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Comparing the Handwriting Behaviours of True and False Writing with Computerized Handwriting Measures

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SUMMARY

The goal of this study is to compare the handwriting behaviours of true and false writing. Based on the cognitive load and dis-automaticity known to be experienced while communicating a deceptive message, we hypothesized a difference (in temporal and spatial, pressure measures and peak velocities) between the handwriting of true *vs.* false messages. Thirty-four participants wrote true and false sentences on a digitizer, which is part of a new system called the Computerized Penmanship Evaluation Tool (ComPET). The ComPET evaluates brain-hand performance, as manifested through handwriting behaviour, and was found to be a valid measure for detecting the dis-automaticity that is indicative of certain diseases in the clinical field. Differences were found in mean pressure, spatial measures (mean stroke length and mean stroke height), but no differences were found in temporal measures and in the number of peak velocities. The use of ComPET in lie detection is discussed. Copyright © 2009 John Wiley & Sons, Ltd.

Detecting deception has been a goal of humankind for centuries (Granhag & Stromwall, 2004) and still presents a challenge that both researchers and practitioners are trying to meet. DePaulo, Lindsay, Malone, Muhlenbruck, Charlton, and Cooper (2003) defines deception as 'a deliberate attempt to mislead others'. The difficulties inherent in detecting deception are demonstrated by the fact that even for people in professions in which it is a vital skill (e.g. police officers, customs inspectors, federal law enforcement officers and judges), no better success rate of detection was found than that of the average observer (Aamodt & Custer, 2006; Bond & DePaulo, 2006).

Three main methods of detecting lies are currently in use:

Examining physiological changes/responses, such as blood pressure, heart rate, sweating palms and body temperature, *via* the polygraph or thermal imaging (e.g. Allen & Iacono, 1997; Ben-Shakhar & Furedy, 1990; Bull, 1988; Pavlidis, Eberhardt, & Levine, 2002).

1. Observing non-verbal behaviour such as body language and vocal pitch (Sporer & Schwandt, 2006, 2007).
2. Analysing speech content (DePaulo et al., 2003).

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Although extensive research has been conducted on these detection methods, there is no 'perfect method' for detecting deception (DePaulo et al., 2003). Even the polygraph, which is the most widely used system, is not fully reliable. It requires the attachment of electrodes on the person's body and is subject to human error in preparation as well as in data interpretation (Lacono & Lykken, 1997; Lykken, 1998; Steinbrook, 1992).

The instruments used in the detection of deception were developed on the basis of the human deception mechanism, which consists of two known reactions experienced when lying: Emotion and content complexity (DePaulo, 1988, 1992; DePaulo, Stone, & Lassiter, 1985). The primary emotional reactions to deception are guilt, fear and excitement (Ekman, 1989, 1992). Thought processes may also play a role in deception insofar as lying can be a cognitively complex task (Vrij, 2008). For example, Vrij, Mann, Fisher, Leal, Milne and Bull (2008b) reviewed reasons for increased cognitive load in deception. First, formulating lies is cognitively taxing; second, liars may be more inclined than truth tellers to monitor and control their demeanor so that they will appear honest; Third, liars may also have the extra load of monitoring the interviewer's reactions more carefully in order to asses whether they are getting away with their lie; Fourth, liars may be preoccupied by the task of reminding themselves to act and role play; Fifth, liars have to suppress the truth while they are lying and finally, activating the truth often happens automatically and activating a lie is more intentional and deliberate.

The present study will focus on cognitive responses and detection. The cognitive approaches explaining detection assume that encoding a deceptive message requires a greater cognitive effort than telling the truth because of higher processing capacity demands (Miller & Stiff, 1993; Sporer & Schwandt, 2006; Sporer & Zander, 2001; Vrij, 2008; Zuckerman et al., 1981), particularly when the lie involves a report about a complex event (Sporer & Zander, 2001). The theoretical models concentrating on the cognitive aspects of deception present the higher cognitive complexity involved in lying through a variety of concepts, such as higher 'cognitive load' (Vrij, 2008), more need for the use of working memory (Baddeley, 2000), and autobiographical memory (Brewer, 1996).

