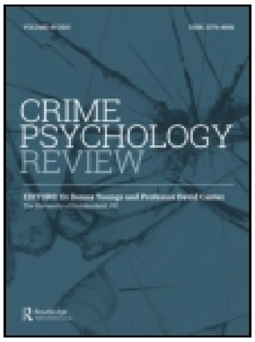

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A review of the polygraph: history, methodology and current status

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The history of research into psychophysiological measurements as an aid to detecting lying, widely known as the 'lie detector' or polygraph, is the focus of this review. The physiological measurements used are detailed and the debates that exist in regards to its role in the investigative process are introduced. Attention is given to the main polygraph testing methods, namely the Comparative Question Test and the Concealed Information Test. Discussion of these two central methods, their uses and problems forms the basis of the review. Recommendations for future research are made specifically in regards to improving current polygraph technology and exploring the role of the polygraph in combination with other deception detection techniques.

Keywords: polygraph; lie detection; deception

Introduction

In 1983, US President Ronald Reagan issued the National Security Decision Directive 84, which authorized all federal agencies to use polygraphs (commonly known as lie detectors) to test if any of their employees had leaked classified information (Brooks, 1985; US Congress, 1983). Following widespread protest and a review of the polygraph by the Office of Technology Assessment (1983), President Reagan rescinded the directive less than 3 months later. As of 4 February 2015, the US Intelligence Community is once again authorized to investigate its members' potential involvement in the leaking of classified information via the use of the polygraph (Intelligence Community Policy Guidance 704.6, 2015). This change in policy is likely to result in a significant increase in the number of polygraph examinations administered by the US intelligence community, making this an opportune and arguably critical time to re-evaluate and scrutinize the scientific merits of the polygraph.

The US polygraph examinations are to be conducted in adherence to the standards set by the National Center for Credibility Assessment, which means that any such examination will be based on a Comparative Question Test (CQT), as opposed to a Concealed Information Test (CIT). The CQT and CIT represent the two predominant types of polygraph testing procedures, which use the same physical apparatus, but differ in terms of their theoretical underpinning and commercial/academic utilization.

Iacono and Lykken (1997) conducted a survey of academic opinion regarding the polygraph amongst the Society for Psychological Research (SPR) and the American Psychological Association's (APA) General Psychology Division 1. In regards to the

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CQT, 36% of SPR and 30% of APA Division 1 members considered the CQT to be based on scientifically sound psychological principles. The trend of these results did, however, not extend to the CIT, for which the survey results were 77% and 72%, respectively.

Although Iacono and Lykken make clear in their paper, that matters of science cannot be settled by vote, these numbers represent a useful point of reference in regards to the polygraph's academic standing. In 2003, the US National Research Council (NRC) conducted a comprehensive review of polygraph research and found it to be severely lacking in validity and scientific rigour. In spite of these criticisms, polygraph research has continued unabated.

When individuals actively attempt to detect deception, their accuracy levels are barely above chance, ranging from 45% to 60% (Vrij, 2000) and averaging 54% (Bond & DePaulo, 2006). Mann, Vrij, and Bull (2004) report that regardless of investigative experience the deception detection accuracy of criminal investigators does not significantly differ from that of laypersons. Considering how vital but difficult the detection of deception is for law enforcement, there has been ample efforts to develop tools to aid investigators in this task.

The polygraph was initially heralded by its proponents as a triumph of science and something that was capable of transforming criminal investigations; however, it has severely struggled to live up to these expectations. In 2003, the most extensive review of the scientific evidence on the polygraph to date was published by the US National Research Council NRC, at the request of the Department of Energy, which was mainly concerned with the use of the polygraph for personnel security screening. The review, entitled 'The Polygraph and Lie Detection', criticized the poor quality and heavily biased nature of most polygraph research. It summarized that polygraph research has failed to build and refine its theoretical base, has proceeded in relative isolation from related fields of basic science and has not made use of many conceptual, theoretical and technological advances in basic science that are relevant to the physiological detection of deception (National Research Council, 2003). In regards to the actual accuracy of the polygraph, it drew the following often-cited conclusion:

> Notwithstanding the limitations of the quality of the empirical research and the limited ability to generalize to real world settings, we conclude that in populations of examinees such as those represented in the polygraph research literature, untrained in countermeasures, specific-incident polygraph tests can discriminate lying from truth telling at rates well above chance, though well below perfection. Because the studies of acceptable quality all focus on specific incidents, generalization from them to uses for screening is not justified. (National Research Council, 2003, p. 4)

A history of the polygraph

The first polygraph was created in 1921, when a California-based policeman and physiologist John A. Larson devised an apparatus to simultaneously measure continuous changes in blood pressure, heart rate and respiration rate in order to aid in the detection of deception (Larson, Haney, & Keeler, 1932; McCormick, 1927). The invention of the polygraph cannot be, however, attributed to a single individual. Seven years prior, in 1914, Italian psychologist Vittorio Benussi had published his findings on the respiratory symptoms of the lie (from German: 'Die Atmungssymptome der Lüge'), and it was American psychologist, lawyer and author William M. Marston who invented the discontinuous systolic blood pressure test for the detection of deception in 1915 (Alder, 2002), which, when taken together, formed the basis for Larson's polygraph.

The polygraph first came into significant contact with the legal system in 1923, when Marston attempted to have the results of a polygraph test admitted as evidence (United States v. Frye, 1923). The court rejected the results as evidence, stating that 'while the courts will go a long way in admitting experimental testimony deduced from a well-recognised scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs' (United States v. Frye, 1923. p. 1). This became known as the Frye Standard, which would govern the admissibility of expert testimony in US courts until well after the end of the Cold War.[1]

The vast majority of early polygraph research was conducted by John Larson, who worked for the Berkley, California, police department throughout the 1920s. Berkley Police Chief August Vollmer saw Larson's work as a means to significantly improve the effectiveness of his department, and thus allowed Larson to test and refine his polygraph through work on real cases (Carte & Carte, 1975). Vollmer's focus on the polygraph's practical value over any other concerns was something that would come to be a common stance within law enforcement in the US.

Larson's early work benefited from the aid of his then-protégée Leonarde Keeler, who is often credited with the creation of the first polygraph testing procedures, such as the Relevant/Irrelevant Question Technique (Keeler, 1930). Keeler was responsible for making the polygraph apparatus portable and was the first to add the galvanic skin response (GSR) channel to it in 1938, based on the work of Fordham University Graduate School psychologist Reverend Walter G. Summers (Summers, 1936). Keeler, however, did not share Larson's dedication to academia, but rather desired financial and commercial success. To this end, Keeler patented his polygraph, became one of the first to found a 'polygraph school' and went so far as to appear as himself in the 1948 noir film *Call Northside 777* (Alder, 2007; Matte, 1996). Prior to his death in 1949, Keeler contributed greatly towards the popularity of the polygraph, much like Marston did, but also became one of the first of many to focus purely on the polygraph's lucrative potential at the expense of any academic contribution. Following Keeler's death, the polygraph's history continued unabated with John E. Reid, who is known for the controversial 'Reid Technique' of interviewing/interrogation (Gudjonsson, 2003; Johnson, 2003; Kassin & Gudjonsson, 2004). Reid did not only establish his own polygraph school, but developed the CQT, the polygraph testing procedure that replaced Keeler's Relevant/Irrelevant Question technique as the most widely used technique, which it remains to date (Raskin & Honts, 1987; Reid, 1947, Wilcox & Madsen, 2009).

The development of new testing procedures and the increasingly widespread use of the polygraph[2] were not matched by academic progression in the field of deception detection. Only a small number of those involved in polygraph testing (e.g. Larson et al., 1932) sought peer-reviewed publication of their work or attempted to intentionally test the effectiveness of polygraph examinations or their underlying theories (e.g. Landis, 1925). This acted as the basis for mounting criticism of the polygraph research later on, on the grounds of a lack of scientific rigour within the early polygraph studies.

It was not until 1965, 41 years after the Frye standard was established, that the first empirical review of the polygraph was conducted. This occurred when a proposal to use the polygraph to screen federal employees prompted the US Committee on Government Operations to evaluate the relevant evidence. It concluded: 'There is no lie detector, neither man nor machine. People have been deceived by a myth that a metal box in the hands of an investigator can detect truth or falsehood' (US Congress, 1965, p. 1).

The proponents of the polygraph remained mostly unphased by this. David T. Lykken, an influential critic of CQT polygraph tests, argued that the apparent disconnection between the science and practice of the polygraph existed in large part because few professional polygraphers have psychological training and there are very few psychologists who know enough about the industry to supervise its practices (Lykken, 1974, 1975). In response to the growing criticisms regarding the lack of scientific support for the polygraph, John E. Reid and his colleague Frank E. Inbau stated that the individual conducting the polygraph examination was the real lie detector (Reid & Inbau, 1977), thus dismissing all concerns regarding the polygraph's scientific validity.

A shift in research standards

After the 1983 issuing of the National Security Decision Directive 84 by US President Ronald Reagan, a noticeable change in polygraph literature followed, starting with the 1984 *American Psychologist* article 'Lie detection in ancient and modern times: A call for contemporary scientific study' (Kleinmuntz & Szucko, 1984). This marked a focused effort to develop better research practices and methodologies (Kircher, Horowitz, & Raskin, 1988; Raskin, 1987), with increased attention to the issue of countermeasures (Honts & Kircher, 1994; Iacono, Cerri, Patrick, & Fleming, 1992), and a consistent increased interest in an alternative polygraph testing method grounded in Orienting Response Theory (Sokolov, 1963), the Guilty Knowledge Test (GKT), now commonly known as the CIT.

This shift can, at least in part, be attributed to the fact that the Frye Standard for the admissibility of expert testimony was largely superseded in 1993, by the new 'Daubert Standard' (Daubert v. Merrell Dow Pharmaceuticals, 1993), which removed the need for scientific evidence in courts to have garnered 'general acceptance' by the relevant scientific community in order to be considered admissible (Giannelli, 1997). As a result, there are examples during this time of the discourse surrounding the polygraph being particularly animated (see Furedy, 1996; in response to Honts, Kircher, & Raskin, 1995; in response to Furedy, 1993), and there continues to be a high degree of polarization amongst polygraph researchers and practitioners (Raskin & Kircher, 2014).

Polygraph technology

Modern polygraphs no longer use pens attached to tambours to write in ink onto a roll of paper driven by clockwork (Mackenzie, 1908) in the way the original Keeler polygraph models used to work. Modern polygraphs produce digital outputs that go directly from the measuring instruments into a computer with the appropriate polygraph software (Hirota, Matsuda, Kobayashi, & Takasawa, 2005) (see Figure 1).

