

Original Paper

Do Child Abuse Pediatricians Search for a “Pediatric Vulcan Planet”? Comparison of Controversies about *the Vulcan-Must-Exist-Theory* and *the Infant-Must-Have-Been-Shaken-Theory*

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Abstract

We argue that there are similarities between the Vulcan-must-exist-theory, derived from the Original Unrestricted Newtonian Gravitational (OUNG) theory, on the one hand, and on the other hand the infant-must-have-been-shaken-theory, derived from the Original Unrestricted Abusive Head Trauma (OUAHT) theory.

Although the Vulcan-must-exist-theory was apparently supported by observations over a period of 50 years, after the introduction of Einstein’s general relativity theory in 1915 and its corroboration in 1919, the alleged planet was subsequently neither observed nor needed.

In analogy with the Einstein/Vulcan reasoning, we suggest that the introduction of the non-shaken baby theory by Geddes et al. in 2001-2004 indicates that in cases where an infant displays no external signs of trauma, the infant-must-have-been-shaken-theory is no longer needed.

Moreover we argue that the two new theories -Einstein’s and Geddes et al.’s- have relevant similarities in terms of the effect on the respective original, unrestricted theory. Just as acceptance of Einstein’s general relativity theory led to the abandonment of the Vulcan-must-exist-theory, it is reasonable to claim that the infant-must-have-been-shaken-theory should also be abandoned. We finally argue that

while the consequences of abandoning the *Vulcan-must-exist-theory* were restricted to some scientific and astronomical issues, the *infant-must-have-been-shaken-theory* has not yet been abandoned because of the societal and legal consequences.

Keywords

scientific controversies, theory impregnated observations, fundamental crisis, senility crisis, responsibility crisis

“A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grow up that is familiar with it.”

Max Planck

1. Introduction

The aim of the present paper is to compare and analyze similarities and differences between two apparently very different research areas: astrophysics and pediatrics, with special reference to two theories: the *Vulcan-must-exist-theory* and the *infant-must-have-been-shaken-theory*. Our thesis is that if there are relevant philosophy of science similarities between the two theories then they should also be treated equally with respect to promotion or abandonment.

Within astrophysics we focus on the development of the Original Unrestricted Newtonian Gravitational (OUNG) theory and the derived *Vulcan-must-exist-theory*. The introduction of Einstein’s general relativity theory showed that the OUNG theory was no longer unrestricted and that the derived *Vulcan-must-exist-theory* was actually false and unnecessary. Within pediatrics we focus on the Original Unrestricted Abusive Head Trauma (OUAHT) theory and the derived *infant-must-have-been-shaken-theory*. In analogy, the introduction of the non-shaken baby theory by Geddes *et al.* showed that the OUAHT theory is also no longer unrestricted and that the derived *the infant-must-have-been-shaken-theory* is actually false and unnecessary, at least in cases of alleged Abusive Head Trauma (AHT) without external signs of trauma.

In comparing the two research areas we shall present the interaction between theories and observations, the appearance of anomalies, paradoxical phenomena, auxiliary and *ad hoc* hypotheses and closure clauses, as well as various associated crises. With respect to associated crises, we focus on three types: *fundamental, senility* and *responsibility* crises. We also present the two theories—Einstein’s general relativity theory and the non-shaken baby theory by Geddes *et al.*

We illustrate how both theories impregnate observations and interpretations. Moreover, we argue that the two theories have relevant similarities in their effect on the original unrestricted theories. As acceptance of Einstein’s general relativity theory meant that the *Vulcan-must-exist-theory* became superfluous and was eventually abandoned, we argue that it is reasonable to claim that the *infant-must-have-been-shaken-theory* is superfluous and could also be abandoned in alleged AHT cases without external signs of trauma. We finally argue that while abandoning the *Vulcan-must-exist-theory*

had solely scientific consequences, the reason the *infant-must-have-been-shaken-theory* has not yet been abandoned is concern over possible negative societal and legal consequences.

1.1 The Development of the Vulcan-Must-Exist-Theory

In 1846, the French mathematician Urbain Le Verrier predicted the existence and position of Neptune, based on a mathematical prediction derived from Newton's gravitational theory. This prediction was intended to explain the gravitational disturbance of the motion of another already known planet, Uranus (Baum & Sheehan, 1997; Levinson, 2015; Johansson & Lynøe, 2008). Le Verrier calculated the interaction of gravitational forces from all the heavenly bodies involved, including the gravitational pull from the sun as well as the position of a hypothetical planet, later referred to as Neptune (Baum & Sheehan, 1997; Levinson, 2015; Johansson & Lynøe, 2008).

Le Verrier sent information about the predicted position of Neptune to a German astronomer, Johann Galle, and asked him to investigate whether a planet could be observed at that position and Galle actually observed Neptune at almost exactly the position predicted by Le Verrier (Baum & Sheehan, 1997; Levinson, 2015). The errant movement of Uranus was thus explained in accordance with Newtonian gravitational theory, by the counter-gravitational pull from Neptune. Le Verrier's reasoning was based on a *ceteris paribus* clause (see Box 1) derived from the Newtonian gravitational theory, suggesting that heavenly bodies, as yet undiscovered (e.g., Neptune), may be involved in the interactions of the gravitational forces concerned (Johansson & Ceteris Paribus Clauses, Closure Clauses and Falsifiability, 1980).

Once Le Verrier received observational support for his prediction, the whole event became a beautiful story about how Newtonian gravitational theory could be used to predict the position and size of a new planet (Baum & Sheehan, 1997; Levinson, 2015).

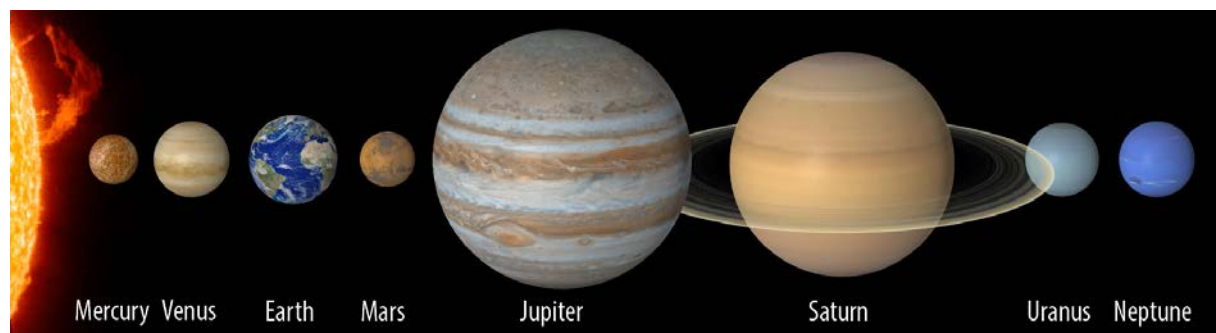


Figure 1. Schematic Position of the Planets in Relation to Each Other and the Sun

At that time, similar errant motions of the planet Mercury, located closest to the sun, had also been observed (Figure 1). In analogy with the reasoning about the Uranus-Neptune gravitational interaction, in 1859 Le Verrier launched the theory that another planet or a belt of asteroids was present inside the orbit of Mercury.

Le Verrier encouraged astronomers to search for dark spots in front of the solar disk (Baum & Sheehan, 1997). In 1859, the French village doctor and amateur astronomer Edmond Lescarbault actually observed a black spot passing the periphery of the solar disk, prior to and independent of Le Verrier's request (Figure 2) (Baum & Sheehan, 1997).

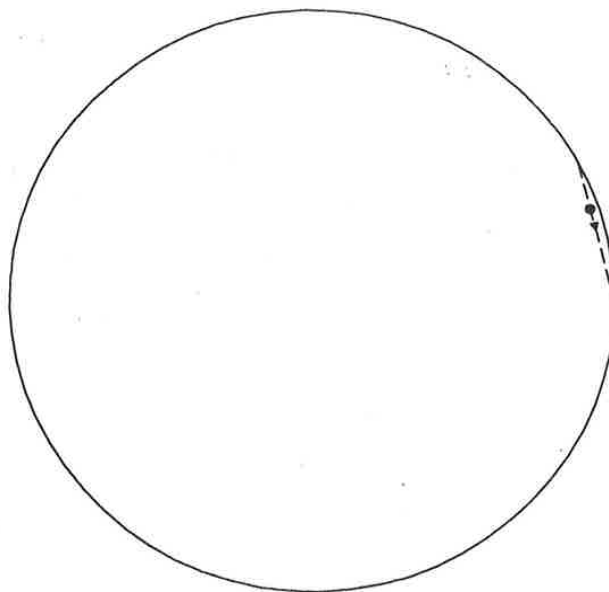


Figure 2. Edmond Lescarbault's Observation of How a Black Spot Passed the Periphery of the Sun Disk, March 26, 1859 (Baum & Sheehan, 1997).

