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Analysis of transferred fragrance and its forensic implications

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ABSTRACT

Perfumes are widely used by many people in developed countries, and a large number of both men and women wear perfumes on a daily basis. Analysis of perfume trace materials from clothing is not commonly employed within forensic casework, yet as a form of trace evidence it has the potential to provide valuable intelligence. In order to appreciate the value of trace evidence there is a fundamental need for an evidence base that can both offer insight into how a trace material behaves under different scenarios and activities, and from which inferences can be made. With this purpose a gas chromatography-mass spectrometry method for trace analysis of perfumes was developed. This paper presents two different series of experiments that investigate the dynamics of perfume transfer as a factor of perfume ageing time, and as a factor of perfume contact time. Empirical data showed that both perfume ageing time, and perfume contact time play a key role in the number of perfume components transferred. These studies have implication for forensic protocols, specifically for perfume trace evidence collection, analysis, interpretation, and presentation, and there is potentially great value in analysing perfumes from clothing exhibits in forensic enquiries that involve close contact between individuals, such as sexual assaults.

1. Introduction

In many economies perfumes and fragrances are perceived as an indispensable part of life, and an increasing number of both men and women are wearing perfumes on a daily basis [1]. The British Market Research Bureau's annual Target Group Index survey identified that up to 89% of women wear fragrance on a regular basis [2], while the Men's Fragrance Track study [3] identified that 63% of adult males aged 18–64 wear fragrance periodically, and 23% use it daily.

Fragrances are volatile components by their nature, and skin and clothing can readily absorb fragrances by direct application, by contact with fragranced items, or by exposure to air containing fragrance chemicals [4]. Clothing is regularly recovered from crime scenes, or collected in the course of an investigation, and is often tested for a range of different forms of trace evidence [5]. However, as yet, there are no published studies aimed at obtaining empirical evidence concerning the behaviour of perfumes and the implications of fragrance identification for forensic enquiries. There has been limited research in the past decade on the analysis of cosmetic products for forensic applications. Research has been carried on the transfer of foundation smears [6] and on study of traces of lipstick to identify the lipstick brand [7]. Also, in a study from 2003 by Gniotek [8], an attempt was made to measure the odor firstly from a piece of cotton that was in direct contact with a fabric that had absorbed an odorant, and secondly from a piece of cotton that was in close proximity to the flavoured fabric. The headspace-gas chromatography results revealed that the first fabric absorbed 58 components of the odorant, and the second 32 components. The identification of components was not performed, as they were not present at high enough concentrations.

How significant or valuable trace material findings are depends not only on the type of trace evidence, but also on the amount of trace evidence, the location where the evidence is found, and the circumstances of the crime [9]. Understanding the persistence of different forms of trace evidence and identifying where that evidence is most likely to be deposited are a mean of developing an empirical evidence base that enables interpretation of the significance of the trace evidence that is identified, collected and analysed in the course of an investigation. Empirical evidence bases such as these have the potential to enable robust interpretation of the context of a particular form of trace evidence in a specific case, and therefore offer potentially valuable intelligence and evidence.

The evidential value of trace evidence is affected by two major factors: transference and persistence. Proof of work-studies for transfer of trace evidence, with a focus on textile fibres, first became available in 1975. In an early study by Pounds and Smalldon [10], looking at the transfer of fibres to wool and acrylic garments, it was identified that

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the force of contact and the nature of the recipient garment had a significant impact on the number of fibres being transferred. In a further study, Pounds and Smalldon [11] investigated the persistence of transferred fibres, finding an initial loss of approximately 80% after 4 h, which increased to around 95% after 24 h. Experimental work offers a means of understanding how perfume trace evidence behaves under certain circumstances and carrying out studies that mimic forensic reality is the first step towards assigning significance and weight to perfume trace evidence.

Gas chromatography coupled to mass spectrometry (GC-MS) is by far the most routinely employed analytical techniques in the perfume industry [12], but also an instrument commonly used in forensic laboratories. GC-MS has a long history and a wide application in forensic science. Its uses include but are not limited to analysis of drugs of abuse [13], of textile fibres [14], of automotive paint traces [15] and of fire debris [16]. GC-MS is particularly useful as samples are regularly composed of very complex matrices, and the results generated satisfy the requirement of high accuracy measurements with a high degree of certainty needed in court.

Multiple studies have shown that some volatile organic compounds (VOCs) are more common than others in fragranced items. In a study based on domestic and occupational products purchased on the European marked, Rastogi et al. [17] found that limonene was the most frequent component, present in 78% of the 59 products analysed, but it also had the highest mean concentration (9443 ppm). Linalool was the second most popular component, present in 61% of products. Other popular ingredients included geraniol (41%), eugenol (27%), and coumarin (25%). These five chemicals were selected to create a fragrance mix (FM) for the preliminary analyses in this study.