The physiological channels that the polygraph measures have remained largely unchanged from Keeler's original models (Buckley, 1980). They are cardiovascular activity (red line, Figure 1), respiratory activity (blue line, Figure 1) and electrodermal activity (green line, Figure 1) which is also known as GSR. Increases in heart rate and blood pressure are brought on by the sympathetic nervous system releasing the postganglionic neurotransmitter norepinephrine, while a decrease in heart rate and blood pressure is brought on by the parasympathetic nervous system releasing postganglionic acetylcholine. Pressure-sensitive receptors, baroreceptors, play a central role in activating the appropriate system when blood pressure suddenly drops or rises, thus maintaining the basal blood pressure required for sustained life (Berntson, Cacioppo, & Quigley, 1991). Cardiovascular activity is, however, modulated by a range of other factors beyond this basic mechanism.

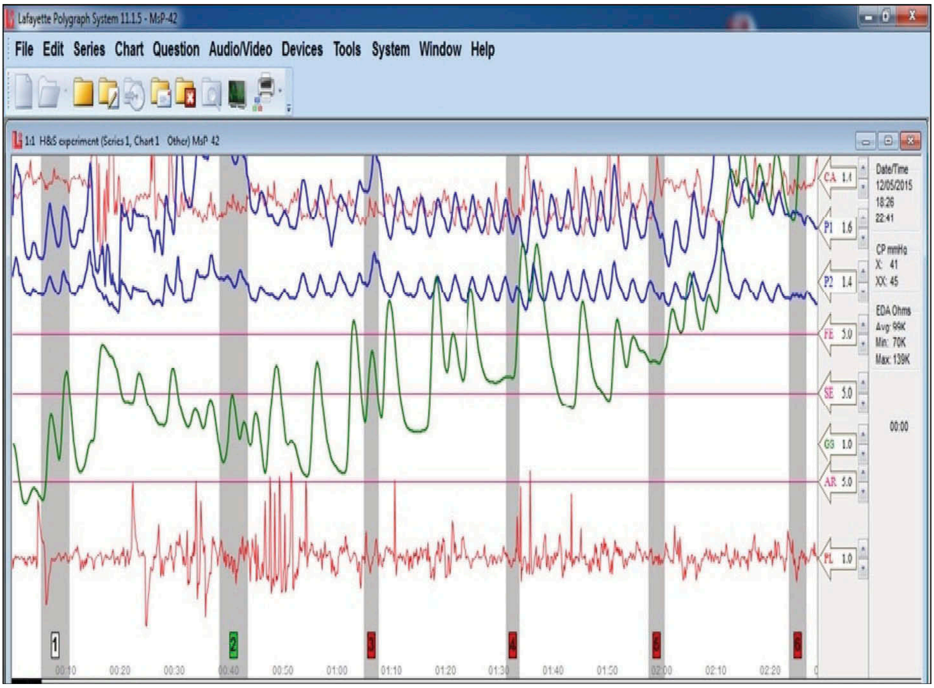

Figure 1. Digital polygraph output.
Note: All pictures are of the Lafayette LX5000 and relating software. Credit to Anita Fumagalli for all pictures.

Perceived threats, increased physical or mental activity, the anticipation of a threat or activity, and effectively any form of specific or general arousal can affect heart rate, blood pressure and other cardiovascular processes in a range of ways. They can differ subtly or radically amongst individuals (especially for those with active mental illnesses or anxiety disorders) and even for the same individual under different circumstances (Berntson et al., 1994; Blasingame, 1998; Kasprowicz, Manuck, Malkoff, & Krantz, 1990; Sherwood, Dolan, & Light, 1990). This has obvious implications for polygraph practitioners, who employ techniques that assume certain patterns of cardiovascular activity to be characteristic of certain psychological states (e.g. deceptiveness) across individuals and situations.

Respiratory activity is even more problematic in this regard as it is affected by both the autonomic and the central nervous system. In the autonomic nervous system, breath intakes are initiated in the medulla and pons by the spontaneous firing of neurons, and then modified based on carbon dioxide and oxygen concentrations in the blood, as respectively detected by central and peripheral chemoreceptors, while stretch receptors monitoring lung inflation modulate respiration further. The central nervous system allows an individual to easily bring respiratory activity under voluntary control, which represents a problem for polygraph examiners due to the fact that both heart rate and GSR can be affected by changes in breathing, e.g. a sharp intake of breath reliably produces an electrodermal response (EDRs) due to respiratory sinus arrhythmia (Homma & Umezawa, 2001).

Electrodermal activity has long been regarded the most sensitive and reliable of the three channels of the polygraph (Kircher & Raskin, 2002; Orne, Thackray, & Paskewitz, 1972). The electrical resistance and conductance of the skin is largely determined by the activity of the sweat-producing eccirine glands, which are controlled by the sympathetic nervous system. However, due to eccirine glands having acetylcholine as their postganglionic neurotransmitter, they are not affected by epinephrine (commonly known as adrenaline) or norepinephrine level fluctuations in the blood, like cardiovascular and respiratory activity are (Stern, Ray, & Quigley, 2001). While this does make the GSR channel less prone to being affected by extraneous factors, it in no way eliminates the inherent problems associated with any attempt to infer psychological states based on peripheral nervous system activity. Furthermore, the frequency with which EDRs occur spontaneously, in the absence of an apparent stimulus, has been found to differ amongst individuals (Waid & Orne, 1982; Waid, Wilson, & Orne, 1981).

A large variety of traditional analogue and modern digitized polygraph models are available to purchase from different companies. Most polygraphs can be used with a combination of different tools that measure the three main channels, with certain models also allowing for the use of additional devices that measure movement, voice pitch and other physiological data that the examiner might find relevant (Geddes, 2002). For the polygraph measurement of cardiovascular activity, the standard tool is the sphygmomanometer arm cuff, similar to those used in medical practice (Turner & van Schalkwyk, 2008), which also comes in wrist cuff and finger cuff varieties. An alternative to using cuffs, which function by measuring changes in pressure, are photoelectric plethysmographs, which are clipped to a finger or ear. They work by sending infrared light (7000 to 9000 Å) into the tissue, where it is scattered by red blood cells, and photo-sensors measure the light that is reflected or passed through the tissue segment where the monitor is placed. The amount of light that reaches the photo-sensors is directly related to the amount of blood through which it passed before reaching the sensor; and thus changes in blood volume can be measured without relying on pressure cuffs (Challoner & Ramsay, 1974). Whether either form of measurement is superior for the purposes of detecting heart rate variability or the difference of the maximum and minimum amplitudes has yet to be established.

Respiration is measured using pneumatic rubber bellows, which are fastened around the thorax and abdomen with a connecting chain so that the changes in thoracic and abdominal circumference concurrent with inhalation and exhalation expand the bellows, causing their internal pressure to change, which can be monitored with a pressure transducer (Isshiki & Snidecor, 1965). This method of measuring respiratory activity is generally considered to have a relatively low frequency response, but this is not thought to be inherently detrimental to polygraph examinations (Baken & Orlikoff, 2000). One available alternative are piezoelectric respiration transducers, which replace the pneumonic rubber bellows with belts that include stretch-sensors, which function based on the property of certain materials, such as crystals, to build up electrical charges (piezoelectricity) when exposed to mechanical stress (Bhaskar, Subramani, & Ojha, 2013). In either case, the acquired measurements of thoracic and abdominal breathing are usually combined (either on paper or by a digitized polygraph) to create a single composite measure of respiration line length for the examiner (Kircher & Raskin, 2002).

Lastly, electrodermal activity is measured either in terms of skin conductance, skin resistance or a combination of both depending on the company that produced the polygraph. Skin conductance is generally considered to be the more efficient and reliable, as measuring changes in resistance magnitude from basal activity level has inherent problems associated with it (Dawson, Schell, & Filion, 2000). To measure conductance, two electrodes are attached to the examinee's palm or fingers and a small current is applied in

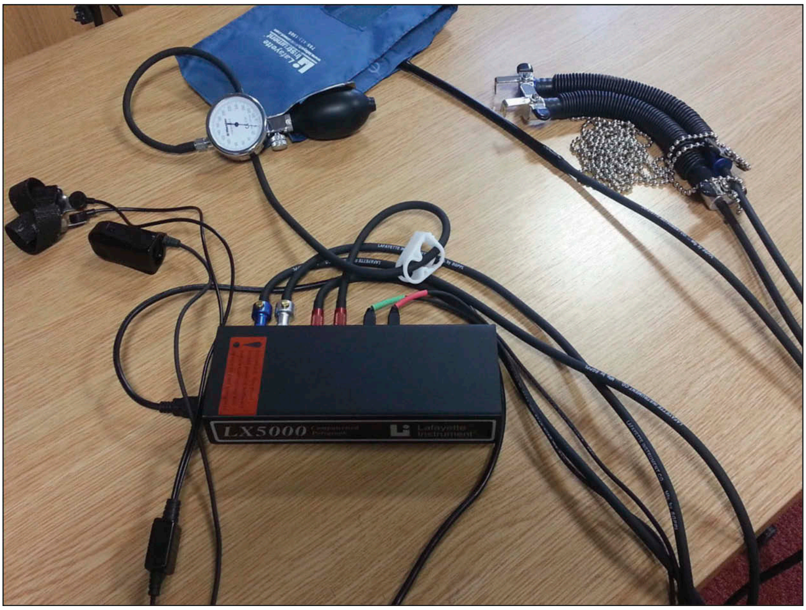

Figure 2. Polygraph equipment.

order to measure factors such as conductance level, changes in conductance level, frequency of spontaneous responses, event-related response amplitude, latency, rise time and half recovery time (Dollins, Krapohl, & Dutton, 2000), See Figure 2 for an example of the polygraph measuring equipment most commonly used.

In addition to the three channels mentioned above, a range of other compatible tools can also be utilized. The most widely used to these are ‘activity sensors’, which can include headsets, seat pads, arm-rest pads, foot-rest pads and special chairs designed to be used in conjunction with said activity sensors (see Figure 3 for an example of the standard polygraph equipment attached to an examinee).

These chairs are designed to detect examinee movement; be it large, small or confined to specific muscles, such as the jaw’s masseter muscle. The main reason why examiners may wish to monitor movement is that movement can affect the monitoring of the three main channels by affecting equipment or the examinee’s physiology. This is particularly relevant when it comes to the matter of countermeasures.

Polygraph methodologies

This review will focus on the two dominant polygraph methodologies, the CQT and the CIT. Both methodologies use the same polygraph apparatus, and share one fundamental premise, namely that certain psychological processes result in physiological cues that can be measured and interpreted with the polygraph for the purpose of aiding in the detection of deception.