Lescarbault reported his findings to Le Verrier, who carefully scrutinized the circumstances under which the observations had been conducted, as well as the trustworthiness of the doctor. Hence, in the beginning of 1860, Le Verrier proclaimed to the French Academy the existence of a planet inside the orbit of Mercury, eventually referred to as Vulcan. According to Le Verrier, Vulcan was a *mathematical necessity*, described as “a cog in the (Newtonian) celestial machinery” and quite in keeping with Le Verrier's prediction of the position of Neptune (Baum & Sheehan, 1997; Levinson, 2015).

After 1860 it was claimed that 11 observations, between 1762 and 1852, of black (or orange) spots (of different sizes) passing the solar disk could be understood as Vulcan-like phenomena (Baum & Sheehan, 1997). Between 1860 and 1915, prominent astronomers as well as amateurs repeatedly reported observing Vulcan (Baum & Sheehan, 1997; Levinson, 2015).

Between 1859 and 1915 there was no scientific controversy: the existence of Vulcan was not really questioned and astronomers continued to provide observational support from many different locations. The scientific controversy about *the Vulcan-must-exist-theory* did not become evident until 1915, when a new theory -Einstein's general relativity theory- was introduced. During the last ten years of the Vulcan era (1919-1929), most efforts were focused on rejecting *the Vulcan-must-exist-theory*. Rejection

was considered to have been achieved during a solar eclipse in 1929 (Johansson & Ceteris Paribus Clauses, Closure Clauses and Falsifiability, 1980; Kennefick, 2019).

According to Einstein's general relativity theory, masses cause space-time to curve. Even light will follow the curvature of spacetime that exists around large gravitational fields such as that of the Sun. Observation of the curvature of light around the sun during a solar eclipse confirmed Einstein's theory, and the curved spacetime that was found around the Sun explained the "errant" motions of Mercury (Baum & Sheehan, 1997; Levinson, 2015; Kennefick, 2019). Although it was the gravitational pull from Neptune which explained Uranus' odd movements, it was not gravitational pull from the theoretically plausible planet Vulcan that explained the apparently odd movements of Mercury (Baum & Sheehan, 1997; Levinson, 2015).

When Einstein presented his general relativity theory in 1915, he also made a prediction of the magnitude of the deflection of light by the sun—1.75 arc-seconds. In 1919, in conjunction with a solar eclipse, two English astronomers, Arthur Eddington and Frank Dyson, were able to observe the deflection of light and concluded that it was in accordance with Einstein's prediction (Kennefick, 2019).

Although astronomers corroborated Einstein's general relativity theory by observations and prominent (mathematically oriented) physicists approved the theory, there were many antagonists (Kennefick, 2019). The resistance to Einstein's general relativity theory was, in part, due to the difficulty many scientists and philosophers had in questioning the OUNG theory. Initially, Newton had united the terrestrial and celestial physics and the OUNG theory was supposed to apply to all kinds of physical bodies (Kennefick, 2019). Moreover, most physicists thought that light was unaffected by gravitation.

It should also be noted that Eddington actually had problems with the solar eclipse observations. It was cloudy on the small island, Príncipe (off the west coast of Africa) where he made the observations. At the second observational location, Sobral in Brazil, there were problems with calibration of the instruments. However, after careful scrutiny of all the astrographic plates, Eddington and Dyson concluded that the observations corroborated Einstein's theory and their interpretation was endorsed by the Royal Astronomical Society in London (Levinson, 2015, Kennefick, 2019). A computerized reanalysis of the 1919 astrographic plates, published in 1979, showed that Eddington's and Dyson's interpretations were actually correct (Harvey, 1979).

It is important to emphasize that although the OUNG theory was no longer unrestricted, the theory almost perfectly explained the odd movements of Uranus and predicted the position of Neptune. So, despite the fact that the OUNG theory is no longer unrestricted, it is still valid in certain settings where observations are not disturbed by huge gravitational forces.

1.2 Astrophysics and Pediatrics—Comparable Scientific Areas?

What is the resemblance between, on the one hand, Newton's original unrestricted gravitational theory making it possible to predict the position and existence of the planet Vulcan, and, on the other hand, the OUAHT theory predicting that an infant must have been violently shaken, based on certain symptoms

and signs but without external signs of trauma? Like the OUNG theory, the OUAHT theory presupposes certain initial conditions, clauses and several auxiliary hypotheses (see Box 1)—something we will return to in the discussion of fundamental crises.

Of course we must acknowledge the many and substantial differences between physics and medicine. A common denominator might be that the point of departure in the development of both theories was derived from observations or observational studies. With respect to astrophysics, both Newton and Einstein developed their theories by means of observations, but also applied thought experiments and mathematical reasoning, building upon others physicists' theories. But thought experiments are also based on observations or observational assumptions and observational studies are always of great importance when corroborating or rejecting theories. Einstein's general relativity theory is complicated, much more complicated than the theory to which it is compared in this paper. Currently, however, both within astrophysics and medicine, researchers consider it essential to have observational support for their theories.

Accordingly, it is not remarkable that when developing theories, OUAHT research also takes as its point of departure observational studies and case studies. The latter procedure was applied when the OUAHT theory was developed in the 1970's (Guthkelch, 1971; Caffey, 1972). The OUAHT theories can, however, also be based on microscopic observations of brain tissue from series of fatal cases of alleged AHT infants *with* and *without* external signs of trauma (Geddes, Hackshaw, Vowles, Nickols, & Whitwell, 2001). Eventually, medical theories might be corroborated empirically by other scientists who conducted observational studies and reproduced the results. Such studies may then be compiled in meta-analyses or systematic reviews (Maguire, Kemp, Lumb, & Farewell, 2011; Piteau, Ward, Barrowman, & Plint, 2012). On the other hand, theories can be questioned or rejected if the results cannot be reproduced and/or if the evidence is biased (Donohoe, 2003; Elinder, Eriksson, Hallberg, Lynøe, Sundgren, Rosén, ... Erlandsson, 2018; Acres & Morris, 2014).

1.3 Our Thesis

Our thesis is that there are some interesting philosophy of science similarities between the past Newton-Einstein controversy and the current controversy over different mechanism theories within the field of AHT research. We suggest that the weakness of the original unrestricted Newtonian gravitational theory was the claim that it represented a solution to *all* issues and conditions involving gravitational forces. In analogy, we suggest that the weakness of the original unrestricted abusive head trauma theory has been claiming that it is applicable to *all* alleged AHT cases, including those *without* external signs of trauma. In order to support these erroneous claims, it was necessary to add the *Vulcan-must-exist-theory* and the *infant-must-have-been-shaken-theory*. We argue that these theories are merely false closure clauses (see Box 1) (Johansson & Ceteris Paribus Clauses, Closure Clauses and Falsifiability, 1980).

The *Vulcan-must-exist-theory* was plausible according to the OUNG theory together with a *ceteris paribus* clause (see Box 1) which states that there might be other phenomena which might interact with

Mercury—such as Vulcan, smaller mercurial bodies or belts of such bodies. But it was actually a quite different theory—Einstein’s general relativity theory—which adequately explained the observed errant movement of Mercury. Moreover, there was no theoretical correspondence between the OUNG theory and Einstein’s general relativity theory.

In analogy, we argue that claiming that AHT cases should include also cases *without* external signs of trauma—which constitute approximately one third (1/3) of all alleged AHT cases (Lynøe & Eriksson, 2018)—is not adequately explained by the OUAHT theory and the derived *infant-must-have-been-shaken-theory*. The alleged AHT cases *with* external signs of trauma (e.g., bruises, ligament injuries or fractures) can, however, perhaps be explained by the *original but restricted* AHT theory. Moreover, we claim that there is no theoretical correspondence between the OUAHT mechanism theory and the more recent *non-shaking baby theory* by Geddes *et al.* which can more adequately explain the alleged AHT cases *without* external signs of trauma (Acres & Morris, 2014).

This more recent mechanism theory was presented in the years 2001-2004 (Geddes, Hackshaw, Vowles, Nickols, & Whitwell, 2001; Geddes, Vowles, Hackshaw, Nickols, Scott, & Whitwell, 2001; Geddes & Whitwell, 2004; Geddes, Tasker, Adams, & Whitwell, 2004). According to this *non-shaken baby* theory it is not reasonable to claim that alleged AHT cases *without* external signs of trauma must have been shaken violently (Geddes, Hackshaw, Vowles, Nickols, & Whitwell, 2001, Geddes, Vowles, Hackshaw, Nickols, Scott, & Whitwell, 2001; Geddes & Whitwell, 2004; Geddes, Tasker, Adams, & Whitwell, 2004; (Lynøe, Juth, & Eriksson, 2019). We suggest that the *infant-must-have-been-shaken-theory* can be compared to the *Vulcan-must-exist-theory* within astrophysics, as applied during the years 1915-1929. Metaphorically we suggest that pediatricians dealing with child abuse currently behave as if they have observed “the pediatric planet Vulcan” and still claim to conduct observations supporting its existence.

