A quantitative approach to assessing the efficacy of occupant protection programs: A case study from Montana

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A B S T R A C T

Quantitative evaluation of vehicle occupant protection programs is critical for ensuring efficient government resource allocation, but few methods exist for conducting evaluation across multiple programs simultaneously. Here we present an analysis of occupant protection efficacy in the state of Montana. This approach relies on seat belt compliance rates as measured by the National Occupant Protection Usage Survey (NOPUS). A hierarchical logistic regression model is used to estimate the impacts of four Montana Department of Transportation (MDT)-funded occupant protection programs used in the state of Montana, following adjustment for a suite of potential confounders. Activity from two programs, Buckle Up coalitions and media campaigns, are associated with increased seat belt use in Montana, whereas the impact of another program, Selective Traffic Enforcement, is potentially masked by other program activity. A final program, Driver’s Education, is not associated with any shift in seat belt use. This method allows for a preliminary quantitative estimation of program impacts without requiring states to obtain any new seat belt use data. This approach provides states a preliminary look at program impacts, and a means for carefully planning future program allocation and investigation.

1. Introduction

Vehicle occupant protection is a critical component of public health (Subramanian, 2005), and seat restraint has been well documented as a major contributor to occupant protection (e.g., Houston and Richardson, 2005; Park et al., 2010). Despite the widely accepted efficacy of seatbelts in preventing automobile-related mortalities, improvement in occupant protection use rates in the United States has slowed in the last 15 years (NHTSA, 2015). Seat belt use among adults nationwide was 87% in 2013 (NHTSA, 2014), with compliance exceeding 90% in 19 states while compliance in Massachusetts, Mississippi, Montana, and South Dakota was below 75% (NHTSA, 2014). This variation across states is often attributed to differences in state-specific laws. In 2014, states with primary enforcement laws averaged 90% seat belt use; in contrast, states with secondary laws had 79% use overall. All states with compliance in excess of 90% had a primary seat belt law except for Nevada, whereas three of the four states with the lowest compliance did have a primary seat belt law (NHTSA 2014).

However, states also vary in their use of state-run occupant protection programs like selective traffic enforcement allocations, media campaigns, buckle-up coalition structure, and driver education.

Beyond enacting and enforcing state-specific laws, state and federal transportation agencies have confronted the stagnation in seat belt compliance rates with a suite of programs designed to increase seat restraint use, including selective traffic enforcement programs (Williams and Wells, 2004; Vasudevan, 2009), education (Shin et al., 1999; Snowdon et al., 2009), media campaigns like “Click It or Ticket” (Preusser Research Group, 2002; Solomon et al., 2004; Vasudevan and Nambisam, 2009), and local organizations and demonstrations (Nichols et al., 2009). However, while some programs like the Click It or Ticket campaign seem very effective (e.g., Insurance Institute for Highway Safety, 2010; Nichols et al., 2009), performance of an ensemble of programs operating together remains unclear. Thoughtful and rigorous program evaluations are necessary to identify efficient financial and time resource allocation among the competing programs and to guide further program development. Many existing examples of rigorous program evaluation hinge on acquisition of new data that isolate program effects (e.g., Pulugurth and Repaka, 2008; Rice et al., 2009).
Here we present an analysis using the nationally available National Highway Traffic Safety Administration (NHTSA) seat belt survey data to evaluate the impacts of local occupant protection programs on seat restraint use in the state of Montana from 2010 to 2012, a period of time for which all necessary records were available and state occupant protection program activities were relatively consistent. Although seat restraint use was on the rise in Montana prior to 2002 (Montana Department of Transportation, 2011), it has since stagnated at between 75% and 80% compliance, reaching a peak of 79.2% in 2009 before declining to 74.6% in 2013 (NHTSA, 2014). In 2013, the Montana Department of Transportation (MDT)’s stated goal was to increase annual observed compliance rates to 89.3% by 2015.