Cognitive load during deception has been found to influence human behaviour. For example, its affect on verbal communication is manifested in hesitations, more frequent pauses, and errors in speech, as well as slower speech (Goldman-Eisler, 1968) and fewer hand and arm movements while speaking (Ekman, 1997). The accepted explanation is that the cognitive load experienced in deceptive communication is a function of differences between the automatic cognitive processing used when telling the truth *vs.* the controlled and more complex information processing employed when communicating lies (Shiffrin & Schneider, 1977). For example, telling the truth relies on ready-made scripts or event schema (Fiske, 1992), whereas deceptive communication does not allow the same benefit and, therefore, taxes the working memory and cognitive capacity to a greater extent (Sporer & Schwandt, 2006). As in verbal communication, the communication of lies in writing also requires a higher cognitive effort and relies less on automatic processing.

When a task is performed automatically, it enables the subject to carry out another task simultaneously, that is, dual-task processing (e.g. Schneider, Domais, & Shiffrin, 1984). According to dual-task studies, human processing resources are shareable (Kahnemann, 1973; Navon & Gopher, 1979), though the difficulty of the tasks at hand limits the ability for dual-task performance (Fisk & Schneider, 1983). Vrij, Fisher, Mann, and Leal (2006, 2008a) demonstrated that lying is an example for dual task processing. Thus, when one cognitive task, such as lying, becomes more complex and demands additional resources, the other task, such as communicating the lie in writing, suffers from a resource loss that influences its performance. Previous research on the detection of deception has focused primarily on face-to-face communication, both verbal and non-verbal (see reviews: DePaulo et al., 2003; Sporer & Schwandt, 2006, 2007). However, this study will also focus on the use of writing as a means of deceptive communication.

Handwriting is a complex activity comprising a blend of cognitive, kinesthetic, perceptual and motor components (Bonny, 1992; Reisman, 1993). It is considered to be an 'over-learned' skill that involves a very rapid sequencing of movements. Several theoretical models have indicated that the phases required in handwriting performance involve retrieving the form, size and direction of the letters, relating them to the sounds (phonemes) of the letters, keeping all the parameters in working memory, and translating them to motor execution on the paper (Weintraub, 1997).

With time, handwriting performance becomes automatic. Some studies show that in comparison to older children, young children need to think more about the size, form and direction of the letters (Berninger, Mizokawa, & Bragg, 1991) and tend to write with decreased speed and larger letters (Wann, 1986). In addition, it was found that they write with a lower flow and higher acceleration (the derivative of velocity), resulting in separate movements rather than a sequential pattern (Meulenbroek & van Galen, 1986; Smits-Engelsman, Van Galen, & Portier, 1994; Wann, 1986). Other studies, however, have shown that higher age is associated with slower performance, lower speed, less pressure, and larger letter size (Dixon, Kurzman, & Friesen, 1993; Rosenblum & Werner, 2006).

Given that handwriting becomes automatic with age, adults (aged 20 and above) are expected to write in an automatic manner unless suffering from some pathology or other physical or mental condition that influences their handwriting performance (Longstaff & Heath, 1999). Automatic handwriting movements increase efficacy and reduce redundancy (Latash, 1998). The more the handwriting act is skilled and automatic, the less variability there will be in temporal (performance time), spatial (length, height and width) and pressure (amount applied on an object or towards a surface) measures, and the more consistency will be evident (Smits-Engelsman & Van Galen, 1997). This means fewer pauses, less variation in letter height and width, more spatial accuracy, and better control of pen pressure levels (Meulenbroek & Van Gemmert, 2003; Schoemaker, Ketelaars, Van Zonneveld, Minderaa, & Mulder, 2005; Wann, 1986).