The CQT aims to detect deception by measuring the physiological arousal patterns that result from the emotional states that the production of deception is argued to evoke, i.e. fear/stress. This line of reasoning is generally supported by the emotional deception detection approach developed by American psychologist Paul Ekman. Ekman (2009)

Figure 3. Polygraph equipment attached to an examinee.

argues that deceptive individuals will likely experience different emotions than someone who was telling the truth would, and that the strength of this emotion is correlated to the likelihood of deceptive cues being leaked. The fear and stress associated with getting caught are the most commonly cited examples of such an emotion and are argued to result in deception cues such as gaze aversion, increased movement (e.g. fidgeting), speech errors and – in line with the CQT – increased heart rate and perspiration. These matters are, however, more complex, as Ekman's approach does not consider deception to be invariably fear inducing or stressful, maintaining that deceptive individuals may well experience a range of other emotional states, such as 'Duping Delight', which describes the pleasure associated with meeting the challenge of a successful deception (Ekman, 1981). This exemplifies the main theoretical caveat of the CQT, in that it is heavily reliant upon evoking the appropriate fear/stress within a deceptive examinee. As will be discussed later, CQT examiners sometimes employ additional strategies to attempt to ensure that deceptive examinees experience the appropriate emotional states; however, this does not resolve the issue in its entirety.

In contrast, the CIT does not rely upon the measurement of physiological signs of emotion, but rather on the physiological signs of what is referred to as an Orienting

Response, or a 'What is it?' reflex, which describes an individual's spontaneous reaction to novel or significant changes in its environment (Lang, Bradley, & Cuthbert, 1990; Sokolov, 1963). The detection of deception through the Orienting Response with the CIT is not affected by the same problems associated with CQT, which we will see.

In addition to the basic theoretical concerns related to the inference of deception via the measurement of physiological cues, it must be noted that the flaws in common polygraph research methodologies have been a frequent and long-running source of debate (NRC, 2003, p. 128). In order to accurately capture the relevant issues and adequately discuss them in the context of current research, a separate review paper is required.

The CQT

Since its inception by John E. Reid in the late 1940s, the CQT remains the most widely used polygraph test (Raskin & Honts, 1987; Wilcox & Madsen, 2009). The CQT is administered in three stages. The first and arguably most integral part of a CQT examination is the pre-test interview, which is usually conducted before the examinee is 'wired up' to the polygraph and any physiological measurements are taken. The examiner always explains the procedure of the test, but depending on the situation, examiner's personal preferences and the 'polygraph school' the examiner subscribes to, the rest of the pre-test interview can vary greatly (American Polygraph Association, 1997). If the questions for the test portion of the examination have already been formulated on the basis of available information, then the examiner may explain these questions to ensure that the examinee understands them as intended. Alternatively, the interview might be used to adjust or formulate the questions in their entirety (Saxe, 1991).

Most CQT schools emphasize that the interview shapes the expectations and emotional state of the examinee and should be used to convince the examinee that the polygraph will detect any deception in order to ensure the proper emotional response in a deceptive examinee. If the examinee is already 'wired up', the examiner may perform a demonstration of the polygraph's accuracy, commonly referred to as a stimulation or acquaintance test, which may on occasion involve deceiving the examinee in the process by using marked cards or other 'tricks' for this demonstration (Simon, 1993).

It is evident that the pre-test interview is far from standardized and can significantly impact how the examinee responds to the test portion of the examination on behavioural, emotional and physiological levels (Furedy & Liss, 1986). The examiner can also be influenced by the interview, forming impressions regarding the examinee's character, truthfulness and likely guilt. Proponents of the CQT consider this an asset while opponents consider this to be a source of unscientific bias (Ben-Shakhar & Furedy, 1990). A pre-test interview can last anywhere between 30 min and 2 h and is often the longest portion of a CQT examination (Kraphhol & Sturm, 2002).

The second stage of a CQT examination is the actual CQT polygraph test, where the examiner asks questions and records physiological responses. Most versions of the CQT use three types of questions: relevant questions, irrelevant questions and comparison questions. The relevant questions pertain to the crime under investigation, so in a murder investigation, the most obvious relevant question could be 'Did you kill the victim?'. Irrelevant questions are in no way related to the crime or crime in general, and often concern simple biographical information, meaning 'Is your name Gary?' could serve as an irrelevant question. Comparison questions are not directly related to the crime, but instead deal with issues concerning the examinee's moral character. Sometimes referred to as probable-lie questions, they are meant to be formulated and asked in a way that is intended to subtly prompt the examinee to answer them with ‘no’ (Raskin, Kircher, Horowitz, & Honts, 1989). Alternatively, the examiner may instruct the examinee to answer ‘no’ to all comparison questions, which is a variant CQT commonly known as the directed-lie test (Honts & Alloway, 2007). In either scenario, comparison questions are generally worded in a manner that is broad in meaning and temporal in scope, as to ensure that ‘no’ is an untruthful response (Elaad, 2003). In a murder investigation, a possible comparison question could be, ‘Have you ever in your life broken even a single law?’.

The number of total questions asked, the order in which relevant, irrelevant and comparison questions are placed and whether any or all questions are repeated a certain number of times are again dependent on the situation, examiner’s preference and the school the examiner subscribes to (Ben-Shakhar, 1991). In general, CQT examiners will refrain from giving the examinee any feedback on whether their physiological response appears to indicate deceptiveness at this stage, but there have been reports where this has been done in order to pressure suspects into confessing to the crime (see Iacono, 1991).

The post-test phase is where the physiological data gathered by the polygraph is evaluated. At its simplest, this evaluation operates under the assumption that irrelevant questions will show baseline physiological responses, guilty examinees will show consistently stronger physiological reactions in response to the relevant question and innocent examinees will show consistently stronger physiological reactions in response to the comparison questions. Several arousal theories are commonly cited as the basis for this assumption, including Threat of Punishment Theory (Davis, 1961), Related Arousal Theory (Prokasy & Raskin, 1973), Dichotomization Theory (Ben–Shakhar, 1977) and Psychological Set Theory (Barland, 1981).

In most cases, it is up to the examiner(s) to set the cut-off points at which a given response is indicative of deception, honesty or inconclusive; whether to weigh all channels and responses equally or assign more weight to some; and lastly whether the overall results indicate guilt/deception, innocence/honesty or are simply inconclusive. Numerical scoring methods are commonly employed in this step and usually involve the assignment of negative scores for indicated deception and positive scores for indicated honesty to each item (e.g. −5 to +5) and adding them together into an aggregate score (Krapohl & McManus, 1999).

There are several computerized scoring systems that aim to nullify the problem of scoring bias, but they have been found to have ‘modest accuracy’ at best (Dollins et al., 2000). Some attempt to recreate the manual scoring process, an example being the Computerized Polygraph System. Its current algorithm is based on real criminal case data provided by US Secret Service (Kircher & Raskin, 2002) and only uses skin conductance amplitude, the amplitude of increase in the baseline of the cardiograph, and combined upper and lower respiration line length as data.

Nelson, Krapohl, and Handler (2008) developed a simple empirically based manual scoring system (ESS) which provided evidence, since replicated (Blalock, Cushman, & Nelson, 2009), that inexperienced examiners could produce blind-scoring polygraph examination data with decision accuracy, inconclusive and inter-rater reliability rates equivalent to those of experienced examiners.

Other systems disregard the approach used by real examiners, instead searching for physiological patterns that an empirical analysis of a large data set has found to be of predictive value, while transforming the data and eliminating outliers as necessary (Olsen, Harris, Capps, & Ansley, 1997). The most prominent example of such a system is PolyScore, which was developed by the Johns Hopkins University Applied Physics

Laboratory based on criminal case data provided by the Department of Defence's Polygraph Institute. The advantage of such a system is that it is not dependent on the validity of any psychophysiological a priori assumptions, although this a-theoretical creation process does conversely makes it susceptible to the problem of overfitting the data (Hastie, Tibshirani and Friedman, 2001). PolyScore and other systems like it are entirely dependent on the quality of the data from which they are developed, which, considering the persistent criticisms regarding the quality of polygraph research, is a noteworthy problem. Research is, however, ongoing and it is likely that a computerized scoring system that outperforms humans will be developed in the near future (Matsuda, Hirota, Ogawa, Takasawa, & Shigemasu, 2009).

Problems with CQT theory

It is important to note that, while all three stages of the CQT examination can be criticized on the grounds of lacking objectivity and standardization, it is the CQT's theoretical underpinning and its derived assumptions that have drawn the most criticisms; especially the notion that an innocent examinee will respond more strongly to a comparison question than to a relevant question (Fiedler, Schmid, & Stahl, 2002; Iacono, 2008; Lykken, 1998). The basic idea behind this notion is that an innocent examinee would (a) believe that the polygraph will detect their honesty in response to the relevant questions, and (b) would subsequently be more worried about their lies in response to the comparison questions being detected, resulting in different physiological patterns of arousal between truth-tellers and liars (Horvath & Palmatier, 2008).

The British Psychology Society (2004) succinctly summarized the most common criticism of this notion in their review:

> This premise is somewhat naive as truth tellers may also be more aroused when answering the relevant questions, particularly: (i) when these relevant questions are emotion evoking questions (e.g. when an innocent man, suspected of murdering his beloved wife, is asked questions about his wife in a polygraph test, the memory of his late wife might re-awaken his strong feelings about her); and (ii) when the innocent examinee experiences fear, which may occur, for example, when the person is afraid that his or her honest answers will not be believed by the polygraph examiner. (BPS, 2004, p. 10)

Proponents of the CQT have naturally attempted to address these criticisms, either maintaining that a skilled polygrapher is capable of formulating comparison questions and creating an atmosphere in which an innocent examinee will be more worried about the comparison questions than about the relevant questions (Raskin & Honts, 1987), or by providing alternative theoretical explanations for the CQT. An evident example of the latter was an argument by Kleiner (2002) that Orienting Response Theory – the basis for the CIT – could be used to explain the CQT-based polygraph examinations as well. The National Research Council reviewed this claim and outright rejected it, stating '[...] we do not take very seriously the argument that the TES (Test of Espionage or Sabotage) or other polygraph examination procedures based on the comparison question technique can be justified in terms of Orienting Theory' (National Research Council, 2003, p. 77). Field studies supporting the effectiveness of the CQT (e.g. Mangan, Armitage, & Adams, 2008) are often criticized on the basis that their criterion for establishing ground truth is confession, which inflates accuracy estimates by creating a sampling bias (Iacono, 2008; Patrick & Iacono, 1991).