But before we further explore relevant similarities and differences between the OUNG theory and the derived *Vulcan-must-exist-theory* on the one hand and the OUAHT theory with the derived the *infant-must-have-been-shaken-theory* on the other, we present some key aspects of the development of the latter.

1.4 The Development of the Original Unrestricted AHT Theory

In 1962 the American pediatrician Henry Kempe and co-workers presented a study concluding that cases of child abuse were often overlooked by pediatricians, indicating underreporting (Kempe, Silverman, Steele, Droegemueller, & Silver, 1962). Apart from fractures, soft tissue swelling and bruises, the authors also suggested that a certain type of intracranial bleeding -subdural hemorrhage (SDH)- was indicative of child abuse. They also stated that SDH was often missed (Kempe, Silverman, Steele, Droegemueller, & Silver, 1962), indicating that child abuse was underreported. The paper had a huge impact in drawing pediatricians’ attention to the issues; thus in 1971 the road was already prepared when the neurosurgeon Norman Guthkelch presented his hypothesis that shaking a baby in a whiplash manner might cause bilateral SDH without external signs of trauma (Guthkelch, 1971).

Guthkelch's hypothesis was further elaborated on by the American pediatrician John Caffey who *reversed* the hypothesis and suggested (abductively) that the finding of SDH and retinal hemorrhages (RH) indicated that the infant had been shaken (Caffey, 1972). According to Caffey, these signs were often observed without external signs of impact to the infants' head. Signs of encephalopathy were later added and the three symptoms and signs—SDH, RH and encephalopathy were referred to as “the triad” (Squier, 2011). The presence of the triad without external signs of trauma has been -and still is- regarded as a very strong indication of violent shaking. In 2018 the triad without external signs of trauma was even described as a “smoking gun” (Brook, 2019).

Experimental studies using bio-mechanical models were conducted in order to examine the forces needed to develop the triad, and indicated that high energy forces are a precondition (Duhaime, Gennarelli, Thibault, Bruce, Margulies, & Wiser, 1987; Duhaime, Gennarelli, Sutton, & Schut, 1988; Duhaime et al., 1992; Prange, Coats, Duhaime, & Margulies, 2003). According to these studies, direct impact on the infant's head will exert ~50 times more force than isolated shaking, indicating that shaking alone might be insufficient for development of the triad (Duhaime, Gennarelli, Thibault, Bruce, Margulies, & Wiser, 1987; Duhaime, Gennarelli, Sutton, & Schut, 1988; Duhaime et al., 1992; Prange, Coats, Duhaime, & Margulies, 2003). Nevertheless, it has been claimed that violent shaking can cause and is a precondition for developing: a) SDH, supposedly caused by rupture of bridging veins (Squier, 2011), b) RH, supposedly caused by cleavage between the vitreous body and the retina (Squier, 2011; Levin, 2009), and c) encephalopathy, supposedly caused by brain injury where nerve fibers are torn apart, resulting in immediate symptoms, thus leaving no room for a so-called *lucid interval* between the suspected violent shaking and the onset of symptoms (Squier, 2011, De Leeuw et al., 2013). Symptoms of encephalopathy include seizures, vomiting, dyspnea, lethargy and unconsciousness.

These three events (a-c) associated with findings of the triad are supposed to take place separately and independently, but are all supposedly caused by the same action: violent shaking. Some studies reported that encephalopathy was rarely observed (Vinchon, de Foort-Dhellemmens, Desurmont, & Delestret, 2010), so the presence of solely SDH and RH (i.e., a “dyad”) has been considered sufficient to conclude that an infant must have been shaken violently, including cases without external signs of trauma (Vinchon, de Foort-Dhellemmens, Desurmont, & Delestret, 2010).

As suggested in biomechanical studies, violent shaking alone is not sufficient for development of the triad (Duhaime, Gennarelli, Thibault, Bruce, Margulies, & Wiser, 1987; Duhaime, Gennarelli, Sutton, & Schut, 1988; Duhaime et al., 1992; Prange, Coats, Duhaime, & Margulies, 2003). In 2020, a Swedish study showed that isolated shaking -even violent shaking- did not result in triad findings in most of the witnessed or video-recorded abused infants (Thiblin, Andersson, Wester, Wikström, Högberg, & Högberg, 2020). Deceleration-forces to the infant's head are also needed, which may result, for example, from a fall or from the impact of the infant's head on a hard surface, resulting in bruises, ligament injuries and/or fractures. In order to discriminate between accidental and intentional (abuse) injuries, certain criteria were developed—also referred to as AHT-predicting tools (Duhaime et al.,

1992; Thiblin, Andersson, Wester, Wikström, Högberg, & Högberg, 2020; Reece & Sege, 2000; Cowley, Maguire, Farewell, Quinn-Scoggins, Flynn, & Kemp, 2018). If an infant presents with the triad and the caregiver claims that the infant fell from a height of less than 3 feet, the caregiver is presumed to be lying. Such a fall is considered trivial and not enough to develop the triad—despite the fact that there are cases where the triad has resulted from witnessed falls from a low height (Gardner, 2007). The caregiver who was with the infant when the symptoms were observed is usually identified as the perpetrator, and some studies focus on identifying the potential perpetrator (De Leeuw et al., 2013; Reece & Sege, 2000; Hettler & Greenes, 2003).

These mechanism theories and the associated criteria are important not only to pediatricians dealing with child abuse and child protection teams making the AHT diagnosis, but also to pediatric researchers who use determination of cases by child protection teams to classify cases *versus* controls in observational studies (Elinder, Eriksson, Hallberg, Lynøe, Sundgren, Rosén, ... Erlandsson, 2018). Such studies are in turn used to corroborate mechanism theories about the triad findings (Lynøe & Eriksson, 2018).

In summary: Although several studies have indicated overdiagnosis of AHT cases (Riggs & Hobbs, 2011; Högberg, Lampa, Högberg, Aspelin, Serenius, & Thiblin, 2018; Andersson & Thiblin, 2018; Lynøe & Eriksson, 2019), child abuse is still purportedly underreported. It is alleged that SDH and RH are often overlooked in cases where there are no external signs of trauma, hence these findings are considered to represent the supposed underreported AHT cases, erroneously justifying the *infant-must-have-been-shaken-theory*.

1.5 Corroborating Theories with Observational Studies

When Le Verrier predicted the position of Neptune and later of Vulcan he sought observational support for his predictions. For Neptune, Le Verrier rapidly obtained support from an independent German astronomer (Baum & Sheehan, 1997; Levinson, 2015). In the search for Vulcan he also sought observational support, but this was initially provided by a local amateur astronomer. Le Verrier's prediction of the position of Vulcan was not as exact as that of Neptune. Nevertheless, over a period of 50 years, dark spots on the solar disk were claimed to have been observed many times by a number of observers—both amateur and professional (Baum & Sheehan, 1997; Levinson, 2015).

In OUAHT research, the observational studies involve epidemiological studies including cohort, case-control, cross-sectional as well as diagnostic accuracy studies. Through a significant number of observational studies, the OUAHT theory has obtained empirical support, particularly in meta-analyses (Maguire, Kemp, Lumb, & Farewell, 2011; Piteau, Ward, Barrowman, & Plint, 2012): hence the OUAHT theory appears to be corroborated and robust. However, the individual clinical studies included in the meta-analyses have been criticized. In particular, a systematic literature review disclosed that the large majority of the individual studies of alleged AHT cases without external signs of trauma are at high risk of bias due to circular reasoning (Lynøe, Elinder, Hallberg, Rosén, Sundgren, & Eriksson, 2017). Circular reasoning in this context implies that determinations of (alleged) AHT

cases by child abuse pediatricians are used by researchers when conducting diagnostic test studies. This means that the diagnostic test and the reference test are not separated and the diagnoses become a self-fulfilling prophecy, as the diagnostic test will almost always be (erroneously) perfect. The “perfect” tests are subsequently assumed to corroborate the theory empirically. Hence, what is supposed to be tested is already taken for granted as true: this constitutes circular reasoning (Lynøe & Eriksson, 2018; Lynøe, Elinder, Hallberg, Rosén, Sundgren, & Eriksson, 2017).

