Themis: Research Journal of Justice Studies and Forensic Science

Volume 5 Article 7

5-11-2017

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Keywords

DNA evidence, collection methods, trace evidence, vehicle crimes

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Abstract

Tape-lifting and swabbing are two methods commonly used for collecting biological samples in the United Kingdom and United States to investigate vehicle crimes. Determining the optimal collection method may lead to an increase in generating DNA profiles and crime-solving. The objective of this study is to evaluate the efficiency of adhesive tape and the double-swab collection methods for investigating vehicle crimes with possible touch DNA samples. Two experiments were conducted to evaluate the use of tape-lifts and swabs on spiked common vehicle fabric materials. The efficiency of recovery between the two collection methods was performed using qPCR. The results from the collection of fabric materials indicated tape-lifts outperformed swabbing on cloth and vinyl substrates, while swabbing resulted in comparable recovery on leather substrates. By optimizing sample collection techniques, we aim to aid not only investigations involving vehicles but also other crimes with touch DNA evidence present.

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Introduction

Vehicle crimes, particularly auto thefts, are becoming a growing concern in the United States. In 2012, there was an estimated 721,053 motor vehicle thefts in the United States that resulted in over $4.3 billion in damages (FBI, 2013). In addition, criminals that are convicted of thefts are also frequently found to have prior convictions. According to Cohen and Kyckelhahn (2016), 77% of felony defendants have at least one prior arrest and 49% have multiple convictions. Due to the high probability of repeat offenders, it is likely that a profile match could be made in the Combined DNA Index System (CODIS). In the United States alone, the introduction of trace DNA collection in property crimes led to an increase in convictions. In a study conducted by the Urban Institute, property crime cases where trace DNA evidence was collected and analyzed resulted in a 19% increase in suspect identification as compared to cases where no trace DNA evidence was analyzed (Ritter, 2008). Therefore, effective collection and processing of trace DNA evidence from vehicle thefts will likely produce higher conviction rates.

In the United States, cotton swabbing is one of the most commonly used collection methods in forensic biological casework (Sweet, M. Lorente, Valenzuela, Lorente, & Alvarez, 1996). Many laboratories use swabs to collect trace DNA from a variety of surfaces with yields of sufficient concentrations for analysis (Verdon, Mitchell, & Oorschot, 2014). In the United Kingdom, trace biological samples from vehicle crimes are often collected using adhesive tape-lifts. Studies have shown that trace samples collected using tape-lifts can provide a high-quality result as compared to results obtained using swabs (Barash, Reshef, & Brauner, 2010; Bond & Weart; Bhoelai, Beenster, &

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DOI: 10.31979/THEMIS.2017.0507

Sijen, 2013; Gunnarsson, Eriksson, & Ansell, 2010; Hansson, Finnebraaten, Heitmann, Ramse, & Bouzga, 2009; Li & Harris, 2003). Adhesive tape-lifts are able to collect trace DNA samples with fewer inhibitory factors and often produce better profiles for analysis (van Oorschot, Ballantyne, & Mitchell, 2010). Adhesive tape-lifts can also produce optimal concentrations of epithelial cells for DNA analysis over the conventional swabbing method (Barash et al. 2010). In addition, studies have shown that adhesive tape-lifts have the ability to remove multi-donor deposits layer by layer using a differential tape-lifting method (Harris, Cardenas, Lee, & Barlowen, 2013; Verdon, Mitchell, & Oorschot, 2015). Forensic laboratories in both the United Kingdom and United States have implemented a 200-picogram template DNA threshold limit for any type of DNA analysis (van Oorschot et al., 2010). Therefore, it is crucial for investigators to select a collection method optimized for recovery that also limits inhibition and degradation of the sample. Not only in investigations involving vehicles, but also other crimes with touch DNA evidence present, will be aided by optimizing the collection technique of touch samples.

The efficiencies of the adhesive tape-lift and double-swab collection methods were evaluated for investigating vehicle crimes with possible touch DNA samples. The tape-lift collection method is hypothesized to recover more trace DNA than the swab method. DNA deposition or recovery is also hypothesized to vary based on the materials used for the headrests.