There is evidence in the literature that a computerized system providing objective measures of the handwriting process (spatial, temporal and pressure measures) may be sensitive to dis-automatization caused by various reasons. The unique characteristics of dis-automatization in handwriting performance, as manifested by the variations in temporal, spatial or pressure measures, were found as the result of several pathologies, including attention deficit disorders (Tucha, Laufkotter, Mecklinger, Klein, & Lange, 2001); Parkinson's disease (Teulings, 2001); schizophrenia (Hulstijn et al., 2001); depression (Mergl et al., 2004); Alzheimer's disease (Werner, Rosenblum, Bar-On, Heinik, & Korczyn, 2006); and multiple sclerosis (Rosenblum, Miller, & Weiss, 2006c). It is important to note that using a computerized system supplies researchers unique, online information such as writing speed, pressure, and amount of time that the pen is not in contact with the writing surface, information which cannot be obtained in a reliable way manually. The aim of the present study is to check whether significant differences will also be found in handwriting measures when writing a deceptive message *vs.* a true message based on the assumption that false writing requires cognitive load, decreases autoimmunization level and manifests in distinctive stroke measures.

The computerized system makes it possible to compare handwriting under different conditions, therefore we compared the handwriting of the same individuals when asked to write truthful and deceptive sentences. Our research hypothesis is that differences will be found between writing of truthful sentences and writing of false sentences in pressure, temporal (stroke duration on paper and in air) and spatial measures (strokes path length, height and width) obtained by the computerized system. Based on the finding of the clinical studies above we predict that in deceptive writing, the mean and standard deviations of handwriting measures of each participant will be varied. Thus while writing deceptive sentences, higher pressure will be implemented, longer duration time per stroke (on paper and in air) will be required, and letter strokes will be larger in comparison to truthful writing.

METHOD

Participants

Participants were 34 healthy students, including 25 females and 9 males, aged 20–35 (mean age 25.51, $SD = 3.41$), who were recruited at the University of Haifa in northern Israel. Seventy per cent of the participants were born in Israel, while 27% were born in the former Soviet Union and 3% in Europe. The majority (85%) of the participants had right-hand dominance, and 15% were left-handed.

The criteria for inclusion were: Residence in Israel for at least 20 years; normal or corrected to normal vision and hearing ability; at least 13 years of education; and a minimum of three sentences in Hebrew written at least three times a week. Anyone suffering from any form of neurological/emotional or physical disease was not eligible to participate in the study.

Instruments

The socio-demographic questionnaire included gender, age and number of years of education.

Digitizing tablet and online data collection and analysis software: The objective spatial, temporal and pressure measures were provided by the Computerized Penmanship Evaluation Tool (ComPET), developed by Rosenblum et al. 2003a (Rosenblum, Parush, & Weiss, 2003a). The ComPET software includes two main parts: (1) data collection, which is language-independent and easy to use; and (2) data analysis, which is programmed *via* MATLAB software toolkits (see Rosenblum, Chevion, & Weiss, 2006a; Rosenblum, Dvorkin, & Weiss, 2006b for more details). The computerized system enables the collection and analysis of spatial, temporal, and pressure handwriting data while the subject is writing on a paper affixed to a digitizer (an electronic tablet) (see picture of the ComPET in Figure 1).

All writing tasks are performed on A4 lined paper affixed to the surface of a WACOM Intuos 2 (model GD 0912-12X18) x-y digitizing tablet, using a wireless electronic pen with a pressure-sensitive tip (Model GP-110). Displacement, pressure and pen-tip angle are sampled at 100 Hz by means of a 1300 MHz Pentium (R) M laptop computer. The digitizer provides accurate temporal measures throughout the writing, both when the pen is touching the tablet (On-paper time) and when it is raised (In-air time). It also provides accurate spatial measures when the pen is touching the tablet and/or when it is lifted above the digitizer up to 6 mm. Beyond 6 mm, the spatial measurement is not reliable.

The ComPET analysis results in several measures:

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Figure 1. The computerized system, including laptop computer, ComPET software, and digitizing tablet.