Accuracy estimates of the CQT range from 74% to 89% for guilty examinees, with 1% to 13% false-negatives, and 59% to 83% for innocent examinees, with a false-positive ratio varying from 10% to 23% (Grubin, 2010). The National Research Council's review (2003), which included 37 laboratory studies and 7 field studies that passed their minimum standards for review, evaluated the accuracy of the CQT using receiver operating characteristic curve statistics and estimated the median accuracy of the CQT at .85, which is in line with the other estimates, indicating that the NRC's afore-quoted '*Well above chance, though well below perfection*' verdict still remains valid.

From an investigative perspective, the value of the CQT extends beyond the accuracy estimates mentioned and does not necessarily concern itself with criticisms of subjectivity or flawed theory. This is demonstrated by research concerning the 'bogus pipeline' technique (Jones & Sigall, 1971; Tourangeau, Smith, & Rasinski, 1997), which shows that examinees 'wired-up' to a fake polygraph are more likely to admit embarrassing beliefs and facts than similar examinees not connected to the 'bogus lie detector'.

Recently, the 'bogus pipeline' has drawn interest in the UK through the application as a 'truth facilitator' for the monitoring and treatment of post-conviction sex offenders, wherein a CQT variant commonly known as a maintenance test is employed (Grubin, 2008). According to McGrath, Cumming, Burchard, Zeoli, and Ellerby (2009), nearly 80% community programmes and over 50% of residential programmes in the US incorporate polygraph maintenance tests for the purpose of sex offender motoring, risk assessment and rehabilitation. In the UK, the Home Office has supported a series of pilot studies to evaluate the usefulness of the polygraph in this context, which have progressed from smaller volunteer-based studies (Madsen, Parsons & Grubin, 2004) to larger studies featuring mandatory participation and improved methodologies (Gannon et al., 2014).

As per the original bogus pipeline concept, the focus in current research lies not in deception detection, but in determining how effective the polygraph is in increasing the number of clinically relevant disclosures (CRD) made by offenders during monitoring visits. In one of the most recent studies to date, Gannon et al. (2014) found that offenders in the polygraph group were three times more likely to make CRDs than offenders in the control group. The results from this study and its predecessors are encouraging, but their methodologies do have several limitations by their own admission, meaning that further research is required before any solid conclusions can be drawn. Additionally, there have been no attempts to incorporate the CIT, instead of the CQT, into these maintenance tests, which may be an advisable avenue to explore in the future, considering the CIT's stronger theoretical foundation.

Proponents of the CQT continue to research the applications and possible improvement to the tool (see Ginton, 2013; Horvath & Palmatier, 2008; Webb, Honts, Kircher, Bernhardt, & Cook, 2009). However, considering the reported flaws of its underlying assumptions, it is uncertain whether its accuracy or academic standing will significantly improve in the near future, unless the technique is modified to function in concordance with a more grounded theoretical basis.

The GKT or CIT

The CIT was first introduced by David Lykken in 1959 in response to growing criticisms of the CQT. CIT is not as widely used as the CQT, except in Japan, where it has seen frequent application by the National Police Agency since the 1980s, being used to test over 5000 suspects each year (Yamamura & Miyata, 1990). Rather than being a 'detection test', the CIT is a 'recognition test', designed to detect whether an examinee recognizes a piece of crime-related information as significant, regardless of their claims to the contrary. For the CIT to be viable for use in any given investigation, the investigators must have access to crime-relevant information that only those who were actually involved in the crime could know, e.g. type of weapon used in a murder case that was not reported by the media. In Japan, law enforcement agencies have a greater control over crime scenes and what information regarding crime is made public than most Western countries do, which is part of the reason why the NPC can use CIT on the scale that they do (Osugi, 2011).

The scientific basis of the CIT rests in Orienting Response Theory (O'Gorman, 1979; Sokolov, 1963, 1966; Verschuere, Crombez, De Clercq, & Koster, 2004). An orienting response describes an individual's immediate reaction to a change in its environment that is novel or significant, but not so sudden or threatening as to evoke a 'fight or flight' startle reflex (Lang et al., 1990). The individual's sensory organs and attention are immediately drawn to this stimulus. This reflex has been shown to develop at a very young age (Posner & Rothbart, 2000) and can easily be observed in noisy social environments where people may completely zone out the surrounding chatter, but then immediately turn their heads when their name is spoken, which is also known as the cocktail party phenomenon. It is important to emphasize that this is explained by cognitive, rather than emotional, factors, thus distinguishing the CIT, on a fundamental level, from all emotion-based polygraph tests, such as the CQT (Ben-Shakhar & Furedy, 1990).

Orienting responses have been shown to be accompanied by a number of measurable physiological reactions, including changes in cardiovascular activity, respiration and most prominently an increase in electrodermal activity, wherein the magnitude of the increase appears to actually be indicative of the stimuli's perceived significance (Bradley, 2009). Reaction time (RT) has been found to be similarly affected by the orienting reflex (Seymour, Seifert, Shafto, & Mosmann, 2000) and RT-based CIT research has subsequently been progressing steadily over the past 14 years, reporting accuracy rates rivalling those of the traditional three-channel polygraph CIT (see Varga, Visu-Petra, Miclea & Bus, 2014, for a recent review).

There is evidence to suggest that individuals who encode the information actively, as a guilty suspect would, while committing a crime, appear to encode crime-relevant information more deeply than individuals who encoded the information incidentally, like a bystander or 'look-out' might; but whether this results in a measurable difference in orienting responses has been a matter of investigation and debate (Ben-Shakhar & Elaad, 2003; Bradley, MacLaren, & Carle, 1996; Elaad, 2009, 2011, 2013, 2014). Additionally, it has been proposed that intoxication at the time of the crime might interfere with the encoding of the memory and thus reduce the accuracy of the CIT, while increased arousal might conversely boost encoding and subsequent CIT results, but the research on this is limited (O'Toole, Yuille, Patrick, & Iacono, 1994).

A standard CIT examination uses the same polygraph technology as any other polygraph examination, and it also consists of a pre-test interview, a testing phase and a post-test phase. The most vital stage of a CIT examination, however, starts before the pre-test interview, namely when the questions for the testing phase are formulated. CIT questions are designed in a multiple-choice format. First, the number of questions, the number of possible answers for each question and whether the questions are to be repeated a certain number of times must be decided on the basis of the available case information. Each question pertains to a detail of the crime under investigation that an examinee, who was involved in the crime (by virtue of either being guilty or a witness), would be likely to remember; e.g. 'What weapon was the victim murdered with?'. One of the possible answers presented to the examinee is correct (e.g. the actual murder weapon: a steak-knife) while the remaining answers are false, distinct but equally plausible alternatives (e.g. a handgun, a steel pipe, a rifle, an axe, etc.).

The number of questions to be asked depends largely on how much of the available crime-related investigation lends itself to being formulated into questions. In this, one important factor to consider is memory, as research has shown that peripheral details of a crime (e.g. the number of chairs a room) are easily forgotten over time by both the guilty and the innocent, while memories of central details of a crime (e.g. the murder weapon) are more readily retained by the guilty (Gamer, 2010). The number of possible answers to allocate to each question depends on a number of factors. First and foremost, to an uninformed examinee, each answer must seem equally plausible, and there may be a limited number of plausible answers to a given question, e.g. there are only so many equally distinct and plausible murder weapons. By having a number of uninvolved and uninformed individuals review the possible answers, an examiner can ensure that none stand out. Secondly, certain types of information have been shown to simply not be suitable for the CIT in this regard, including colours, time and numerical information such as exact amounts of numbers, objects or repetitions of an action or event (Hasselmo, 2012; Moscovitch et al., 2005).

Furthermore, answers may be perceived as significant by an examinee, and subsequently elicit an orienting response, for reasons other than it being recognized as the correct answer, e.g. an examinee may have an orienting response at the mention of a gun due to a past traumatic experience involving a gun, such as getting robbed at gunpoint. An examiner cannot always foresee whether certain answers may be of incidental significance to the examinee, which is why the pre-test interview should address this issue so that inappropriate questions and answers can be removed before the actual testing phase (Krapohl, McCloughan, & Senter, 2009). Generally speaking, having a greater number of possible answers (usually 5 or 6) is advantageous as it reduces the risk of an unknowing examinee physiologically responding to the correct answer by chance, therefore reducing the rate of false positives in a statistically reliable manner (Ben-Shakhar, Bar-Hillel, & Kremnitzer, 2002; Elaad, 1999).

While it may seem equally advisable to have a greater number of question repetitions, to account for the reliability of any results, there are both practical and theoretical issues associated with this. The main practical issue is that each round of question repetition significantly increases test duration, which may be limited by time constraints. The main theoretical issue stems from the possibility of an examinee becoming habituated to the questions, meaning that their physiological responsiveness to the presented answers decreases over time (Barry, 2009). Habituation has also been suggested to be a potential problem in relation to the pre-viewing of test items, but the literature on how much of an issue habituation represents for CITs is limited (Elaad & Ben-Shakhar, 1997).

In the practical context of an investigation, the formulation of appropriate CIT questions is complex. If a crime has received considerable media attention, or if an innocent suspect has acquired knowledge of the crime's details while involved with the investigation, or if the investigators do not have sufficient knowledge of the crime, then the CIT is of little use. Critics of the CIT regularly claim that this constraint makes the CIT a highly situational and thus impractical tool, often citing a survey of FBI polygraph investigations conducted by Podlesney (1995), which concluded that the CIT could only have been applied in 13% of all cases. Proponents of the CIT contest that, if criminal investigations were conducted with the CIT in mind (as in Japan), then it could easily be applied on a large scale, as demonstrated by how most modern forensic tools (e.g. fingerprinting, DNA analysis) could only find their way into widespread usage after investigation practices were adjusted to accommodate them (Lykken, 1998).

The difficulty of formulating appropriate multiple-choice questions for the CIT is not mirrored by any difficulty in actually administering a CIT examination. The pre-test interview serves to explain the procedure and questions to the examinee to ensure that they are properly understood. Additionally, the examinee is often asked to explain and sometimes write down any and all knowledge he may possess regarding the crime and inform the examiner whether any of the questions or answers are of particular personal significance. In Japan, the examinee must give written consent at this stage for the test to proceed (attorneys can be consulted but are not required to consent), and while examinees are free to refuse, they rarely do so (Osugi, 2011).