However, the systematic literature review (Lynøe, Elinder, Hallberg, Rosén, Sundgren, & Eriksson, 2017) and its criticism of the circular reasoning issue have also been repeatedly criticized, and in a so-called consensus statement the researchers concerned stated what they consider to be the state of art of AHT literature, including AHT cases without external signs of trauma (Choudhary et al., 2018).

1.6 The Development of a Scientific Controversy

A scientific controversy is defined as “*a persistent antagonistic discussion about a disagreement concerning a substantial scientific issue that is not resolvable by standard means of the discipline involved*” (Freudenthal, 2000). As long as everybody embraced the OUNG theory and the derived *Vulcan-must-exist-theory*, there was no scientific controversy. It was not until 1915, when Einstein presented his general relativity theory, that a controversy emerged. In analogy, when the OUAHT mechanism theory was embraced by all child abuse pediatricians, there was no scientific controversy. It was not until the period between 2001 and 2004, when the English neuropathologist Jennian Geddes and her co-workers presented a completely different mechanism theory, that a scientific controversy emerged (Geddes, Hackshaw, Vowles, Nickols, & Whitwell, 2001; Geddes, Vowles, Hackshaw, Nickols, Scott, & Whitwell, 2001; Geddes & Whitwell, 2004; Geddes, Tasker, Adams, & Whitwell, 2004).

Geddes and coworkers presented studies based on the autopsy results of 37 infants—median age 2.4 months (Geddes, Hackshaw, Vowles, Nickols, & Whitwell, 2001). Twenty-eight exhibited no nerve fiber disruption, but hypoxic changes only. Only two infants, who also had severe impact injuries with skull fractures, had brain damage with torn nerve fibers. Twelve of the 28 infants were triad cases, *without* external signs of trauma (Geddes, Hackshaw, Vowles, Nickols, & Whitwell, 2001; Geddes, Hackshaw, Vowles, Nickols, & Whitwell, 2001; Geddes & Whitwell, 2004; Geddes, Tasker, Adams, & Whitwell, 2004).

Geddes *et al.* proposed that the SDH was caused by global hypoxia, brain swelling and raised intracranial pressure, which also resulted in increased vascular pressure, particularly in the venous system (Geddes, Hackshaw, Vowles, Nickols, & Whitwell, 2001; Geddes & Whitwell, 2004; Geddes, Tasker, Adams, & Whitwell, 2004). It was suggested that the SDH was the result of leakage from small veins and capillaries, not rupture of bridging veins (Geddes & Whitwell, 2004; Geddes, Tasker, Adams, & Whitwell, 2004). Neuroimaging studies supported the hypoxia theory and other research groups have subsequently published studies which support the hypoxia theory (Acres & Morris, 2014; Kemp, Stoodley, Cobley, Coles, & Kemp, 2003; Oehmichen, Schleiss, Pedal, Saternus, Gerling, & Meissner, 2008; Cohen, 2009; Cohen, Sprigg, & Whitby, 2010; Matshes, Evans, Pinckard, Joseph, & Lew, 2011;

Scheimberg et al., 2013; Kadom, Khademian, Vezina, Shalaby-Rana, Rice, & Hinds, 2014; Mack, Squier, & Eastman, 2009; Zahl, Wester, & Gabaeff, 2020).

In 2003 and 2004 Geddes *et al.* focused on a subgroup of deceased infants and fetuses, evidently not exposed to inflicted trauma (Geddes & Whitwell, 2004). They concluded that “the subdural and retinal bleeding in such cases may well have a physiological cause, rather than being caused by trauma”. In other words, violent shaking was no longer necessary to explain triad cases *without* external signs of trauma—so the *infant-must-have-been-shaken-theory* was no longer needed in these cases.

It is important to recall that the OUAHT theory might be correct and applicable in the approximately two thirds of all alleged AHT cases where triad findings are *accompanied* by external signs of trauma (Lynøe & Eriksson, 2018). External signs of trauma can implicate a high energy force which can cause disruption of nerve fibers and immediate onset of symptoms (Duhaime, Gennarelli, Thibault, Bruce, Margulies, & Wisner, 1987; Duhaime, Gennarelli, Sutton, & Schut, 1988; Duhaime et al., 1992; Prange, Coats, Duhaime, & Margulies, 2003). Furthermore, high impact trauma might also result in disruption of bridging veins and SDH (Squier, 2011). The primary question is thus whether the OUAHT theory is applicable to the remaining one-third of alleged AHT cases *without* signs of external trauma (Lynøe & Eriksson, 2018).

2. Comparison of the *Vulcan-Must-Exist-Theory* and the *Infant-Must-Have-Been-Shaken-Theory*

In the following we compare the Original Unrestricted Newtonian Gravitational (OUNG) theory and the derived *Vulcan-must-exist-theory* with the OUAHT theory and the derived *infant-must-have-been-shaken-theory*. We compare the two theories in the light of more recent competing theories—Einstein’s general relativity theory and the non-shaken baby theory by Geddes *et al.* The two original unrestricted theories and their derived theories are compared with respect to different types of crises, the signs and symptoms of such crises, as well as the use of *ceteris paribus*—and closing clauses (see Box 1) and different auxiliary hypotheses and *ad hoc* hypotheses.

Our point of departure is to compare the following two statements:

The observation of the odd movements of Mercury prove -according to the OUNG theory- that Vulcan must exist, independent of what astronomers have actually observed.

The observation of the triad (also without external signs of trauma) proves -according to the OUAHT theory- that the infant must have been violently shaken, independent of the caregiver’s narration.

In order to scrutinize further our thesis about the analogies between the OUNG theory and the OUAHT theory, let us first focus on the implications of the two more recent alternative theories: Einstein’s general relativity theory and the non-shaken baby theory by Geddes *et al.*

2.1 The Implications of Einstein’s Theory

Despite the fact that Einstein’s theory was corroborated by Eddington and Dyson in 1919, observations of Vulcan continued for at least another ten years. The *Vulcan-must-exist-theory* was, however, eventually rejected and abandoned after a solar eclipse in 1929 when astronomers found no sign of

Vulcan or any other objects inside the mercurial orbit. Most researchers realized that searching for Vulcan was a dead end: scientific interest in Vulcan faded away, as did the scientific controversy (Baum & Sheehan, 1997; Levinson, 2015; Kennefick, 2019). The effect of Einstein's theory was also that Newtonian physics was no longer considered to be unrestricted but still valid and applicable when describing gravitation, such as the interaction between Uranus and Neptune, as well as between any bodies that have mass (Levinson, 2015).

Einstein's general relativity theory not only added something new to astrophysics—it also, eventually, resulted in a new and fruitful research area. Einstein's theory led to a new and productive research program, first during the mid-1950's when observation of quasars and pulsars eventually led to the development of theories about black holes (Levinson, 2015; Kennefick, 2019; Thorne, 1995).

2.2 *Implications of the Non-Shaken Baby Theory by Geddes et al.*

The publications by Geddes and coworkers during 2001-2004 presented a new mechanism theory which made the *infant-must-have-been-shaken-theory* unnecessary in triad cases *without* external signs of trauma (Geddes, Hackshaw, Vowles, Nickols, & Whitwell, 2001; Geddes, Vowles, Hackshaw, Nickols, Scott, & Whitwell, 2001; Geddes & Whitwell, 2004; Geddes, Tasker, Adams, & Whitwell, 2004). Although this non-shaken baby theory received support from a range of different studies (Acres & Morris, 2014; Squier, 2011; Kemp, Stoodley, Cobley, Coles, & Kemp, 2003; Oehmichen, Schleiss, Pedal, Saturnus, Gerling, & Meissner, 2008; Cohen, 2009; Cohen, Sprigg, & Whitby, 2010; Matshes, Evans, Pinckard, Joseph, & Lew, 2011; Scheimberg et al., 2013; Kadom, Khademian, Vezina, Shalaby-Rana, Rice, & Hinds, 2014; Mack, Squier, & Eastman, 2009; Zahl, Wester, & Gabaeff, 2020), it was heavily criticized and is still ignored by large sections of the medical community concerned (Choudhary et al., 2018; Punt, Bonshek, Jaspan, McConachie, Punt, & Ratcliffe, 2004; Richards et al., 2006; Jenny, 2014; Supreme Court of Judicature Court of Appeal (Criminal Division), n.d.; Strouse, 2016).