Pressure measure—the mean pressure implemented towards the writing surface for the entire task measured in non-scaled units from 0–1024 (For further details about the implications of the pressure measure see for example: Werner et al., 2006). Whereas the other measures are related to writing strokes and not to whole letters or the whole task, this measure is not specific for a single stroke but for the entire task. Stroke refers to the curve created by the movement of the pen-tip on the paper, which is represented on the X, Y coordinate system (Mergl, Tigges, Schröter, Möller, & Hegerl, 1999). That is, the computerized analysis does not recognize letters but points while writing, when the pen is in contact with the paper and those in which the pen leaves the paper. It is important to note that there is variability between and within writers. That is, some will write the same letter with one continuous stroke while others will write it with several strokes, and the same individual may write a letter in one stroke once and in several strokes in other words within the same sentence. Therefore, in alignment with the clinical technique of analysing handwriting behaviour, we chose to measure aggregated measures of the entire task. The mean as well as the standard deviation of each measure was examined for each participant in order to follow the intra-individual variability across different measures:

1. *Temporal measures*: Stroke duration in air (while the pen is not in contact with the writing surface) and on paper, both measures reported in seconds.
2. *Spatial measures*:
   - 3.1 Stroke path length in millimeters, which measures the total path length from the starting point to the finishing point for each written stroke.
   - 3.2 Stroke height (on the Y-axis), which measures the direct distance from the lower point of the stroke to the highest point in millimeters.
   - 3.3 Stroke width (on the X-axis), which measures the direct distance from the left side of the stroke to the right side in millimeters.

Number of peak velocities per stroke: A measure for handwriting movement regularity, with the assumption being that the more peaks there are in one stroke, the less regular the movement will be (Mavrogiorgou et al., 2001; Mergl et al., 1999).

Based on previous handwriting analysis (Lacquaniti, Ferrigno, Pedotti, Soechting, & Terzuolo, 1987), the coefficient of variance (the standard deviation divided by the mean) for the stroke duration, path length, height and width was analysed as a measure of the consistency of handwriting performance.

Several studies have indicated the ComPET's validity for differentiating between children with and without dysgraphia (handwriting difficulties) (Rosenblum et al., 2003a; Rosenblum, Parush, & Weiss, 2003b); Developmental Coordination Disorders (DCD) (Rosenblum & Livneh-Zirinski, 2008); and Multiple Sclerosis (Rosenblum et al., 2006). The system has also been shown to differentiate between age groups (Rosenblum & Werner, 2006).

Procedure

Signed informed consent was obtained from the participants following approval by the Ethical Committee of the University of Haifa. Advertisements at the University were used to recruit students to participate in the study. Based on Johnson and his colleagues (Johnson, Foley, Suengas, & Raye, 1988), the participants were asked to write two short paragraphs in sequence describing autobiographical events and memories, one about a true event and the other a false description of the same event. The students were requested to write the true and false paragraphs in Hebrew (about five lines) on a paper that was affixed to the digitizing tablet. The order of the true and false events was varied, with half of the participants writing the description of the true event first and the other half writing the description of the false event first.

Data analysis

Descriptive statistics of the dependent variables were tabulated and examined.

The number of strokes for the truth and false paragraphs were compared by paired sample *t*-test. Following the finding that there were significant differences between the groups for the number of strokes, a measure of the difference between number of strokes at the truth task and number of strokes at the false task was computed (d-stroke).

Two MANOVAs were done for each of the following three types of measures, one to the mean values and the other MANOVA to the standard deviation of the values.

1. Pressure implemented towards the writing surface.
2. Temporal measures (stroke's duration in air and on paper).
3. Spatial measures (stroke's path length, width and height).

Further MANOVA was done for the coefficient of variance of the measures (stroke duration, path length, height and width) and the peak velocities measure.

It is important to note that all the data collection is performed automatically by the ComPET data collection part, in real time while the subject is writing. This data, obtained as a text file, is objective and exact data with physical nature (length, time and pressure measures). The raw data is then aggregated to a final measure with the ComPET data analysis part based on MATLAB with no subjective interpretation by the researcher.

RESULTS

T-test analysis indicated significant differences between the truth writing paragraphs and the false paragraphs for the number of written strokes (truth $M = 420.06$, $SD = 129.71$; False: $M = 350.00$, $SD = 97.33$, $t\ (33) = 3.50$, $p = .001$).