With a high number of people wearing perfume, and with a very reproducible analytical technique such as GC-MS, analysis of perfumes from garments can potentially aid in the investigation of crimes that involve close contact between individuals. A clear crime type that could benefit from perfume analysis as an additional piece of evidence is sexual assault, given the proximity of offender and victim during such a crime. Serious sexual assault is one of the most difficult crimes to prosecute as a great number of the offences are committed by a partner/ex-partner (52%), by a family member (6%) or by someone else known to the victim (39%), which can make inference of activity level from physical evidence difficult [18,19]. The nature of the encounter can be argued to have been consensual, and in such instances it is usually the word of one person against another, as in many cases there are no witnesses, contusions or conventional forensic evidence available [20]. In cases where the offender is a stranger to the victim, preserving the DNA is crucial evidence, however, even in these cases it has been identified that many victims bathe or shower before a forensic medical exam, making the recovery of a viable DNA sample difficult.

Due to the close contact between the victim and assailant during sexual assault, fragrance analysis has the potential to be an additional forensic tool that could be used to demonstrate a contact has taken place, and potentially indicate the type of contact made and the timeframe since the contact. However, this needs to be achieved through experimental studies to establish an evidence base for the dynamics of fragrance as a form of trace evidence, so that the identification and the interpretation of that fragrance can be transparent, reproducible and evidence based. This research addresses the current lack of published literature regarding perfume trace evidence. The main aim was to establish whether fragrance could be a viable form of trace evidence for crime reconstructions, achieved via the development of an analytical method that enables the analysis of perfumes from clothing, and also the development of a perfume transfer mechanism able to mimic the transfer of perfume between garments in order to assess the detectability of transferred fragrance.

Further, as perfume transfer is expected to be a dynamic process, this study sought to test the hypotheses that an increased perfume ageing time leads to the observation of predominately heavier molecular mass molecules onto a second piece of garment, and that the length of time two pieces of garment are in contact influences the number of perfume components transferred onto a second piece of garment.

2. Materials and methods

2.1. Chemicals and materials

Methanol (HPLC grade) was purchased from Fisher Scientific (UK). Reference standards of limonene, linalool, geraniol, eugenol, and coumarin with a purity of 96, 97, 98, 99, and 99% respectively were obtained from Sigma-Aldrich (UK).

This study focused upon a commercially available male perfume purchased from a mainstream retailer. Despite a moderate incidence of perfume use amongst men, this was chosen to reflect the high percentage of serious sexual assaults committed by men (up to 99%) [21].The fabric used was 100% cotton, and was selected because it is understood to be one of the most common garments encountered by forensic textile examiners [22]. For all perfume transfer experiments, cotton swatches of approximately 1 cm × 1 cm were used. To ensure that the fabric was not contaminated with any volatile organic compounds, a washing step was carried out ahead of any analysis. The washing was performed in a conventional washing machine without the use of detergent. After a drying step, the cotton was kept within a closed plastic bag to prevent contamination. All experiments involving transfer of perfume between cotton swatches were carried out in duplicates.

2.2. Instrumentation

GC-MS analyses were performed on a Thermo Scientific™ Trace™ 1310 Gas Chromatography system coupled to a Thermo Scientific™ ISQ™ Single Quadrupole Mass Spectrometer and connected to a Thermo Scientific™ TriPlus™ RSH Autosampler. Samples were injected on a Thermo Scientific™ TRACE TR-5MS column (30 m × 0.25 mm i.d., 0.25 μm film thickness) using liquid injection in splitless mode. Helium was employed as a carrier gas at a constant column flow of 1.2 mL/min.

The GC oven temperature was programmed from 40 °C (held for 1 min) to 270 °C (held for 3 min) at 40 °C/min rate. The injection volume was 0.2 μL and the injector temperature was set to 250 °C. The transfer line and the ion source temperatures of the ISQ mass spectrometer were set to 230 °C. The ISQ mass spectrometer was operated in Electron Impact (EI) ionisation mode at 70 eV. Data acquisition rate was of 5 spectra/s, and the mass range was scanned from m/z 10 to 400. EI mass spectrum of each component eluted from the GC column was compared with EI mass spectra from the National Institute of Standards and Technology (NIST) v 2.0 (2011) EI mass spectral library for identification.

During the experimental work, a portable thermometer-hygrometer (model 82021, VWR Scientific) was used to measure the ambient laboratory temperature and humidity. The temperature values ranged between 21 and 22 °C, and the humidity ranged between 23 and 46%.

2.3. Sample preparation for GC-MS analyses

Throughout the development of the GC-MS method, a fragrance mixture (FM) standard consisting of approximately 30 mM limonene, linalool, geraniol, eugenol and 15.2 mM of coumarin dissolved in methanol was used for the optimisation of the GC separation.

To build up a library of the components detected in the male perfume, a 1% perfume solution was prepared, by pipetting 10 μL perfume to a GC vial and adding methanol to a final volume of 1 mL.