There are, however, signs that non-shaken baby theories by Geddes *et al.* and by others might introduce a range of fruitful research areas (Acres & Morris, 2014; Lynøe, Juth, & Eriksson, 2019; Mack, Squier, & Eastman, 2009; Zahl, Wester, & Gabaeff, 2020). We suggest that the non-shaken baby theories could have a similar effect on the OUAHT theory and the derived the *infant-must-have-been-shaken-theory* as did Einstein's general relativity theory combined with Eddington's and Dyson's observational support upon the OUNG theory and the derived *Vulcan-must-exist-theory*.

2.3 *The Reception of the Theories by Einstein and Geddes et al.*

There were discrepancies in how the two theories and the supporting observations were received. The reception of Einstein's general relativity theory was somewhat hesitant, if not reluctant, among the majority of physicists and philosophers, but not among the few who actually understood the theory, such as Arthur Eddington.

Although the non-shaken-baby-theory by Geddes *et al.* was positively received by a minor group of pediatric neuropathologists, the attitudes of the large majority of child protection clinicians and

scientists were negative or ignorant. Pediatric researchers criticized (Punt, Bonshek, Jaspán, McConachie, Punt, & Ratcliffe, 2004; Richards et al., 2006; Jenny, 2014) and still criticize the theory (Choudhary et al., 2018; Jenny, 2014; Strouse, 2016). This non-shaken baby theory has even been banned in UK courtrooms and classified as a “premature hypothesis” (Supreme Court of Judicature Court of Appeal (Criminal Division), n.d.)! Consequently, the non-shaken baby theory has generally been denied or ignored (Choudhary et al., 2018; Strouse, 2016).

When empirical observations were conducted to test Einstein’s general relativity theory and the non-shaken baby theory by Geddes *et al.*, the corroborating studies were also received differently. Einstein’s general relativity theory was supported by observations, although Eddington’s and Dyson’s analyses of the photographic plates were later questioned (Kennefick, 2019). Actually, Eddington’s and Dyson’s photographic plates were not finally corroborated until 1979 (Kennefick, 2019; Harvey, 1979). But even in 1981, Earman and Glymour questioned whether Eddington was biased when he analyzed the photographic plates (Earman & Glymour, 1981). It should also be noted that when Einstein received the Nobel Prize in 1921 it was demonstratively *not* for his general relativity theory, but for the law of the photoelectric effect (Hansson, 2017). Currently, there might still exist a small number of denialists of the general relativity theory (Hansson, 2017), but today the large majority of physicists find the theory not only corroborated—it has become a very fruitful theory within modern astrophysics (Thorne, 1995).

Despite the fact that post mortem examinations of fetuses who died *in utero* (and obviously were never shaken) supported the hypoxia-brain-swelling-high-intracranial-pressure-cascade theory (Geddes, Vowles, Hackshaw, Nickols, Scott, & Whitwell, 2001; Geddes & Whitwell, 2004; Geddes, Tasker, Adams, & Whitwell, 2004), this was never generally accepted among the pediatric researchers concerned.

Einstein’s general relativity theory was eventually accepted, but there was also resistance to the theory, for both scientific and non-scientific reasons: there was reluctance to question Newton’s gravitational theory and in 1930’s Germany there was anti-semitism. In relation to Newton’s gravitational theory, Einstein’s general relativity theory represented a scientific revolution. In analogy, the non-shaken baby theory might also represent a scientific revolution, at least for triad cases without external signs of trauma. Both theories were initially denied and the criticism of the Eddington-Dyson observations continued even after a computerized reanalysis corroborated their observations (Kennefick, 2019; Harvey, 1979). It was probably the accumulation of observational support and the fruitfulness of the general relativity theory which eventually led to its acceptance by the large majority of physicists—but this lasted at least one whole generation of physicists. The reception of the non-shaken baby theory was rather hostile, even though independent researchers have supported the theory. We do not yet know the fate of this theory; we may have to wait a further generation before the pediatric clinicians and researchers concerned will accept the non-shaking baby theory and abandon the *infant-must-have-been-shaken-theory*.

We now turn to different types of crises and types of auxiliary hypotheses which might occur within a scientific research program under circumstances associated with the *Vulcan-must-exist-theory* and the *infant-must-have-been-shaken-theory*.

3. Signs of Fundamental Crises and Use of Different Auxiliary- and ad hoc Hypotheses

The predicted position and movement of Vulcan was rather difficult to corroborate by observations. This in turn might have indicated that the *Vulcan-must-exist-theory* was inadequate. Under such circumstances it can be reasonable to develop certain auxiliary hypotheses including *ceteris paribus clauses*, to specify initial conditions when conducting observations, as well as using *closure clauses*; it might even be reasonable to develop *ad hoc hypotheses* (see Box 1). Doing so is not dubious or a sign of a scientific crisis—such procedures might be part of the normal scientific process when testing theories. However, auxiliary hypotheses, initial conditions and closure clauses might be true, truth-like, or false. An accumulation of false assumptions can indicate a fundamental crisis.

In the subsequent text we compare the OUNG theory and the derived *Vulcan-must-exist-theory* with the OUAHT theory and the *infant-must-have-been-shaken-theory*, with reference to the use of auxiliary hypotheses, initial conditions and closure clauses. The definitions of the concepts used are presented in Box 1.

One *ceteris paribus clause* about the OUNG theory was that planets or smaller heavenly bodies might interact with Mercury, thus making the *Vulcan-must-exist-theory* plausible, in analogy with the Uranus-Neptune interaction.

An example of an auxiliary hypothesis was the examination of black spots observed on the solar disk during the period 1762-1852. These black spots were later interpreted as Vulcan-like and the different sizes and colours of the suspected Vulcan-like phenomena might be understood as an *initial condition* issue—e.g., a refraction phenomenon (see Box 1).

Another example of an *initial condition* issue is that it was difficult to observe a heavenly body (e.g., Vulcan) or belts of heavenly bodies close to the sun. Moreover, heavenly bodies can move in an irregular manner and under certain occasions become invisible (Harvey, 1979)—an example of an *ad hoc hypothesis* (see Box 1).

Certain *initial conditions* were probably related to technical issues associated with the suboptimal astronomical devices available during the period 1850-1919.

A closure clause (see Box 1) related to the OUNG theory was that light was supposed to be unaffected by gravitation—all other relevant conditions that might be influenced by gravitational forces were excluded, e.g., the notion that even light might be affected by gravity (Table 1).

As it was difficult to question the OUNG theory as a universal theory, supporters of the *Vulcan-must-exist-theory* had three possible options: (i) continue conducting observational studies and hope that they would eventually be able to corroborate the *Vulcan-must-exist-theory* (Harvey, 1979; Levinson, 2015), or (ii) develop more speculative auxiliary and *ad hoc* hypotheses that could explain

why the observations of Vulcan were irregular, unpredictable, complicated or impossible (Johansson & Ceteris Paribus Clauses, Closure Clauses and Falsifiability, 1980), or (iii) classify the odd Mercury movements as a scientific anomaly in the Newtonian clockwork universe and learn to live with these anomalies without rationalizing them with, *e.g.*, *ad hoc* hypotheses (Johansson & Lynøe, 2008).

A scientific paradigm might be born, live and die with its anomalies, but generally, signs of a fundamental crisis are, among others, that (i) scientific anomalies become more and more problematic, not only quantitatively but also qualitatively, (ii) several auxiliary hypotheses and essentially defensive *ad hoc* hypotheses are proposed in order to either make exceptions, help or obscure observational anomalies, and (iii) competing theories have been developed—theories that can provide more plausible explanations or undermine what are currently accepted as the basic theoretical assumptions (Johansson & Lynøe, 2008).

When Einstein presented his general relativity theory in 1915, the curvature of spacetime due to huge gravitational fields became a plausible explanation of Mercury's odd movements. If Einstein's theory was actually correct, the *Vulcan-must-exist-theory* became superfluous. This state of affairs also became a sign of a fundamental crisis for the universalized Newtonian gravitational theory.

Similarly, within the OUAHT theory and the associated research program we can identify several signs of a fundamental crisis.