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Table 1. Comparison of the pressure's means and standard deviations for true and false writing

Pressure measures	True $n = 34$ Mean(*SD*)	False $n = 34$ Mean(*SD*)	F (1,33)	p	ES η^2
Mean pressure	879.52 (80.42)	893.52 (72.69)	5.89	.021	.152
Standard deviation pressure	162.97 (17.89)	160.47 (17.95)	2.15	N.S	.061

Hence a measure of the difference was computed (number of strokes in the truth writing–number of strokes in the false writing) for each participant (d-stroke) and was held as constant while conducting the following MANOVA's with repeated measures.

1. The MANOVA analysis's indicated that the mean pressure implemented towards the writing surface in the false writing was significantly higher in comparison to that implemented in the truth writing (False: $M = 893.52$, $SD = 72.69$; truth $M = 879.52$, $SD = 80.42$, $F(1,33) = 5.89$, $p = .021$, ES $\eta^2 = .15$). No significant differences were found for the pressures standard deviation measure (see Table 1).
2. The results of the MANOVA with repeated measures done for the means and standard deviations of the temporal measures indicated no significant differences between truth and false writing ($F(2,31) = .246$, $p = .78$, $\eta^2 = .016$) The means and standard deviations are presented in Table 2.

Table 3 shows the results for the means and standard deviations of the spatial measures.

The MANOVA with repeated measures done for the means of the spatial measures indicated significant differences between truth and false writing ($F(3,30) = 3.39$, $p = .031$, ES $\eta^2 = .253$). *Post hoc* ANOVA indicated that in false writing, the strokes were significantly longer and higher (see Table 3).

Although no significant differences were found for the MANOVA of the standard deviations of the spatial measures ($F(3,30) = 2.13$, $p = .117$, ES $\eta^2 = .176$), *post hoc* ANOVA indicated significant difference between the true and false writing for the standard deviation of stroke height ($F(1,32) = 4.73$, $p = .033$, ES $\eta^2 = .134$).

The MANOVA with repeated measures conducted for the measure's Coefficient of variance (stroke duration, path length, height and width) and peak velocity indicated no significant differences between truth and false writing ($F(5,28) = .64$, $p = .67$, $\eta^2 = .103$).

An example of the handwriting paragraphs of one participant is presented in Figure 2 in order to illustrate the differences between the true (A) and false (B) paragraphs.

The differences are also presented for one specific stroke, the letter L in Hebrew, which was chosen in both paragraphs in the same location (two examples in which the writer wrote the letter in one stroke and not in several strokes). The analysis software points to the number of the stroke and the designated letter in both paragraphs as being the 70th stroke.

Table 2. Comparison of the temporal measures (stroke duration on paper and in air)—means and standard deviations for true and false writing

Temporal measures	True $n = 34$ Mean (*SD*)	False $n = 34$ Mean (*SD*)	F (2,31)	p
Mean stroke duration on paper	0.150 (0.026)	0.153(0.026)	.153 (.026)	N.S
Mean stroke duration in air	0.242 (0.112)	0.244 (0.076)	.246	N.S
Stroke duration on paper Standard deviation	0.092 (0.025)	0.091 (0.016)	.073	N.S
Stroke duration in air Standard deviation	0.582 (0.426)	0.544 (0.318)	.234	N.S

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Table 3. Comparison of the spatial measures (stroke's path length, width and height)- means and standard deviations for true and false writing

Spatial measures	True $n = 34$ Mean (SD)	False $n = 34$ Mean (SD)	F (3,30)	p	ES η^2
Mean stroke length	0.554 (0.141)	0.590 (0.147)	.598	.020	.158
Mean stroke width	0.201 (0.050)	0.212 (0.048)	2.27	N.S	.066
Mean stroke height	0.262 (0.076)	0.278 (0.077)	10.33	.003	.244
stroke length Standard deviation	0.411 (0.079)	0.429 (0.097)	.569	N.S	.017
stroke width- Standard deviation	0.201 (0.050)	0.145 (0.031)	.206	N.S	.006
stroke height Standard deviation	0.163 (0.034)	0.172 (0.038)	4.93	.033	.134

Table 4 presents the length and height measures for that specific stroke made by that one participant.

In order to further illustrate the differences, the measures of two representative participants when writing true and false paragraphs are presented in Table 5.