MDT runs a mixture of occupant protection programs intended to complement the state’s secondary seat restraint law. Education, outreach and enforcement are all key to increasing seat belt usage (Williams and Wells, 2004; Vasudevan and Nambisan, 2005; Houston and Richardson, 2006; Vasudevan, 2009), and MDT programs target each of these strategies. The Montana Office of Public Instruction (OPI) provides voluntary driver education instruction throughout the state. State-sponsored media campaigns are enacted at regular intervals throughout the year. MDT’s Selective Traffic Enforcement Program (STEP) provides financial resources to applicant enforcement agencies which allow for additional targeted enforcement efforts as deemed necessary by enforcement personnel. Buckle up Montana (BUMT) coalitions operate throughout the state disseminating information and raising seat belt awareness. In this investigation, we present a statistical model evaluating the efficacy of each of these programs at increasing seat restraint use in Montana.

2. Materials and methods

2.1. Data preparation

Our analysis hinges on the assumption that “effective” programs lead to increased seat belt use in the surrounding area. Our dependent variable in this analysis was seat belt use at a set of sites throughout Montana from 2010 to 2012, as measured through NHTSA’s National Occupant Protection Usage Survey (NOPUS). NOPUS sampling is conducted at sites across the United States. Survey events are controlled for time of day and day of week, and are conducted at the same sites every late-April/early-May and every June. In Montana, there are 120 NOPUS sites (12 interstate highway sites, 24 National Highway System (NHS) sites, 20 secondary/county sites and 64 city sites; Fig. 1). These sites are located in 30 of Montana’s 56 counties, and in 19 cities/towns throughout the state. Fifty-five of the 120 sampling sites are in regions the U.S. Census Bureau classifies as rural (U.S. Census Bureau, 2010). Data came from six different NOPUS sampling events in April and June of 2010–2012. Sample sizes and compliance rates for each sampling event are summarized in Table 1. Because NOPUS is collected at numerous sites throughout the state and each site is subject to a unique ensemble of occupant protection program activities, NOPUS data provided a means of comparing program influences on compliance rates.

A covariate set containing independent variables quantitatively describing local activity for each MDT program (e.g., OPI driver education activity, media campaign activity, STEP activity, BUMT coalition presence) was constructed for each NOPUS site, as well as relevant confounding variables (e.g., road type, local socioeconomic and demographic metrics, weather condition).

To measure driver education “effort” associated with each NOPUS survey site, we compiled school-district-level information on driver education completion rates using the Montana Office of Public Instruction’s Growth and Enhancement of Montana Students (GEMS) tools. (Montana Office of Public Instruction 2010–2012). MDT’s Selective Traffic Enforcement Program (STEP) is a grant-based program that provides resources for additional officer-hours aimed at targeting high-traffic or high-risk events (for example, holidays, college football games, arts festivals, etc.). STEP activity occurs at three spatial scales, municipality, county, and Department of Justice region, and most specific decisions about STEP allocations are left to the jurisdiction awarded the grant. STEP hours were summed over the municipality, county, and Department of Justice region overlapping each NOPUS site in each study year to reflect overall local STEP activity. BUMT coalition presence was incorporated as an indicator variable: if a NOPUS site was located in a county with an active BUMT coalition, the BUMT variable was set to 1; otherwise it was set to 0. Media effort was measured as the sum of all paid and earned media expenditures in the media area into which a particular NOPUS site fell. MDT concentrates is media effort during the month of May in a major pre-summer media campaign. Therefore, compliance improvements between April surveys and June surveys were attributed to

![Fig. 1. NHTSA seat belt survey sites and average number of responses observed for 2010–2012. Point size gets larger as the average number of individuals observed at each sampling site increases. Red points are city road sites, green points are Interstate sites, blue points are secondary/county road sites, and orange points are US highway sites (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).](image-url)
media campaign impacts. Additional information on program-specific covariates and data sources are available in the Supplementary Information.