The non-shaken baby theory by Geddes *et al.* was presented during 2001-2004, pointing out that violent shaking is not necessary for the development of the isolated triad (Geddes, Vowles, Hackshaw, Nickols, Scott, & Whitwell, 2001; Geddes & Whitwell, 2004; Geddes, Tasker, Adams, & Whitwell, 2004). Moreover, Geddes *et al.* demonstrated that there were no torn nerve fibers in isolated triad cases (Geddes, Hackshaw, Vowles, Nickols, & Whitwell, 2001; Geddes, Vowles, Hackshaw, Nickols, Scott, & Whitwell, 2001). Instead, it was suggested that the encephalopathy symptoms resulted from hypoxia, brain-swelling and increased intracranial pressure cascade theory, which contradicted the OUAHT theory. In 2010, Dr Squier presented a paper in which she demonstrated and specified several anomalies and paradoxical phenomena in the *infant-must-have-been-shaken-theory* (Squier, 2011), all indicating signs of a fundamental crisis. Dr Squier asked, for example, why SDH in alleged AHT cases are thin-film and bilateral; if the source of bleeding really was a disrupted bridging vein, a large, space occupying, localized unilateral hemorrhage would be expected (Squier, 2011)—but this is paradoxically not what is found in these cases (Lynøe, Juth, & Eriksson, 2019). Further, if violent shaking according to the OUAHT theory is supposed to result in disrupted nerve fibers, why are such brain injuries identified only in triad cases which also have external signs of trauma? If violent shaking without external signs of trauma causes nerve fiber injury, disrupted bridging veins, SDH and RH, such forces would probably also result in other injuries, *e.g.*, bruises, ligament injuries and/or skull fractures, which are not found in isolated triad cases. Indeed, we would expect such injuries to occur due to violent shaking *before* disruption of nerve fibers and bridging veins. This also represents a paradoxical phenomenon (Lynøe, Juth, & Eriksson, 2019).

3.1 Anomalies and Auxiliary Hypotheses

In order to protect the OUAHT theory and the *infant–must-have-been-shaken-theory* from troublesome anomalies, the advocates have developed *auxiliary hypotheses*, *initial conditions*, *closure clauses* and *ad hoc hypotheses* (Johansson & Ceteris Paribus Clauses, Closure Clauses and Falsifiability, 1980; Lynøe, Juth, & Eriksson, 2019). Necessary *auxiliary hypotheses* and *closure clauses* -which can also become *ad hoc*- include: (i) An isolated triad cannot develop spontaneously = an *ad hoc hypothesis*. (ii) If *known medical conditions or diseases* have been excluded, the only remaining cause is traumatic shaking = an *ad hoc closure clause*. As biomechanical studies have indicated that shaking alone -even violent shaking- is insufficient to cause the triad, an additional, auxiliary hypothesis has been formed: (iii) The only acceptable explanation in isolated triad cases is that the infant has been violently shaken and if this is questioned, then violent shaking has been combined with slamming the infant's head against a padded surface, which does not result in external signs of trauma = an *auxiliary hypothesis*. (iv) No unknown causes bring about the isolated triad = an *ad hoc closure clause*. (v) The incidence of alleged AHT cases is underreported = an *auxiliary hypothesis*. (vi) If the caregiver can provide no "acceptable" explanation as to why the infant exhibits the isolated triad, the caregiver is hiding something and accordingly lying = an *ad hoc hypothesis*. (vii) If the caregiver states that the infant was actually shaken, but as an attempt at resuscitation, such a claim is considered impossible. As an effect cannot precede the cause, the caregiver must be lying = an *ad hoc hypothesis* (Johansson & Ceteris Paribus Clauses, Closure Clauses and Falsifiability, 1980; Lynøe, Juth, & Eriksson, 2019). (viii) An example of an initial condition issue is the use of a child protection team's determination of alleged AHT cases, despite the obvious and well-known risks of circular reasoning and thus high risk of bias (Lynøe & Eriksson, 2018) (see Box 1).

3.2 Auxiliary Hypotheses, Initial Conditions and Closure Clauses

The auxiliary hypotheses, the initial conditions and the closure clauses might be true, truth-like, or false (Table 1). Although several of the hypotheses and clauses presented might appear reasonable, they are actually false, *e.g.*, the claim that *all* known medical conditions are excluded. Does this mean that there are no new conditions or diseases still to be discovered, or that medical conditions which currently have no known etiology or pathogenesis will remain unexplained and become unexplainable forever? Several medical conditions are still, or have previously been, unexplained. A related example is the *sudden and unexpected infant death syndrome*, an unexplained medical condition with a peak incidence similar to all alleged AHT cases (Hansson, 2017; Squier & Mack, 2016; Parks, Kegler, Annet, & Mercy, 2012; Parks, Sugeman, Xu, & Coronado, 2012; Lynøe, n.d.; Duncan & Byard, 2018; Lynøe & Eriksson, 2020). Initially, in cases of Sudden Infant Death Syndrome (SIDS), parents were accused, but as there are no signs of trauma or impact, the caregiver is no longer suspected of foul play (Duncan & Byard, 2018; Lynøe & Eriksson, 2020).

In other words, the *ad hoc* closure clause, that all relevant medical conditions have been excluded, is certainly false. This is supported by the non-shaken baby theory by Geddes *et al.* and the theory about

benign external hydrocephalus (Geddes, Vowles, Hackshaw, Nickols, Scott, & Whitwell, 2001; Geddes & Whitwell, 2004; Geddes, Tasker, Adams, & Whitwell, 2004; Zahl, Wester, & Gabaeff, 2020).

Finally, claims that a caregiver is lying if he/she cannot explain why the infant has developed the triad signs and symptoms may seem reasonable—but only if the OUAHT theory with all its *ad hoc* hypotheses and clauses are presupposed to be true, or at least truth-like. They are, however, contradicted by biomechanical studies, as well as by several non-shaken baby theories, which indicate that the triad might develop spontaneously, or represents the sequelae of a delivery-associated SDH (Zahl, Wester, & Gabaeff, 2020). In other words, in triad cases *without* signs of external trauma, no obvious events have necessarily occurred prior to the infant’s collapse. If the caregiver claims that the infant was actually shaken, but only *after* the onset of symptoms, this might be correct. Accordingly, these auxiliary hypotheses are also false (Table 1).

Table 1. Comparison of the Vulcan-Must-Exist-Theory and the Infant-Must-Have-Been-Shaken Theory with Reference to the Use of Different Hypotheses, Conditions and Clauses. The First Three Issues Might Be True, Truth-like, or False; + Indicates How often Hypotheses, Conditions and Clauses Appear in the Present Context. One Issue Can Appear Twice, e.g., Initial Conditions and Closure Clauses Can also Become ad hoc Hypotheses

	Vulcan-must-exist-theory	Infant-must-have-been-shaken-theory
	<i>After 1919</i>	<i>After 2004</i>
Auxiliary hypotheses:		
True		
Truth-like		
False	++	+++
Initial conditions:		
True		
Truth-like		
False	+++	+
Closure clauses:		
True		
Truth-like		
False	+	++++
Ceteris paribus clauses	+	-
Ad hoc hypotheses	++	++++++

In summary, we identified new, competing non-shaken baby theories and the existence of a scientific controversy; we have pointed out several anomalies and paradoxical phenomena, as well as false *auxiliary hypotheses*, false *initial conditions* and false *closure clauses*. The presence of the many false hypotheses, conditions and closure clauses indicates that both theories suffer from a fundamental crisis (Table 2). Moreover, both theories illustrate that because of anomalies and the different types of *auxiliary* and *ad hoc hypotheses*, clauses and conditions, it is as difficult to falsify a theory as it is to verify it (Johansson & Ceteris Paribus Clauses, Closure Clauses and Falsifiability, 1980).

We identified one additional *ad hoc hypothesis* associated with circular reasoning. However, because the associated tests will not reveal new knowledge, this hypothesis is associated merely with stagnation. This is in turn a sign of another type of crisis: *the senility crisis*.

3.3 The Senility Crisis

The Hungarian philosopher Imre Lakatos has described how a scientific *research program* degenerates if the scientists concerned are unable to rethink the program (Lakatos, 1970). Lakatos contrasts such tendencies to progressive and fertile scientific research programs. The Danish philosopher Stig Andur Pedersen, who further developed Lakatos' ideas and the Kuhnian crisis concept (Andur Pedersen, 1976; Kuhn, 1970), suggested that apart from a fundamental crisis about basic theoretical assumptions, it is also possible to identify a *senility crisis* and a *responsibility crisis* (Andur Pedersen, 1976).

According to Andur Pedersen, a senility crisis can be characterized by: (i) stagnation and degeneration of creativity and (ii) focusing on defensive strategies. In accordance with Pedersen's reasoning, we have added: (iii) circular reasoning (this can be considered a defensive strategy, *i.e.*, using non-scientific methods to defend the theory).