Experimental Details

Materials

Lab coats, facemasks, and gloves were worn during collection and pre-amplification procedures. Two sets of

experiments were conducted to evaluate the effectiveness of tape-lifts and swabs on vehicle fabrics and headrests. In both experiments, Puritan Sterile Cotton Tipped Applicator Swabs and SceneSafe Touch DNA FAST Tape-lifts were used to collect samples from the substrates. Under the given circumstances of sampling techniques used, the Santa Clara County Crime Lab protocols for DNA collection, extraction, amplification, and quantification were followed for the experiment when applicable.

Sample Preparation, Storage and Collection of Trace DNA from Vehicle Fabrics

Cloth, leather, and vinyl vehicle seat fabric obtained from Valencia Auto Shop were each cut into two sets of three rectangles with dimensions of 25 cm by 75 cm. Each set of fabric was spiked with varying volumes of saliva to simulate touch DNA contact: one set of was spiked with 5 μL of saliva and the other set was spiked with 10 μL of saliva. Although saliva can have a higher cellular content than most trace DNA samples, this body fluid was selected to give a measurable comparison between the different substrate types and the efficacy of the two collection methods tested. Each cut of fabric received two drops of the designated volume using a micropipette. Each set of fabric was exposed in the lab at room temperature for 1, 2, or 3 days of storage time (incomplete sampling was observed for Day 1 cloth substrates). Each set of substrates was double swabbed or tape-lifted to recover the spiked saliva after exposure. Samples were placed in Qiagen Lyse&Spin Basket tubes for extraction.

DNA Extraction

Sample tubes containing cotton tips were minced using a scalpel to extract the cotton from the tip of the swab. Within

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each sample tube, 400 µL of digestion buffer and 6 µL of 20 mg/mL proteinase K were added. Sample tubes containing the tape-lift required an additional 200 µL of digestion buffer to fully submerge the tape-lifts in the solution. Each tube was vortexed and then incubated at 56 °C for 8 hours. The tubes were then centrifuged at 7500 RPM for 2 minutes. Then, 400 µL phenol-chloroform was added to each tube and centrifuged at 5500 RPM for 3 minutes. The aqueous layer from each sample tube was transferred to a centrifuge tube with a Microcon MRCF0R100 filter unit and centrifuged at 3500 RPM for 30 minutes. Each Microcon filter was washed with 200 µL of Tris-EDTA (TE) buffer and centrifuged at 3500 RPM for 30 minutes. DNA was collected by inverting the Microcon unit in a new tube and eluting with 20 µL TE buffer via centrifugation at 5000 RPM for 3 minutes. Extracted DNA was stored at –20 °C until the quantification step could be performed.

DNA Quantification

Extraction samples were quantified using a Quantifiler™ Duo Human DNA Quantification Kit and an Applied Biosystem 7500 Real-Time PCR system. Reactions were carried out in a 96-well plate; each reaction contained 10.5 µL Quantifiler™ Primer Mix, 12.5 µL Quantifiler™ PCR Reaction Mix, and 2 µL sample. Standards ranging in concentration from 50 ng/µL to 0.023 ng/µL were generated according to the Santa Clara County Crime Lab Protocol.

Results and Discussion

DNA Yields from Mock Headrests

A total of 72 samples were collected from spiked cloth, vinyl, and leather strips (36 swabbed samples and 36 tape-lifted samples). The total amount of DNA was calculated by multiplying the concentration of DNA with the volume of

sample collected. Overall, the average DNA yields ranged from 0 ng to 43.5 ng for swabbed samples and 2.3 ng to 41.8 ng for tape-lifted samples. The tape-lift collection method outperformed swabbing for 4 out of the 6 points tested for cloth materials (Figures 1A and 2A). Incomplete sampling was observed for Day 1 cloth substrates. No results were obtained for the swabbing of cloth substrates for the Day 1 storage time. In a recent comparison study, adhesive tape lifts demonstrated comparable or better yields than swabbing from fingerprints (Plaza et al., 2015). In this study, tape-lifts also outperformed swabbing for 5 of the 6 points tested for vinyl substrates (Figures 1B and 2B). The leather material samples showed slightly higher DNA recovery with swabbing at 4 out of the 6 points tested (Figures 1C and 2C). Out of the three vehicle fabrics tested, leather resulted in the highest amount of DNA recovered.