Previous work shows that increased seat belt compliance is associated with a set of other factors outside of MDT’s control, including higher population densities and socioeconomic status (Morgan, 1967; Robertson et al., 1972; Hansell and Mechanic, 2007; Piani and Schoenborn, 1993; Nelson et al., 1998; Schoenborn, 1988; Colgan et al., 2004; Demirer et al., 2012), larger roads and heavier trafficscenarios (NHTSA, 2014), and increased precipitation, fog, and snow (Simsekoglu and Lajunen, 2012). Covariates associated with each of these factors were included to adjust for confounding effects. Site-level demographic data were extracted from 2010 U.S. Census information. We used road type as recorded in the NOPUS sampling records. Temperature and precipitation records were extracted from weather stations near NOPUS sites at the time of sampling (day and hour) for each sampling event. See Supplementary information for additional descriptions of covariate metrics and data.

All response and factor datasets were compiled by constructing a geographic information system (GIS) using the maptools (Bivand and Lewin-Koh, 2013), and sp (Pebesma and Bivand, 2005; Bivand et al., 2013) packages in the statistical computing environment R (R Core Team, 2013). We then “drilled down” through the GIS at each NOPUS sampling site to extract site-specific values associated with each covariate layer. The resulting dataset of NOPUS sampling events and corresponding covariate values formed the basis for the statistical assessment.

2.2. Data analysis

Prior to model fitting, we checked for systematic differences between seat restraint survey samples that were excluded from the analysis due to missing covariate data, and documented differences to track any exclusion bias. Colinearity among model covariates was assessed, and we subsequently limited our covariate list to include only relatively independent covariate metrics (see Supplementary information: data preparation).

A hierarchical logistic regression model (e.g., Agresti, 2012; Gelman and Hill, 2007) was used to evaluate occupant protection program efficacy. The hierarchical structure accounted for NOPUS’s distinct spatiotemporal structure: sampling events occur at the same sites in multiple years, and multiple times per year, and these sites are nested in municipalities, high school districts, counties, and DOJ MHP regions. Accounting for this structure is necessary, since the structure can impose unintentional correlations between observed seat belt compliance rates in different NOPUS samples. Failing to account for those correlations equates to assuming that adjacent sample sites are driven by independent processes. The assumption of independence between adjacent sites is problematic, for example, in a situation where two NOPUS sampling sites that are close together have similar seat belt compliance rates, but this similarity is due to some unmeasured factor not included in the model.

Formally, let \( y_{ijk} \) be a binomial random variable describing the number of belted individuals out the total number of individuals observed at the \( k \)th sampling event at the \( j \)th site during the \( i \)th year. Let \( X_{ijk} \) be a vector containing all covariate and confounder values associated with the \( i \)th sampling event at the \( j \)th site during the \( k \)th year. Let \( \beta \) be a vector of regression coefficients linking the covariate and confounder values to the response. Let \( Z_k \) and \( Z_j \) be matrices of year- and site-year-specific random effects, respectively. In general, the fitted models were of the following form:

\[
P(y_{ijk} = 1) = \logit^{-1}(X_{ijk}^T \beta + Z_k \beta_k + Z_j \beta_j + \epsilon_{ijk})
\]

where \( i \) indexes sampling events \((i \in \{1, 2\})\), \( j \) indexes sites \((j \in \{1, \ldots, 120\})\), and \( k \) indexes years \((k \in \{2010, 2011, 2012\})\). Models were fit using the total seat belt compliance rates aggregated over both drivers and passengers, since only total values were available in 2011.

Hierarchical models like the one used here incorporate covariates in two different ways, as either “fixed” or “random” effects. Factors that are explicitly measured and take on a particular value for each site (e.g., the presence or absence of a BUMT coalition, the county-level population density for a particular site, etc.) are fixed effects, and their relationships to seat belt compliance rate are directly estimated in the model. By contrast, our random effects account for spatially structured variation not associated with a particular measured factor included in the model (i.e., they account for some unidentified and unmeasured attribute that makes compliance at one site higher than at another). Random effects absorb correlated variations that could not be accounted for otherwise, and that might cloud the model’s ability to detect important fixed effects.