For the analysis of fragranced fabrics, the cotton swatch was placed into a 1.5 mL glass vial following the addition of 1 mL of methanol for the extraction of the components from the fabric. The solvent was then transferred into a disposable 1.5 mL Eppendorf tube and centrifuged for 2 min at 12,000 rpm in a VWR Galaxy 14D micro centrifuge, following by transfer to into a GC vial for GC-MS analysis.

2.4. Perfume transfer methods

Developing a reproducible and repeatable method for the transfer of perfume between garments represents a major first step for the potential use of perfume analysis in forensic reconstructions. The transfer of trace evidence (including diatoms, pollen grain, powder and metal particulates) between clothing has been the focus of a number of studies [23,24]. However, to our knowledge, there is currently no method in the published literature for replicating the transfer of a fragrance between garments. In a pilot study, two perfume transfer methods using a fragranced cotton swatch and a fragrance free cotton swatch were tested: (1) direct contact under the pressure of an external force ($m = {\sim}660$ g, $A_{\text{weight}} = 0.0048\ \text{m}^2$, $p = {\sim}1350$ Pa) and (2) a hand rubbing method.

To test the two perfume transfer methods, a cotton swatch was placed using tweezers on a clean Petri dish. Using a Gilson PIPETMAN P100 pipette, 20 μL of perfume was added to the cloth, which was then dried with natural air movement around it for a set period of time. This time was called in this study the perfume ageing time (PAT). For both transfer experiments a 30-minute PAT was used.

For the direct contact experiment, after the set PAT passed, a perfume free cotton swatch was placed on top and left in contact for a set period of time (10 min), which was termed the contact time. A piece of paper was placed between the weight and the top cotton swatch to prevent contamination. The process is graphically shown in Fig. 1. For the hand rubbing transfer experiment, after the set PAT, the fragranced swatch was rubbed with a perfume free cotton swatch between hands wearing gloves for 2 min. After the contact time or rubbing time passed, the cotton swatch with transferred fragrance was prepared for GC-MS analysis as discussed in Section 2.3.

2.5. Perfume ageing time (PAT)

An experimental study was designed to test the hypothesis that the period of time that a perfume is left to dry for prior to its transfer affects how the perfume transfers onto a secondary fabric. Twenty μL of the male perfume were pipetted in duplicate to a piece of cotton placed on a Petri dish and left to dry for different perfume ageing times: 5 min, 30 min, 1 h, 3 h, 6 h, 24 h, 48 h, 72 h and 7 days. The samples were left to dry on a storage shelf in the laboratory.

After each PAT, the direct contact transfer method and a constant contact time of 10 min were used to enact the transfer between the two cotton swatches. The perfume components from the secondary cotton swatch were extracted as described in Section 2.3.

2.6. Perfume contact time

In a second time related experiment, the impact of five different contact times was tested. The male perfume was aged in duplicate for 30 min on a piece of cotton, and then a new piece of cotton was placed on the top of it and then left in contact for 1 min, 5 min, 10 min, 30 min or 60 min using the direct contact transfer method. The components from the second piece of cotton were extracted as described in Section 2.3.

3. Results

3.1. Method development

A preliminary GC-MS method utilised a GC gradient starting from 60 °C oven temperature to 250 °C, at a rate of 30 °C/min, and the injection volume was 0.6 μL. Using this GC gradient initially broad chromatographic peaks were observed. The initial temperature of the GC oven was then adjusted to 40 °C, and a steeper GC gradient was utilised from 40 °C to 270 °C at 40 °C/min. A decrease in the injection volume from 0.6 μL to 0.2 μL led to detecting significantly sharper GC peaks. The width at 50% of the GC chromatographic peak for limonene was 0.9 s. As a result, a good separation was achieved, while using a shorter GC-MS run time, which translates into a faster, but also cheaper analytical method that can provide an invaluable aid in forensic analyses.

In order to analyse perfumes from fabric, a solvent extraction step was carried out. Methanol was chosen, as it a commonly employed organic solvent, including for the analysis of VOCs in environmental samples [25,26], it poses a low environmental hazard and a relatively low health hazard [27], and it is relatively inexpensive (an important consideration for forensic applicability). Prior to analysis of fragranced fabric, a blank sample of a cotton swatch in 1 mL of methanol was analysed on the GC-MS. No major peaks were detected with the exception of a very low abundance GC peak at retention time (RT) 4.07 min, which was identified as undecane using its EI mass spectrum through the NIST library. Undecane is common contaminant in HPLC grade methanol.

In a further experiment, 20 μL of the FM were pipetted to a piece of cloth, which was then transferred to a GC vial, and 1 mL of methanol was added. The GC chromatogram (Fig. 2) shows the presence of five well-separated GC peaks: limonene at RT 3.82 min, linalool at RT 4.11 min, geraniol at RT 4.71 min, eugenol at RT 5.14 min and coumarin at RT 5.56 min.