The testing stage of the CIT proceeds as follows. The examinee is attached to the polygraph and practice questions are asked to acclimatize the examinee to the set-up. After the practice questions, the actual questioning begins. The examiner asks a question, e.g. ‘What was stolen from the safe?’, and then slowly lists each of the possible answers, ‘Was it money? Was it jewellery?’ and so on. Depending on variations to the CIT, the questions either do not have to be verbally answered, have to be answered ‘yes’ or ‘no’, or all answers must be ‘no’ (Meijer, Smulders, Johnston, & Merckelbach, 2007). It has been recommended that the examiner should remain silent for intervals of up to 30 s following the last answer to a question, as to let the examinee’s physiological responses return to baseline, and notify the examinee as to whether each question is to be asked multiple times and when a set of questions has ended (Krapohl et al., 2009), although the benefit of these practices has not yet been investigated to any great extent.

The post-test stage of the CIT consists of an analysis of the collected physiological data. The recordings of the examinee’s cardiovascular activity, respiration and GSR immediately following the examiner’s presentation of each possible answer are compared to determine whether they match the pattern of an OR. The GSR is usually used as the main indicator of this since, as previously stated, it has long been considered to be the most reliable measure (Slowik & Buckley, 1975). If the data show the examinee to have consistently exhibited an OR following the correct answer across repetitions, it is indicated that the examinee has concealed knowledge in regards to that question. Numerical scoring procedures, similar to those used for the CQT, are commonly employed in order to reach a conclusion on whether the examinee has concealed information pertaining to the crime under investigation. More advanced statistical discrimination methods have also been developed (Matsuda et al., 2009) and software packages to aid in the analysis of CIT data are commercially available (e.g. Polygraph Profession Suite), but neither have been sufficiently validated through empirical studies (Breska, Ben-Shakhar, & Gronau, 2012).

Current CIT research

Research on the CIT is ongoing and mostly focuses on proving its effectiveness in the field (Gamer, 2012), but one particular newly developed investigative application of the CIT deserves mention in this context.

Meijer, Bente, Ben-Shakhar, and Schumacher (2013) developed what they refer to as a dynamic questioning approach for the detection of concealed information from groups. In this approach, a group of examinees is tested simultaneously while in each other’s presence, with the examiner asking everyone the same questions and listing the same possible answers as each examinee's electrodermal activity is monitored in real time. Unlike with regular CITs, the questions asked are not in regard to specific pieces of information that the investigator knows, but instead pertain to a more general matter of investigation of which the investigator does not know the details. If the average GSR of the group exceeds a threshold in response to a presented answer to one of these broader question, it is indicated that the examiner is 'on the right track', which prompts him/her to next ask a more specific question that follows from the previous question, so as to 'zoom in' on the specific concealed information.

This technique is not intended for the investigation of specific incidents, but for the investigation of security threats posed by a group of people (i.e. terrorist suspects), which is illustrated by the experiment that Meijer et al. (2013) used to test their approach. Twenty mock-terrorist groups of 5 (n = 100) were asked to select a street, within a city, within a country from a presented list and then plan a mock-terrorist attack in this location. The examiner was left blind as to the street/city/country selected, as well as the details of the planned attack. After the location selection and attack planning, each member of a given group of examinees was simultaneously hooked up to the GSR measuring apparatus. As per standard CIT procedure, the examiner then first asked which country the attack was planned in and then read out the list of countries from which the examinees had selected. The examinees were instructed to answer 'no' to each suggested answer. If the average GSR of the group exceeded a pre-set threshold in response to a certain country being suggested, then this was taken to indicate that the suggested country was the one they had selected, i.e. possessed concealed knowledge off. This process was then repeated with the list of possible target cities, and lastly possible target streets. In a manner, the deductive process employed can be likened to the parlour game known as '20 Questions' (Walsorth, 1882), with the difference being that correct guesses were identified by group GSR as opposed to a confirmatory answer. In the end, the country of the mock-terrorist attack was identified in 19 out of 20 cases (no false positives), the city was identified in 13 of these 20 cases (2 false positives) and the street was identified in 7 out of these remaining 13 cases (4 false positives, out of which 2 followed the city-level false positives). The significance of this study should under not be overestimated as it was only the first test of a newly conceived approach which only produced moderate results. In its current format, the CIT appears to be able to detect the presence of concealed information at accuracy rates ranging from 76% to 84%, while the absence of concealed information is seemingly detected with 83–94% accuracy (Ben-Shakhar & Elaad, 2003; MacLaren, 2001).

The P300-based CIT

The P300 component is a positive event-related potential (commonly known as a brain-wave) that occurs approximately 300–800 ms after meaningful piece of information is recognized within a series of more frequently presented, non-meaningful stimuli (Fabiani, Karis, Coles, & Donchin, 1983), and when applied to an investigative context, the P300 can be used to detect concealed information in a manner that is similar to the CIT polygraph test (Johnson & Rosenfeld, 1992; Rosenfeld, Angell, Johnson, & Qian, 1991; Rosenfeld et al., 2008; Rosenfeld, Soskins, Bosh, & Ryan, 2004). Rather than competing for dominance, the polygraph- and P300-based CIT are complimentary techniques, and there is little conflict between the academic communities respectively researching them (Iacono, 2008).

There have been no noteworthy attempts to integrate the two CIT approaches, be it by adding the P300 as a fourth channel to the polygraph or by using polygraph channels (e.g. GSR) as part of P300 research. One possible explanation hereof is that the polygraph CIT bases itself in Orienting Theory, while the P300-CIT is an entirely neuropsychological concept, meaning that, despite their obvious similarities in application, there is little common ground in terms of theory and research practice. The National Research Council (2003) made note of this and advised the exploration of a potential collaboration.

There are several directions that future polygraph research could take. Exploring the potential improvements to the polygraph apparatus itself would be one. In this, the current three channels would undergo re-evaluation as to their usefulness. Gamer, Verschuere, Crombez, and Vossel (2008), for example, have already conducted a study investigating the relative predictive value of the channels and found GSR to be far more reliable than heart rate and respiration line length. Further in-depth comparative investigation of the channels may give grounds to remove some and/or assign more weight to other channels in standard polygraph examinations, thus providing the benefits of simpler and/or more standardized evaluation procedures.

In addition to this re-evaluation of the channels themselves, the technology through which they are measured could potentially also benefit from revision. In their comprehensive review, the NRC (2003) already pointed to several modern non-invasive measurement techniques that may prove to be more reliable than traditional polygraph components if investigated in this context (e.g. Berntson et al., 1994; Cacioppo et al., 1994). Examining these two approaches may result in more accurate measurements as well as a better understanding of the relative worth of what is being measured.

A further potentially productive direction for future research may be the exploration of additional channels that could be added to the polygraph. An obvious choice to be investigated would be the P300 as previously discussed. Its direct relation to Orienting Response Theory makes it suitable for potential combination with the CIT.

Discussion

The polygraph holds a unique position in academia, law enforcement and the public sector, which is important to keep in mind when evaluating any given anecdotal account or piece of academic work pertaining to its use, accuracy and potential. Current scientific opinions pertaining to the polygraph are polarized, especially in regards to the different polygraph testing methods, wherein both the CQT and the CIT have their own avid supporters and critics.

It is important to note that, just as how Chief Vollmer, Larson, Keeler and Moulton had their own motivations in their work relating to the polygraph during its early days, there still exists a split of interests in the modern field of polygraph use, application and research. The divide between polygraph practitioners and researchers that Lykken (1974, 1975) lamented still persists in the absence of a unified international ruling body/authority on polygraph practice/research. The polygraph industry, by virtue of being an industry, has an inherent interest in the promotion of the polygraph, but is not dependent upon the support of the scientific community, which arguably impedes its interest in scientific advancement and validation. Law enforcement agencies, on account of necessity and accountability, have a greater interest in the scientific validity of polygraph techniques than the polygraph industry, but also place great value on the practical use of what is available. These conflicting interests can prove detrimental to the advancement of the field as a whole, but are not likely to unify.

The CIT is, from a purely academic standpoint, the superior polygraph testing method, due to its stronger scientific basis and potential for further improvement. The CQT, on the other hand, is easier to apply and already in widespread usage, which serves in part to explain its steady popularity as a tool amongst investigators, and current endorsement by the US government (Intelligence Community Policy Guidance 704.6, 2015). Attempts to reconcile the two methods have naturally been made, but these tend to garner little support (e.g. see Palmatier & Rovner, 2015b; in response to Ginton, 2015; Ogawa, Matsuda, & Tsuneoka, 2014; Ben-Shakhar, Gamer, Iacono, Meijer, & Verschuere, 2015; and Vrij, 2014; all in response to Palmatier & Rovner, 2015a).

At the current point in time, the research on both the CQT and the CIT is insufficient. The majority of published laboratory studies – especially those pre-dating the NRC's 2003 review – tend to suffer from a variety of methodological flaws and problems of ecological validity, which holds particularly true for field studies on the CQT. While CIT field studies are severely lacking in numbers, meaning neither test has achieved an acceptable degree of empirical validation.

Conclusion

The quality of polygraph research has improved considerably over the past three decades. In its current state, the polygraph can already serve as a viable investigative tool to investigators, and its value is likely to increase as research continues to improve and address its current shortcomings. The CIT holds the greatest potential in this regard as its limitation lies mostly in its applicability in practice, which – as demonstrated by the Japanese NPC – is in not an insurmountable hurdle. It appears unlikely that the proponents of the CQT will be able to reconcile the theoretical flaws of their technique in the foreseeable future, but its long history and general usefulness in practice are likely to preserve its popularity with the law enforcement agencies employing it. While it may not be possible to improve the polygraph to the level where it can truly be thought of as 'The Lie Detector', it does appear to hold the potential of becoming one of the most effective tools for the purpose of aiding investigators in the detection of deception. The polygraph suffered as a result of its own initial fame and overt optimism regarding what it could do. The greatest benefit of the polygraph within an investigative setting has not yet been realized, but there is plenty to suggest, from the research that has taken place, that its use for assisting the investigative process through, for instance, identifying persons of interest primarily, is not too far away.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. For a comprehensive review of the Frye Standard, see Meaney (1995).
2. For a historical review, see Grubin and Madsen (2005).

References

Alder, K. (2002). A social history of untruth: Lie detection and trust in twentieth-century America. *Representations*, *80*(1), 1–33. doi:10.1525/rep.2002.80.1.1

Alder, K. (2007). America's two gadgets. *Isis*, *98*(1), 124–137. doi:10.1086/522310

American Polygraph Association. (1997). *Manual for polygraph school accreditation*. Chattanooga, TN: APA National Office.

Baken, R. J., & Orlikoff, R. F. (2000). *Clinical measurement of speech and voice*. San Diego, CA: Cengage Learning.

Barland, G. H. (1981). *A validation and reliability study of counterintelligence screening test* (Unpublished manuscript). The Department of Defense Polygraph Institute, Fort Jackson, SC.