To determine an appropriate set of fixed and random effects, we fit a series of models, and used likelihood ratio tests to identify the effects structure best supported by the dataset. A factor was omitted only if it had no detectable relationship with seat belt compliance rate after accounting for other variables in the model. In accordance with accepted hierarchical modeling protocols, likelihood ratio tests were first conducted on restricted error maximum likelihood (“REML”) fits to establish an appropriate random effects structure on models containing all fixed effects. Next, univariate models were fit for each MDT program in a model with all non-MDT-related fixed effects (e.g., Fig. 3). Finally, a saturated model with all MDT predictors and higher order interaction terms was fit, and likelihood ratio tests were used to establish fixed effects structure in the presence of the selected random effects. All quantitative factors were standardized (observed median value/standard deviation) prior to model fitting to allow for comparison of all factors on a common scale. Model fits

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Sampling events used</th>
<th>Total observations (mean, minimum, maximum)</th>
<th>Total number buckled (mean, minimum, maximum)</th>
<th>Seat belt compliance rate (95% binomial confidence limits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>April</td>
<td>102</td>
<td>11,332 (1113, 0, 397)</td>
<td>7,884 (773, 0, 297)</td>
<td>0.696 (0.687, 0.704)</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>102</td>
<td>13,465 (1320, 13, 523)</td>
<td>9,759 (956.6, 4, 199)</td>
<td>0.725 (0.717, 0.732)</td>
</tr>
<tr>
<td>2011</td>
<td>April</td>
<td>101</td>
<td>11,548 (1143, 0, 545)</td>
<td>7,694 (76,2, 0, 430)</td>
<td>0.666 (0.658, 0.675)</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>101</td>
<td>13,383 (1225, 0, 803)</td>
<td>9,575 (94.8, 0, 495)</td>
<td>0.715 (0.708, 0.723)</td>
</tr>
<tr>
<td>2012</td>
<td>April</td>
<td>102</td>
<td>14,145 (1387, 2, 787)</td>
<td>9,448 (92,6, 1, 559)</td>
<td>0.668 (0.660, 0.676)</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>102</td>
<td>14,804 (1451, 8, 658)</td>
<td>10,471 (1027, 4, 497)</td>
<td>0.707 (0.708, 0.715)</td>
</tr>
</tbody>
</table>
were generated using the lme4 \cite{Bates2013} library in R \cite{RCoreTeam2013}.

3. Results

3.1. Missing data, standardization, and model selection

The final covariate matrix used for the analysis consisted only of sites with no missing values for any MDT predictor. Of the 720 seat belt survey samples available, 110 had missing values for one or more predictors included in the model, and were therefore eliminated. Removal of sites with missing data resulted in complete elimination of seven counties (Fig. 2). Excluded counties typically had smaller populations than included counties (median county population is approximately 5000 for removed counties vs. 30,000 for included counties) and represent less than 5% of Montana’s population. The complete dataset included five sites on tribal lands: four on the Crow and Northern Cheyenne Indian Nations in Big Horn County, and one on the Flathead Nation in Lake County. Removed sites disproportionately represented the northeastern and northwestern regions of the state. Driver education compliance rates were the most common missing covariate. There was insufficient data to estimate weekday-specific effects, so day of the week was eliminated at the outset of the modeling procedure. A likelihood ratio test indicated that site variation was non-negligible ($X^2 = 554.8$ on 1 degree of freedom; $p$-value $< 0.0001$), so we included random effects for both site and county in the model. Urban/rural status and all interactions involving STEP or driver education did not improve model fit, and were eliminated.

The final model retained all main effects, both from MDT programs and non-MDT confounders, as well as a quadratic term for media. Inclusion of MDT program covariates significantly improved model fit (see Table 2), suggesting seat belt use in Montana is associated with MDT program activity. While all programs were related with increased compliance when examined in the absence of other programs (Fig. 3), some of these effects were no longer detectable when all programs were examined in a single model (Fig. 4). This underscores a weakness in the dataset: multiple programs impact the same set of NOPUS survey sites, making it difficult to differentiate between different programs’ effects. The specific estimates of each program’s impact are shown in Figs. 3 and 4, and statistically described in Table 3.