3.3.1 Stagnation and Degeneration of Creativity

(I) Within a research program means that new ideas and promising theories are rejected, neglected or ignored and not developed or properly tested (Lynøe & Eriksson, 2020; Lakatos, 1970). This seems to characterize both the *Vulcan-must-exist-theory* and the *infant-must-have-been-shaken-theory*. Instead of reflection and reconsideration the focus might be on routine research -“business as usual”- and the creativity will be limited to developing defensive auxiliary hypotheses and *ad hoc* hypotheses. Research on both the *Vulcan-must-exist-theory* and the *infant-must-have-been-shaken-theory* ignored and ignore, respectively, new theories that might develop new foci, create new frameworks for interpretations and development of methods, research areas and studies. For almost 70 years (1860-1929)—the *Vulcan-must-exist-theory*, and during 2004-2020 the *infant-must-have-been-shaken-theory* and the associated research programs seem to suffer from stagnation, not only lack of creativity. Here is a difference—the *Vulcan-must-exist-theory* was derived from Newton's gravitational theory, whereas the *infant-must-have-been-shaken-theory* is derived from an unsubstantiated theory, far from the mathematical power of the Newtonian gravitational theory. It is understandable that abandoning Newton's theory was difficult, but why the Kempe-Guthkelch-Caffey based AHT theory still attracts many advocates is difficult to understand. Nevertheless, proponents of

both theories seem to be interested only in research which can support and defend their preferred theory (Baum, R., & Sheehan W., 1997; Levinson, 2015; Kennefick, 2019; Lynøe, Juth, & Eriksson, 2019).

3.3.2 Defensive and Preserving Strategies

(II) Another sign of a senility crisis is that a research program does not focus on issues which are relevant or which are in conflict with the basic theoretical assumptions. Instead, the research program will focus on defending and preserving strategies. Both the *Vulcan-must-exist-theory* and its associated research program and the *infant-must-have-been-shaken-theory* research program have provided several defensive and speculative auxiliary and *ad hoc* hypotheses. Within the *Vulcan-must-exist-theory*, the claim that the intra-mercurial bodies might be *invisible* seems to be the ultimate defensive *ad hoc* hypothesis. If this *ad hoc* hypothesis were to be taken seriously we would neither be able to support nor question the existence of Vulcan (Johansson & Ceteris Paribus Clauses, Closure Clauses and Falsifiability, 1980). Moreover, if Vulcan or other mercurial bodies were so small (or had other properties) that they could not be observed, the size of Vulcan would not be sufficient to produce the gravitation pull on Mercury and hence explain its odd movements—unless other *ad hoc* hypotheses were produced.

Under the *infant-must-have-been-shaken-theory* we identified several defensive auxiliary and *ad hoc* hypotheses intended to defend and preserve the OUAHT and the *infant-must-have-been-shaken-theory*, and protect it from criticism (Parks, Sugeman, Xu, & Coronado, 2012). If we assume that it is correct that whatever the caregiver's version of events in isolated triad cases, the caregiver is assumed to be lying unless he/she admits to having shaken the infant, then it will also become impossible to question the *infant-must-have-been-shaken-theory*.

3.3.3 Circular Reasoning

(III) If the OUAHT theory is applied by a child protection team to diagnose isolated triad cases as AHT cases, and this diagnostic procedure is subsequently applied to classify allegedly true AHT cases in clinical studies, then the *infant-must-have-been-shaken-theory* will apparently become corroborated, as will the OUAHT theory. Hence, the theory becomes a self-reinforced, self-fulfilling prophecy based on circular reasoning (Lynøe & Eriksson, 2018).

Under the *Vulcan-must-exist-theory*, circular reasoning can appear in the following way: if the OUNG theory is correct, the planet Vulcan must exist. By means of the OUNG theory we might presuppose and predict the orbit and position of Vulcan as a mathematical necessity. If a number of observations indicate various black spots or objects with a range of positions and velocities, it could be assumed that the observations which do not follow the predictions for Vulcan are false, whilst those which do follow the predictions are true. Even though the observations are *prima facie* of equal quality, those observations which follow the predictions could be used to prove that the predictions were true. So you have used the prediction to select which observations to retain and which to reject, and then used the retained observations to prove the prediction! Accordingly, what is supposed to be demonstrated by observational studies is already taken for granted as truth. As suggested by Eddington, corroboration of

theories based on circular reasoning is like the sculptor who claims that the head he is going to carve out of a marble stone is already pre-shaped in the stone; when he carves out the head-Eureka! —he has proved that the head was indeed pre-shaped in the stone (Eddington, 2012). According to Eddington, this kind of reasoning is common in astrophysics. If circular reasoning is accepted and applied in science in the described manner, there is a high risk that the research programs concerned will not create new knowledge and the research results will become futile.

So far there seem to be several similarities with reference to the fundamental crisis and the senility crisis between, on the one hand, the OUNG theory and the derived *Vulcan-must-exist-theory* and on the other hand, the OUAHT theory and the derived the *infant-must-have-been-shaken-theory* (Table 2).

Table 2. Similarities and Differences between the Original Unrestricted Newtonian Gravitation Theory and the Derived Vulcan-Must-Exist-Theory, and the Original Unrestricted AHT Theory and the Derived the Infant-Must-Have-Been-Shaken-Theory regarding Signs of Scientific Crises

+ means that the signs of crisis are present; – means that such signs are lacking.

	<i>Vulcan-must-exist-theory</i> (1919-1929)	<i>Infant-must-have-been-shaken-theory</i> (2004-2020)
Signs of fundamental crisis		
Presence of competing theories +	+	+
Several false auxiliary hypotheses	+	+
Ignoring anomalies	+	+
Ignoring paradoxical phenomena	+	+
Ignoring alternative theories	+	+
Signs of senility crisis		
Lack of new ideas/stagnation	+	+
Focus on preserving strategies	+	+
Circular reasoning research	+	+
Theories become dogmas	+	+
Signs of responsibility crisis		
Undesirable consequences	-	+
Undesirable societal consequences	-	+

Undesirable legal consequences	-	+
Denialism and burnout	-	+

We now turn to the last proposed type of scientific crisis: the *responsibility crisis*.

3.4 Responsibility Crisis

A responsibility crisis might occur when the results of a scientific research program have significant and undesirable societal consequences (Andur Pedersen, 1976). During the 1940's, scientists in the field of quantum physics found themselves in a deep responsibility crisis. Progressing from theoretical reasoning to concrete application in the Manhattan project was a big leap and resulted in huge consequences for mankind. When the nuclear bombs were dropped on Hiroshima and Nagasaki, several prominent scientists felt responsible and left the program.

In the context of concerned development of astrophysics there were no direct societal or legal consequences. The fact that Eddington and Dyson as well as the Royal Astronomical Society in London endorsed Einstein's general relativity theory probably sent signals that within the astrophysical sciences, peace between Germany and Great Britain was now declared (Kennefick, 2019). Both Einstein and Eddington were pacifists and might both have appreciated the fact that scientists from Great Britain – one of the important victors in WWII—acknowledged that Einstein, a German researcher, had dethroned Newton, one of Great Britain's most prominent physicists. It might have been this signal that made Einstein a scientific celebrity in the media (Kennefick, 2019). But this is the only consequence and it does not result in a responsibility crisis.

This is in contrast to the situation in the field of OUAHT research, including the *infant-must-have-been-shaken-theory*. In 2012 Guthkelch re-evaluated and clarified his 1971 hypothesis that shaking an infant might result in an SDH, as he began to feel responsible for having facilitated the imprisonment of innocent parents (Guthkelch, 2012). Drs Waney Squier, Julie Mack and Martha Cohen might also have suffered from a responsibility crisis when -following the presentation of the non-shaken baby theory by Geddes *et al.*- they converted from appearing as expert witnesses for the prosecution, to expert witnesses for the defence (Squier, n.d.; Lynøe, n.d.). Like Guthkelch and later Dr Patrick Barnes, they became aware of the legal and societal ramifications that ensued because of the doubts being raised about the diagnostic accuracy of the isolated triad findings for determining that an infant must have been shaken violently (Barnes, 2017).

3.4.1 Responsibility Crisis and Social Consequences

Those who still embrace the *infant-must-have-been-shaken-theory* may of course also eventually experience a responsibility crisis, once they begin to doubt the theories. A recently published study showed that child abuse clinicians suffer from so-called secondary traumatic stress associated with burnout (Hymel, 2019). Could this burnout be caused by uncertainty and doubt after diagnosing triad cases without external signs of trauma as AHT and the consequences became obvious, such as

unnecessary removal of infants, splitting up of families and sentencing innocent caregivers to prison (Guthkelch, 2012; Squier, n.d.)? If the number of wrongful diagnoses and wrongful convictions in isolated triad cases could be minimized, burnout might decrease (Passmore, Hemming, Chancellor McIntosh, & Hellman, 2020; Lynøe & Eriksson, 2020). Another reason for burnout might be the dilemma that child abuse clinicians have a responsibility to protect infants and it is mandated that the welfare of the infant takes precedent. But this precedence leads to a loss of objectivity. The clinicians do not want to feel responsible for having missed an abuse diagnosis which leads to embracing the diagnosis, rather than questioning it and scrutinizing it.

