Disentangling Heterogeneity Among Driving While Intoxicated Offenders: The Effect of Subgroups and Sex

Manuscript 1: A Narrative Review of the Driving While Intoxicated Offender Subgroup Literature

Manuscript 2: Driving While Intoxicated Subgroups among Female Offenders

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General Abstract

Background: Driving while intoxicated by alcohol (DWI) is a leading threat to public health across the globe. Subgrouping is a means to disentangle DWI offender heterogeneity and thus improve understanding, prediction and prevention. The current thesis explores subgrouping in DWI offenders in two manuscripts: i) a review that consolidates and synthesizes DWI subgrouping studies to answer the main research question: does subgroup classification increase understanding, improve predictive accuracy, or enhance intervention effectiveness among DWI offenders?; and ii) an empirical study that builds upon previous research to investigate DWI subgroups in female offenders hypothesizing that they will exhibit distinct risk-taking profiles.

Method: i) A narrative review that examines peer-reviewed studies identified through a variety of data sources (e.g., PubMed, Medline, and PsycINFO); ii) a cross-sectional, retrospective analysis of a sample of first-time DWI offenders and control drivers that classifies subgroups using documented driving behaviour.

Results: The review identified 18 studies that fell into two categories: statistical and empirical subgrouping. Two key subgroups emerged: i) subgroups classified by the severity of their alcohol misuse and/or depressive/neurotic characteristics; and ii) subgroups classified by related high-risk externalizing behavioural and biological characteristics. The empirical study found that the female DWI subgroups exhibited distinct risk profiles: i) one with elevated antisocial characteristics (pDWI); and ii) one with elevated substance and alcohol misuse, antisocial, PTSD, and impulsivity characteristics (MIXED).

Discussion: The review suggests that subgroup classification can deepen our understanding of DWI offenders and may be an effective method to enhance prediction and prevention. The empirical study suggests that a simple algorithm based on driving behavior can be

used to identify two female DWI subgroups with clinical relevance.

Conclusion: Subgroup classification of DWI offenders remains a relatively nascent approach to deepening our understanding of DWI behaviour and enhancing the efficacy of prevention efforts. Further subgrouping research, particularly in female offenders, is recommended.

Résumé général

Contexte: La conduite avec des facultés affaiblies est une menace majeure pour la santé publique dans le monde. Le sous-groupement est un moyen de démêler l'hétérogénéité des contrevenants à la conduite avec facultés affaiblies (CFA) et d'améliorer ainsi la compréhension, la prévision et la prévention. Par conséquent, la thèse actuelle explore le sous-groupement des CFA dans deux manuscrits: i) une revue qui consolide et synthétise les études de sous-groupement pour répondre à la principale question de recherche: la classification des sous-groupes augmente-t-elle la compréhension, améliore la précision prédictive ou améliore l'efficacité des interventions chez les CFA? ; ii) une étude empirique qui s'appuie sur des recherches antérieures pour examiner les sous-groupes de CFA en émettant l'hypothèse qu'elles présenteront des profils de prise de risque distincts.

Méthode: i) Une revue narrative qui examine les études évaluées par des pairs identifiées à travers une variété de sources de données (par exemple, PubMed, Medline et PsychINFO); ii) une analyse transversale et rétrospective d'un échantillon de nouveaux CFA et de conducteurs témoins qui classe les sous-groupes à l'aide d'un comportement de conduite documenté.

Résultats: La revue a identifié 18 études classées en deux catégories, sous-groupes statistiques et empiriques. Deux sous-groupes clés ont émergé: i) des sous-groupes classés selon la gravité de leur abus d'alcool et / ou leurs caractéristiques dépressives / névrotiques; et ii) sous-groupes classés par caractéristiques comportementales et biologiques à haut risque connexes. L'étude empirique a révélé que les sous-groupes des CFA femmes présentaient des profils de risque distincts: i) un avec des caractéristiques antisociales élevées; et ii) un avec des caractéristiques élevées d'abus de substances et d'alcool, antisocial, SSPT et impulsivité.

Discussion: La revue suggère que la classification en sous-groupes peut approfondir notre

compréhension des CFA et peut être une méthode efficace pour améliorer la prédiction et la prévention. L'étude empirique suggère qu'un algorithme simple basé sur le comportement de conduite peut être utilisé pour identifier deux sous-groupes des CFA femmes présentant une pertinence clinique.

Conclusion: La classification par sous-groupe des CFA reste une approche relativement naissante pour approfondir notre compréhension de la conduite avec des facultés affaiblies et améliorer l'efficacité des efforts de prévention. Il est recommandé de poursuivre la recherche en sous-groupes, en particulier chez les femmes.

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I would like to thank my supervisor, Dr. Thomas Brown, for providing the opportunity to develop as a researcher and person. Tom encouraged my every step and stood by supportively. Specifically, he supervised my undergraduate thesis and co-authored its subsequent publication, funded travel so that I could present at national and international conferences, worked tirelessly to help me apply to scholarships and awards, counselled me during my applications to Ph.D. programs, and his guidance and corrections have been crucial the development of this thesis. As a role model, his professionalism and dedication to the betterment of his craft propelled me to seek ever higher standards of excellence. Under his tutelage, I have become a stronger and more confident individual.

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Preface & Contribution of Authors

This thesis represents a work of original scholarship. I, Nathaniel Moxley-Kelly, am its author. Thomas Brown, my supervisor, provided continual feedback and guidance during the thesis's development. Manal El Deb, a doctoral candidate in the Psychiatry Department at McGill University and a colleague, collaborated by reviewing articles for inclusion during the initial stages of the narrative review.

General Introduction

The Driving While Impaired (DWI) Problem

Worldwide, road traffic injury kills over one-million people annually, making it the 9th leading cause of death for the total population and the number one cause of death for 15-29-year-olds (Toroyan et al., 2013). Crashes injure and disable an additional 50 million people, resulting in significant economic burdens averaging 3% of nations' gross domestic products (World Health Organization, 2015). In Canada annually, approximately 2000 individuals are killed (roughly 20 city busses full of people), 150,000 injured, and 10,000 permanently disabled (Transport Canada, 2017); in Quebec, crashes kill 300-400 people (*Bilan Routier*, 2018). Across the province, nation and world, driving while intoxicated (DWI) drivers are responsible for roughly 30% of all road traffic-related fatalities (*Bilan Routier*, 2018; World Health Organization, 2015). Further, the risk of a fatal crash increases with subsequent DWI infractions (Rauch et al., 2010). DWI is a major cause of preventable morbidity, yet approximately 30% of first-time offenders will re-offend within 5 years (Rauch et al., 2010). Better understanding, prediction and prevention of DWI are therefore critical for protecting public health.

One challenge to our understanding of DWI comes from the observation that DWI offenders differ widely in their criminality, substance use, psychiatric symptomatology, and risk-taking characteristics (Miller et al., 2015; Nochajski & Stasiewicz, 2006; Wells-Parker et al., 1995). This heterogeneity can contribute to ineffective prediction and prevention as an understanding of offenders as a homogenous group ignores the likelihood that the pathways leading to DWI are not common to all members of the offender population. A "one-size-fits-all" approach is unlikely to sufficiently explain or prevent all DWI behaviour (Medicines Agency, 2000; Nochajski &

Stasiewicz, 2006). A more targeted approach based on distinct risk factors, mechanisms, and intervention responsivities in DWI offenders is needed.

Subgrouping represents a strategy for disentangling population heterogeneity. A specific pathway to problem behaviour, if shared among members of a subgroup and modifiable by intervention, can be targeted to increase predictive accuracy and intervention efficacy (Nielsen et al., 2018). Further, the more heterogeneous the population, the more beneficial investigations into treatment effects in subgroups (Medicines Agency, 2019). Hence – in line with initiatives toward personalized medicine across psychiatry – studying subgroups of DWI offenders represents an opportunity to improve historically modest predictive accuracy and intervention efficacy (Miller et al., 2015).

In sum, DWI is a significant public health issue. DWI offenders are highly heterogeneous, which obscures our understanding of DWI behaviour and practically vexes prediction and intervention with offenders. Subgroup analysis to identify shared risk factors, mechanisms, and intervention responsivity represents a promising avenue for research to better prevent DWI recidivism.

This dissertation comprises two chapters that address subgroup analysis in DWI offenders. The first chapter is entitled "A narrative review of the impaired driving offender subgroup literature". It asks: does subgroup classification increase understanding, improve predictive accuracy, or enhance intervention effectiveness among DWI offenders? It thus identifies the most promising subgroup classification schemas for tackling the heterogeneity dilemma and informing more targeted approaches to prevention. It selected for review studies that have identified or tested DWI subgroup classifications and summarized their findings. This chapter ends with an appraisal

of the methodological strengths and weaknesses in the extant DWI subgroup literature and recommendations for future research.

The second chapter, entitled "driving while intoxicated subgroups among female offenders", describes a study that built upon a platform of previous research. In a preliminary study (Brown et al., 2016), our research group identified two DWI subgroups based upon their real-world driving behaviour who exhibited distinct characteristics. This finding led us to posit that the mechanisms promoting their DWI behaviour were also distinct. In a follow-up study (Moxley-Kelly et al., 2018), we found that these subgroups were associated with different rates of recidivism over several years follow-up as well as selective treatment responsivity to a brief motivational interviewing (BMI) intervention in males. This evidence suggests that these subgroups are clinically relevant, but that further investigation into their characteristics is needed.

Historically, research into female DWI offenders has been underdeveloped as the majority of DWI offenders are male (Lapham et al., 2001). However, the rate of female DWI is rising (Perreault, 2016; Federal Bureau of Investigation, 2012). Female DWI is thus a pressing public safety concern, making a better understanding of female offenders essential. To address this need, the second chapter describes a secondary analysis study that retrospectively classifies a sample of female DWI offenders into the previously identified subgroups (Brown et al., 2016; Moxley-Kelly et al., 2019). It then explores these female DWI subgroups for their specific personality and cognitive characteristics relevant to DWI. This study thus aimed to extend our understanding of DWI subgroups in the under-addressed female population.

A Narrative Review of the Impaired Driving Offender Subgroup Literature

Abstract

Background: Driving while impaired (DWI) offenders are implicated in roughly 30% of fatal traffic crashes, and one-in-three DWI offenders will re-offend within 5 years. The prevention of DWI recidivism is thus a leading public safety concern. Heterogeneity within the population, however, has contributed to the modest efficacy of risk assessment and intervention. To unravel this heterogeneity and ultimately to enhance predictive accuracy and intervention efficacy, one approach is to identify subgroups classified by their shared pathways to DWI.

Aims: The current review explores the literature that investigates DWI-subgroup classification and asks the following question: does subgrouping deepen understanding, enhance predictive accuracy, and/or improve intervention efficacy among DWI offenders? Hence, it summarizes i) the DWI subgroup classification schemas; ii) the effect of these schemas on prediction and prevention; iii) the methodological strengths and weaknesses of the research in this area; and iv) the recommendations that can be made to advance research into DWI subgroup classification.

Method: A narrative review that examined the published English-language peer-reviewed studies on DWI subgrouping. Several data sources were searched, with studies organized based upon the two principal approaches to subgrouping in the literature, namely statistical and empirical.

Results: The present review identified 18 studies that investigated DWI subgroups – ten studies that investigated statistically derived subgroups, and eight that investigated empirically derived subgroups. The subgroups that emerged from this review fell into two main categories: i) subgroups based upon the severity of alcohol misuse and/or depressive/neurotic characteristics; and ii) subgroups with related high-risk externalizing behavioural and biological characteristics.

Membership in these subgroups was found to predict increased risk for DWI recidivism and, more rarely yet tantalizingly, selective responsivity to treatment.

Conclusion: Subgrouping DWI offenders is promising for improving predictive accuracy and intervention efficacy. Research exploring the prospective targeting of intervention to distinct DWI pathways among offender subgroups is now needed.

Un examen narratif du contrevenant pour conduite avec facultés affaiblies

Littérature du sous-groupe

Résumé

Contexte: Les contrevenants à la conduite avec facultés affaiblies (CFA) sont impliqués dans environ 30% des accidents de la route mortels, et un CFA sur trois récidivera dans les 5 ans. La prévention de la récidive est donc une préoccupation majeure en matière de sécurité publique. Cependant, l'hétérogénéité au sein de la population CFA a contribué à la modeste efficacité de l'évaluation des risques et de l'intervention. Pour démêler cette hétérogénéité et, en fin de compte, améliorer la précision prédictive et l'efficacité de l'intervention, une approche consiste à identifier les sous-groupes classés selon leurs voies communes vers la conduite avec facultés affaiblies.

Objectifs: La présente revue explore la littérature qui étudie la classification des sous-groupes des CFA et pose la question suivante: le sous-groupe approfondit-il la compréhension, améliore la précision prédictive et / ou améliore l'efficacité des interventions chez les CFA? Par conséquent, il résume: i) les schémas de classification des sous-groupes CFA; ii) l'effet de ces schémas sur la prédiction et la prévention; iii) les forces et faiblesses méthodologiques de la recherche dans ce domaine, et iv) les recommandations qui peuvent être faites pour faire avancer la recherche sur la classification des sous-groupes CFA.

Méthode: Une revue narrative a examiné les études révisées par des pairs publiées en anglais sur le sous-groupe CFA. Plusieurs sources de données ont été recherchées, les études étant organisées en fonction des deux principales approches de sous-regroupement dans la littérature, à savoir statistique et empirique.

Résultats: La présente revue a identifié 18 études qui ont enquêté sur les sous-groupes de CFA - dix études qui ont étudié des sous-groupes statistiquement dérivés et huit qui ont étudié des

sous-groupes empiriquement dérivés. Les sous-groupes issus de cette revue se répartissaient en deux catégories principales: i) sous-groupes basés sur la gravité de l'abus d'alcool et / ou des caractéristiques dépressives / névrotiques; et ii) sous-groupes présentant des caractéristiques comportementales et biologiques à haut risque connexes. Il a été constaté que l'appartenance à ces sous-groupes prédisait un risque accru de récidive et, plus rarement mais de manière tentante, une réponse sélective au traitement.