3.2. Model interpretation

Logistic regression models relate changes in the odds that a person uses his or her seat belt (in this case, based on local NOPUS seat belt use surveys) with changes in particular covariates. The logistic regression model estimates coefficients describing the effect of each predictor on the likelihood of seat belt use. This coefficient can be transformed via exponentiation to describe the multiplicative change in the odds that an individual uses his or her seat belt when the predictor is present, relative to a baseline scenario where the predictor is absent. Any combination of covariates could have served as the baseline group, but here we chose to use April, 2010 surveys on city roads. April 2010 was a natural choice, since it is the first sampling event in this analysis, and city roads were chosen because they have the lowest compliance of any road type in our dataset.

All continuous predictor variables included in this analysis (temperature, precipitation, population density, median population income) were standardized so that a covariate’s effect on seat belt use is estimated relative to its overall variation. This makes the estimated effect of population density (which varies massively across the study area) on seat belt use comparable to the estimated effect of total precipitation on the day of sampling (which takes on values over a much narrower range). The transformed coefficients associated with continuous predictor variables shown in Table 3 reflect the change in odds of seat belt use associated with increasing that particular covariate from its median value to approximately its 85th percentile.

3.3. Effects of confounder variables

There were substantial differences in seat belt compliance rates between the four NHTSA seat belt survey strata. Compliance at City sites was significantly lower than at interstate, primary, and secondary/county sites (Table 3; Fig. 4). In general, compliance was slightly (but significantly) lower in 2011 and 2012 than in 2010, consistent with MDT’s concerns regarding the potential for declining seat belt use rates in Montana (Table 3; Fig. 4). Compliance was slightly, but statistically significantly, lower on days of precipitation than on dry days, and lower on hot days than cooler ones. Use was significantly higher in June than in April/May, and this effect is likely driven by the timing of MDT spring media campaigns. County population density and median income were both significantly associated with higher seat belt compliance rates.

3.4. Effects of occupant protection programs

There was a significant increase in seat belt compliance associated with increasing STEP activity (upper left panel, Fig. 3) when STEP was examined in the absence of other programs. This pattern was less pronounced at sites in rural counties than at sites in urban ones (upper right panel, Fig. 3), likely reflecting differences in the total number of drivers that passed STEP patrols. Sites near active BUMT coalitions had significantly higher compliance rates than did sites away from BUMT coalitions (lower right panel, Fig. 3). Analysis of the aggregate media metric suggested that additional media expenditures were significantly associated with increased compliance, up until about $12,000 of investment (lower left panel, Fig. 3). At that point, media impacts plateaued. Media-related inference is limited by the geographic extent of the media campaigns, however, and merits further exploration.

In a model examining all MDT programs simultaneously, driver education completion rate had no detectable relationship with seat restraint usage rates (Fig. 4; Table 3). Although STEP was
associated with increased seat belt use when examined on its own (Fig. 3A,B), that effect was no longer detectable in a model that accounted for all programs (Fig. 4; Table 3). BUMT coalitions were generally associated with increased compliance (Figs. 3D and 4; Table 3). However, the impact of BUMT was diminished in cases with higher media intensity, suggesting that these two programs may be redundant with one another.

4. Discussion

The analysis presented here provides a framework for quantitatively evaluating state occupant protection programs using the readily available NOPUS seat belt compliance data. Although this framework was successful at identifying some program-related impacts on seat belt use, the limitations of this dataset make strong inferences difficult. While a broad analysis like ours provides some general inferences on program impacts, our work also underscores the importance of program-specific studies designed to explicitly isolate and evaluate the impacts of a single program