3.2. Development of a perfume transfer method

A commercially available male perfume was used to test both transfer methods. For a better understanding of the VOCs present, a 1% solution of the male perfume dissolved in methanol was analysed, and the resulting chromatogram is shown in Fig. 3. Using a S/N ratio

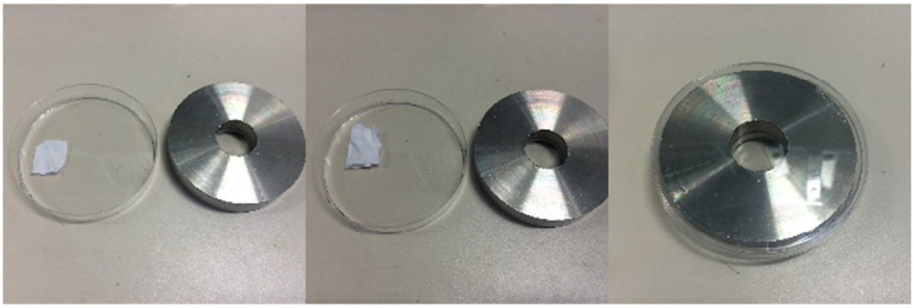

Fig. 1. Step by step illustration of the perfume transfer method involving direct contact under the pressure of a weight. From the left, the first picture shows a piece of cloth impregnated with perfume left to dry, the second picture shows the addition of a second piece of cloth and the third picture shows the addition of the weight.

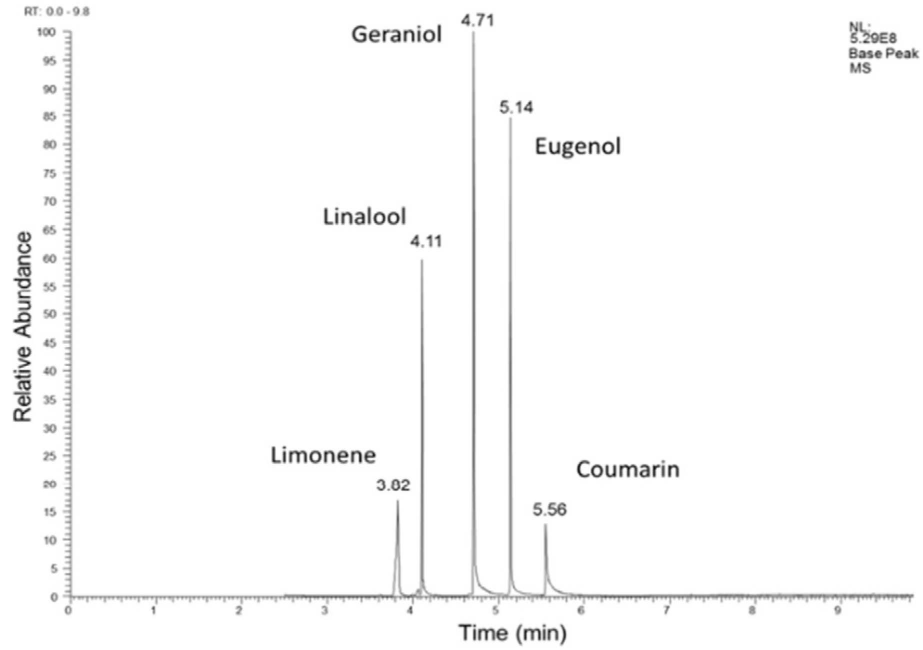

Fig. 2. GC chromatogram of a fragrance mixture (FM) containing 30 mM limonene, linalool, geraniol, eugenol and 15.2 mM coumarin analysed using liquid injection.

of 200, the chromatographic peaks were imported into an Excel file to build up a reference table of the components detected. The EI spectrum of each component was searched against the NIST library for tentative identification using a match factor of at least 750. The identification of the components from cotton swatches with transferred fragrance was based on a comparison of the GC retention times, as well as their corresponding EI mass spectra.

Using the direct contact method (30 min perfume ageing time and 10 min contact time under the force of an approximately 660 g weight), VOCs were clearly transferred from the initial piece of cotton impregnated with the male perfume to the perfume free piece of cotton (Fig. 4) Some of the GC chromatographic patterns from the original perfume can also be observed in the transferred perfume swatch, for example the cluster of peaks around 6 and 6.5 min retention time.