Conclusion: Le sous-regroupement des CFA est prometteur pour améliorer l'exactitude des prévisions et l'efficacité des interventions. Des recherches futures explorant une intervention de ciblage prospective sur des voies distinctes envers la conduite avec des facultés affaiblies parmi les sous-groupes CFA sont maintenant nécessaires.

Introduction

Researchers have investigated driving while intoxicated (DWI) subgroup classification for at least 40 years (Steer, Fine, & Scoles, 1979; Moxley-Kelly et al., 2019). Remarkably, the literature on DWI subgrouping has not, to our knowledge, been reviewed. To address this gap, this review responds to the following question: does subgroup classification increase understanding, improve predictive accuracy, or enhance intervention effectiveness among DWI offenders? It begins by defining what subgrouping is and attempts to do. It then describes the two main subgroup classification approaches and the methods used for establishing subgroup validity and clinical relevance. Accordingly, the body of the review consists of two sections: i) studies investigating statistically derived subgroups; and ii) studies investigating empirically derived subgroups. Finally, the main findings are discussed, and methodological issues and recommendations for future subgroup research are considered.

What is a subgroup and how is subgroup research conducted?

A subgroup is comprised of a subset of a population that shares attributes (Medicines Agency, 2019). The attributes used to classify subgroups include demographic (Lee et al., 2013), psychiatric (Holt et al., 2009), and biological attributes (Eensoo et al., 2018), among others. The derivation of subgroups may be based upon *post hoc* statistical methods or *a priori* empirical methods. Once segregated, subgroups can then be compared cross-sectionally on data from a single time point, longitudinally for outcomes on variables of interest (e.g., DWI recidivism or alcohol consumption), and in terms of their treatment responsivity.

Subgroup classification research can be partitioned based upon two principal classification approaches: i) *post hoc* statistical approaches (e.g., cluster analysis); and ii) *a priori* empirically-based classifications. Cluster analysis is a statistical classification technique that optimizes within-

group homogeneity and between-group heterogeneity on multiple variables (Blashfield & Aldenderfer, 1978). To accomplish this, statistical algorithms generate subgroups within a data set (Blashfield, 1980) using hierarchical or iterative partitioning of clusters. Hierarchical clustering creates a connectivity matrix of pairwise similarities between all participants then combines participants into clusters in a stepwise fashion based on closeness using a metric (e.g. Euclidean distance, maximum distance). The algorithm thus gradually builds clusters until only one cluster remains. Researchers then identify the optimal number of clusters by either visually inspecting a graphic display of the clusters or using a metric that indicates the optimal number of clusters (e.g. the Bayesian Information Criterion). Iterative approaches require the researcher to first specify the desired number of clusters. The algorithm, through repeated iterations, optimizes within-group homogeneity and between-group heterogeneity for those clusters until no further optimization is possible.

In contrast, *a priori* approaches to DWI subgroup classification investigate conceptually coherent subgroups based on previous observations in the field (e.g., in DWI, classification by criminality). The classification schema may also reflect a theory that is grounded in findings from previous research (e.g., clinically depressed offenders are at greater risk for recidivism). These classification schemas may also posit the following: i) DWI offenders are heterogeneous on a measure or characteristic, ii) variation in that measure or characteristic may explain variation in DWI behaviour, ii) those who are either low or high on a measure may represent a subgroup with a distinct pathway to DWI, and iv) subgrouping with the measure or characteristic may have utility for prediction or treatment matching. For instance, in the first study reviewed below in the subsection "*Empirically Derived Subgroups*" (Holt et al., 2009), the authors noted that: i) DWI offenders have varying levels of depression; ii) high depression predicts DWI; iii) a high

depression subgroup may have a distinct pathway to DWI (e.g. drinking to cope with depression leads to alcohol abuse and DWI); and iv) a targeted treatment to reduce depression may selectively reduce DWI in this population.

Once segregated, subgroups can be tested for construct validity. Construct validity in subgroup research can be established by testing for concurrent or prospective association with variables hypothesized to relate to the subgroup (i.e. criterion-based validity). For example, a study might classify a subgroup by severity of depression and then hypothesize that the subgroup will have higher rates of alcohol misuse (the criterion) as depression is known to covary with alcohol misuse. Association with alcohol misuse is thus an empirical test of construct validity for a depressive subgroup. A criterion for DWI offenders may also include psychiatric issues, risk-taking personality features (e.g., impulsivity and sensation-seeking), and cognitive factors, among others. Subgroup validity is also supported by a cogent, plausible theory for how subgroup characteristics reflect a pathway to a disorder and its responsivity to a specific treatment (Nielsen et al., 2018; Medicines Agency, 2019). To build upon the previous example, if depression is reduced by cognitive-behavioural therapy, and the reduction in depression significantly mediates reductions in DWI, then construct validity is supported. Such arguments for subgroup validity are typically enhanced by drawing on research and from disparate fields (e.g. addiction research or criminology) and levels of analysis (e.g., basic science or epidemiology). Further, to support the validity of subgroups generated by cluster analysis, arguments can be made for why the input measures and clustering approach were selected (Hastie et al., 2009) and previously identified classifications can be replicated (Medicines Agency, 2019; Oxman & Guyatt, 1992; Sun et al., 2012). Once construct validity is supported in this way, subgroup classifications may then be tested for their clinical relevance.

The clinical relevance of a subgroup (sometimes referred to as clinical significance) reflects the subgroup's potential for implementation in clinical settings (Ranganathan et al., 2015). Clinical relevance is high if the subgroup is prevalent, associated with large effects, and easily identified within the target population. Together, these factors result in a positive benefit-to-cost ratio and would render identifying and intervening with a subgroup both practicable and cost-efficient. Benefits are established by testing subgroups for differential rates of recidivism, thus providing evidence for the predictive value of the classification schema. Additionally, benefits are established by testing for differential response to treatment, as targeting treatment to subgroups most likely to benefit can enhance overall prevention efficacy. Costs may include training and purchasing the technology required to undertake a subgroup classification protocol. Overall, a subgroup classification schema that produces more accurate risk assessment and/or treatment, is easily deployable, and sustainable cost-wise would yield a favorable benefit-to-cost ratio and hence, contribute to its clinical relevance.

In sum, a DWI subgroup represents a subset within the DWI population that shares attributes relevant to their DWI behaviour. Subgroup studies may use *post hoc* statistical methods or *a priori* empirical methods to classify their subgroups. Construct validity can be supported with a cogent rationale for the subgroup classification and testing. Finally, a large effect of subgroup classification on prediction and prevention, and a low cost when implementing the classification schema, provide evidence for the subgroup's clinical relevance.

The scope of the following narrative review spans the peer-reviewed literature on DWI subgroups classifications by referencing several databases including PubMed, Medline, PsychINFO, Psychiatry Online Core, Scopus, Wiley-Blackwell Cochrane Library, and Web of Science. Search terms focused on common phrases within the DWI intervention literature and

subgroup research. Terms were expanded through Automatic Term Mapping and the MeSH system, then combined with Boolean operators (e.g., “OR” and “AND”). The base search terms – ("driving under the influence" OR "drinking and driving" OR "driving while intoxicated" OR "drunk driving" OR "drunken driving") AND ("classification" OR "typology" OR "subtype" OR "subclassification" OR "phenotype" OR "cluster") – were modified to suit the data sources. Additional articles were identified upon reviewing the references of articles from the initial search. All eligible articles were pre-screened by author NMK and collaborator ME to establish that participants had one or more verifiable DWI offences and that the sample has been divided into subgroups. Articles were excluded if not peer-reviewed or available in English. The selected studies are presented below in historical order, from earliest to most recent.

Results

Statistically Derived Subgroups

Steer, R. A., Fine, E. W., & Scoles, P. E. 1979. Table 1 summarizes the studies that investigate statistically derived subgroups identified by this review. In an early US cross-sectional study of 1500 male DWI offenders with a mean age of 38, subgroups were classified by patterns of alcohol impairment and personality. Arrest breath alcohol, two measures of self-report drinking, and a personality inventory (Eysneck Personality Inventory) were used as inputs in the clustering algorithm and dependant variables. The resulting seven clusters represented all possible combinations of patterns of above or below the mean on 4 scales. Roughly 35% of the sample was classified into a low alcohol and psychiatric severity subgroup. The remaining clusters ranked above the mean on one or all the risk indices investigated. Of these high-risk clusters, the clusters that ranked above the mean on neuroticism and drinking scales were more likely to have multiple DWI’s, have received alcohol misuse treatment, and have fathers who used alcohol. It was argued

Table 1

Summary of statistically derived driving while impaired (DWI) subgroup studies

Author(s)	Participant Characteristics	Subgroup Classification	Key findings
Steer, R. A., Fine, E. W., & Scoles, P. E. 1979.	1500 male DWI offenders with a mean age of 38 years	7 subgroups classified by alcohol use and personality characteristics	Those subgroups with elevated alcohol use and neuroticism were more likely to have multiple DWI's
Donovan & Marlatt, 1982.	172 male DWI offenders with a mean age of 37 years	5 subgroups classified by driving attitude, personality, and hostility characteristics	Two high-risk subgroups emerged: a high depression subgroup, and a high aggression and sensation seeking subgroup
Donovan et al., 1986.	161 male DWI offenders followed from *Donovan & Marlatt, 1982*	5 subgroups from *Donovan & Marlatt, 1982*	The 2 high-risk subgroups were significantly more likely to engage in non-alcohol-related offending (e.g. speeding)
Saltstone & Poudrier, 1989.	113 male DWI offenders with a mean age of 36 years	4 subgroups classified by demographic, personality, driving and alcohol use	The subgroup with the highest alcohol use had significantly more past DWI's than the other subgroups
Wieczorek and Miller, 1992.	156 DWI offenders who were predominantly male (87%). The mean age of the subgroups was 28 to 38 years	5 subgroups classified by alcohol use, social instability, driving behavior, and psychiatric issues	Subgroups with elevated alcohol use problems and social instability exhibited the highest risk.
Wells-Parker, Anderson, Pang, & Timken, 1993.	517 male and female DWI offenders. The mean age of the subgroups was 29 to 39 years	Several sets of subgroups derived from a variety of clustering algorithms	Subgroups did not replicate across samples, clustering methods or input measures

Table 1 (cont.)

Summary of statistically derived DWI subgroup studies

Author(s)	Participant Characteristics	Subgroup Classification	Key findings
Moore, 1994.	180 female DWI offenders with a mean age of 17.9 years	4 subgroups classified by personality	Two high-risk subgroups emerged: an antisocial subgroup and a neurotic subgroup
Ball, Jaffe, Crouse-Artus, Rounsaville, & O'Malley, 2000.	246 predominantly male (78%) first-time DWI offenders with a mean age of 32 years	2 subgroups classified by alcohol use, psychiatric problems and family risk factors	Type A and B "alcoholic" subgroups emerged, and type B exhibited worse drinking outcomes at a 1-year follow-up
Okamura, Kosuge, Kihira, & Fujita 2014.	219 male DWI offenders with a mean age of 43.5 years	5 subgroups classified by age, DWI attitudes, personality, and alcohol use	DWI specific attitudes are informative for the conceptualization of DWI subgroups
Nelson, Shoov, LaBrie, & Shaffer, 2019.	743 DWI offenders with a mean age of 39.6 years	3 subgroups classified by criminal history and psychiatric morbidity	At 4-5-year follow-up, a high-externalizing subgroup had the highest recidivism, and a poor mental health group had higher recidivism than a low risk subgroup

that as the subgroups had statistically significant differences in the measures used for generating the clusters, they could not have occurred by chance. In sum, this study suggests that neurotic and high alcohol misuse DWI offender subgroups may be at high risk for recidivism.

Donovan & Marlatt, 1982. In a US cross-sectional study with a male DWI offender sample (N = 172; mean age = 36.7 years) recruited from compulsory alcohol-related education courses, 5 subgroups of male DWI offenders were derived using driving attitudes, personality, and hostility measures. Offenders were classified with Ward's method clustering, and the optimal number of clusters (5) was established by observing discontinuity in the fusion coefficient – a metric of the distance between clusters. Two clusters emerged with attributes that indicate high risk: one with marked depression and low emotional adjustment, and the other with aggression and sensation seeking. Clusters were validated by making comparisons on demographic, drinking, and driving factors. The high-risk clusters self-reported more frequent DWI, driving accidents and convictions and scored higher on a risky driving scale. As significant differences were found between the validation factors, the groups were posited to represent meaningful subgroups. This study suggested that subgroups characterized by either depression and low emotional adjustment or aggression and sensation-seeking show severer risky driving behaviour, and that subgroups may be amenable to targeted interventions that can alter these characteristics.

Donovan et al., 1986. In a longitudinal 3-year follow-up of driving records of 161 DWI offenders from the above study (Donovan & Marlatt, 1982), the cluster-derived subgroups were compared on rates of recidivism. The rate of DWI recidivism was 30.5% (n = 53) for the total sample. Tests of independence (chi-square) failed to detect subgroup differences in recidivism rates. However, the subgroups did differ significantly on non-alcohol-related offences such as speeding, failing to yield at a stop, reckless driving, and driving with a suspended license. Specifically, the

subgroups high in hostility and tension reduction contained drivers with higher rates of speeding and general non-alcohol-related offending. This study is the earliest study identified by this review to investigate longitudinal follow-up on DWI recidivism and is thus noteworthy for its use of a clinically relevant outcome.

Saltstone & Poudrier, 1989. This cross-sectional study was again inspired by Donovan & Marlatt's (1982) five-subgroup classification schema. The sample of 113 male DWI offenders (mean age = 36 years) recruited from community corrections programs in Canada were administered a battery of demographic, personality (e.g. the Minnesota Multiphasic Personality Inventory), driving and alcohol use questionnaires. Scores were entered into Ward's Method cluster analysis with a solution of 5 clusters prespecified. Four subgroups were identified with the following characteristics: i) elevated alcohol use; ii) elevated internalizing and depression; iii) episodic drinking; and iv) elevated hostility and sensation seeking. Cross-sectional comparisons indicated that subgroup i had significantly more DWIs than the other subgroups. This study suggested that subgroups with elevated alcohol misuse are associated with high rates of DWI and strengthened the validity of the findings derived from the previous two articles discussed in this review.