The goal of this study was to systematically determine whether different vehicle fabrics and exposure times would affect DNA recovery from vehicle headrests using either swabs or tape-lifts. In most instances, tape-lifts indicated better or comparable DNA recovery than swabs. Cloth and vinyl fabric materials in particular showed better recovery with tape-lifts when compared with swabs. This might be due to the inherent textures of the fabrics. Vinyl fabric material is non-absorbent, causing cells from touch contact to be deposited on the surface of the material. Further testing is needed to understand how the textures and characteristics of cloth could affect higher DNA recovery when using tape-lifts. Results also indicated that swabs showed slightly higher recovery on leather fabric material. Leather is a less pliable material when compared with cloth fabric. In addition, leather fabric consists of grooves and ridges where cells may be sequestered. It is difficult for tape-lifts to

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DOI: 10.31979/THEMIS.2017.0507

recover samples from leather due to these characteristics and the pliable cotton tip of swabs is able to recover cells deposited into the grooves.

The results from the experiments indicated exposure time did not affect the sample recovery for both tape-lifts and swabs. Comparable results were observed for 1-day and 3-day samples (Figures 1A and 1B). Factors that may have attributed to this result include incomplete sampling on the Day 1 samples, uneven deposition of spike samples in the replicates, and sample degradation.

Conclusion

These preliminary results suggest tape-lifting may produce higher recovery than swabbing. Analysis of the data indicates tape-lifting results in higher recovery from cloth and vinyl substrates, whereas either collection method results in comparable recovery from leather substrates. In addition, recovery using either method was not affected by storage time. Similar recovery was observed for 3-day and 1-day storage times. However, further experimentation is required with a greater number and range of substrates.

In conclusion, this research indicates that the use of different collection techniques can have a direct effect on the quantity of DNA recovered from a crime scene. Although further experimentation should be conducted, we recommend forensic laboratories re-evaluate current collection protocols for biological samples to ensure the optimal profiling can be achieved.

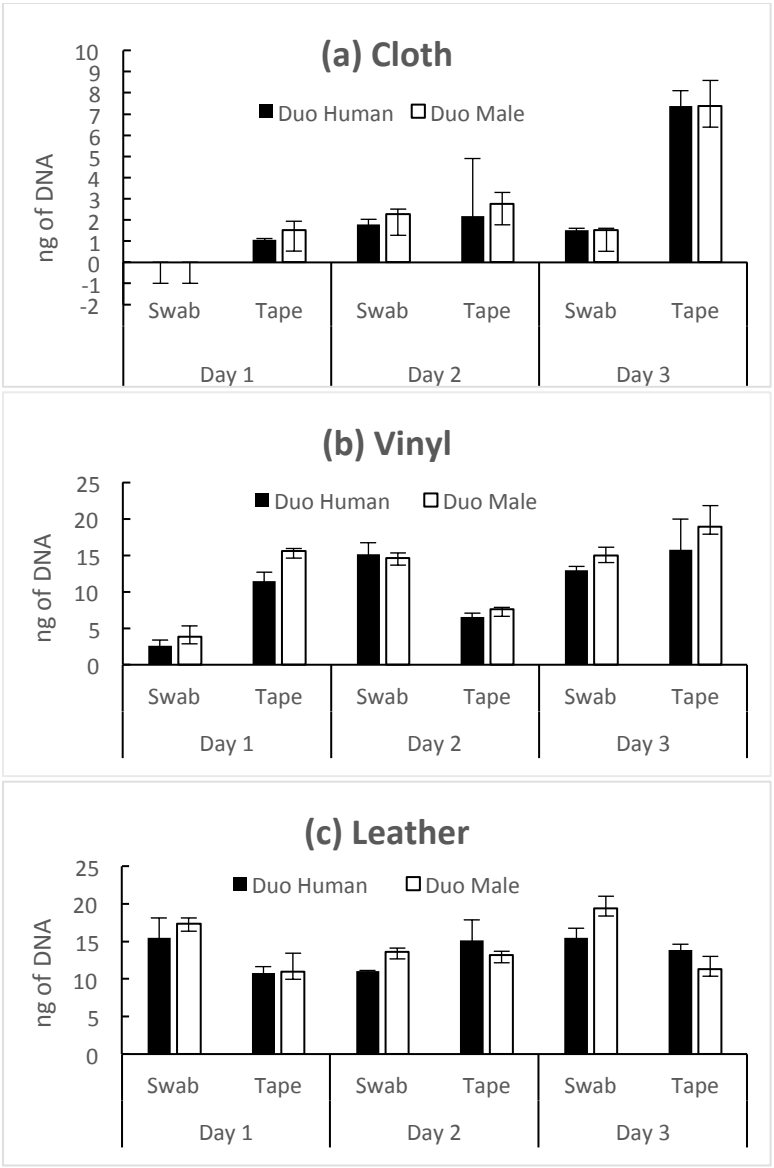

FIG. 1 – *Quantity of DNA recovered by either swab or tape from 5 µL deposit on (a) cloth, (b) vinyl and (c) leather and left for 1, 2, or 3 days. Note the differing scales on the vertical axes.*