Barry, R. J. (2009). Habituation of the orienting reflex and the development of preliminary process theory. *Neurobiology of Learning and Memory*, *92*(2), 235–242. doi:10.1016/j.nlm.2008.07.007

Ben-Shakhar, G. (1991). Clinical judgment and decision-making in CQT-polygraphy. *Integrative Physiological and Behavioral Science*, *26*(3), 232–240. doi:10.1007/BF02912515

Ben-Shakhar, G. (1977). A further study of the dichotomization theory in detection of information. *Psychophysiology*, *14*(4), 408–413. doi:10.1111/psyp.1977.14.issue-4

Ben-Shakhar, G., Bar-Hillel, M., & Kremnitzer, M. (2002). Trial by polygraph: Reconsidering the use of the guilty knowledge technique in court. *Law and Human Behavior*, *26*(5), 527–541. doi:10.1023/A:1020204005730

Ben-Shakhar, G., & Elaad, E. (2003). The validity of psychophysiological detection of information with the Guilty Knowledge Test: A meta-analytic review. *Journal of Applied Psychology*, *88*(1), 131–151. doi:10.1037/0021-9010.88.1.131

Ben-Shakhar, G., & Furedy, J. J. (1990). *Theories and applications in the detection of deception: A psychophysiological and international perspective*. New York: Springer-Verlag Publishing.

Ben-Shakhar, G., Gamer, M., Iacono, W., Meijer, E., & Verschuere, B. (2015). Preliminary process theory does not validate the comparison question test: A comment on Palmatier and Rovner (2015). *International Journal of Psychophysiology*, *95*(1), 16–19.

Benussi, V. (1914). *Die atmungssymptome der Lüge*. Leipzig: W. Engelmann.

Berntson, G. G., Cacioppo, J. T., & Quigley, K. S. (1991). Autonomic determinism: The modes of autonomic control, the doctrine of autonomic space, and the laws of autonomic constraint. *Psychological Review*, *98*(4), 459–487. doi:10.1037/0033-295X.98.4.459

Berntson, G. G., Cacioppo, J. T., Binkley, P. F., Uchino, B. N., Quigley, K. S., & Fieldstone, A. (1994). Autonomic cardiac control. III. Psychological stress and cardiac response in autonomic space as revealed by pharmacological blockades. *Psychophysiology*, *31*(6), 599–608. doi:10.1111/psyp.1994.31.issue-6

Bhaskar, A., Subramani, S., & Ojha, R. (2013). Respiratory belt transducer constructed using a singing greeting card beeper. *Advances in Physiology Education*, *37*(1), 117–118. doi:10.1152/advan.00166.2012

Blalock, B., Cushman, B., & Nelson, R. (2009). A replication and validation study on an empirically based manual scoring system. *Polygraph*, *38*(4), 281–288.

Blasingame, G. D. (1998). Suggested clinical uses of polygraphy in community-based sexual offender treatment programs. *Sexual Abuse: A Journal of Research and Treatment*, *10*(1), 37–45.

Bond, C. F., & DePaulo, B. M. (2006). Accuracy of deception judgments. *Personality and Social Psychology Review*, *10*(3), 214–234. doi:10.1207/pspr.2006.10.issue-3

Bradley, M. M. (2009). Natural selective attention: Orienting and emotion. *Psychophysiology*, *46*(1), 1–11. doi:10.1111/psyp.2008.46.issue-1

Bradley, M. T., MacLaren, V. V., & Carle, S. B. (1996). Deception and nondeception in guilty knowledge and guilty actions polygraph tests. *Journal of Applied Psychology*, *81*(2), 153–160. doi:10.1037/0021-9010.81.2.153

Breska, A., Ben-Shakhar, G., & Gronau, N. (2012). Algorithms for detecting concealed knowledge among groups when the critical information is unavailable. *Journal of Experimental Psychology: Applied*, *18*(3), 292.

Brooks, J. (1985). Polygraph testing: Thoughts of a skeptical legislator. *American Psychologist*, *40*(3), 348–354. doi:10.1037/0003-066X.40.3.348

Buckley. J. P. (1980). *Polygraph technology*. In W. J. Curran, A. L. McGarry, & C. S. Petty (Eds.), Modern legal medicine, psychiatry and forensic sciences (pp. 1187–1207). Philadelphia, PA: Davis.

Cacioppo, J. T., Berntson, G. G., Binkley, P. F., Quigley, K. S., Uchino, B. N., & Fieldstone, A. (1994). Autonomic cardiac control. II. Noninvasive indices and basal response as revealed by autonomic blockades. *Psychophysiology*, *31*(6), 586–598.

Carte, G. E., & Carte, E. H. (1975). *Police reform in the united states: The era of August Vollmer, 1905–1932*. Berkeley, CA: University of California Press.

Challoner, A. V. J., & Ramsay, C. A. (1974). A photoelectric plethysmograph for the measurement of cutaneous blood flow. *Physics in Medicine and Biology*, *19*(3), 317–328. doi:10.1088/0031-9155/19/3/003

Committee to Review the Scientific Evidence on the Polygraph, Board on Behavioral, Cognitive, and Sensory Sciences, & National Research Council (US). Committee on National Statistics. (2003). *The polygraph and lie detection*. Washington, D.C.: National Academies Press.

Conduct of Polygraph Examinations for Personnel Security Vetting, Intelligence Community Policy Guidance 704.6. (2015, February 4). Retrieved from http://fas.org/irp/dni/icd/icpg704-6.pdf

Daubert v. Merrell Dow Pharmaceuticals, Inc., 509 U.S. 579, 113 S. Ct. 2786, 125 L. Ed. 2D 469 (1993).

Davis, R. C. (1961). *Physiological responses as a means of evaluating information*. In A. D. Biderman & H. Zimmer (Eds.), The manipulation of human behavior (pp. 142–168). New York: Wiley.

Dawson, M. E., Schell, A. M., & Filion, D. L. (2000). *Handbook of psychophysiology* (pp. 200–223). Cambridge: Cambridge University Press.

Dollins, A., Krapohl, D., & Dutton, D. (2000, August). Comparison of computer programs designed to evaluate psychophysiological detection of deception examinations. In *Psychophysiology* (Vol. *37*, pp. S19–S19). Department of Defense, Fort Jackson, SC: Polygraph Institute.

Ekman, P. (1981). Mistakes when deceiving. *Annals of the New York Academy of Sciences*, *364*(1), 269–278. doi:10.1111/j.1749-6632.1981.tb34479.x

Ekman, P. (2009). *Telling lies: Clues to deceit in the marketplace, politics, and marriage* (Revised ed.). London: WW Norton & Company.

Elaad, E. (1999). A comparative study of polygraph tests and other forensic methods. In D. Canter & L. Alison (Eds.), *Offender profiling series, Vol. 1: Interviewing and deception* (pp. 209–231). Aldershot, England: Ashgate Publishing.

Elaad, E. (2003). Is the inference rule of the “control question polygraph technique” plausible? *Psychology, Crime and Law*, *9*(1), 37–47. doi:10.1080/10683160308143

Elaad, E. (2009). Effects of context and state of guilt on the detection of concealed crime information. *International Journal of Psychophysiology*, *71*(3), 225–234. doi:10.1016/j.ijpsycho.2008.10.001

Elaad, E. (2011). Effects of incomplete information on the detection of concealed crime details. *Applied Psychophysiology and Biofeedback*, *36*(3), 159–171. doi:10.1007/s10484-011-9153-2

Elaad, E. (2013). Effects of goal-and task-oriented motivation in the guilty action test. *International Journal of Psychophysiology*, *88*(1), 82–90. doi:10.1016/j.ijpsycho.2013.02.004

Elaad, E. (2014). Differences in the readiness of guilty and informed innocent examinees to cooperate on the guilty action test. *Psychophysiology*, *51*(1), 70–79. doi:10.1111/psyp.2014.51.issue-1

Elaad, E., & Ben-Shakhar, G. (1997). Effects of item repetitions and variations on the efficiency of the Guilty Knowledge Test. *Psychophysiology*, *34*(5), 587. doi:10.1111/j.1469-8986.1997.tb01745.x

Fabiani, M., Karis, D., Coles, M. G. H., & Donchin, E. (1983). P300 and recall in an incidental memory paradigm. *Psychophysiology*, *20*(4), 439–439.1010 Vermont Ave Nw Suite 1100, Washington, DC 20005: Soc Psychophysiol Res

Fiedler, K., Schmid, J., & Stahl, T. (2002). What is the current truth about polygraph lie detection? *Basic and Applied Social Psychology*, *24*(4), 313–324. doi:10.1207/S15324834BASP2404_6

Friedman, J., Hastie, T., & Tibshirani, R. (2001). *The elements of statistical learning (Vol. 1)*. Berlin: Springer. Springer series in statistics.

Frye v. United States, 293 F. 1013 (Court of Appeals, Dist. of Columbia) (1923).

Furedy, J. J. (1993). The ‘control’question ‘test’(CQT) polygrapher’s dilemma: Logico-ethical considerations for psychophysiological practitioners and researchers. *International Journal of Psychophysiology*, *15*(3), 263–267. doi:10.1016/0167-8760(93)90010-M

Furedy, J. J. (1996). Some elementary distinctions among, and comments concerning, the ‘control’-question ‘test’(CQT) polygrapher’s many problems: A reply to Honts, Kircher and Raskin. *International Journal of Psychophysiology*, *22*(1–2), 53–59. doi:10.1016/0167-8760(96)00007-4

Furedy, J. J., & Liss, J. (1986). Countering confession induced by the polygraph: Of confessionals and psychological rubber hoses. *Criminal LQ*, *29*, 91.

Gamer, M. (2010). Does the guilty actions test allow for differentiating guilty participants from informed innocents? A re-examination. *International Journal of Psychophysiology*, *76*(1), 19–24. doi:10.1016/j.ijpsycho.2010.01.009

Gamer, M. (2012). Validity of the Concealed Information Test in realistic mock crime scenarios: Comment on Bradley, Malik, and Cullen. *Perceptual and Motor Skills*, *115*(2), 427–431. doi:10.2466/22.07.27.PMS.115.5.427-431

Gamer, M., Verschuere, B., Crombez, G., & Vossel, G. (2008). Combining physiological measures in the detection of concealed information. *Physiology & Behavior*, *95*(3), 333–340. doi:10.1016/j.physbeh.2008.06.011

Gannon, T. A., Wood, J. L., Pina, A., Tyler, N., Barnoux, M. L., & Vasquez, E. A. (2014). An evaluation of mandatory polygraph testing for sexual offenders in the UK. *Sexual Abuse: A Journal of Research and Treatment*, *26*, 178–203. doi:10.1177/1079063213486836

Geddes, L. A. (2002). The truth shall set you free [development of the polygraph]. *Engineering in Medicine and Biology Magazine, IEEE*, *21*(3), 97–100. doi:10.1109/MEMB.2002.1016854

Giannelli, P. C. (1997). Polygraph evidence: *Post-Daubert*. *Hastings Law Journal*, *49*, 895.