Wieczorek and Miller, 1992. In a cross-sectional study, cluster analysis was undertaken on a sample (84%, white, 87% male) of 156 DWI offenders recruited from a voluntary educational Drinking Driver Program in New York, United States. Clusters were classified using measures of four domains relevant to the treatment of DWI: alcohol dependence, social instability, driving behaviour, and psychiatric issues. Two-step hierarchical Ward's clustering method established that five clusters yielded an optimal solution. Next, non-hierarchical k-means clustering was used for maximal separation. The resulting five subgroups were characterised by showing: i) moderate

problems with alcohol use and reckless driving; ii) moderate alcohol problems and extreme reckless driving; iii) high levels of alcohol dependence and social instability; iv) low problem severity; and v) severe alcohol use problems. This study indicated that subgroups iii and v represented the highest risk subgroups, and that characteristics within each subgroup might be targeted by intervention. The study design was strengthened by the use of a 2-step clustering method.

Wells-Parker, Anderson, Pang, & Timken, 1993. A cross-sectional study with 517 DWI offenders recruited from US probation departments assessed alcohol use, driving and personality to appraise the replicability across independent samples of several cluster-based classifications methods. The study tested unweighted pairs group method, median, single linkage, complete linkage, centroid, Ward's, K means and McQuitty's similarity analysis. None of these approaches produced subgroups that were replicable across independent samples, regardless of clustering methods or input measures. Thus, this largely parametric exercise indicated that variation in clustering algorithms can lead to inconsistencies in the findings. Importantly, it represents the sole attempt to explore the relative validity of cluster analysis approaches for DWI subgroup classification identified by this review.

Moore, 1994. In a US cross-sectional study, 180 female DWI offenders aged 16 - 20 (mean = 17.9 years) recruited from presentencing court were tested using the California Psychological Inventory. Factors derived from principal components analysis were used to generate 10 clusters via centroid sorting cluster analysis. The clusters were then organized into 4 subgroups designated as antisocial, neurotic, well-adjusted, and other (i.e., less severe maladjustment). The authors concluded that the antisocial and neurotic subgroups, consisting of 56% of the entire sample, may represent high-risk subgroups amenable to targeted treatment. They also posited that the antisocial

subgroup would selectively benefit from supervision and specialized counselling for family and academic problems while the neurotic subgroup would selectively benefit from therapy focusing on improving perceptions of self-worth, coping strategies and interpersonal skills. This study is one of the few to investigate subgrouping in female offenders. Future work might not only expand this line of inquiry by replication, but by applying it to a larger age range as well.

Ball, Jaffe, Crouse-Artus, Rounsaville, & O'Malley, 2000. In a randomized trial of DWI Education, Coping Skills, and Interactional Therapy, Type A and B alcoholic DWI subgroups were discerned from a predominantly male (78%) and White (84%) first-time DWI offender sample (N = 246; mean age = 31.7) attending alcohol treatment. Type A "alcoholics" were defined in this study as those individuals suffering from alcohol use disorder with a late age of onset, low heritability, and less severe alcoholism; Type B "alcoholics" were defined as those individuals with early age onset, high heritability, severer alcohol use disorder, and an impulsive/antisocial behavioural pattern. Clusters were generated with a k-means clustering algorithm using measures related to alcohol use, psychiatric problems and premorbid risk factors (e.g. family and childhood problems). Ball and colleagues hypothesized that: i) the Type A and Type B-like DWI subgroups would emerge; ii) the Type B subgroup would have a greater alcohol consumption and alcohol-related consequences over a one-year follow-up; and iii) the Type B subgroup would show a greater response to psychotherapeutic treatment compared to DWI education intervention. As hypothesized, a Type B subgroup did emerge with more severe alcoholism and antisocial characteristics. Drinking outcomes over a one-year follow-up revealed that the Type B subgroup fared significantly worse compared to the Type A subgroup. Finally, participants were randomized into treatment conditions (DWI Education, Coping Skills, Interactional), but tests for subgroup X treatment interaction effects produced inconclusive results. Despite these null findings, this study

is a valuable contribution as it is one of the few identified by this review that goes beyond mere description to prospective testing for potential matching of DWI subgroups to intervention for optimizing outcomes.

Okamura, Kosuge, Kihira, & Fujita 2014. In a Japanese cross-sectional study of 219 male convicted DWI offenders (mean age = 43.5 years) that were recruited from driver re-licensing centers, subgroups were classified by age, DWI attitudes, personality, and alcohol use. Five subgroups were identified with Ward's method clustering, and validity was established by testing bivariate factors not included in the clustering schema including the alcohol dependence biomarkers gamma-glutamyl transferase, aspartate aminotransferase, alanine aminotransferase, and mean corpuscular red blood cell volume. The rationale for this study included the observation that DWI specific attitude had not been used in previous research into DWI subgroups and might provide insight. The generated subgroups included: i) a low risk, low alcohol consumption subgroup; ii-iii) two subgroups that were characterized as young, heavily involved in alcohol, and prone to rationalizing their DWI behaviour; iv) a subgroup that was older, had more frequent previous DWI offences and near hazardous levels of alcohol consumption, and v) a distressed, impulsive, alcohol-dependent subgroup with low self-efficacy for avoiding DWI. It was argued that DWI offenders should reflect on past behaviour and underlying problems to reduce DWI. This study is noteworthy as it is the only study identified by this review to assess DWI specific driving attitudes, and its use of alcohol use biomarkers for validation is laudable.

Nelson, Shoov, LaBrie, & Shaffer, 2019. In a longitudinal study with a sample of 743 DWI offenders (mean 39.6 years, 19-77) recruited in a US court-mandated DWI inpatient program, criminal history and psychiatric morbidity were used to classify offenders. Psychiatric morbidity was measured via the Composite International Diagnostic Interview and criminal history was

measured using criminal records. Two-step hierarchical clustering method with a Bayesian Information Criterion approach determined an optimal three cluster solution: i) a poor mental health subgroup; ii) an externalizing subgroup; and iii) a low-risk subgroup without mental health or externalizing issues. Cox regression revealed significant between cluster differences in recidivism over 4-5-year follow-up, with a high-externalizing cluster exhibiting increased recidivism compared to the other 2 clusters. Further, in a direct comparison between the poor mental health cluster and the low-risk subgroup, the poor mental health cluster had significantly greater recidivism. Sex analysis revealed that female offenders were more likely to classified into the poor mental health subgroup. These findings suggest that DWI offender subgroups showing high externalizing and poor mental health are at high risk for recidivism. Further, sex analysis adds valuable nuance to the generalizability of the subgroup findings.

Empirically Derived Subgroups

Argeriou, McCarty, and Blacker, 1985. Table 2 summarizes the empirically derived studies identified by this review. In a US longitudinal-observational study, a sample of 1406 convicted DWI offenders was recruited from probation records and classified into four subgroups; i) prior criminal offences only; ii) prior DWI only, iii) prior DWI and criminal offences, and iv) no prior offences. This study's classification schema is based on the observed elevated rates of criminality among DWI offenders and criminology theory that posits that generalized propensity for criminal behaviors may demarcate a high-risk DWI subgroup (Yoder & Moore, 1973). Data on DWI arrests and the number and type of other criminal offences were extracted at study intake and a three-year follow-up. Results indicated that 63% of DWI offenders had prior non-DWI criminal offences. Moreover, offenders with non-DWI priors had higher rates of DWI recidivism compared to offenders without prior non-DWI criminal offences. This study uses driving records to classify

Table 2

Summary of empirically derived DWI subgroup studies

Author(s)	Participant Characteristics	Subgroup Classification	Key findings
Argeriou, McCarty, and Blacker, 1985.	1406 DWI offenders	4 subgroups classified by prior criminal history	Subgroups with non-DWI priors had higher rates of DWI recidivism
LaBrie, Kidman, Albanese, Peller & Shaffer, 2007.	1,281 DWI offenders with a mean age of 37.2	4 subgroups classified by prior criminal history	Subgroups with non-DWI priors, particularly substance related priors, had higher rates of DWI recidivism
Woodall, Delaney, Kunitz, Westerberg, & Zhao, 2007.	305 predominantly male (80%) DWI offenders with a mean age of 27.1 years	2 subgroups classified by antisocial personality disorder diagnosis (i.e. present or absent)	The antisocial personality disorder subgroup had a greater reduction in alcohol use over 2-year follow-up
Holt, O'Malley, Rounsaville & Ball 2009.	184 predominantly male (80%) DWI offenders	2 subgroups classified by depression severity	A high depression subgroup with high alcohol use may be especially responsive to treatment
Thombs, O'Mara, Hou, Wagenaar, Dong, Merves, Goldberger, Weiler, Dodd & Clapp, 2011.	225 male (58.2%) and female bar patrons	2 subgroups classified by serotonin transporter gene polymorphism	The subgroup with the high-risk polymorphism was three times more likely to report having an intention to drive after consuming alcohol

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Table 2 (cont.)

Summary of empirically derived DWI subgroup studies

Author(s)	Participant Characteristics	Subgroup Classification	Key findings
Brown, Ouimet, Eldeb, Tremblay, Vingilis, Nadeau, Pruessner & Bechara, 2016.	113 DWI offenders. The mean age of the subgroups was 27-36 years	2 subgroups classified by DWI and non-DWI traffic offending	Subgroups emerged with distinct personality, cognitive and neurobiological characteristics associated to distinct driving behaviour
Moxley-Kelly, Ouimet, Dongier, Chanut, Tremblay, Marcantoni, & Brown, 2019.	184 predominantly male DWI offenders. The mean age of the subgroups was 41-48 years	2 subgroups classified by characteristics identified in *Brown et al., 2016*	A "fearlessness" subgroup had higher rates of recidivism, while an alcohol misuse and disinhibited subgroup was selectively responsive to brief motivational interviewing
Tokko, Eensoo, Vaht, Lesch, Reif, & Harro, 2019.	203 DWI offenders with a mean age of 33 years	3 high-risk biomarker subgroups classified by dopamine transporter and neuropeptide S allele polymorphisms and platelet monoamine oxidase enzyme levels	The high-risk neuropeptide S allele subgroup had higher rates of recidivism

subgroups and thus provides an accessible schema to identify high-risk subgroups.

LaBrie, Kidman, Albanese, Peller & Shaffer, 2007. A cross-sectional study replicated the DWI offender subgroup classification schema proposed in Argeriou et al., (1985) (N = 1,281; mean age = 37.2) in offenders participating in a court-mandated education program from 1996 to 1997. Four subgroups were formed based on criminal history and compared for recidivism rates: i) substance-related (60%), ii) property crime (18%), iii) crime against persons (8%), and iv) crime against both persons and property (13%). Similar to previous findings (Argeriou et al., 1985), engagement in other criminal behaviour along with DWI predicted greater recidivism risk compared to DWI alone. Moreover, DWI recidivists with a history of substance-related offences had higher rates of recidivism than multiple DWI offenders without. This study represents one of the few attempts at replication seen among DWI subgroup research and reaffirms that a subgroup with engagement in non-DWI criminal behaviour may demarcate a DWI subgroup with elevated risk for recidivism.

Woodall, Delaney, Kunitz, Westerberg, & Zhao, 2007. A US randomized and controlled trial recruited a predominantly Native American (76%) and male (86%) sample of incarcerated first time DWI offenders (N = 305; mean age = 27.1) to investigate the interaction between anti-social personality disorder (ASPD) and treatment on drinking outcomes over two years follow-up. The empirical classification used in this study was grounded in the theory that ASPD is a risk factor for DWI and may interact with treatment. Participants were randomly assigned to either motivational interviewing (MI) (n = 177) or a no-treatment control condition (n = 128). Thirty-six participants (20.3%) in the MI condition and 16 (12.5%) in the control condition met ASPD criteria. Contrary to hypotheses, participants with ASPD had significantly greater improvements over time compared to non-ASPD participants irrespective of treatment assignment. As the sample consisted

primarily of incarcerated Native-American offenders, it is possible cultural factors biased the findings. Despite inconclusive findings however, this study is one of the few randomized and controlled trials to investigate the possibility of targeted treatment based on subgroup characteristics.

Holt, O'Malley, Rounsaville & Ball 2009. In a US randomized trial of 10-week interactional therapy, alcohol education, coping skills and relapse prevention, a predominantly male (80%) sample of first-time offenders (N = 184) was classified into either high (>10) or low (<10) depression subgroups using the Beck Depression inventory and compared for recidivism rate at 6- and 12-months follow-up. This classification schema was predicated on the positive correlation between depression and recidivism in previous research. The high depression subgroup showed both high baseline alcohol use severity and significant reductions in alcohol use over time but no corresponding reductions in self-reported DWI. The high depression subgroup did report more motivation to change despite lower self-efficacy and more alcohol problems throughout the 12-month follow-up. The low depression subgroup did not show significant reductions in alcohol use. Treatment effects were not investigated. This study thus suggests that a high depression subgroup has greater alcohol involvement and greater responsivity to therapy compared to a low depression subgroup. Future work might compare the above treatments for relative efficacy within the high depression subgroup.

Thombs, O'Mara, Hou, Wagenaar, Dong, Merves, Goldberger, Weiler, Dodd & Clapp, 2011. This study investigated the predictive power of the 5-HTTLPR biomarker, a polymorphism in the promoter region of a serotonin transporter gene (5-HTT) associated with anxiety, depression, and substance misuse among 225 predominantly young adult (22.2%), male (58.2%), white (76.4%) intoxicated bar patrons. Results indicated the participants with the high-risk allele had three times

the likelihood of self-reporting intention to drive after consuming alcohol. In sum, this study provides insight into the predictive power of subgrouping by genetic markers and suggests that the 5-HTTLPR polymorphism represents a means to identify a high-risk phenotype.