DISCUSSION

In this preliminary study, we applied the ComPET for purposes of detecting deception. It was assumed that greater mental complexity would be evident in the handwriting of participants when describing false autobiographical events or memories as opposed to true events. Temporal and spatial measures were derived for each writing stroke, as well as a

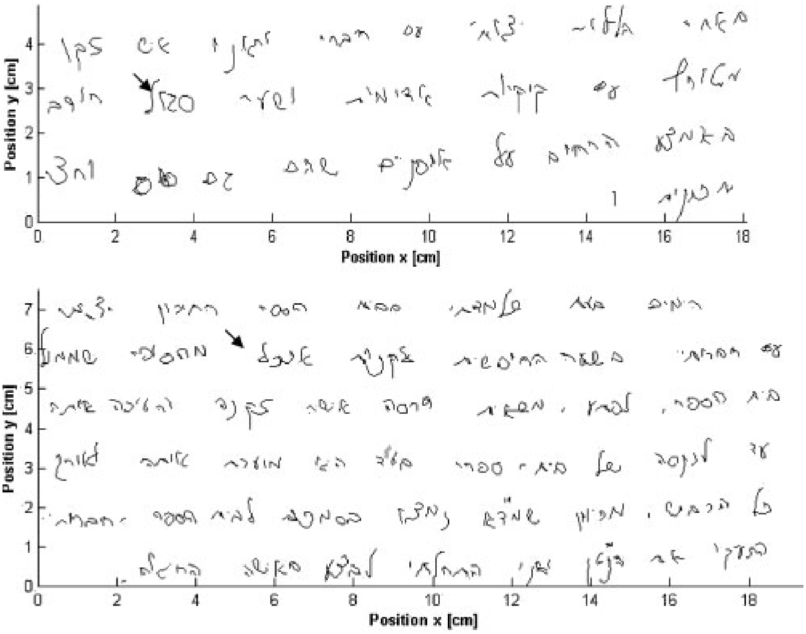

Figure 2. An example of true (first) and false (second) writing paragraphs by the same writer. The sizes of the 70th letter in each paragraph (sign by arrow) appear in Table 3.

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Table 4. A visual presentation of the 70th stroke of one participant, as appears in true and false writing, and the stroke's length and height

Variables	True	False
The letter appearance		
Mean stroke length (mm)	9.90	10.56
Mean stroke height (mm)	4.75	7.40

pressure measure and number of peak velocities for the entire task, in order to enable a comparison of the performance between writing true and false statements. Results show that in the false writing condition, the mean pressure, stroke length and height were significantly higher than in the true writing condition. Furthermore, the standard deviations of stroke heights were significantly higher in the false condition than in the true condition.

Our results are partly aligned with studies conducted by Van Gemmert and Van Galen (1994, 1996, 1997, 1998) on the effects of physical and mental stress on fast and accurate spatial control while performing handwriting tasks. They assumed that dis-automatization as a result of mental stress will manifest in increased variability in handwriting velocity, longer movement durations and reduced writing size (Van Gemmert, Teulings, & Stelmach, 1998). They found that auditory stress did indeed cause longer reaction times and higher axial pen pressure among adults (Van Gemmert & Van Galen, 1998). Similarly, Bailey, (1988) found that higher pressure indicates mental stress.

Our results support the automatic and controlled information processing model (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). It seems that in a task with higher mental load, such as writing a lie, the automatic process involved in normal handwriting is replaced with a more controlled process, which is sensitive to task difficulty and thereby limits dual-task performance (Fisk & Schneider, 1983; Kahnemann, 1973; Navon & Gopher, 1979; Wickens, 1991; Vrij et al., 2006, 2008a,b).

Furthermore, it seems that by virtue of concentrating more on the deceptive cognitive task, subjects are more limited in their movements in order to save cognitive resources. Their limitations in writing movements manifested in higher stroke length and height (and standard deviation), which together indicate less regularity (Mavrogiorgou et al., 2001).

In relation to the temporal measure and unlike previous studies, we measured stroke duration and not reaction time in the present study (e.g. Van Gemmert & Van Galen, 1998).