Ginton, A. (2013). A non-standard method for estimating accuracy of lie detection techniques demonstrated on a self-validating set of field polygraph examinations. *Psychology, Crime & Law*, *19*(7), 577–594. doi:10.1080/1068316X.2012.656118

Ginton, A. (2014). Good intentions that fail to cope with the main point in CQT: A comment on Palmatier and Rovner (2014). *International Journal of Psychophysiology*, *95*(1), 25–28.

Grubin, D. (2008). The case for polygraph testing of sex offenders. *Legal and Criminological Psychology*, *13*(2), 177–189.

Grubin, D. (2010). The polygraph and forensic psychiatry. *Journal of American Academic Psychiatry Law*, *38*, 446–451.

Grubin, D., & Madsen, L. (2005). Lie detection and the polygraph: A historical review. *The Journal of Forensic Psychiatry & Psychology*, *16*(2), 357–369. doi:10.1080/14789940412331337353

Grubin, D., Madsen, L., Parsons, S., Sosnowski, D., & Warberg, B. (2004). A prospective study of the impact of polygraphy on high-risk behaviors in adult sex offenders. *Sexual Abuse: A Journal of Research and Treatment*, *16*(3), 209–222.

Gudjonsson, G. H. (2003). *The psychology of interrogations and confessions: A handbook*. Chichester: John Wiley & Sons.

Hasselmo, M. E. (2012). *How we remember: Brain mechanisms of episodic memory*. Cambridge: MIT Press.

Hastie, T., Tibshirani, R., & Friedman, J. (2001) *Elements of Statistical Learning: Data Mining, Inference and Prediction*. New York: Springer-Verlag.

Hirota, A., Matsuda, I., Kobayashi, K., & Takasawa, N. (2005). Development of a portable digital polygraph system. *Japanese Journal of Forensic Science and Technology*, *10*(1), 37–44. doi:10.3408/jafst.10.37

Homma, I., & Umezawa, A. (2001). Respiration and emotion. In Y. Masaoka (Ed.). Tokyo: Springer.

Honts, C. R., & Alloway, W. R. (2007). Information does not affect the validity of a comparison question test. *Legal and Criminological Psychology*, *12*(2), 311–320. doi:10.1348/135532506X123770

Honts, C. R., & Kircher, J. C. (1994). Mental and physical countermeasures reduce the accuracy of polygraph tests. *Journal of Applied Psychology*, *79*(2), 252–259. doi:10.1037/0021-9010.79.2.252

Honts, C. R., Kircher, J. C., & Raskin, D. C. (1995). Polygrapher's dilemma or psychologist's chimaera: A reply to Furedy's logico-ethical considerations for psychophysiological practitioners and researchers. *International Journal of Psychophysiology*, *20*(3), 199–207. doi:10.1016/0167-8760(95)00038-0

Horvath, F., & Palmatier, J. J. (2008). Effect of two types of control questions and two question formats on the outcomes of polygraph examinations. *Journal of Forensic Sciences*, *53*(4), 889–899. doi:10.1111/jfo.2008.53.issue-4

Hebb, J. (2012). Pre-conviction and post-conviction polygraph testing: A brief history. In D. T. Wilcox, (Ed.), *The Use of the Polygraph in Assessing, Treating and Supervising Sex Offenders: A Practitioner's Guide* (pp. 31–48). Chichester UK: Wiley.

Iacono, W. G. (1991). Can we determine the accuracy of polygraph tests. *Advances in Psychophysiology*, *4*, 201–207.

Iacono, W. G. (2008). Effective policing understanding how polygraph tests work and are used. *Criminal Justice and Behavior*, *35*(10), 1295–1308. doi:10.1177/0093854808321529

Iacono, W. G., Cerri, A. M., Patrick, C. J., & Fleming, J. A. (1992). Use of antianxiety drugs as countermeasures in the detection of guilty knowledge. *Journal of Applied Psychology*, *77*(1), 60–64. doi:10.1037/0021-9010.77.1.60

Iacono, W. G., & Lykken, D. T. (1997). The validity of the lie detector: Two surveys of scientific opinion. *Journal of Applied Psychology*, *82*(3), 426–433. doi:10.1037/0021-9010.82.3.426

Isshiki, N., & Snidecor, J. C. (1965). Air intake and usage in esophageal speech. *Acta Oto-Laryngologica*, *59*(2–6), 559–574. doi:10.3109/00016486509124587

Johnson, M. B. (2003). The interrogation of Michael Crowe: A film review focused on education and training. *American Journal of Forensic Psychology*, *21*(3), 71–79.

Johnson, M. M., & Rosenfeld, J. P. (1992). Oddball-evoked P300-based method of deception detection in the laboratory II: Utilization of non-selective activation of relevant knowledge. *International Journal of Psychophysiology*, *12*(3), 289–306. doi:10.1016/0167-8760(92)90067-L

Jones, E. E., & Sigall, H. (1971). The bogus pipeline: A new paradigm for measuring affect and attitude. *Psychological Bulletin*, *76*(5), 349–364. doi:10.1037/h0031617

Kasprowicz, A. L., Manuck, S. B., Malkoff, S. B., & Krantz, D. S. (1990). Individual differences in behaviorally evoked cardiovascular response: Temporal stability and hemodynamic patterning. *Psychophysiology*, *27*(6), 605–619. doi:10.1111/psyp.1990.27.issue-6

Kassin, S. M., & Gudjonsson, G. H. (2004). The psychology of confessions a review of the literature and issues. *Psychological Science in the Public Interest*, *5*(2), 33–67. doi:10.1111/j.1529-1006.2004.00016.x

Keeler, L. (1930). Deception tests and the lie detector. *International Association for Identification Proceedings*, *16*, 186–193.

Kircher, J. C., Horowitz, S. W., & Raskin, D. C. (1988). Meta-analysis of mock crime studies of the control question polygraph technique. *Law and Human Behavior*, *12*(1), 79–90. doi:10.1007/BF01064275

Kircher, J. C., & Raskin, D. C. (2002). Computer methods for the psychophysiological detection of deception. In M. Kleiner, (Ed.), *Handbook of polygraph testing* (pp. 287–326). San Diego, CA: Academic Press.

Kleiner, M. (Ed.). (2002). *Handbook of polygraph testing* (pp. 287–326). San Diego, CA: Academic Press.

Kleinmuntz, B., & Szucko, J. J. (1984). Lie detection in ancient and modern times: A call for contemporary scientific study. *American Psychologist*, *39*(7), 766–776. doi:10.1037/0003-066X.39.7.766

Krapohl, D., & Sturm, S. (2002). Terminology reference for the sceince of psychophysiological detection of deception. *Polygraph*, *31*(3), 154–239.

Krapohl, D., & McManus, B. (1999). An objective method for manually scoring polygraph data. *Polygraph*, *28*(1), 209–222.

Krapohl, D. J., McCloughan, J. B., & Senter, S. M. (2009). How to use the Concealed Information Test. *Polygraph*, *38*(1), 34–49.

Landis, E. M. (1925). Conjugation of paramecium multimicronucleata, powers and mitchell. *Journal of Morphology*, *40*(1), 111–167. doi:10.1002/(ISSN)1097-4687

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1990). Emotion, attention, and the startle reflex. *Psychological Review*, *97*, 377–395. doi:10.1037/0033-295X.97.3.377

Larson, J. A., Haney, G. W., & Keeler, L. (1932). *Lying and its detection: A study of deception and deception tests* (p. 99). Chicago, IL: University of Chicago Press.

Lykken, D. T. (1959). The GSR in the detection of guilt. *Journal of Applied Psychology*, *43*(6), 385–388. doi:10.1037/h0046060

Lykken, D. T. (1974). Psychology and the lie detector industry. *American Psychologist*, *29*(10), 725–739. doi:10.1037/h0037441

Lykken, D. T. (1975). Right way to use a lie detector. *Psychology Today*, *8*(10), 56.

Lykken, D. T. (1998). *A tremor in the blood: Uses and abuses of lie detection* (2nd ed.). New York, NY: Plenum.

Mackenzie, J. (1908). The ink polygraph. *British Medical Journal*, *1*(2476), 1411. doi:10.1136/bmj.1.2476.1411

MacLaren, V. V. (2001). A qualitative review of the Guilty Knowledge Test. *Journal of Applied Psychology*, *86*(4), 674–683. doi:10.1037/0021-9010.86.4.674

Madsen, L., Parsons, S., & Grubin, D. (2004). A preliminary study of the contribution of periodic polygraph testing to the treatment and supervision of sex offenders. *Journal of Forensic Psychiatry & Psychology*, *15*(4), 682–695.

Mangan, D. J., Armitage, T. E., & Adams, G. C. (2008). Rebuttal to objections by Iacono and Verschuere et al. *Physiology & Behavior*, *95*(1–2), 29–31. doi:10.1016/j.physbeh.2008.06.004

Mann, S., Vrij, A., & Bull, R. (2004). Detecting true lies: Police officers' ability to detect suspects' lies. *Journal of Applied Psychology*, *89*(1), 137–149. doi:10.1037/0021-9010.89.1.137

Matsuda, I., Hirota, A., Ogawa, T., Takasawa, N., & Shigemasu, K. (2009). Within-individual discrimination on the Concealed Information Test using dynamic mixture modeling. *Psychophysiology*, *46*(2), 439–449.

Matte, J. A. (1996). *Forensic psychophysiology using the polygraph: Scientific truth verification, lie detection*. Preston: JAM Publications.

McCormick, C. T. (1927). Charges on presumptions and burden of proof. *NCL Reviews*, *5*, 291.

McGrath, R. J., Cumming, G. F., Burchard, B. L., Zeoli, S., & Ellerby, L. (2009). *Current practices and emerging trends in sexual abuser management*. Brandon, VT: The Safer Society Press.

Meaney, J. R. (1995). From Frye to Daubert: Is a pattern unfolding?. *Jurimetrics*, *35*(2), 191–199.

Meijer, E. H., Bente, G., Ben-Shakhar, G., & Schumacher, A. (2012). Detecting concealed information from groups using a dynamic questioning approach: simultaneous skin conductance measurement and immediate feedback. *Frontiers in Psychology*, *4*, 68.