Brown, Ouimet, Eldeb, Tremblay, Vingilis, Nadeau, Pruessner & Bechara, 2016. A cross-sectional study purposefully recruited two DWI subgroups: i) DWI (pDWI) only (n = 36; mean age = 30); and ii) DWI with other traffic offending (MIXED) (n = 27; mean age = 27.8), as well as a non-offender control group (n = 47; mean age = 30.1), and compared them on their multidimensional characteristics and driving behaviour in simulation. The MIXED subgroup showed blunted cortisol stress response, low agreeableness, sensation seeking, reward sensitivity, greater poly-substance misuse, criminality and more aggressive driving behaviour in simulation. These attributes were posited to reflect a neurobiologically-based phenotype in which offenders engage in DWI because of pathways stemming from shared traits. The pDWI subgroup showed elevated alcohol misuse and disinhibition but no driving risk-taking when sober, suggesting a subgroup whose DWI risk emerges from alcohol's disruptive effect on a weakened cognitive control system. This study is notable for its multi-level analysis to better clarify potential mechanisms underlying subgroup classification.

Moxley-Kelly, Ouimet, Dongier, Chanut, Tremblay, Marcantoni, & Brown, 2019. Building on the preliminary work of Brown et al., (2016) above, a secondary analysis of 5-year follow-up data from a randomized and controlled trial (Brown et al., 2010) of DWI offender recidivists compared the outcomes of retrospectively classified pDWI (n = 97) and MIXED (n = 87) subgroups exposed to one 30-minute session of either Brief Motivational Interviewing (BMI) vs. information and advice. Results indicated that the MIXED subgroup had greater recidivism irrespective of treatment assignment, while the pDWI subgroup was selectively more responsive

to BMI compared to the MIXED subgroup, such that on average pDWI offenders re-offended 201 days later than MIXED offenders. This study, though preliminary, suggests that pDWI offenders can be targeted for BMI treatment for more optimal DWI outcomes.

Tokko, Eensoo, Vaht, Lesch, Reif, & Harro, 2019. An Estonian longitudinal study investigated a sample of convicted DWI offenders (n = 203, mean age = 33 years) and non-DWI control drivers (n = 211, mean age = 36 years) recruited for 2 gene polymorphisms and 1 enzyme biomarker posited to demarcate high-risk phenotypes. The gene polymorphisms included a gene coding for a dopamine transporter (DAT1), which has been associated with alcohol dependence; and a gene coding for a high-risk neuropeptide S (NPSR1) allele that has been associated with road accidents. Additionally, the platelet monoamine oxidase (MAO) enzyme was measured, which is a marker of serotonergic activity and is associated with impulsivity, sensation seeking, and DWI (Eensoo et al., 2004). Participants were followed over ten years to determine whether these subgroups exhibited differential rates of recidivism. Baseline analyses indicated that the lower MAO subgroup was associated with a lower frequency of past DWI, the high-risk DAT1 allele carriers were associated with traffic accidents due to driver error, and the high-risk NPSR1 allele carriers were associated with alcohol problems and impulsivity. Follow-up over ten years indicated that the high-risk NPSR1 allele subgroup was at greater risk for recidivism (HR = 1.78). This study thus suggests that genetically based biomarkers (i.e., DAT1, MAO, and NPSR1) may be useful to identify higher-risk phenotypes).

Discussion

This review set out to answer the following question: does subgroup classification increase understanding, improve predictive accuracy, or enhance intervention effectiveness among DWI offenders? To the authors' knowledge, this is the first review of DWI subgrouping studies. Only

18 studies were identified – ten statistically driven and eight empirically driven studies – suggesting the literature is nascent. The subgroups that emerged could be categorized into two main types: i) subgroups with severe alcohol misuse and/or depressive/neurotic characteristics; and ii) subgroups with related high-risk behavioural and neurobiological characteristics representative of an externalizing complex. There was some preliminary evidence that membership in these subgroups, in addition to being associated with increased risk for DWI, predicted selective responsivity to treatment. To address the findings, the current discussion is divided into three subsections: i) *summary of findings on key subgroups*; ii) *methodological issues*; and iii) *recommendations for future research*.

Summary of findings on key subgroups

Subgroups classified by alcohol misuse and/or depressive/neurotic characteristics were found in several studies. Alcohol misuse subgrouping was associated with increased rates of recidivism (Ball et al., 2000; Saltstone & Poudrier, 1989; Wieczorek & Miller, 1992). This finding is in line with research that has supported the intuitive relationship between alcohol misuse severity and frequency of DWI (Lapham et al., 2001; LaPlante et al., 2008). Importantly, preliminary evidence suggests that this subgrouping predicted selective responsivity to a very brief (one 20-30 minute session) adapted form of motivational interviewing (BMI) in delaying DWI recidivism over at least a five-year follow-up (Moxley-Kelly et al., 2019). Further, BMI is established as an effective treatment for alcohol use disorder (Vasilaki et al., 2006), and treatment targeting alcohol use reduces recidivism among DWI offenders (DeYoung, 1997). Thus, if these findings stand up to prospective replication, BMI, a relatively exigent intervention to mount and sustain, could be efficiently targeted at those offenders most likely to benefit.

Subgroups classified by depressive/neurotic features were associated with an array of risky behaviors (Moore, 1994; Donovan & Marlatt, 1982) as well as DWI recidivism (Nelson et al., 2019; Steer et al., 1979), and showed significant declines in risky drinking when receiving alcohol misuse prevention treatments (Holt et al., 2009). However, no plausible rationale for a link was established between DWI and depression. Increased depression, though, may precipitate increased alcohol misuse among DWI offenders (Windle & Miller, 1990), making alcohol a potential mediator of the relationship between depression and DWI (Pogue, Hakes, & Sloan, 2017). Future studies using a "mechanisms of change" design (Nielsen et al., 2018) might explore the mediating effect of changes in alcohol misuse and depression/neuroticism in reducing recidivism in this subgroup following intervention exposure.

Several studies reviewed here investigated subgroups with related high-risk behavioural and neurobiological characteristics that reflect a shared externalizing complex (Quinn & Harden, 2013). Most showed that DWI subgroups classified by antisocial characteristics, hostility, and criminality were associated with elevated rates of risky driving, including DWI (Donovan & Marlatt, 1982; Moore, 1994) and DWI recidivism (Brown et al., 2016; Moxley-Kelly et al., 2019; Argeriou et al., 1985; LaBrie et al., 2007a; Donovan et al., 1986). Subgroups possessing biomarkers of externalizing, hostile, and risk-taking characteristics predicted intention to drive after consuming alcohol (Thombs et al., 2011), more frequent past DWI's, and increased risk of DWI recidivism (Moxley-Kelly et al., 2019; Tokko et al., 2019). Subgroups with high-risk behavioural and neurobiological characteristics may encompass a large proportion of the DWI population, as roughly half of DWI offenders have a history of engagement in non-DWI crime (LaBrie et al., 2007a) and externalizing behaviours (Cavaiola et al., 2003), as well as possessing

impulsive (Stacy et al., 1991a), hostile, and sensation-seeking traits (Nochajski & Stasiewicz, 2006).

In sum, subgroups classified by severe alcohol misuse and/or depressive/neurotic characteristics and high-risk behavioural and neurobiological characteristics emerge repeatedly across studies and methodologies. These classifications also have strong validity, are associated with large effects, and although their identification is feasible in research, in clinical settings the identification of multidimensional and genetic subgroups may be intractable. Future research might prioritize the investigation of subgroups that are feasible to identify in real-world contexts to increase clinical relevance.

Methodological Issues

Statistical approaches represent a readily available method for subgroup classification. Their relative ease and accessibility render them an ideal approach to initiate the search for homogeneous subgroups and theory development. However, subgroups derived from statistical approaches have been difficult to replicate. Statistical methods are sensitive to variations in software algorithms, data inputs, and sampling (Blashfield, 1980). When this issue was directly addressed in the context of DWI, different approaches to cluster analysis failed to replicate subgrouping results (Wells-Parker et al., 1993). It could be argued that continued research using cluster analysis to identify new subgroups, in the absence of replication and prospective clinical validation, has reached a certain saturation in the literature.

As empirical approaches are predicated on *a priori* theories or concepts, they are well suited to test hypotheses concerning subgroup classification and their clinical relevance. Moreover, they frequently use simple and clearly outlined classification criteria (e.g., driving and/or criminal behaviour), making subgroups more feasible to reconstitute. At the same time, in research,

purposeful sampling to constitute subgroups according to an *a priori* schema can be prohibitively time consuming and expensive – particularly as stratification by age, sex, and socioeconomic status, among other factors, may be needed. This can represent a substantive pragmatic barrier to the conduct of research using this approach.

Recommendations for Future Research

Both statistical and empirical approaches to subgroup classification have a role in research. The results of this review suggest that subgroup research could be further advanced through a systematic, multi-stage study design involving: i) subgroup identification; ii) investigation into construct validity; iii) replication using separate datasets; and iv) hypothesis testing for differential recidivism or selective treatment response. Statistical subgrouping methods are apt for stage i, while empirical methods are apt for stages ii-iv. Research could be further enhanced by using a "mechanisms of change" approach at stage iv. This approach specifically attempts to link changes in processes to changes in DWI recidivism risk and to interventions that selectively disrupt those processes. This knowledge can be leveraged in research targeting subgroups whose members share specific risk-promoting processes for exposure to appropriate interventions. Retrospective secondary analysis of historical data, despite its limitations, represents a potential avenue to reduce the expense of subgrouping research, at least at a preliminary stage. As DWI courts, alcohol ignition interlock programs, motivational interviewing, and alcohol-monitoring programs have to date shown significant effects in reducing recidivism (Fell, 2019; Moxley-Kelly et al., 2019; Ouimet et al., 2013), investigating plausible interactions between key subgroups and these interventions may also be fruitful to further optimize outcomes. Finally, future work is needed to explore subgrouping classification schemas in female DWI offenders, as they remain an under-researched population.

Limitations

The DWI subgrouping literature is nascent and between-study methodologies vary greatly. Hence, a systematic review, though capable of providing more definitive inferences than the narrative approached used here, was deemed premature. Nevertheless, the conclusions here may provide a foundation to inform future research into DWI subgrouping, as well as to gauge progress in the field in future systematic reviews.

Conclusion

Subgroup classification of DWI offenders reflects recent trends towards personalized interventions for alleviating maladaptive behaviour. This review indicates that subgroup classification also represents a promising yet challenging paradigm shift in how research into human factors in DWI risk and prevention is conducted in the traffic safety field.

Driving While Intoxicated Subgroups among Female Offenders

Abstract

Background: A better understanding of female driving while intoxicated (DWI) offenders is required to slow the rising rates of female DWI. Research into male DWI offending suggests that identifying clinically relevant subgroups is a means to enhance understanding and prevention. In previous research, two subgroups of male DWI offenders with putative clinical relevance were identified based upon their driving behaviours: 1) offenders who engage in a mixture of DWI and other risky driving behaviour (MIXED); and 2) offenders who engage primarily in DWI behaviour (pDWI). These subgroups also showed different rates of recidivism and response to treatment. However, this subgroup classification schema has yet to be tested in females. In the current secondary analysis-based study, female DWI offenders previously recruited in other research were retrospectively classified into the above subgroups and tested for their psychological and cognitive characteristics shown to promote DWI and other risky driving behaviours.

Hypotheses: It was hypothesized that MIXED and pDWI female offender subgroups exhibit: i) elevated psychological and cognitive dysfunction compared to female low-risk non-offender control drivers; and ii) distinct patterns of psychological and cognitive dysfunction compared to each other as well as compared to male offender subgroups.

Method: This secondary analysis used a cross-sectional, quasi-experimental design. A sample of first-time DWI offenders (male = 158, female = 87) and control drivers (male = 58, female = 42) were constituted retrospectively into pDWI and MIXED subgroups using documented driving behaviour. Analyses to test hypotheses were then conducted on measures of impulsivity, disinhibition, sensation seeking, alcohol and substance use, and psychiatric characteristics involving antisocial, depressive, and post-traumatic stress features.

Results: Compared to the female non-offenders, the female-MIXED subgroup showed elevated alcohol and substance misuse, and antisocial, PTSD and impulsive features, while the female-pDWI subgroup showed elevated antisocial features. Additionally, the female-MIXED subgroup showed elevated alcohol misuse, PTSD and impulsive dysfunction compared to the female-pDWI subgroup, and elevated antisocial, PTSD and impulsive dysfunction compared to the male-MIXED subgroup.

Discussion: The findings lean in support of the hypotheses. This study supports the conjecture that distinct characteristics are associated with female DWI subgroups. In sum, the MIXED and pDWI subgroups may be clinically relevant for tailored intervention in female DWI offenders and warrant further investigation.

Conclusion: Classifying female DWI offenders into subgroups is a promising avenue to clarify heterogeneity.

Les sous-groupes des contrevenants à la conduite avec facultés affaiblies de sexe féminine

Abstrait

Contexte: Une meilleure compréhension de la conduite avec des facultés affaiblies est nécessaire pour ralentir la hausse des taux chez les femmes. La recherche sur la conduite avec des facultés affaiblies chez les hommes suggère que l'identification des sous-groupes cliniquement pertinents est un moyen d'améliorer la compréhension et la prévention. Dans des recherches antérieures, deux sous-groupes des contrevenants à la conduite avec facultés affaiblies (CFA) de sexe masculin ayant une pertinence clinique putative ont été identifiés en fonction de leurs comportements de conduite: 1) les CFA qui adoptent d'autres comportements à risque au volant (MIXTE); et 2) les contrevenants qui adoptent principalement des comportements de la conduite avec des facultés affaiblies (pDWI). Ces sous-groupes ont également montré des taux différents de récidive et de réponse au traitement. Cependant, le schéma de classification des sous-groupes n'a pas encore été testé chez des contrevenants à la conduite avec facultés affaiblies de sexe féminine. Dans l'étude secondaire actuelle fondée sur l'analyse, les CFA de sexe féminine précédemment recrutées dans d'autres recherches ont été rétrospectivement classées dans les sous-groupes ci-dessus et testées pour leurs caractéristiques psychologiques et cognitives qui favorisaient la CFA et d'autres comportements de conduite à risque.

Hypothèses: On a émis l'hypothèse que les sous-groupes de CFA MIXTE de sexe féminine et pDWI de sexe féminine présentaient: i) un dysfonctionnement psychologique et cognitif élevé par rapport aux conductrices témoins à faible risque non délinquantes; et ii) des schémas distincts de dysfonctionnement psychologique et cognitif par rapport les uns aux autres ainsi que par rapport aux sous-groupes de délinquants de sexe masculin.

