²	18%	14%	12%
Factor	Female drivers		
	PCA 1	PCA 2	PCA 3
Slippery road (due to weather)	0.72	-0.10	0.25
Disobeyed automatic traffic signal	-0.10	0.01	-0.57
Disobeyed give way, stop sign, or markings	-0.24	0.73	0.09
Exceeding speed limit	0.12	0.03	-0.37
Travelling too fast for conditions	0.60	-0.05	0.11
Following too close	0.01	-0.79	0.22
Junction overshoot	0.06	0.61	0.08
Poor turn or manoeuvre	-0.34	0.22	0.04
Failed to look properly	-0.70	0.19	0.17
Failed to judge other person's path or speed	-0.53	-0.30	0.21
Sudden braking	0.33	-0.60	0.39
Loss of control	0.75	0.02	-0.02
Impaired by alcohol	0.17	0.01	-0.78
Careless, reckless, or in a hurry	-0.03	0.13	-0.22
Learner or inexperienced	0.19	0.24	0.42
Eigenvalues	2.58	2.16	1.65
R ²	17%	14%	11%

Note. Values are rotated factor loadings based on principal components analyses conducted on contributory factors in Great Britain during years 2005–2012. Values in bold identify factors clustering on each principal component as per the criteria of a rotated factor loading greater than 0.30.

Disobeyed give way, stop sign, or markings and junction overshoot clustered on PCA2 (Table 3). These two factors were positively associated in the correlation matrices (Table 4), indicating that overshooting a junction due to failure to give way or stop at a stop sign or markings is a cause of 17- to 20-year-old drivers colliding with other vehicles.

Sudden braking and inexperience (and further slippery road [due to weather], traveling too fast for conditions among male drivers) clustered on PCA3 (Table 3), suggesting that among male 17- to 20-year-olds slippery road (due to weather) and traveling to fast for conditions may exacerbate risk of sudden braking leading to a crash with another vehicle.

Our PCA indicated negative loadings of some contributory factors on the clusters for two-car crashes (Table 3). Among male and female drivers, poor turn or manoeuvre, failure to look properly, and failure to judge another person's path or speed loaded negatively on PCA1, suggesting that some crashes that involve combinations of the road environment (e.g., slippery road [due to weather]) and risk taking behaviors (traveling too fast for conditions) or injudicious actions (exceeding the speed limit) less often involve also judgment and decision making errors.

4. Discussion

The aim of the current research was to investigate whether combinations of factors underlie crashes of young drivers. A combination of characteristics of the road environment (slippery road due to weather, road layout [e.g., bend, hill, narrow carriageway]), traveling too fast for the conditions, inexperience, and loss of control accounted for the greatest portion of variance in young drivers' one-car crashes. While previous research has implicated individual factors (e.g., inexperience, excessive speed; Gonzales et al., 2005; McCartt et al., 2003) in the crashes of young drivers, our findings reveal co-occurrences of factors that indicate traveling too fast for the road conditions and inexperience raise young drivers' risk of losing control of their vehicle in challenging driving conditions. Hence, some road conditions pose greater risk to young drivers who are inexperienced and likely to exceed the appropriate speed.

In European countries, skid training on slippery roads has been included in driver training courses with limited success in reducing numbers of slippery road accidents (Katila, Keskinen, & Hatakka, 1996; Katila, Keskinen, Hatakka, & Laapotti, 2004). A criticism of these training programs is that the manoeuvring exercises they include lead to false impressions among students that development of manoeuvring skills is more important than anticipation skills for slippery roads (Katila et al., 1996). Our findings suggest that young drivers poorly anticipate manoeuvring on slippery roads by traveling too fast for the conditions, which may partly reflect poor judgment of the appropriate speed due to inexperience. It is known that young drivers are prone to speeding (Gonzales et al., 2005). Our findings further show that speeding is particularly dangerous for young drivers in challenging road conditions as this often co-occurs with losing control of their vehicle. Driver training programs may be enhanced if they educate drivers about the importance of adjusting their speed to the road conditions and advise on appropriate speeds for conditions. Further, vehicle licensing for novice drivers could focus more on driving in poor weather and assess novice drivers' skills in judging acceptable driving speeds in adverse weather conditions. Previous research has shown that young drivers, in comparison with drivers in other age ranges, overestimate their driving skills (De Craen, Twisk, Hagenzieker, Elffers, & Brookhuis, 2011; Mueller & Trick, 2012). In the Mueller and Trick (2012) study, young novice drivers exhibited slower hazard response times in a driving simulator than more experienced drivers and adjusted their speed less in response

Table 4
Tetrachoric inter-correlations across factors for two-car crashes of male and female 17- to 20-year old drivers.