This analysis suggested that the factors most strongly associated with seat belt use in Montana are road type, population density, and income (Table 3; Fig. 4). Lower compliance was also associated with low county population sizes and lower...
median county income levels. Increased precipitation was also associated with a very small decrease in compliance (Table 3), but this was likely attributable to reduced observer accuracy during periods of precipitation. This discrepancy does not compromise the overall model performance, since a model excluding precipitation had qualitatively identical results for all other covariates to

![Graph showing transformed coefficients for predictors included in the final model. The plot shows the change in odds of seat belt use when moving from the baseline group to a group including each predictor. Thin lines are 95% confidence intervals and thick lines are 50% confidence intervals describing effect size. Covariates overlapping the “equally likely” line have no detectable impact on occupant protection after accounting for all other factors in the model. The baseline model describes seat belt compliance in 2010 on city roads in April, in the absence of any MDT programs.]

**Fig. 4.** Transformed coefficients for all predictors included in the final model. The plot shows the change in odds of seat belt use when moving from the baseline group to a group including each predictor. Thin lines are 95% confidence intervals and thick lines are 50% confidence intervals describing effect size. Covariates overlapping the “equally likely” line have no detectable impact on occupant protection after accounting for all other factors in the model. The baseline model describes seat belt compliance in 2010 on city roads in April, in the absence of any MDT programs.

**Table 3**

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Exp (coefficient)</th>
<th>Std. errora</th>
<th>Z-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.19</td>
<td>0.14</td>
<td>1.29</td>
<td>0.20</td>
</tr>
<tr>
<td>Strata</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interstate</td>
<td>3.73</td>
<td>0.13</td>
<td>10.19</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>NHS Primary</td>
<td>3.10</td>
<td>0.11</td>
<td>10.27</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sec county</td>
<td>1.40</td>
<td>0.09</td>
<td>3.78</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>0.892</td>
<td>0.03</td>
<td>-4.15</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>2012</td>
<td>0.835</td>
<td>0.02</td>
<td>-4.51</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>County demographics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co. median income standardized</td>
<td>1.22</td>
<td>0.07</td>
<td>2.96</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Co. 2010 population density</td>
<td>1.31</td>
<td>0.08</td>
<td>3.34</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sampling event factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean temperature</td>
<td>1.05</td>
<td>0.01</td>
<td>5.12</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Precipitation</td>
<td>0.969</td>
<td>0.01</td>
<td>-4.15</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MDT programs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPI completion rate</td>
<td>0.942</td>
<td>0.05</td>
<td>-1.12</td>
<td>0.26</td>
</tr>
<tr>
<td>Total media cost</td>
<td>0.999</td>
<td>0.00</td>
<td>-2.21</td>
<td>0.03</td>
</tr>
<tr>
<td>Total media cost squared</td>
<td>1.00</td>
<td>5.77 x e^-10</td>
<td>2.09</td>
<td>0.04</td>
</tr>
<tr>
<td>Summed STEP hours</td>
<td>1.00</td>
<td>0.0002</td>
<td>3.16</td>
<td>0.002</td>
</tr>
<tr>
<td>BUMT present</td>
<td>1.15</td>
<td>1.46</td>
<td>0.93</td>
<td>0.35</td>
</tr>
<tr>
<td>MDT interactions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total media cost: BUMT present</td>
<td>2.53</td>
<td>0.0153</td>
<td>-4.8707</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

*a Reported standard errors are associated with raw coefficients, prior to exponentiation.*
the model presented in Table 3. Since none of these factors are under MDT’s control, it would be easy to overlook the role of state-run occupant protection programs. However, BUMT coalition presence and media effort were also both associated with significant, albeit relatively small, increases in seat belt use. The absence of significant interaction terms between all programs except BUMT and media indicates that program effects are generally additive: the impact that one program has on seat belt compliance rates does not depend on whether other programs are present. When a new program is added to a region, its impact is added to those of other local programs. Therefore, using multiple programs in the same region should increase local seat belt compliance. In this analysis, only media campaigns and BUMT coalition presence were exceptions to that rule.