Méthode: Cette analyse secondaire a utilisé un plan transversal quasi expérimental. Un échantillon de CFA (hommes = 158, femmes = 87) et de conducteurs témoins (hommes = 58, femmes = 42) a été constitué rétrospectivement en sous-groupes pDWI et MIXED en utilisant un comportement de conduite documenté. Des analyses pour tester des hypothèses ont ensuite été menées sur les mesures de l'impulsivité, de la désinhibition, de la recherche de sensations, de la consommation d'alcool et de substances, et des caractéristiques psychiatriques impliquant des caractéristiques de stress antisocial, dépressif et post-traumatique.

Résultats: Les résultats appuient les hypothèses. Comparé aux femmes non CFA, le sous-groupe féminin MIXTE a montré une consommation excessive d'alcool et de substances, ainsi que des caractéristiques antisociales, PTSD et impulsives, tandis que le sous-groupe féminin pDWI a également montré des caractéristiques antisociales élevées. De plus, le sous-groupe féminin MIXED a montré un abus d'alcool élevé, un SSPT et un dysfonctionnement impulsif par rapport au sous-groupe féminin pDWI, et un dysfonctionnement antisocial, SSPT et impulsif élevé par rapport au sous-groupe masculin MIXED.

Discussion: Cette étude soutient l'hypothèse selon laquelle des caractéristiques distinctes sont associées aux sous-groupes CFA féminins . En résumé, les sous-groupes MIXTE et pDWI féminins peuvent être cliniquement pertinents pour ciblant des interventions sur mesure chez les CFA féminins et justifier une enquête plus approfondie.

Conclusion: La classification des CFA en sous-groupes est une avenue prometteuse pour clarifier l'hétérogénéité et approfondir la compréhension.

Introduction

Despite increases in law enforcement and public awareness (Rauch et al., 2010), driving while intoxicated with alcohol (DWI) remains a major public safety issue and a leading cause of morbidity worldwide (World Health Organization, 2015). As roughly 85% of DWI offenders are male (Lapham et al., 2001), research has focused on male offenders, leaving research into female DWI underdeveloped. However, the rate of DWI among females is rising in Canada (Perreault, 2016) and the United States (Federal Bureau of Investigation, 2012), and female alcohol-impaired drivers are now present in 7% of road traffic crashes resulting in death (World Health Organization, 2015). Given the scarcity of research and growing epidemiology of female DWI, research into understanding the risks and needs of female offenders represents a major gap in traffic safety research.

Subgrouping represents a strategy to improve understanding, prediction and prevention in the heterogeneous DWI population (Medicines Agency, 2000; Nochajski & Stasiewicz, 2006). An ongoing line of research (Brown et al., 2016; Moxley-Kelly et al., 2018) has investigated high-risk drivers to clarify subgroups whose members share both discrete risky driving patterns and putative underlying mechanisms to their DWI risk. Two subgroups have been identified, and preliminary evidence tentatively supports the clinical relevance of this classification schema in male DWI offenders. The current study thus investigates the generalizability of this subgroup classification schema in female DWI offenders. The following introduction reviews pertinent research on female DWI offenders and then presents the current study's rationale and hypotheses.

Female DWI Offenders

Female DWI offenders appear to possess different characteristics compared to both female non-offenders and male offenders. Female DWI offenders, compared to female non-offenders,

have higher rates of alcohol and substance dependence, antisocial personality, major depression, dysthymic disorder, and post-traumatic stress disorder (PTSD) (Lapham et al., 2001). Compared to male DWI offenders, female offenders were more likely to have past-year diagnoses of major depression (6.6% in males vs. 17.2% in females) and PTSD (6.5% in males vs. 16.5% in females) (Lapham et al., 2006). Further, sensation seeking (SS), which is associated with risky driving and DWI generally (Jonah, 1997), was found to be elevated in female DWI offenders compared to female non-offenders (Arnett et al., 1997) and male offenders (Stacy et al., 1991b). Female DWI offenders were also observed to show higher impulsivity and cognitive disinhibition compared to female non-offenders – a difference that was not observed in male DWI offenders compared to their non-offender comparators (Brown et al., 2015). Sexual dimorphism has been observed in DWI offenders, with cortical thinning in the posterior cingulate cortex (PCC) found in male DWI offenders but not in female offenders (Dedovic et al., 2016). Female DWI offenders appear distinct from male offenders based upon their individual alcohol and substance misuse and psychiatric, sensation seeking, impulsivity, cognitive disinhibition and morphological features.

Female offenders have also shown a differential treatment response compared to males. While victim impact panels (C'De Baca et al., 2001) and life activities interviews (Wells-Parker et al., 1991) have been associated with decreased recidivism rates in male DWI offenders, they were associated with increased recidivism rates in female DWI offenders. The authors of these studies posited that these differences in treatment response could arise from the increased feelings of guilt and shame they evoked in female offenders specifically. These feelings may, in turn, increase DWI, possibly by increasing drinking. In sum, the available evidence suggests that certain features that characterize female DWI offenders, and which may interact with intervention to produce different outcomes compared to male offenders.

Overall, female DWI offenders compared to males show characteristics indicative of their putative pathways to DWI, distinct needs, and treatment responsivity. However, the heterogeneity in the DWI offender population generally (Miller et al., 2015; Nochajski & Stasiewicz, 2006; Wells-Parker et al., 1995) likely extends to the female DWI population. Thus, certain characteristics may not be equally germane to DWI for all individuals within the female DWI population. In sum, delineating subgroups among female DWI offenders with distinct characteristics may clarify heterogeneity and thus inform future treatment matching studies.

Foundational subgroup research

Phenotypes are subgroup classifications that signify developmental interactions between genes and the environment (O'Brien, 2006). They bridge the gap between behaviour and its biological, environmental, and trait causes and have been studied in fields adjacent to DWI, such as addiction (Kreek et al., 2005). Classifying offenders into DWI-relevant phenotypes represents a potential avenue to deepen understanding of DWI as it incorporates biological and genetic factors.

In a study (Brown et al., 2016) that laid the foundation for the current work two phenotypes with putative clinical relevance demarcated by driving behaviour were identified among male DWI offenders: offenders who engage in a mixture of DWI and other risky driving behaviour (MIXED), and offenders who engage primarily in DWI behaviour (pDWI). In this cross-sectional study, participants were purposefully sampled to obtain the subgroups and comparisons were made between the subgroups and with a non-offender control group. Cortisol stress response, personality (i.e. impulsivity, sensation seeking, and the "Big Five" personality dimensions: neuroticism, extraversion, openness, agreeableness, conscientiousness and neuroticism), and cognitive function (i.e. disinhibition and decision making) were measured.

The MIXED phenotype was correlated with severely blunted cortisol fear response, low agreeableness, sensation seeking, criminality, and alcohol and substance misuse – characteristics that are associated with a "fearlessness" phenotype (Hawes et al., 2009; Zuckerman, 1994). The hypothesized pathway to this phenotype's risk-taking behaviour involves chronic hypoactivity of the amygdala (i.e. blunted fear response), which in turn produces hypoactivity in afferent receiving cortices: the bed nuclei of the stria terminalis, the medial prefrontal cortex, and the nucleus accumbens (Carroll et al., 2017). Hypoactivity in these regions is associated with reduced empathy, inability to adhere to societal rules and norms, and disrupted learning from negative consequences (Lavallo, 2007; Ritsner, 2009). These characteristics may lead to the combination of criminality, recklessness, and frequent alcohol intoxication that has been observed in MIXED offenders and represent their pathway to DWI.

Alternatively, the pDWI phenotype was found to have severely elevated alcohol misuse, cognitive impulsivity, and blunted cortisol fear response – though cortisol was less blunted than in the MIXED phenotype. Moreover, in functional neurocognitive testing and behavioural risk-taking tasks (e.g., simulated driving), they showed little risk-taking propensity when sober. These factors are hypothesized to signifying an "alcohol and cognitive risk" phenotype. Blunted cortisol fear response is associated with the inherited risk for alcohol use disorder, impaired self-regulation and poor treatment response (Couture et al., 2015; Gianoulakis, Dai, & Brown, 2003; Junghanns et al., 2005). Hence, the pDWI phenotype engages in more heavy drinking that appears to render them more susceptible to alcohol's disruptive effects on the self-regulatory processes that are likely needed to avoid DWI. As acute alcohol intoxication increases cognitive impulsivity (Rose & Duka, 2008) and reduces visuospatial ability, balance, and various executive processes (Bates et al., 2002; Sullivan et al., 2000), the combined effects of alcohol and cognitive impulsivity represent a

putative pathway to DWI for this phenotype. In aggregate, these cross-sectional findings suggest that as DWI risk is promoted by different processes in each subgroup, effective interventions would likely need to be targeted to interrupt these specific processes.

Building upon Brown et al., 2016, our research group conducted a secondary analysis (Moxley-Kelly et al., 2018) of an randomized and controlled trial (Brown et al., 2010; Ouimet et al., 2013) to investigate the MIXED and pDWI phenotypes in a sample of predominantly male (89%) DWI recidivists (N = 184). The phenotypes fell into one of two 30-minute treatment conditions: i) BMI, or ii) a control information-advice session (IA) matched to the BMI condition in therapist time and attention. Four subgroups were thus formed: pDWI-BMI (n = 46), MIXED-BMI (n = 45), pDWI-IA (n = 51) MIXED-IA (n = 42). A main effect of phenotype was found such that the MIXED subgroup had higher rates of recidivism (hazard ratio (HR) = 2.9) than the pDWI subgroup over the 5-year follow-up. The strength of the effect of this classification schema exceeded the effects of nontraffic criminal behaviour predictors reported elsewhere in the literature, which ranged up to HR = 2.3 (Marowitz, 1998) and HR = 2.4 (Impinen et al., 2009). The current classification scheme may thus increase specificity to DWI as it derives subgroups based on driving behaviours. Further, the pDWI phenotype was selectively responsive to BMI compared to the MIXED phenotype such that they exhibited a seven-fold increase latency to recidivism. The MIXED offenders, given their resistance to BMI, may be candidates for constraint technologies such as ignition interlock, which are effective for reducing recidivism while installed (Elderet al., 2011). Overall, risky driving preference appears to be a useful marker for classifying DWI offenders into phenotypes with distinct recidivism risk, explanatory pathways to their risky driving, and selective response to treatment.

Summary

Despite the promise of the MIXED and pDWI subgroup classification schema, its generalisability to the female offender population is unknown. Indeed, though statistical subgrouping studies have been conducted with female offenders (i.e., Moore, 1994), to our knowledge, no study has examined empirical subgroup classification within the female offender population. Accordingly, the present study classified a sample of female DWI offenders into the MIXED and pDWI subgroups using the driving behaviour-based subgroup classification schema above (Brown et al., 2016). It then examined these subgroups for their substance use, psychological and cognitive characteristics, especially those that are associated with female DWI behavior. We hypothesized that: 1) female-MIXED and female-pDWI offenders exhibit elevated alcohol and substance misuse and psychiatric characteristics, sensation seeking, impulsivity and cognitive disinhibition compared to female non-offender comparators; and 2) female subgroups differ from each other and their male MIXED and pDWI subgroup comparators on alcohol and substance misuse and psychiatric characteristics, sensation seeking, impulsivity and cognitive disinhibition. In sum, this study aimed to obtain evidence that would: i) fill an evidence gap in the literature; ii) advance our research into DWI subgrouping; and iii) open a potential avenue for future investigations into personalized intervention approaches adapted to female DWI offenders, who represent a growing traffic safety concern.

Method

Study site, design and ethical oversight

The present study was conducted at Addiction Research Program of the Douglas Hospital Research Center located in Quebec, Canada. This quasi-experimental, cross-sectional study is based upon secondary analysis of data from a previously recruited cohort of female and male DWI

first-time offenders who were retrospectively classified into MIXED and pDWI subgroups, as well as matched, non-DWI controls. The original study was approved and monitored by the Douglas Hospital Ethics Board (REB # 08/11) and represented a collaboration with the Quebec licensing authority (Société de assurance automobile du Québec; SAAQ).

Sample

The sample consisted of first-time DWI offenders (male = 158, female = 87) and control drivers (male = 58, female = 42) previously recruited for a larger longitudinal cohort study into sex (Brown et al., 2015; Dedovic et al., 2016) and neurobiological (Brown et al., 2019; Couture et al., 2015) correlates of DWI recidivism. The inclusion criteria for the DWI offenders were: i) a minimum of a sixth-grade reading capacity; ii) experience with alcohol consumption; iii) an age ranging from 18 to 44 years; and iv) a verifiable DWI conviction within the previous 24 months. The inclusion criteria for the control drivers were: i) a minimum of a sixth-grade reading capacity; ii) experience with alcohol consumption; iii) age ranging from 18 to 44 years; and iv) current possession of a valid driver's licence. An age range of 18 to 44 was selected as unintentional injury, including traffic related injury, is the leading cause of death within this age group (Friis & Sellers, 2021). Participants were excluded if they had reading skills less than the 6^{th}-grade level or were deemed by the team physician to be put at risk by exposure to the experimental procedures.

Measures

For sample description analyses, sociodemographic information, substance use, and driving behavior were measured. Sociodemographic information including age, sex, ethnic origin, and number of years of education was obtained via the Addiction Severity Index (ASI; Thomas McLellan et al., 1985). The ASI has been found to be reliable and valid in offender populations (McLellan et al., 2006).

Several measures were employed to assess alcohol and substance misuse. Past 12-month alcohol misuse and its associated problems were measured with the 10-item Alcohol Use Disorder Identification Test (AUDIT; Conley, 2001). This measure was developed by the World Health Organization and has been shown to be valid in individuals with alcohol and substance misuse (Babor et al., 2001), DWI offenders (Conley, 2001), and across cultures (Allen et al., 1997). The 10-item Michigan Alcoholism Screening Test (MAST) has been validated among DWI offenders (Conley, 2001) and was used to measure lifetime alcohol misuse severity and its consequences. Lifetime substance misuse and its consequences were measured by the 20-item Drug Abuse Screening Test (DAST; Skinner, 1982). The DAST is a reliable measure that has been validated in DWI offender populations (Skinner et al., 1995). The Timeline Follow Back (TLFB; Sobell & Sobell, 1992) is a validated (Moxley-Kelly et al., 2018; Pedersen et al., 2012) measure that involves the presentation of a calendar to aid the accurate recall of the previous 90 days. The TLFB was used to measure recent driving behaviour and alcohol use. The above measures were selected because female DWI offenders have shown higher rates of alcohol and substance misuse compared to female non-offenders (Lapham et al., 2001) and male DWI offenders (Lapham et al., 2006).