Meijer, E. H., Smulders, F. T., Johnston, J. E., & Merckelbach, H. L. (2007). Combining skin conductance and forced choice in the detection of concealed information. *Psychophysiology*, *44*(5), 814–822. doi:10.1111/j.1469-8986.2007.00543.x

Moscovitch, M., Rosenbaum, R. S., Gilboa, A., Addis, D. R., Westmacott, R., Grady, C., & Nadel, L. (2005). Functional neuroanatomy of remote episodic, semantic and spatial memory: A unified account based on multiple trace theory. *Journal of Anatomy*, *207*(1), 35–66. doi:10.1111/j.1469-7580.2005.00421.x

Nelson, R., Krapohl, D. J., & Handler, M. (2008). Brute force comparison: A Monte Carlo study of the objective scoring system version 3 (OSS-3) and human polygraph scorers. *Polygraph*, *37*, 185–215.

O'Gorman, J. G. (1979). The orientation reflex: Novelty or significance detector? *Psychophysiology*, *16*, 253–262. doi:10.1111/j.1469-8986.1979.tb02988.x

O'Toole, D., Yuille, J. C., Patrick, C. J., & Iacono, W. G. (1994). Alcohol and the physiological detection of deception: Arousal and memory influences. *Psychophysiology*, *31*(3), 253–263. doi:10.1111/j.1469-8986.1994.tb02214.x

Ogawa, T., Matsuda, I., & Tsuneoka, M. (2014). The comparison question test versus the Concealed Information Test? That was the question in Japan: A comment on Palmatier and Rovner (2014). *International Journal of Psychophysiology*, *95*(1), 29–30.

Olsen, D. E., Harris, J. C., Capps, M. H., & Ansley, N. (1997). Computerized polygraph scoring system. *Journal of Forensic Sciences*, *42*, 61–70.

Orne, M. T., Thackray, R. I., & Paskewitz, D. A. (1972). On the detection of deception: A model for the study of the physiological effects of psychological stimuli. In N. S. Greenfield & R. A. Sternbach (Eds.), *Handbook of psychophysiology* (pp. 743–785). New York: Holt, Rinehart & Winston.

Osugi, A. (2011). 14 Daily application of the Concealed Information Test: Japan. In B. Verschuere, G. Ben Shakhar, & E. Meijer, (Eds.), *Memory Detection: Theory and application of the concealed information test* (pp. 63-89) Cambridge: Cambridge University Press.

Palmatier, J. J., & Rovner, L. (2015a). Credibility assessment: Preliminary process theory, the polygraph process, and construct validity. *International Journal of Psychophysiology*, *95*(1), 3–13.

Palmatier, J. J., & Rovner, L. (2015b). Rejoinder to commentary on Palmatier and Rovner (2014): Credibility Assessment: Preliminary Process Theory, the Polygraph Process, and Construct Validity. *International Journal of Psychophysiology*, *95*(1), 31–34. doi:10.1016/j.ijpsycho.2014.11.009

Patrick, C. J., & Iacono, W. G. (1991). Validity of the control question polygraph test: The problem of sampling bias. *Journal of Applied Psychology*, *76*(2), 229–238. doi:10.1037/0021-9010.76.2.229

Podlesney, J. A. (1995). *A lack of operable case facts restricts applicability of the Guilty Knowledge Deception Detection Method in FBI criminal investigations* (FBI Technical Report). Quantico, VA: FBI.
Posner, M. I., & Rothbart, M. K. (2000). Developing mechanisms of self-regulation. *Development and Psychopathology*, *12*(3), 427–441. doi:10.1017/S0954579400003096
Prokasy, W.F & Raskin, D.C. (1973). *Electrodermal Activity in Psychological Research*. New York: Academic Press.
Raskin, D. C. (1987). Methodological issues in estimating polygraph accuracy in field applications. *Canadian Journal of Behavioural Science/Revue canadienne des sciences du comportement*, *19* (4), 389–404. doi:10.1037/h0079999
Raskin, D. C., & Honts, C. R. (1987). The comparison question test. Handbook of polygraph testing, 1–47.
Raskin, D. C., & Kircher, J. C. (2014). Validity of polygraph techniques and decision methods. In D. C. Raskin, C. R. Honts, & J. C. Kircher (Eds.), *Credibility assessment, scientific research and applications* (pp. 65–132). London: Academic Press.
Raskin, D. C., Kircher, J. C., Horowitz, S. W., & Honts, C. R. (1989). Recent laboratory and field research on polygraph techniques. In J. C. Yuille (Ed.), *Credibility Assessment* (pp. 1–24). Deventer, the Netherlands: Kluwer.
Reid, J. E. (1947). A revised questioning technique in liedetection tests. *Journal of Criminal Law and Criminology*, *37*, 542–547.
Reid, J. E., & Inbau, F. E. (1977). Truth and deception: The polygraph (lie-detector) technique. Williams & Wilkins Company. Reid, J. E. (1947). A revised questioning technique in liedetection tests. *Journal of Criminal Law and Criminology*, *37*, 542–547.
Rosenfeld, J. P., Angell, A., Johnson, M., & Qian, J. (1991). An ERP-based, control-question lie detector analog: Algorithms for discriminating effects within individuals' average waveforms. *Psychophysiology*, *38*, 319–335. doi:10.1111/j.1469-8986.1991.tb02202.x
Rosenfeld, J. P., Labkovsky, E., Winograd, M., Lui, M. A., Vandenboom, C., & Chedid, E. (2008). The Complex Trial Protocol (CTP): A new, countermeasure-resistant, accurate P300-based method for detection of concealed information. *Psychophysiology*, *45*, 906–919. doi:10.1111/psyp.2008.45.issue-6
Rosenfeld, J. P., Soskins, M., Bosh, G., & Ryan, A. (2004). Simple, effective countermeasures to P300-based tests of detection of concealed information. *Psychophysiology*, *41*(2), 205–219. doi:10.1111/psyp.2004.41.issue-2
Saxe, L. (1991). Science and the CQT polygraph. *Integrative Physiological and Behavioral Science*, *26*(3), 223–231. doi:10.1007/BF02912514
Seymour, T. L., Seifert, C. M., Shafto, M. G., & Mosmann, A. L. (2000). Using response time measures to assess" guilty knowledge". *Journal of Applied Psychology*, *85*(1), 30–37. doi:10.1037/0021-9010.85.1.30
Sherwood, A., Dolan, C. A., & Light, K. C. (1990). Hemodynamics of blood pressure responses during active and passive coping. *Psychophysiology*, *27*(6), 656–668. doi:10.1111/psyp.1990.27.issue-6
Simon, R. J. (1993). Adopting a military approach to polygraph evidence admissibility: Why federal evidentiary protections will suffice. *Texas Technical Law Reviews*, *25*, 1055.
Slowik, S. M., & Buckley, J. P. (1975). Relative accuracy of polygraph examiner diagnosis of respiration, blood-pressure, and GSR recordings. *Journal of Police Science and Administration*, *3*(3), 305–309.
Sokolov, E. N. (1963). *Perception and the conditioned reflex*. New York, NY: Macmillan.
Sokolov, E. N. (1966). Orienting reflex as information regulator. *Psychological Research in the USSR*, *1*, 334–360.
Stern, R. M., Ray, W. J., & Quigley, K. S. (2001). *Psychophysiological recording*. Oxford: Oxford University Press.
Summers, W. G. (1936). Guilt distinguished from complicity. *Psychological Bulletin*, *33*(9), 787.
The British Psychology Society (2004). *A review of the current scientific status and fields of application of Polygraphic Deception Detection. Final report from the BPS Working Party.* Leicester, UK: British Psychological Society
Tourangeau, R., Smith, T. W., & Rasinski, K. A. (1997). Motivation to report sensitive behaviors on surveys: Evidence from a Bogus pipeline experiment1. *Journal of Applied Social Psychology*, *27*(3), 209–222. [09:15:46]. doi:10.1111/jasp.1997.27.issue-3

Turner, M. J., & van Schalkwyk, J. M. (2008). Blood pressure variability causes spurious identification of hypertension in clinical studies: A computer simulation study. *American Journal of Hypertension*, *21*(1), 85–91. doi:10.1038/ajh.2007.25

U.S. Congress, Office of Technology Assessment. (1983). *Scientific validity of polygraph testing (OTA-TM-H-15)*. Washington, DC: GPO.

United States Congress, House Committee on Government Operations, Subcommittee on Government Information and Foreign Operations. (1965). *Use of polygraphs as 'lie detectors' by the federal government* (House Report No. 198). Washington, DC: US Government Printing Office.

US Congress. (1983). *Scientific validity of polygraph testing: A research review and evaluation –A technical memorandum*. *Washington*, DC: Office of Technology Assessment, OTATM- H-15.

Varga, M., Visu-Petra, G., Miclea, M., & Buş, I. (2014). The RT-based Concealed Information Test: An overview of current research and future perspectives. *Procedia-Social and Behavioral Sciences*, *127*, 681–685. doi:10.1016/j.sbspro.2014.03.335

Verschuere, B., Crombez, G., De Clercq, A., & Koster, E. H. (2004). Autonomic and behavioral responding to concealed information: Differentiating orienting and defensive responses. *Psychophysiology*, *41*(3), 461–466. doi:10.1111/j.1469-8986.00167.x

Vrij, A. (2000). *Detecting lies and deceit: The psychology of lying and the implications for professional practice*. Chichester, UK: Wiley.

Vrij, A. (2014). The protection of innocent suspects: A comment on Palmatier and Rovner (2014). *International Journal of Psychophysiology*, *95*(1), 20–21.

Waid, W. M., & Orne, M. T. (1982). Reduced electrodermal response to conflict, failure to inhibit dominant behaviors, and delinquency proneness. *Journal of Personality and Social Psychology*, *43*(4), 769–774. doi:10.1037/0022-3514.43.4.769

Waid, W. M., Wilson, S. K., & Orne, M. T. (1981). Cross-modal physiological effects of electrodermal lability in the detection of deception. *Journal of Personality and Social Psychology*, *40*(6), 1118–1125. doi:10.1037/0022-3514.40.6.1118

Walsorth, M. T. (1882). *Twenty questions: A short treatise on the game*. New York: H. Holt & Company.

Webb, A. K., Honts, C. R., Kircher, J. C., Bernhardt, P., & Cook, A. E. (2009). Effectiveness of pupil diameter in a probable lie comparison question test for deception. *Legal and Criminological Psychology*, *14*(2), 279–292. doi:10.1348/135532508X398602

Yamamura, T., & Miyata, Y. (1990). Development of the polygraph technique in Japan for detection of deception. *Forensic Science International*, *44*(2–3), 257–271. doi:10.1016/0379-0738(90)90256-X