STEP was the most effective program when analyzed in the absence of other programs (upper left and right panels of Fig. 3), but that effect eroded when other programs were included in the model (Fig. 4, STEP). This is likely an artifact of our dataset, and may not reflect a true absence of STEP effects on compliance. STEP activities had similar impacts on seat belt use regardless of the population density or spatial jurisdiction in which they were allocated. Therefore STEP effort in urban and rural jurisdictions appear to influence roughly the same number of vehicle passengers, suggesting that rural jurisdictions must be very effective at allocating STEP toward periods of intense vehicle travel. The apparent absence of a STEP effect (e.g., Fig. 4; Table 3) may occur because STEP efforts were allocated to events where seat belt use might otherwise be very low. However, STEP’s impacts are particularly difficult to estimate when it is applied in the presence of other programs. Estimates would dramatically improve with data from studies designed to examine STEP’s effects in isolation.

Significant quadrature was detected in the relationship between additional media investment and seat belt use when media was examined alone (lower left panel of Fig. 3). This analysis suggested that while the first $12,000 of media investment are very effective at increasing compliance, further investments have diminishing returns (Fig. 4). Additionally, this analysis suggests a significant negative interaction between BUMT presence/absence and total local media expenditures (see Fig. 4, media $ with buckle up MT vs. media $ with no buckle up MT): the simultaneous effect of these two programs in a given county is less than the sum of their individual effects. This may be because BUMT coalitions and media campaigns either reach overlapping audiences or target similar strategies for increasing compliance. Having both programs present is still superior to only one program, but the simultaneous impact of both programs is slightly less than the sum of the two programs’ effects when operating alone. Removing redundancy in target audience or method may improve both programs’ efficiency. However, both media trends needs further investigation. Media investment was very similar throughout the state, which clouded estimates about the per-capita, per-dollar benefit of media campaigns.

The limited impact of driver’s education could reflect the fact that seat restraint usage was only one of many areas emphasized in the driver education curriculum. Since this study, MDT and the Montana Office of Public Instruction have collaborated to update traffic education curriculum, which now includes a special segment focused on seat belt use by teens. This update may impact the influence of driver education on future occupant protection use.

While we took extensive steps to ensure that this assessment leveraged the best available data, some data-based limitations remain. The spatial scales represented our models assume strong mixing within counties, such that county-level resource allocations impact all parts of the county equally. In reality, resource allocations are likely to scale with population density at a finer spatial scale. Additionally, individual choice about seat restraint usage is driven by numerous factors, only a few of which were available for incorporation here. Our results rest on the assumption that most of the important determinants of seat restraint use are included among the model covariates, however it seems likely that some factors contribution to seat belt use were overlooked. NOPUS data were sometimes spatiotemporally separated from program activities, which limits the model’s power to detect true program effects. While we are confident that effects detected in this assessment (with the possible exception of precipitation, which may have induced NOPUS observer bias) are real, the failure to detect an effect of a given program could stem from limited statistical power, and should therefore be viewed as grounds for further investigation. To improve model strength and more precisely identify program impacts on seat belt use, would require additional data collection aimed at isolating the effects of specific programs.

Finally, even the strongest associations uncovered in this analysis do not imply causal relationship between program activities and seat belt use. This limitation is universal in analyses of observational data. It is particularly important to take this into account when assessing the inconsistent relationship between STEP and seat belt compliance rates. While this analysis describes associations between program activity and seat belt use, causal linkages can only be established through designed experiments in which some sites are randomly chosen to receive programs, while others are not.

Nonetheless, this study underscores the positive role that STEP, BUMT, and media play in increasing seat belt use in Montana. Experimental diversification of media investment size and type, experimental separation of media and BUMT efforts, and experimental isolation of STEP would each provide valuable data streams and important additional insights. Finally, occupant protection program planning would benefit from a more comprehensive approach beyond the data-driven methods described here. In particular, it is critical to obtain driver’s attitudes and behaviors regarding seat restraint usage. Human factors assessments of drivers are likely to provide critical new insights into the current traffic safety culture, and might illuminate gaps in current occupant protection programming in Montana.

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