In addition, psychiatric, sensation seeking, and impulsivity characteristics were measured with the Millon Clinical Multiaxial Inventory (MCMI-III), the Barratt Impulsivity Scale (BIS), the Sensation Seeking Scale (SSS), and the Connor's Continuous Performance Test (CPT-II). The 175-item Millon Clinical Multiaxial Inventory (Millon, 1985) is a reliable and validated measure that assesses characteristics that correspond to DSM-5 diagnoses (Cutler et al., 2013). In particular, the antisocial, depressive, dysthymic, and post-traumatic stress subscales were extracted as the prevalence of these disorders is elevated in female DWI offenders compared to female non-offenders (Lapham et al., 2001). The 30-item, 11th version of the Barratt Impulsivity Scale (Patton

et al., 1995) was used to measure facets of impulsivity, including attention, motor, and non-planning impulsivity. The BIS-11 is valid and reliable for the measurement of impulsivity in adult populations (Fossati et al., 2002). It was selected because it has been used to identify elevated impulsivity in female DWI offenders compared to female non-offenders (Brown et al., 2015). The 5th version of the Sensation Seeking Scale (Zuckerman, 2007) is a 40-item self-report measure of thrill and adventure seeking, experience-seeking, disinhibition, and boredom susceptibility. The SSS has been shown to have reliability and validity (Beauducel et al., 1999; Wang et al., 2000) and was selected as sensation-seeking is elevated in DWI offenders compared to non-offenders (Wilson, 1992), and female DWI offenders exhibit significantly different levels of sensation-seeking compared to male DWI offenders (Stacy et al., 1991b). Finally, Connor's Continuous Performance Test (CPT-II) was used to measure functional executive control. This reliable and validated (Shaked et al., 2019) measure assesses the number of commission errors, preservation errors, and the hit reaction time when asked to respond to a prompt, the CPT-II can provide separate measures of cognitive disinhibition and impulsivity. This test was sensitive in DWI offenders for detecting elevated disinhibition (Ouimet et al., 2007) and poor impulse control (Glass et al., 2000) compared to non-offenders.

Procedures

Recruitment and *retrospective subgroup classification*

Participants were recruited between January 2009 to July 2012 through newspaper advertisements and via an invitation letter enclosed in correspondence to first-time offenders from the SAAQ. Study candidates were forwarded an information package detailing study experimental procedures and objectives, and compensation of $160 CDN as well as potential additional bonuses dependant on experimental task performance. The experimental protocol involved one session

lasting from 9:00 A.M. to 4:00 P.M. Upon arrival at the research centre, candidates received an informed consent package, which was discussed and with any questions or concerns addressed, subsequently signed. Participants were then tested for blood alcohol concentration, and if it was above .01% the participant was rescheduled. Participants then underwent a medical examination. Finally, participants were administered the intake battery of questionnaires, assays and tasks.

Participants were empirically organized by behavioral driving profiles related to DWI phenotypes by adapting a previously published (Brown et al., 2016) and replicated (Brown et al., 2017) algorithm to match the current sample: i) pDWI drivers (Male = 62, Female = 35) who have at least one verifiable DWI and < 2 non-alcohol moving violations within the past 10 years, and ii) MIXED drivers (Male = 96, Female = 52) who have at least one verifiable DWI and ≥ 2 moving violations in the previous 10 years. In addition, a control group (male = 58, female = 42) of non-offending drivers was included for comparison.

Analyses

Pre-analysis of dependent variables identified outliers (SD ≥ 3.29) on the CPT-II task (n = 2) and the BIS (n = 1) which were replaced with the next most extreme values to reduce their impact on analyses while maintaining their relative position in the distribution (Tabachnick & Fidell, 2012). All dependant variables fell within normality cut-offs (skewness ≥ 1, kurtosis ≥ 3). To describe the subgroups' characteristics and identify potential confounding variables, between-group comparisons were made on sociodemographic data using sex (2) x group (3) factorial ANOVA. When the subgroups significantly differed on sociodemographic variables, sensitivity analyses were conducted that entered the sociodemographic variables as covariates. These analyses are reported in the results section.

To test hypotheses, a planned comparison approach was used. Overall, hypotheses were tested using sex (2) x group (3) factorial ANOVA to model and generate the statistics required for planned comparisons. Hypotheses were tested in two stages: 1) female DWI offender subgroups were compared to non-offender comparators (i.e. female-MIXED offenders vs. female non-offenders; female-pDWI offenders vs. female non-offenders) for each dependant variable; 2) variables detected to be significantly elevated in the female offender subgroups in the first stage were compared: a) between the female offender subgroups (i.e. female-MIXED offenders vs. female-pDWI offenders); and then b) between the female offender subgroups and their male subgroup comparators (i.e. female-MIXED offenders vs. male-MIXED offenders; female-pDWI offenders vs. male-pDWI offenders). Alpha for inferences of significance was set at $p < .05$, with Holm-Bonferroni corrections for multiple comparisons. Partial eta squared (η^2) contrasts were used to estimate the effect sizes of significant analyses. Power analyses were conducted with G*Power® software and indicated that with the current sample size all comparisons were sufficiently sensitive to detect small effects. All descriptive and hypothesis testing analyses were made using SPSS® version 24 software.

Results

Sociodemographic and Descriptive Analyses

Table 1 summarizes the descriptive comparisons between the subgroups on sociodemographic and driving histories. Pairwise comparisons indicated that the female-MIXED (95% CI = 0.60, 2.71, p = .002, $\eta^2 = 0.11$) and the female-pDWI subgroups (95% CI = 1.22, 3.54, $p < .001$, $\eta^2 = .16$) had significantly fewer years of education than the female control drivers. Between sex comparisons found that the female-MIXED offenders were significantly older (95% CI = 2.03, 7.31, $p < .001$, $\eta^2 = 0.08$) and had more years of education (95% CI = 0.08, 1.83, p =

Table 1

Sociodemographic and driving history of the female-MIXED, female-pDWI, female control, male-MIXED, male-pDWI, and male control and between-group comparisons.

	Female Control[a]	Female-MIXED[b]	Female-pDWI[c]	Male Control[d]	Male-MIXED[e]	Male-pDWI[f]
	M (SD)	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**
Demographics						
Age	32.2 (7.6)	**33.0 (8.7)[a,e]**	30.2 (8.8)	31.8 (7.8)	28.4 (6.8)	29.0 (8.0)
Education	**16.4 (2.6)[b,c]**	**14.7 (2.2)[e]**	14.03 (2.8)	15.5 (2.9)	13.8 (2.5)	14.4 (2.7)
% income < 30K	47.6	44.2	25.0	62.1	43.7	33.3
% white ethnicity	80.9	94.2	91.4	67.2	90.6	87.1
Driving						
KM driven in past 5 years (thousands)	35.2 (42.0)	96.3 (90.5)	54.6 (56.8)	68.7 (78.0)	100.8 (74.3)	74.2 (58.1)
Risky driving questionnaire	53.4 (13.3)	60.7 (15.0)	54.0 (14.2)	60.4 (17.3)	62.7 (13.3)	58.4 (13.8)

Notes. Letter superscripts indicate significantly ($p < .05$) higher scores than the group denoted (female control = a, female-MIXED = b, female-pDWI = c, male control = d, male-MIXED = e, male-pDWI = f).

.033, $\eta^2 = .02$) than the male-MIXED offenders. To control for these sociodemographic differences, sensitivity analysis retested all contrasts covarying age and years of education. Significant inferences from all the results of the hypothesis testing reported below were maintained at the $p < .05$ level. No significant differences on driving measures were observed between subgroups.

Hypothesis Testing

Tables 2 and 3 summarize the psychiatric characteristics, sensation seeking, impulsivity and cognitive disinhibition by groups. Results from analyses to test hypothesis 1 are graphically depicted in Figures 1-6. Compared to female non-offenders, the female-MIXED offenders showed significantly elevated PTSD (95% CI = 3.93, 21.08, $p = .004$, $\eta^2 = 0.09$) and antisocial (95% CI = 10.30, 28.96, $p < .001$, $\eta^2 = 0.19$) characteristics on the MCMI-III; higher non-planning impulsivity scores (95% CI = 0.46, 4.02, $p = .014$, $\eta^2 = 0.07$) and motor impulsivity scores (95% CI = 1.32, 4.82, $p = .001$, $\eta^2 = 0.15$) on the BIS; higher TLFB (95% CI = 0.96, 2.49, $p < .001$, $\eta^2 = 0.19$), AUDIT (95% CI = 3.98, 8.74, $p < .001$, $\eta^2 = .26$), and MAST (95% CI = 2.03, 15.18, $p < .001$, $\eta^2 = .22$) scores indicating greater past 90-day, 12-month and lifetime alcohol problem severity, respectively. The female-MIXED also showed significant elevations on the DAST compared to the female control drivers (95% CI = 0.58, 2.83, $p = .003$, $\eta^2 = 0.59$) indicating greater lifetime substance misuse. In contrast, female-pDWI offenders showed significantly elevated antisocial (95% CI = 1.51, 22.09, $p < .025$, $\eta^2 = 0.08$) characteristics.

Subscale scores of the CPT-II and SSS, the cognitive impulsivity subscale on the BIS, and the dysthymic and depressive subscales from the MCMI-III were not significantly elevated in the female-MIXED and female-pDWI subgroups compared to female control drivers and were thus not tested in the following step in the hypothesis testing.

Table 2

Psychiatric characteristics and sensation seeking of the female-MIXED, female-pDWI, female control, male-MIXED, male-pDWI, and male control and between-group comparisons

	Female Control[a]	Female-MIXED[b]	Female-pDWI[c]	Male Control[d]	Male-MIXED[e]	Male-pDWI[f]
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
MCMI-III						
Dysthymic	11.6 (21.9)	24.2 (31.2)	22.7 (28.6)	25.7 (32.0)	24.6 (30.1)	25.0 (27.8)
Depressive	14.1 (22.3)	26.5 (32.7)	32.7 (30.2)	23.3 (31.5)	21.8 (28.1)	19.6 (24.9)
PTSD	56.0 (18.7)	**68.5 (20.4)[a,c,e]**	59.1 (23.3)	46.8 (22.3)	59.0 (21.6)	52.0 (22.4)
Antisocial	45.7 (20.5)	**65.3 (19.4)[a,e]**	**57.5 (20.9)[a]**	48.7 (25.3)	56.0 (24.6)	51.1 (25.7)
SSS						
Thrill/adven-ture seeking	5.8 (2.3)	6.5 (2.7)	5.6 (2.6)	6.6 (2.9)	7.4 (2.3)	7.6 (2.3)
Experience seeking	6.8 (2.0)	7.0 (1.4)	6.5 (2.1)	6.4 (2.1)	6.3 (1.9)	6.4 (2.1)
Disinhibition	3.6 (2.1)	4.3 (2.3)	3.9 (3.3)	4.9 (2.7)	5.3 (2.5)	5.2 (2.5)
Boredom susceptibility	2.4 (2.0)	2.8 (1.7)	1.7 (1.6)	3.5 (2.4)	2.9 (2.0)	2.7 (1.8)

Notes. Letter superscripts indicate significantly ($p < .05$) higher scores than the group denoted (i.e., female control = a, female-MIXED = b, female-pDWI = c, male control = d, male-MIXED = e, male-pDWI = f). MCMI-III: Millon Clinical Multiaxial Inventory; PTSD: Post Traumatic Stress Disorder; SSS: Sensation Seeking Scale.

Table 3

Impulsivity, cognitive disinhibition and substance use of the female-MIXED, female-pDWI, female control, male-MIXED, male-pDWI, and male control and between-group comparisons

	Female Control[a]	Female-MIXED[b]	Female-pDWI[c]	Male Control[d]	Male-MIXED[e]	Male-pDWI[f]
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
BIS						
Non-Planning impulsivity	20.2 (2.9)	**26.4 (4.3)[a,e]**	25.2 (3.3)	24.0 (5.6)	24.0 (5.6)	24.7 (4.3)
Motor impulsivity	20.2 (2.9)	**23.3 (4.1)[a,c]**	21.3 (3.7)	23.1 (6.7)	23.1 (6.7)	22.1 (4.0)
Cognitive impulsivity	16.4 (2.5)	17.5 (2.6)	16.9 (3.4)	17.7 (4.3)	17.7 (4.3)	17.6 (3.5)
CPT-II						
Commission errors	56.5 (12.8)	55.3 (13.2)	50.7 (7.9)	49.7 (10.1)	49.7 (10.1)	50.5 (9.0)
Hit reaction time	40.3 (10.0)	41.3 (11.6)	43.6 (8.4)	47.5 (11.1)	47.5 (11.1)	42.4 (9.6)
Perseveration errors	49.0 (6.0)	50.7 (9.7)	48.4 (4.8)	75.0 (110.5)	75.0 (110.5)	50.0 (15.6)
Substance Use						
AUDIT	3.3 (3.4)	**9.7 (6.7)[a]**	6.9 (5.3)	5.2 (5.5)	8.6 (6.1)	8.5 (6.4)
MAST	3.6 (5.7)	**17.9 (18.1)[a]**	12.2 (8.7)	4.3 (6.3)	15.2 (17.8)	15.1 (16.8)
DAST	1.1 (2.3)	**2.9 (3.3)[a]**	2.0 (3.3)	1.1 (1.5)	2.7 (3.2)	1.7 (2.1)
TLFB Risky drinking days	4.0 (6.7)	**13.4 (14.3)[a,c]**	9.8 (12.5)	3.6 (7.4)	9.0 (11.5)	10.5 (13.0)
TLFB Drug use days	8.0 (23.4)	14.8 (28.6)	10.8 (25.4)	8.8 (24.9)	17.1 (29.1)	16.7 (30.1)

Notes. Letter superscripts indicate significantly ($p < .05$) higher scores than the group denoted (i.e., female control = a, female-MIXED = b, female-pDWI = c, male control = d, male-MIXED = e, male-pDWI = f). AUDIT: Alcohol Use Identification Test; BIS: Barratt Impulsivity Scale; CPT-II: Connor's Continuous Performance test; DAST: Drug Abuse Screening Test; MAST: Michigan Alcohol Screening Test; TLFB:Timeline Followback.