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DOI: 10.31979/THEMIS.2017.0507

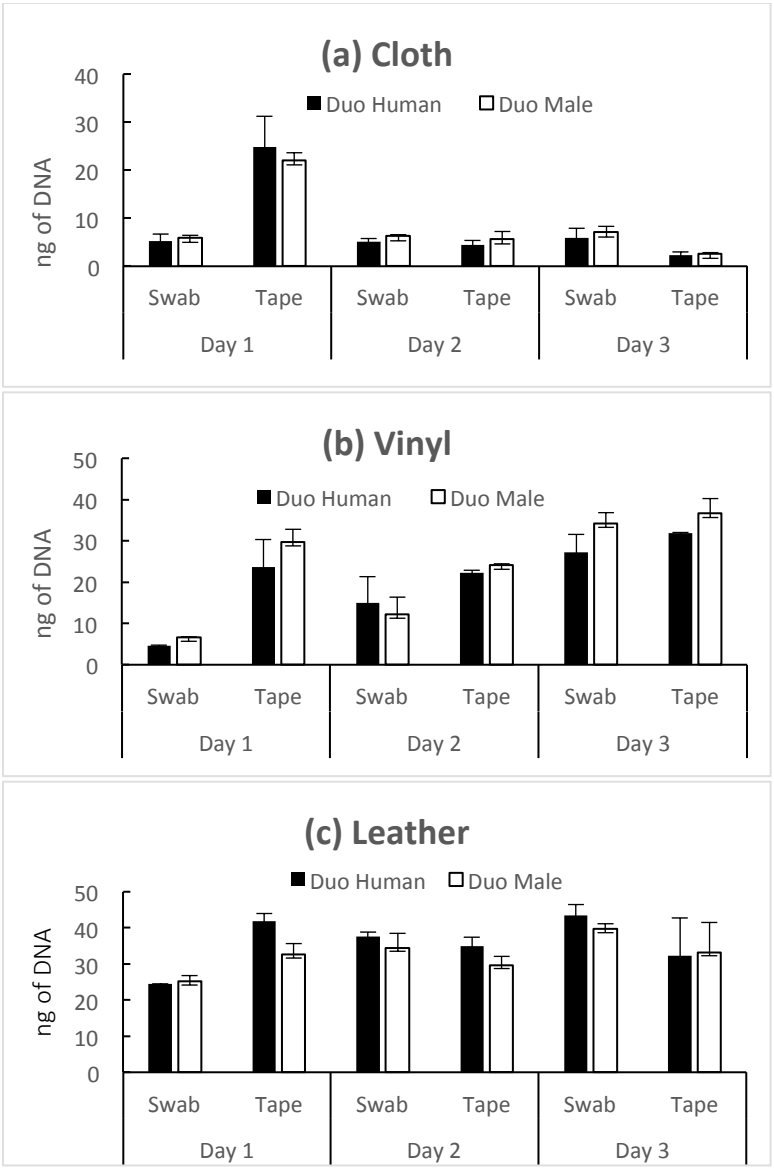

FIG. 2 – *Quantity of DNA recovered by either swab or tape from 10 μL deposit on (a) cloth, (b) vinyl, and (c) leather and left for 1, 2, or 3 days. Note the differing scales on the vertical axes.*

Acknowledgments

The authors would like to acknowledge support from an NSF Grant # 1262832 to PI Dr. Miri VanHoven and Co-PI Dr. Rachel French of Biology and research mentor Steven Lee of Forensic Science at SJSU and technical support and assistance of Criminalists Jeremiah Garrido and Tahnee Mehmet of the Santa Clara County Crime Laboratory. This work was supported by a 2015 California Association of Criminalists A Reed and V. McGlaughlin endowment SJSU FS research scholarship.

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DOI: 10.31979/THEMIS.2017.0507

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https://scholarworks.sjsu.edu/themis/vol5/iss1/7
DOI: 10.31979/THEMIS.2017.0507