		Male drivers														
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	
F1	1															
F2	-0.19	1														
F3	-0.18	-0.17	1													
F4	-0.02	0.04	0.02	1												
F5	0.39	-0.15	-0.10	0.20	1											
F6	0.02	-0.29	-0.39	-0.09	0.07	1										
F7	-0.03	0.00	0.43	-0.02	-0.06	-0.35	1									
F8	-0.23	-0.12	-0.03	-0.10	-0.18	-0.22	-0.10	1								
F9	-0.39	-0.02	0.27	-0.18	-0.33	-0.04	0.04	0.21	1							
F10	-0.20	-0.16	0.00	-0.09	-0.21	0.15	-0.15	0.10	0.24	1						
F11	0.26	-0.31	-0.32	0.01	0.14	0.39	-0.10	-0.27	-0.23	0.04	1					
F12	0.29	-0.29	-0.32	0.28	0.35	-0.21	-0.12	-0.09	-0.50	-0.37	0.16	1				
F13	-0.15	0.10	-0.05	0.24	-0.05	-0.18	0.02	-0.19	-0.33	-0.29	-0.20	0.18	1			
F14	-0.15	0.03	0.07	0.20	0.09	-0.09	0.01	0.03	-0.02	-0.10	-0.06	0.11	0.01	1		
F15	0.09	-0.06	-0.02	0.01	0.08	-0.04	0.03	-0.03	-0.09	-0.03	0.06	0.12	-0.22	0.02	1	

		Female drivers														
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	
F1	1															
F2	-0.11	1														
F3	-0.22	-0.19	1													
F4	-0.07	0.04	-0.01	1												
F5	0.41	-0.13	-0.11	0.14	1											
F6	0.05	-0.22	-0.47	-0.07	0.16	1										
F7	-0.04	0.03	0.37	0.02	0.01	-0.30	1									
F8	-0.27	-0.10	0	-0.01	-0.17	-0.30	-0.11	1								
F9	-0.44	-0.07	0.26	-0.01	-0.26	-0.12	0.03	0.16	1							
F10	-0.24	-0.20	-0.06	0.04	-0.17	0.13	-0.13	0.10	0.17	1						
F11	0.31	-0.25	-0.39	-0.03	0.19	0.45	-0.21	-0.31	-0.26	0.02	1					
F12	0.34	-0.30	-0.29	0.15	0.30	-0.13	-0.11	-0.06	-0.46	-0.36	0.20	1				
F13	-0.09	0.11	-0.02	0.19	-0.01	-0.14	-0.01	-0.15	-0.26	-0.16	-0.25	0.11	1			
F14	-0.17	0.02	0.12	0.18	0.11	-0.08	-0.04	0.08	0.08	-0.03	-0.10	0.07	0.02	1		
F15	0.09	-0.04	-0.04	0.00	0.04	-0.09	0.06	0	-0.09	-0.06	-0.01	0.11	-0.27	-0.06	1	

Values are tetrachoric correlations between contributory factors in Great Britain during years 2005–2012. F1 = slippery road (due to weather); F2 = disobeyed automatic traffic signal; F3 = disobeyed give way or stop sign or marking; F4 = exceeding speed limit; F5 = travelling too fast for conditions; F6 = following too close; F7 = junction overshoot; F8 = poor turn or manoeuvre; F9 = failed to look properly; F10 = failed to judge another person's path or speed; F11 = sudden braking; F12 = loss of control; F13 = impaired by alcohol; F14 = careless, reckless, or in a hurry; F15 = Learner or inexperienced

to weather hazards. Our findings resonate with these studies by showing that excessive speed among young drivers raises their risk of a crash in challenging driving conditions.