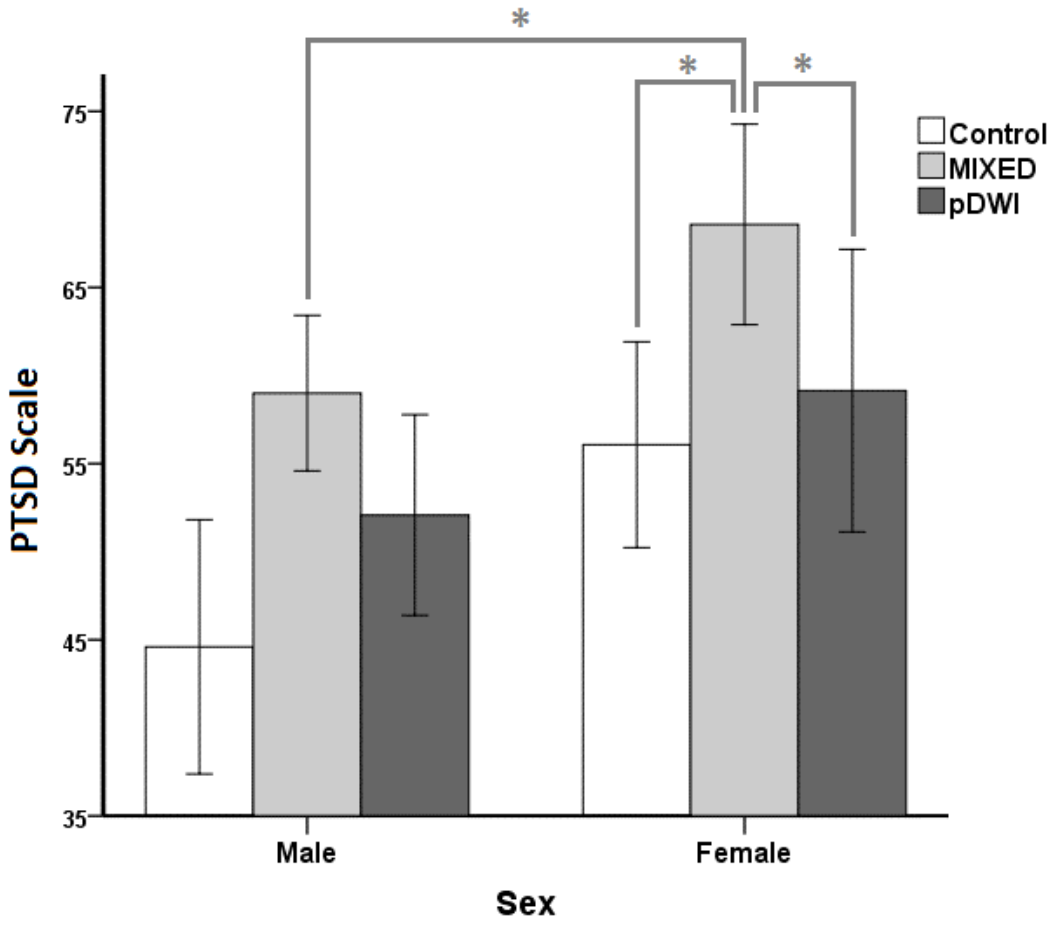

Figure 1. Mean score on the Post-Traumatic Stress Disorder (PTSD) scale from the Millon Clinical Multiaxial Inventory in males and females offender subgroups and non-offender comparators. Asterisks indicate significant subgroup differences ($p < .05$).

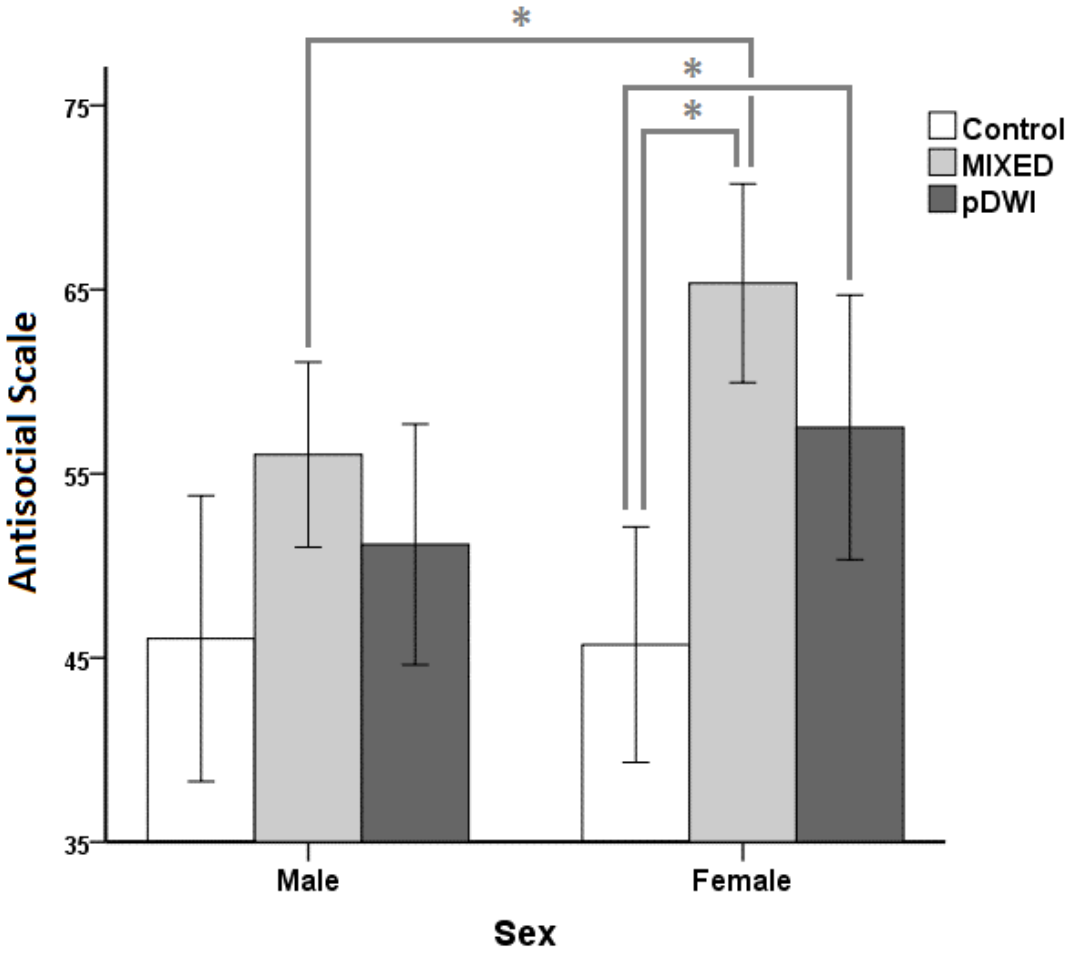

Figure 2. Mean score on the Antisocial scale from the Millon Clinical Multiaxial Inventory in male and female offender subgroups and non-offender comparators. Asterisks indicate significant subgroup differences ($p < .05$).

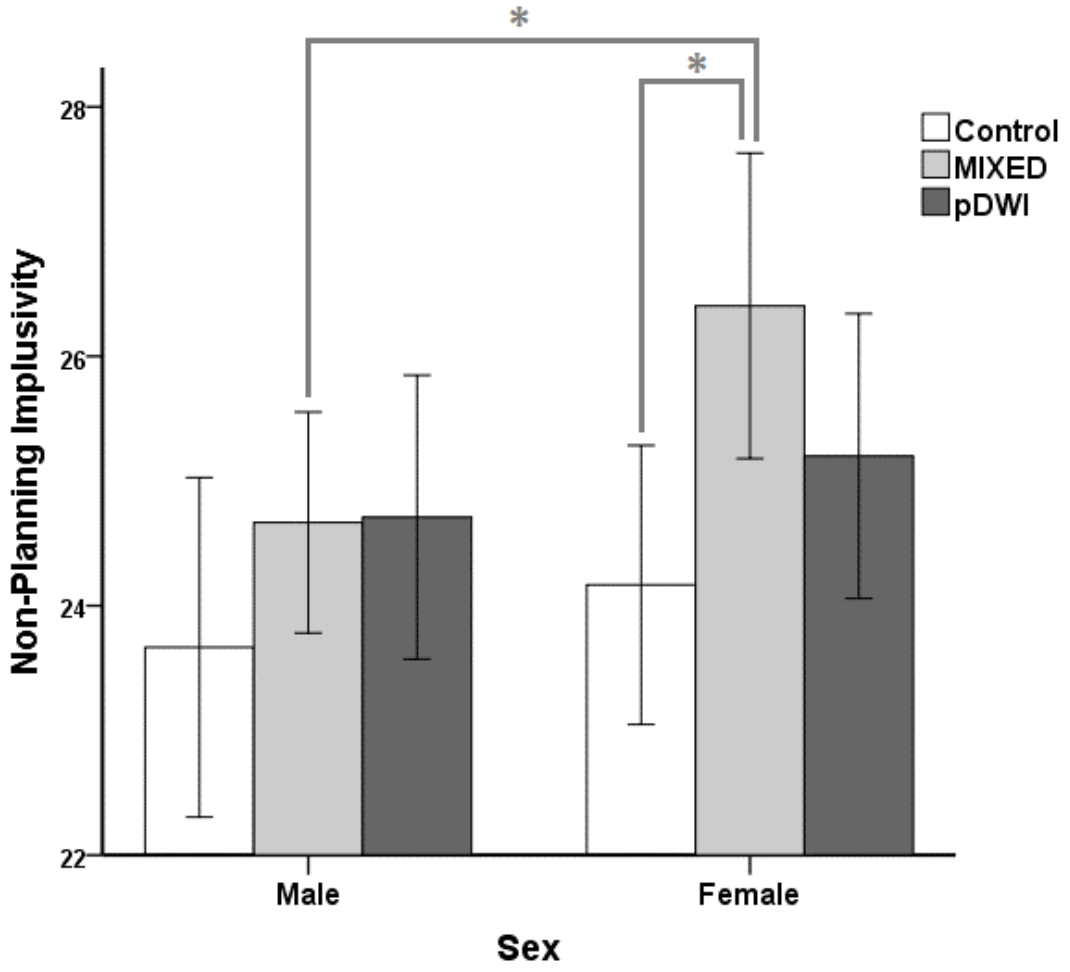

Figure 3. Mean score on the Non-Planning Impulsivity scale of the Barratt Impulsivity Scale in male and female offender subgroups and non-offender comparators. Asterisks indicate significant subgroup differences ($p < .05$).

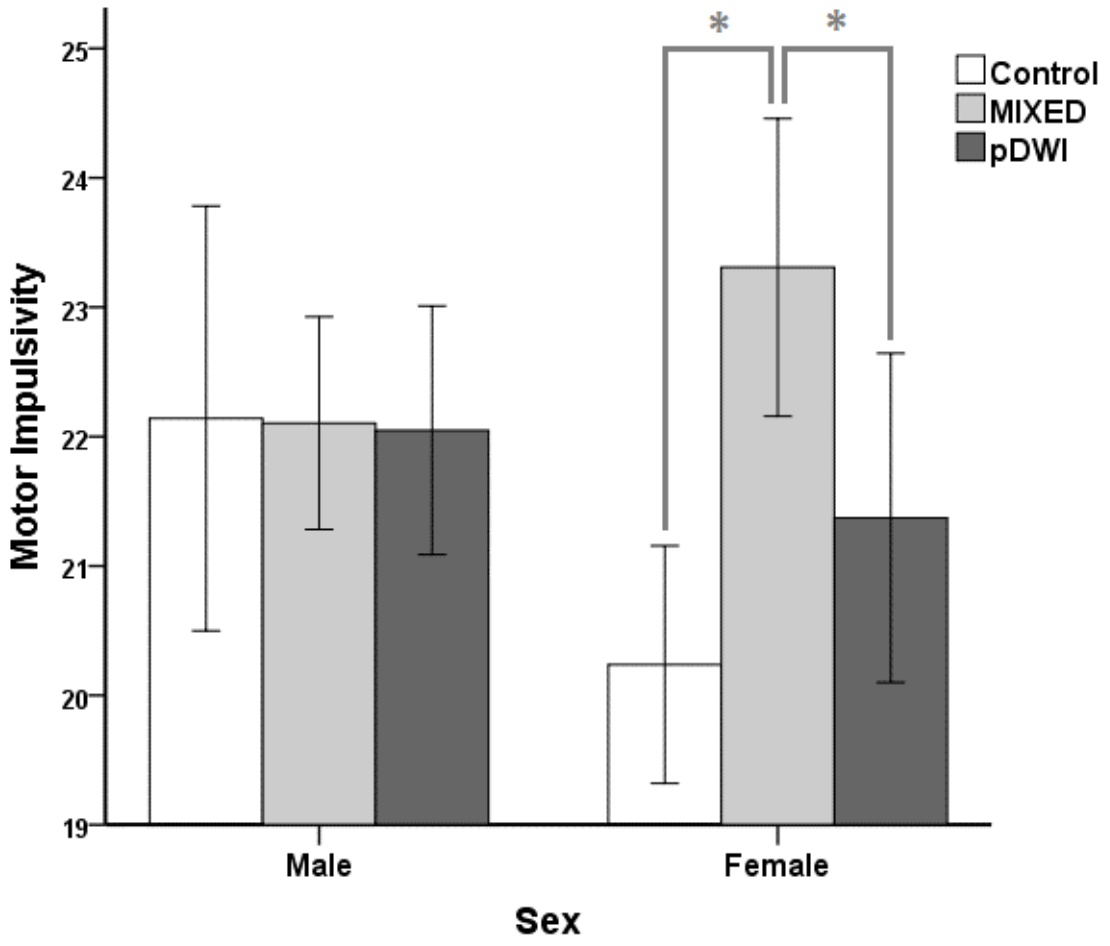

Figure 4. Mean score on the Motor Impulsivity scale of Barratt Impulsivity Scale in male and female offender subgroups and non-offender comparators. Asterisks indicate significant subgroup differences ($p < .05$).