Forty-four different components were tentatively identified in the 1% solution male perfume, and 22 out of these 44 components were present in the transfer sample using direct contact. The GC-MS chromatograms of the transferred sample and the 1% solution of the male perfume were compared, and, as expected the intensity of the peaks was considerably lower in the former. The peaks at 6.47 and 6.57 min RT were still present, however their intensity is significantly lower in the transferred sample than in the 1% solution of the male perfume. Whether a perfume component is transferred onto another piece of fabric depends not only on its volatility and in turn on its vapour pressure, but also on its abundance. EI mass spectra

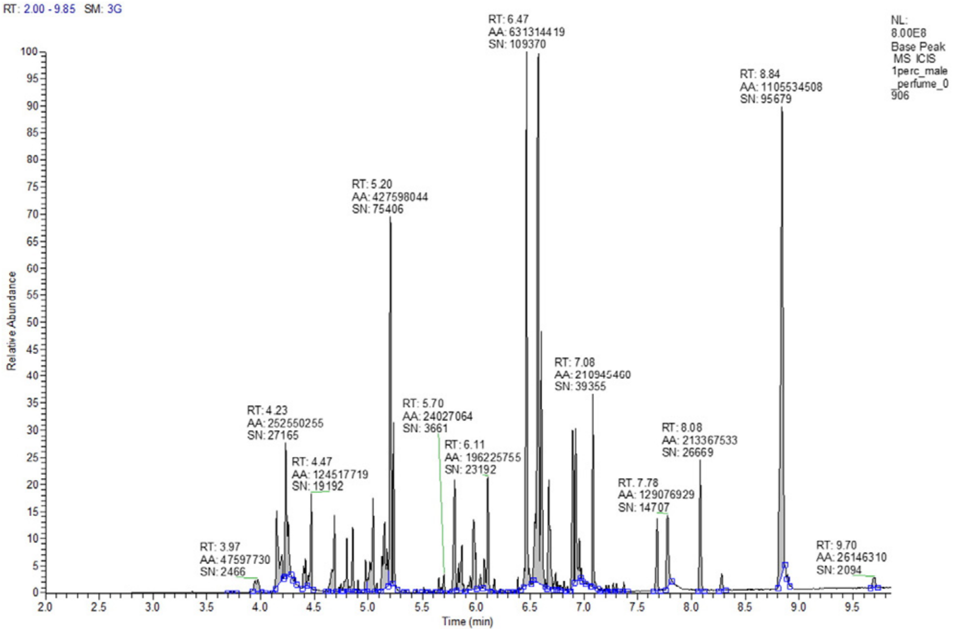

Fig. 3. GC chromatogram of the 1% solution male perfume.

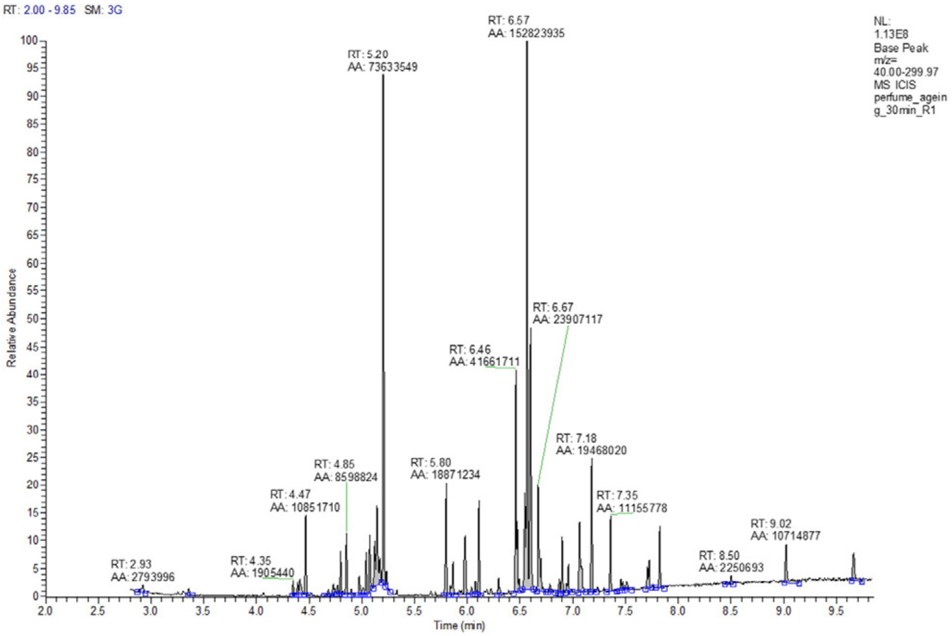

Fig. 4. GC chromatogram of transferred perfume (30 min ageing time and 10 min contact time using direct contact method)-Replicate 1.

of the GC peaks at RT 5.8 min (di-epi-α-cedrene) and 6.04 min (Guaia-1(10),11-diene) from both chromatograms are provided in the Supplementary Material.

The direct contact method tested so far involved pressure, but not friction. The second transfer experiment involved hand rubbing a cotton swatch impregnated with male perfume and a fragrance free cotton swatch (30 min perfume ageing time and 2 min rubbing time). This method enabled the transfer and detection of an overage of 19 out of the 44 perfume components. A higher degree of variability was noticed between the hand rubbing replicates compared to direct transfer replicates. Table 1 also summarises whether the tentatively identified components in solution were transferred and detected using the two different transfer methods.