The co-occurrence of injudicious (exceeding the speed limit, impairment by alcohol) and risk taking (being careless, reckless, or in a hurry) behaviors in the one-car crashes of young male and female drivers indicates that certain combinations of behaviors are associated with young drivers' crashes. Alcohol impairment and being careless, reckless, or in a hurry were independent of each other, but each occurred in association with exceeding the speeding limit, which in turn, was associated with loss of control. This pattern of findings implies that impairment by alcohol and being careless, reckless, or in a hurry are two separate causes of speeding among young drivers, raising their risk of losing control of their vehicle. Alcohol consumption is known to impair driving ability by reducing inhibitions, clouding judgment, and by slowing reactions (Howat, Sleet, & Smith, 1991; Petridou & Moustaki, 2000). Our findings indicate that consuming alcohol raises the likelihood that young drivers will exceed the speed limit. The combination of driving at high speed and slowed reactions due to alcohol impairment generates a potentially highly dangerous driving situation for young drivers. Aside from alcohol, our findings indicate that being careless, reckless, or in a hurry also co-occurs with speeding in the cause of young drivers' crashes. Graduated driver licensing (GDL) systems differ in the restrictions (e.g., carrying passengers, night-time driving) applied to young novice drivers (Chen, Baker, & Li, 2006; Shope, 2007). An implication of our findings is that GDL systems may be enhanced if aimed at the combi-

nations of factors that underlie young drivers' crashes. For instance, the full benefits of limiting young drivers' exposure to high-risk driving conditions (e.g., night-time driving) may not be realised unless combined with effective initiatives to mitigate of other hazardous driving behaviors.

Disobeying right-of-way, stop signs, or road markings and overshooting a junction combined to cause young drivers to collide with another vehicle. This finding indicates that young drivers' crashes can be caused by crossing into another vehicle's path due to overshooting a junction. Previous research has identified colliding with another vehicle that had right-of-way in the crashes of young drivers (Baitman, Kirley, McCartt, & Chaudhary, 2008). Our findings suggest that young drivers' failure to heed the highway code at junctions contributes to such crashes, suggesting that young drivers either lack adequate knowledge or experience adhering to the highway code at junctions or disobey driving codes. Indeed, previous research has shown that young drivers are more likely drive through red lights (Lucidi et al., 2010; Retting & Williams, 1996). An important aspect of our current study is that our findings provide a causal link between driving violations and car crashes of young drivers. That is, while traffic violations are a known risk factor among young drivers, our findings identify a specific pathway to their crashes via junction overshooting to collide with other vehicles. Therefore, to reduce young driver crashes, road safety authorities could seek to target young drivers' tendency to disobey right-of-way, stop signs, and road markings as a route cause of some of their crashes involving other drivers.

Our study has limitations. First, we focussed our analysis on Great Britain. National differences in road safety policies, especially those targeted at youngest drivers (McCartt, Teoh, Fields, Braitman, & Hellinga, 2010), could lead to different patterns of results across countries. Second, we included all crashes involving at least one road user injury, but we did not stratify by crash severity (e.g., fatal, non-fatal). We did so to maximise our power to detect combinations of factors underlying the crashes of young drivers. It is possible that some factors (e.g., exceeding the speed limit) are associated with more serious (e.g., fatal) crashes than with less serious crashes. Third, our analysis of factors recorded in accident records assumes that all factors involved in crashes are reported by police officers. Factors that are hard to verify, such as mobile phone use, may be underreported in accident records (NHTSA, 2009; Rolison et al., 2018), possibly influencing our results. Finally, the reliability of our results depends on crash data being accurately reported by police officers. Contributory factors data reflect police officers' subjective judgments and may be susceptible to age and gender bias (Rolison, 2020).

In conclusion, our findings reveal combinations of factors underlying younger drivers' one- and two-car crashes that highlight a need to address how co-occurrences of driver-related factors (e.g., exceeding the speed limit) and the road environment (e.g., poor weather conditions) lead to crashes among younger drivers.

Conflicts of interest (COI) and source of funding

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