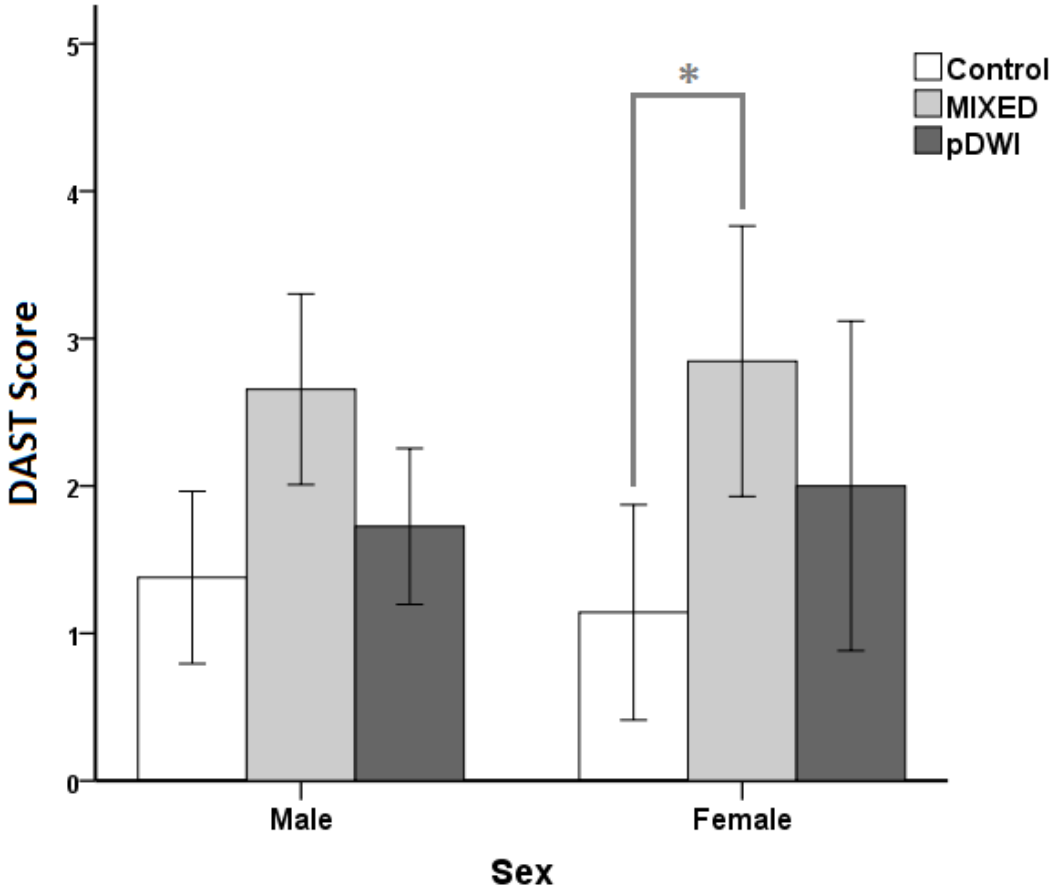

Figure 5. Mean score on Drug Abuse Screening Test (DAST) in male and female offender subgroups and non-offender comparators. Asterisks indicate significant subgroup differences ($p < .05$).

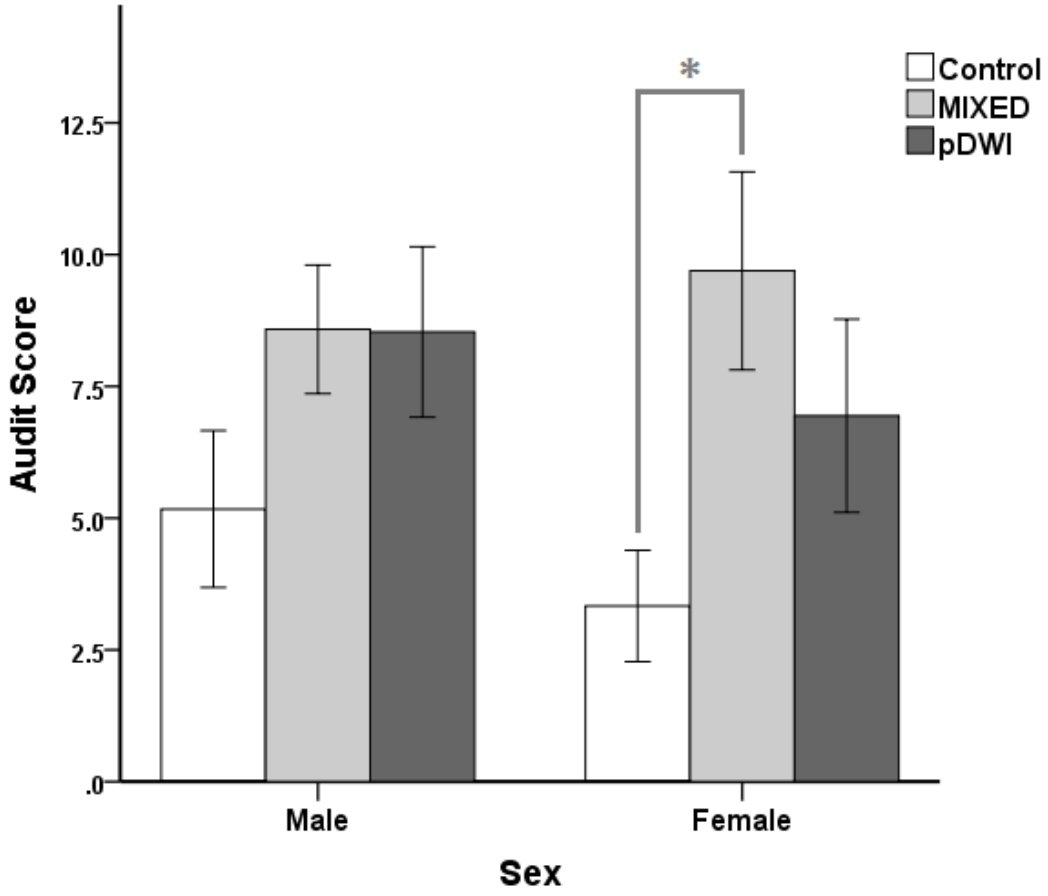

Figure 6. Mean score on the Alcohol Use Disorder Identification Test (AUDIT) in male and female offender subgroups and non-offender comparators. Asterisks indicate significant subgroup differences ($p < .05$).

Results from analyses testing hypothesis 2 showed that female-MIXED offenders had significantly elevated PTSD (95% CI = .40, 18.47, p =.041, $\eta^2 = 0.44$) characteristics and motor impulsivity (95% CI = 0.09, 3.78, p = .040, $\eta^2 = .06$) compared to the female-pDWI offenders. Moreover, female-MIXED offenders had significantly elevated PTSD (95% CI = 1.40, 15.92, p = .020, $\eta^2 = 0.05$) and antisocial (95% CI = 0.50, 16.34, p = .037, $\eta^2 = 0.04$) characteristics and non-planning impulsivity (95% CI = 0.36, 3.39, p = .015, $\eta^2 = 0.04$) compared to male-MIXED offenders. Between subgroup comparisons showed that the female-MIXED had more frequent past 90-day risky drinking than the female-pDWI subgroup (95% CI = .27, 1.96, p = .032, $\eta^2 = 0.02$). The female-pDWI subgroup did not significantly differ from the male-pDWI subgroup on PTSD characteristics, alcohol or substance use, or impulsivity.

Discussion

The current study sought to contribute to this underdeveloped area of investigation, advance research into classifying DWI subgroups, and lay the groundwork for future research into personalized prediction and intervention efforts among female offenders. Overall, the hypotheses were supported. The subgroup classification based on documented driving history effectively distinguished distinct risk profiles in female offenders. The female-pDWI showed greater antisocial characteristics, while the female-MIXED showed greater substance and alcohol misuse, antisocial, PTSD, and impulsivity characteristics. These risk profiles suggest distinct pathways to DWI in each subgroup. Hence, subgrouping represents a promising approach for improve understanding of female DWI offenders.

Classification to the female-MIXED offender subgroup was associated with several high-risk characteristics, suggesting more severe dysfunction than has generally been observed in male DWI subgroups (Argeriou et al., 1985; Brown et al., 2016; Donovan et al., 1986; Donovan &

Marlatt, 1982; Moxley-Kelly et al., 2019; Thombs et al., 2011; Tokko et al., 2019). The array of problem characteristics in female-MIXED offenders suggest a high-risk developmental trajectory involving delinquency, alcohol and substance use, exposure to trauma, and elevated driving risk (Bingham & Shope, 2004; Shope et al., 1996). Indeed, female DWI offenders have more partners who abuse alcohol, parents with alcohol problems, histories of domestic violence (Lapham et al., 2000) and higher rates of PTSD (Lapham et al., 2006; LaPlante et al., 2008) than male DWI offenders. In sum, female-MIXED offenders represent a homogeneous subgroup with a markedly high-risk profile. Also, the severity of this profile and the dysfunction it implies hints at the possibility that they may also be more refractory to intervention (Moxley-Kelly et al., 2018).

In contrast, classification to the female-pDWI offender subgroup was associated with a substantially lighter loading on risk characteristics, suggesting less severe dysfunction compared to that of the female-MIXED. Antisocial characteristics among the female-pDWI subgroup may signify adolescent maladjustment and capacity for rule breaking. At the same time, with little evidence of other dysfunction, the female-pDWI may be at lower risk for recidivism and amenable to brief and less intensive interventions such as BMI, as were the male-pDWI offenders in previous research (Moxley-Kelly et al., 2018).

A prior statistical subgrouping study of female DWI offenders identified two subgroups with elevated risk: one with elevated antisocial characteristics, and another with elevated neuroticism (Moore, 1994). In the current study, trends in the data hint at the possibility that the female-pDWI subgroup had elevated depression characteristics compared to their female control comparators. Given this trend, and that several subgrouping studies have identified subgroups with depressive characteristics (Moore, 1994; Donovan & Marlatt, 1982; Nelson et al., 2019; Steer et al., 1979; Holt et al., 2009), further research into the role of depression and negative affect in

female offender subgroups is recommended.

In sum, the current classification scheme based upon driving behaviour identified a homogeneous, particularly high-risk vulnerable subgroup of female offenders. The weight and possibly the developmental origins of the dysfunction associated with membership to the female-MIXED subgroup suggest that they may be more vulnerable to recidivism and refractory to intervention. These results suggest that direct investigation into the relative recidivism risk in female-MIXED and female-pDWI subgroups to test this hypothesis is warranted.

Limitations

This study has both strengths and weaknesses. It built upon previous research by using phenotypic classifications that have been validated (Brown et al., 2016) and show to have clinical relevance (Moxley-Kelly et al., 2018) and thus has a strong theoretical foundation. Despite this strength, as it is a cross-sectional study, it cannot support inferences of a causal relationship. Hence, further investigation into the female-MIXED and female-pDWI subgroups with a longitudinal design is recommended. Another limitation involves the potential lack of generalizability of the present findings to jurisdictions with different BAC driving limits (e.g., 0.08% vs. 0.05% in European jurisdictions). Furthermore, the current sample was recruited a decade ago and traffic law, police enforcement policies, and violation patterns may have shifted. Thus, DWI offenders identified in other jurisdictions, or more recently, may represent distinct populations and may not reflect the current sample.

Conclusion

Classifying female DWI offenders into subgroups based on risky driving profiles is a promising method to clarify heterogeneity and an avenue to deepen understanding of the needs of

female offenders. Thus, the present study represents an initial step in a process that may contribute to forestalling the rising rates of female DWI.

General Conclusion

DWI offenders are responsible for 30% of traffic deaths (*Bilan Routier*, 2018; World Health Organization, 2015), which represents a leading cause of morbidity worldwide (Toroyan, Peden, & Iaych, 2013; World Health Organization, 2015). Though DWI recidivism is theoretically preventable, in real-world contexts 1 in 3 first-time offenders re-offend within 5 years (Rauch et al., 2010). Historically, research into DWI prevention has been predicated on a "one-size-fits-all" approach, and primarily conducted with male offenders. This approach ignores the possibility that distinct pathways to DWI are shared by subgroups within the population. Subgrouping is a method to investigate distinct pathways to DWI and may inform personalized – and thus enhanced – prediction and prevention (Medicines Agency, 2000; Nochajski & Stasiewicz, 2006). The current thesis represented an exploration of this method of investigation.

The review suggests that increasing the depth of subgroup analyses can improve research quality. Plausible theoretical pathways to DWI that are distinct between subgroups and targetable by treatment provide a useful foundation for inquiry. Converging research domains (e.g., epidemiology and criminology) can further enhance the depth of understanding and increase clinical relevance. Finally, investigations incorporating biomarkers have begun to emerge in the DWI subgrouping literature and represent a promising avenue as they can lend insight into biological processes that might be amenable to treatment and can characterize underlying traits independently of other measures (e.g., self-reports or clinical interviews) (Aharoni et al., 2013). Future work should continue in this direction.

Broadly, the findings of the review were consistent with those from the empirical study. A

DWI subgroup that shows elevated antisocial features, alcohol and substance misuse, and engages in more general criminality emerged from several of the reviewed studies. In the present empirical study, we found that these features were specifically associated with a subgroup of female DWI offenders. The review only identified a single previous study that explored subgrouping in females (Moore, 1994). Further research into female DWI subgroups, especially regarding the meaning of female subgroup classification to recidivism risk and treatment responsivity, is clearly needed.

Overall, given the heterogeneity in the DWI population, a one-size-fits-all approach may only improve DWI prevention to a point. Further progress will likely require more investigation into the characteristics and the pathways to DWI shared by homogeneous subgroups, and the interventions that these subgroups are most likely to benefit from.

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