3.3. Perfume ageing time

With an increase in the perfume ageing time, a lower number of perfume components were transferred and detected onto the second piece of cloth. It was possible to identify a progressive disappearance of the most volatile components (i.e. the top notes) over time. This gradual decay trend is illustrated in Fig. 5.

For the shortest perfume ageing time tested (5 min) there were on average 24 components transferred, out of the 44 components detected in the 1% solution of the male perfume. After 1 h, there were 20 components transferred, after 6 h 12 components, and after 48 h 9 components. Finally, after 7 days of perfume ageing time, only 6 components, mostly non-volatile components as their retention times were higher than 6.2 min, were transferred and measured by the GC-MS.

3.4. Perfume contact time

With an increase in the fabric contact time, a higher number of perfume components were detected on the second cotton swatch (Fig. 6). A contact time of 5 min led to 16 perfume components out of 44 to be transferred and measured. When the contact time was increased to 10 min an additional 2 components were transferred. However, even with a contact time as short as 1 min as many as 15 components (out of the original 44) were transferred and measured by the GC-MS.

4. Discussion

4.1. Method development

Solvent washing provides a fast and inexpensive way to extract the volatile organic components from the fabric into the solvent itself, which can be further analysed. Using methanol, all five reference standards were recovered from a cotton swatch. Besides the short GC-MS analysis time of 10 min, the sample preparation time involves a straightforward and short procedure, which includes the soaking of the clothing sample in methanol, the extraction of methanol into a centrifuge tube, a 2 min centrifugation step, followed by the transfer of the solvent into a GC vial. The overall short time of the method described in this paper for the analysis of fragrances from clothing has important cost implications for forensic laboratories, as it allows more samples to be analysed, in addition to providing quick turnaround times.

4.2. Development of a perfume transfer method

Using a commercially available male perfume, two different perfume transfer methods were tested including: (1) direct contact under the pressure of an external force, and (2) a hand rubbing method.

Twenty-two out of 44 perfume components were transferred onto a second cotton swatch using the direct contact method, which involved loading around 1.3 kPa of weight on top of the fabrics. The amount of human pressure exerted during an assault is determined by many variables, such as the weight of the person/object, the area on which the force is applied, and the acceleration involved. As a reference, Thorgren and Werner [28] determined a mean pressure value of approximately 113 kPa for the hand grip of a healthy 25–30 years old male.

The hand rubbing method enabled a good number of components to be transferred (an average of 19 out of 44 perfume components). The heat generated while rubbing the pieces of cotton together might have facilitated the ease of the perfume transfer, which could explain the high number of perfume components transferred in such a short period of time.

The hand rubbing method may simulate more closely the transfer mechanism in a sexual assault scenario, however it was considered that this method, as conducted here, provides a lower degree of reproducibility compared to direct contact method, as it involves a human

Table 1
Compounds tentatively identified in 1% solution of male perfume, and their transfer onto a second piece of cloth using the two different transfer methods.

RT (min)	Proposed perfume component	Match factor	In solution	In the transfer sample using direct contact method		In the transfer sample using hand rubbing method	
				Replicate 1	Replicate 2	Replicate 1	Replicate 2
3.72	Unidentified		Yes				
3.74	1R-α-Pinene	772	Yes				
3.97	β-Pinene	918	Yes				
4.15	1,1′-Oxybis-2-propanol	874	Yes				
4.23	2-(2-Hydroxypropoxy)-1-propanol	923	Yes				
4.31	γ-Terpinene	846	Yes				
4.42	Unidentified		Yes	Yes	Yes		
4.47	Linalool	956	Yes	Yes	Yes	Yes	Yes
4.68	Unidentified		Yes	Yes	Yes		
4.75	Unidentified		Yes	Yes	Yes		
4.8	Unidentified		Yes	Yes	Yes	Yes	Yes
4.85	Ethyl linalool	848	Yes	Yes	Yes	Yes	Yes
4.9	Unidentified		Yes	Yes	Yes	Yes	
4.97	Unidentified		Yes	Yes	Yes	Yes	
5.04	Linalyl anthranilate	950	Yes	Yes	Yes	Yes	
5.15	Unidentified		Yes	Yes	Yes	Yes	Yes
5.2	p-Menthan-8-ol	788	Yes	Yes	Yes	Yes	Yes
5.23	Hydroxycitronellal	912	Yes	Yes			
5.45	Nerol acetate	844	Yes				
5.51	Geranyl acetate	856	Yes				
5.7	2-tert-butyl-1,4-dimethoxybenzene	926	Yes				
5.8	Di-epi-α-cedrene	922	Yes	Yes	Yes	Yes	Yes
5.87	cis-Thujopsene	946	Yes	Yes	Yes	Yes	
5.97	Unidentified		Yes	Yes	Yes	Yes	Yes
6.04	Guaia-1(10),11-diene	910	Yes	Yes	Yes		
6.11	Lilial	879	Yes	Yes	Yes	Yes	Yes
6.17	α-Longipinene	855	Yes				
6.22	Unidentified		Yes				Yes
6.39	Unidentified		Yes				
6.47	Methyl (3-oxo-2-pentylcyclopentyl)acetate	824	Yes	Yes	Yes	Yes	Yes
6.58	Methyl β-Ionone	753	Yes	Yes	Yes	Yes	Yes
6.64	Unidentified	768	Yes				
6.67	Unidentified		Yes	Yes	Yes	Yes	Yes
6.75	Unidentified		Yes				
6.82	Unidentified		Yes				
6.85	Acetic acid, (1,2,3,4,5,6,7,8-octahydro-3,8, 8-trimethylnaphth-2-yl) methyl ester	763	Yes				
6.9	Unidentified		Yes	Yes	Yes	Yes	Yes
6.92	2-Ethylhexyl salicylate	906	Yes				
6.96	Unidentified		Yes	Yes	Yes	Yes	Yes
7.08	Galaxolide	914	Yes	Yes	Yes	Yes	Yes
7.68	Ethylene brassylate	943	Yes			Yes	
7.78	Oxybenzone	918	Yes				
8.08	Unidentified		Yes			Yes	Yes
8.84	Octinoxate	946	Yes			Yes	Yes
Number of perfume components detected			44	23	22	21	17