Table 5. Examples of two writers' (1 and 2) mean stroke length/ height/width, standard deviation values as appears in their true and false writing

Participants	1		2	
Variables	True	False	True	False
Mean stroke length (mm)	0.51	0.59	0.60	0.65
Mean stroke height (mm)	0.23	0.28	0.26	0.27
Mean stroke width (mm)	0.18	0.21	0.23	0.25
Standard deviation of stroke length (mm)	0.36	0.38	0.44	0.56
Standard deviation of stroke height (mm)	0.15	0.17	0.18	0.23
Standard deviation of stroke width (mm)	0.12	0.13	0.15	0.18

Based on the lack of significant differences for both 'on paper' and 'in air time' in the deception writing, it seems that these measures are not sensitive enough to deception writing, despite the fact that they have previously been found sensitive to cognitive deficits in pathologies such as Alzheimer disease (Werner et al., 2006). Another option may be that it depends on the kind of task given to the subject, a point which could be elaborated in future studies. Along the same lines, the fact that no significant differences were found for the coefficient of variance of the measures as well as for peak velocity may indicate that in the case of lie detection, the focus needs to be on the differences in the spatial characters of the strokes, that seems to be alerted as a result of the cognitive load.

These results suggest that a documentation of handwriting process measures with a computerized system such as ComPET while focusing on amount of automatization/regularity may be used as another tool for lie detection. Such a tool may have advantages over other lie detecting methods in that it is not intrusive and is user friendly. It can improve the accuracy of other lie detectors by offering additional measures to existing ones in order to reduce errors of interpretation. Furthermore, though other methods are useful in detecting lies during verbal communication, the ComPET is the only measure that we know of which can be used to detect lies in written communication.

The ComPET is an easy to use system that generates objective data automatically, which cannot be obtained manually by observing handwriting behaviour or by analysing written text. The system is so user-friendly that training the research assistant on how to collect data using the device took less than one hour. Measures such as the standard deviation of stroke height of each participant or pressure applied are unique measures received easily and in an objective way. Furthermore, the writer is not aware of the kind of data being measured and, even if aware, measure such as writing pressure, stroke height, width or standard deviation of stroke height cannot be actively controlled in a consistent way. The analysis done to strokes and not to letters enables implementation of this technique to writing in various languages. Overall, we find this technique useful for researchers and practitioners studying deception.

The significant results of the present study call for future use of the ComPET in applied studies of lie detection. However, this is a preliminary study and as such has its limitations, including a small sample consisting only of students. Future studies using a larger sample size with randomly sampled participants may improve the generalizability of the results. Likewise, whereas one short task was used for this preliminary test, future studies should employ a variety of tasks that may be more effective in detecting deception. For example, these tasks should use more complex deception scenarios and measure the ground truth base line more systematically. In the current study we cannot be sure that the subjects reported correctly when they wrote the truth and when they wrote deception sentences, although they did not have a reason to lie about this. Furthermore, we did not control for the content of the text the participants wrote in their truth sentences and lie sentences. Therefore it is possible that these lies and truths differed in content, and the impact of any content differences on the current results is not known.

We believe that an important future goal should point to an applied tool for practitioners and researchers based on these findings. Future research should make it possible to determine norms and standardized measures that can help in the detection of deception. For example, a simple calculation (algorithm) of the ComPET measures that are influenced from deception will be useful to users. Such algorithm can enable the users to compare the results of their analysis with norms of writing truth sentence or norm of writing deceptive sentence and to decide whether the subject wrote a deceptive or truth sentence. After such a decision rule for deception is established one can calculate the ComPET reliability and validity in detection.

We propose a few possible directions for sequel studies in the field of lie detection using the ComPET, such as in the area of manipulation. For example, in one study, participants were asked to write the truth or to lie about slides that had a strong emotional component (Lubow & Fein, 1996). Results of the ComPET can also be crossed with those of other valid lie detectors, such as the polygraph, in order to increase its validity while also providing empirical data that will enrich our understanding of the physiological and psychological processes involved in deceptive behaviour. We also propose that the ComPET has potential use for other types of studies in applied and cognitive psychology, such as examining the level of automaticity achieved while performing a complex task and testing whether subjects have reached the 'expert' level.

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