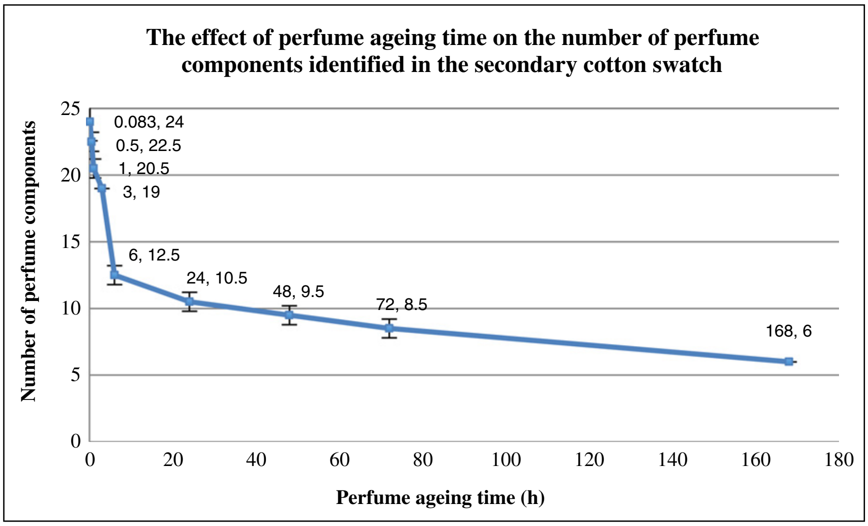

Fig. 5. Decline in the number of perfume components detected with increase in perfume ageing time (constant contact time of 10 min).

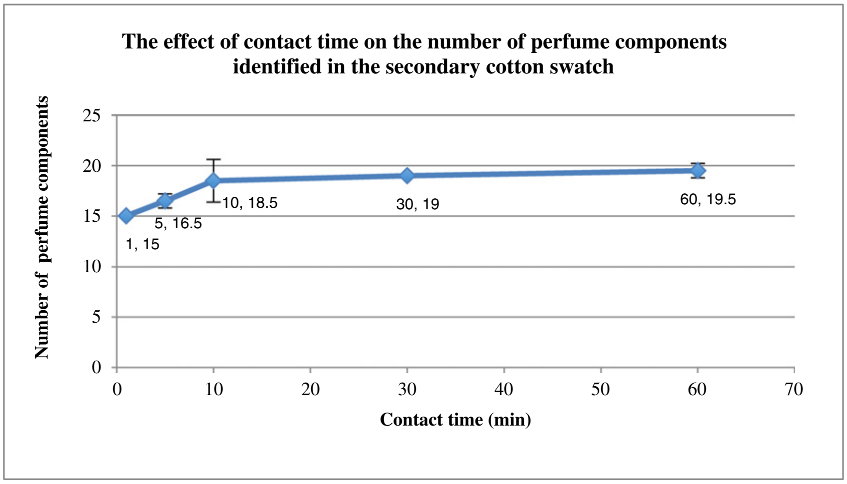

Fig. 6. Increase in the number of perfume components detected with increase in contact time (constant ageing time of 30 min).

factor. In consequence, the direct method was used to enact transfer between fabrics throughout the two time related experiments.

The results from the two experiments on transfer methods demonstrate that fragrance transfer between the clothing of two individuals occurs in a measurable manner. Therefore, fragrances can be considered to have the potential to offer a valuable form of trace evidence for forensic reconstructions. A future investigation into different methods for extracting perfumes from clothing may increase the efficiency of the perfume extraction from clothing, which could help overcome the low instrumental sensitivity observed when analysis cotton swatches onto which perfume was transferred.

4.3. Perfume ageing time

This experiment assessed the transferability of perfumes depending on the length of time for which a perfume is applied prior to its transfer (termed perfume ageing time). For the shortest ageing time (5 min), 24 out of 44 perfume components were transferred onto a second piece of cotton. As the ageing time increased, there was a progressive disappearance of the top notes. Six-hour perfume ageing time led to the transfer of 12 perfume components and 7 days led to 6 components being transferred.

Not surprisingly, these findings suggest that the more volatile a perfume component is the less likely it is to persist on the fabric over time, and as result the less likely is to be transferred onto another fabric. These results also demonstrate that perfume transfer is a dynamic process, and that perfume composition can change over relatively short time frames. This has important implications and may represent a challenge for forensic investigation protocols, especially the collection, analysis and interpretation phase of perfume evidence analysis. A criminal investigation involving perfume analysis should take into account the time between the application of perfume to fabric, and the time the fabric came into contact with a second piece of fabric.

4.4. Perfume contact time

The impact that contact duration between fabrics has on perfume transfer was examined using various contact times, from 1 min to 60 min. A longer contact time contributed to a higher number of perfume components being transferred onto a second piece of fabric. A contact time of 1 min led to 15 out of 44 components to be transferred, 5 min to 16 components and 10 min to 18 components. When the contact time was increased from 10 to 30 min only one additional compound was measured by the GC-MS.

Therefore, the time two fabrics are in contact affects the amount of perfume transfer, and also a short contact time of only 1 min facilitates the transfer of a considerable amount of perfume components. These results offer initial empirical evidence that transfer of fragrance components does take place, and this finding could therefore be used to inform forensic reconstructions of cases involving fabrics that have been in contact for different periods of time.

5. Conclusions

This research sought to determine the potential of fragrance as a viable form of trace evidence. Since there have been no previously published experimental studies, this study represents the first of its kind to demonstrate empirically the transfer of perfume between items of clothing, and the potential of fragrances to act as a form of trace evidence in forensic enquiries.

The liquid injection GC-MS method for the analysis of perfumes from solutions and garments presented here offers the means for a quick, accurate analysis of fragrance components present on clothing, and the potential to develop the utility of fragrance as a form of trace evidence. Further work will involve the improvement of the extraction of VOCs from fabrics by testing different solvents and the use of solid-phase micro extraction (SPME) prior to GC-MS analysis.

It was demonstrated that perfume transfers onto secondary clothing in a qualitative, and potentially in a quantitative manner. Therefore, there is potential for the use of fragrance traces in forensic enquiries that involve close contact between individuals. The highest number of perfume components transferred onto a second fabric was 24 out of 44 components identified for a specific male perfume under set conditions. Furthermore, under experimental conditions, the dynamics of perfume transfer were investigated. With an increased perfume ageing time there was a progressive evaporation of the most volatile perfume components and less perfume components transferred onto the second piece of cotton. On the other hand, longer garment contact time lead to a progressive increase in the number of perfume components transferred and detected. This study also highlighted that a short contact of only 1 min enabled the transfer of a large number of perfume components. It is therefore worthwhile ensuring that clothing from the victim and suspect recovered from a violent assault, are appropriately collected and analysed.

The initial empirical data presented in this study supports further investigation into the viability of the use of fragrance materials as a valuable form of trace evidence. The insights provided into the dynamics of perfume transfer as a factor of time, particularly perfume ageing time and perfume contact time, are important for producing an evidence base for the interpretation of fragrance trace evidence. These results represent the foundations upon which further empirical work can be carried out to create an evidence base to underpin our understanding of the behaviour of perfumes. It is essential that such work is repeated and developed in order to assess the degree of variability in order to enable reasonable inferences of the significance of such traces identified in a forensic context. It is important to note that this form of analysis (in a similar manner to other trace evidence) needs to carried out in an exclusionary manner [29], i.e. aiming to refute a claim that two samples have the same origin, as opposed to seeking associations or the identification of a match between samples.

Additionally, as Houck [9] underlines, it is important to consider the period of time between the offence and the analysis of the trace material, and to take into account the degree of activity undertaken by the suspect or the victim following trace transfer. There might be a considerable time delay between the crime and the collection of the evidence, in addition to a delay from collection to the analysis of the evidence, which can make an accurate interpretation of perfume trace evidence difficult. To consolidate the analysis of fragrances from clothing as a usable tool in crime reconstructions, research must be carried on the different time delays and levels of activity, but also on different transfer scenarios that simulate the realities of forensic enquiries. There is therefore significant potential for fragrances to be utilised as part of the suite of different forms of trace evidence in an exclusionary manner to aid crime reconstruction and to assist investigators and the court.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.scijus.2016.08.004.

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