Because the Vulcan theory had no negative societal or legal consequences, no responsibility crisis occurred among the scientists concerned. A responsibility crisis is expressed solely in the *infant-must-have-been-shaken-theory*. The responsibility issue is probably also more clearly expressed in pediatrics, at least compared to astrophysics. The majority of pediatricians practice as clinicians rather than as scientists, and hence have limited or no scientific experience and are probably unable to identify scientific fallacies. Some pediatricians who actually have scientific training but also work as clinicians, can also have difficulty in transitioning from the clinical to the scientific setting—and even more so in transitioning from the clinical to the legal setting—and accordingly behave as clinicians in all three settings (Lynøe & Eriksson, 2019).

Within astrophysics the large majority of the physicists are, on the contrary, scientists and a corresponding problem consequently does not occur in this field.

4. Discussion

Obviously there are differences between the two scientific areas—the OUNG theory with the derived *Vulcan-must-exist-theory* and the OUAHT theory and the derived the *infant-must-have-been-shaken-theory*. Newton based his theories on observations, mathematics and thought experiments—standing on the shoulders of *i.a.* Galileo Galilei and Johannes Kepler—and the theory was corroborated by telescopic observations and measurements. Similarly, Einstein based his general relativity theory on mathematics and thought experiments, in order to explain observations which contradicted the accepted theories of the time—standing on the shoulders of other scientists such as Newton, Kepler, Riemann, Maxwell and Lorenz.

The OUAHT theory was initially based on case studies—on the assumptions launched by Kempe, Guthkelch and Caffey—and eventually extrapolated into biomechanical models and experiments: it was apparently supported by observational studies. However, as illustrated, the large majority of these observational studies were biased (Lynøe & Eriksson, 2018). Evidence-based systematic literature reviews have shown that the observational studies and the diagnostic accuracy studies of allegedly shaken baby cases *without* external signs of trauma are biased: mainly due to circular reasoning but also due to a number of other methodological shortcomings (Donohoe, 2003; Elinder, Eriksson, Hallberg, Lynøe, Sundgren, Rosén, ... Erlandsson, 2018).

One reason why circular reasoning in AHT diagnostics was possible was that *pediatric researchers* accepted child abuse clinicians' determination of alleged AHT cases without external signs of trauma to determine true positive AHT cases—*i.e.*, as a *reference test*. Child abuse clinicians are not necessarily scientifically trained, which impedes a critical reflective attitude to their own practice and could make it difficult to acknowledge that current knowledge is fallible (Johansson & Lynøe, 2008). A pediatric researcher is supposed to embrace a scientific attitude, including being critical of one's own assumptions and theories. Accordingly, a clinical researcher would have been expected to abstain from accepting the child abuse clinicians' determination of alleged AHT cases as a *reference test*. But such a scientific approach seems to decrease or disappear when it comes to child abuse, and pediatric researchers have, contrary to *e.g.*, astrophysicists, found it difficult to retreat to the “scientific ivory tower” and discipline their subjectivity (Lynøe & Eriksson, 2019).

4.1 Philosophy of Science Similarities

Despite the differences, astrophysics and medical science also have several common denominators with respect to philosophy of science. This becomes apparent when comparing, on the one hand the OUNG theory and the derived *Vulcan-must-exist-theory* with, on the other hand, the OUAHT mechanism theory and the derived *infant-must-have-been-shaken-theory*. First of all, both cases illustrate that observations, analyses and interpretations are *theory impregnated*. Moreover, there are several similarities with respect to anomalies and the different applied auxiliary hypotheses, as well as the signs of a fundamental crisis and a senility crisis.

Because of the lack of legal and societal consequences of the *Vulcan-must-exist-theory*, it is only in the *infant-must-have-been-shaken-theory* that we can identify a responsibility crisis. We suggest that the legal and societal consequences explain why the non-shaking baby theory by Geddes *et al.* is not yet accepted, and that the OUAHT theory has not yet been restricted to alleged AHT cases *with* external signs of trauma and impact.

The non-shaken baby theory was presented in 2001-2004 and introduced new and different explanations of alleged AHT cases *without* external signs of trauma and impact. Although Einstein's general relativity theory is much more complicated, the function of the non-shaken baby theory was in principle rather similar. The non-shaken baby theory made it possible to rethink the brain injury (as torn nerve fibers) theory as well as the sources of the SDH and the RH. Moreover, this theory also made the *infant-must-have-been-shaken-theory* superfluous, at least with respect to triad cases *without* external signs of trauma. The work of Geddes and coworkers also paved the way for a new and fruitful research program for isolated triad cases. Unfortunately, however, the *infant-must-have-been-shaken-theory* has not yet been abandoned. The possibility to rethink, revise and develop the research program was never taken seriously, but has on the contrary been largely ignored (Choudhary *et al.*, 2018; Punt, Bonshek, Jaspán, McConachie, Punt, & Ratcliffe, 2004; Richards *et al.*, 2006; Jenny, 2014). The proponents of the *infant-must-have-been-shaken-theory* behave as if they were still searching for the “pediatric

Vulcan planet”—but without the support of a Newtonian gravitational theory. The Kempe-Guthkelch-Caffey theory is based merely on anecdotal evidence and assumptions.

4.2 *The Reception of the Theories*

The reception of the non-shaken baby theory by Geddes *et al.* may be understood as analogous to a scenario in which Einstein’s general relativity theory was ignored and/or denied when it was presented in 1915 and thus never corroborated. We suggest that the lack of interest in rethinking and revising the OUAHT theory may be attributable to concerns over the clinical, legal and societal consequences of acceptance of the non-shaken baby theory. If child abuse pediatricians and other clinicians concerned were to admit that the non-shaken baby theory is actually more plausible than the OUAHT theory, at least in triad cases *without* external signs of trauma, they would probably feel responsible for not having acted in the best interests of the infant; instead they would feel responsible for unwarranted splitting of families, unwarranted removal of infants and siblings, and for having contributed to the conviction of innocent caregivers. This might already present a problem for at least some neuropathologists and probably also some child abuse pediatricians (Passmore, Hemming, Chancellor McIntosh, & Hellman, 2020; Lynøe & Eriksson, 2020).

The general relativity theory eventually brought about an interesting and fruitful research program (Kennefick, 2019; Thorne, 1995). Compared to the research related to the *infant-must-have-been-shaken-theory*, the non-shaken baby theory might also bring about interesting and fruitful new foci and research programs. However, it may be necessary to await a generational change, following the retirement of those who believed that they were acting in the best interests of the child and its family, but were not (Lynøe & Eriksson, 2020).

4.3 *Concluding Remarks*

Although astronomy and medicine are quite different research areas, both use observations to corroborate theories. Both theories discussed here illustrate that observations are theory impregnated. Although the societal consequences are different, there are several similarities between, on the one hand, the controversy between the original unrestricted Newtonian gravitational theory and the derived *Vulcan-must-exist-theory*, versus Einstein’s general relativity theory and, on the other hand, the controversy between the original unrestricted AHT theory and the derived *the infant-must-have-been-shaken-theory*, versus *the non-shaken baby theory*. As both *the infant-must-have-been-shaken-theory* and the non-shaken theory may have considerable legal and societal consequences, it is solely within this area that scientists might suffer a responsibility crisis. When comparing research about the *Vulcan-must-exist-theory* and the *infant-must-have-been-shaken-theory*, both fundamental and senility crises seem to be almost equal, in terms of signs of crisis such as anomalies, paradoxical phenomena, false auxiliary hypotheses, and debatable *ad hoc* hypotheses.

In analogy with the introduction of Einstein’s general relativity theory, which made the *Vulcan-must-exist-theory* superfluous, and the fact that the latter theory was subsequently abandoned,

we suggest that the introduction of the non-shaken baby theory will make the *infant-must-have-been-shaken-theory* superfluous and should therefore be abandoned, regarding the alleged AHT cases *without* external signs of trauma. But because of ethical concerns and a motivation to protect infants -even when no abuse has taken place- we estimate that it will take at least one or two more generations of pediatricians before the *infant-must-have-been-shaken-theory* will finally be abandoned. Until then, we will likely witness pediatric researchers, assisted by child abuse pediatricians, continuing the futile search for a “pediatric planet Vulcan”—but instead of standing on Newton’s shoulders, standing on Kempe’s-Guthkelch’s-Caffey’s shoulders.

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References

- Acres, M., & Morris, J. A. (2014). The pathogenesis of retinal and subdural haemorrhage in non-accidental head injury in infancy: Assessment using Bradford Hill criteria. *Medical Hypotheses*, 82, 1-5. <https://doi.org/10.1016/j.mehy.2013.09.017>
- Andersson, J., & Thiblin, I. (2018). National study shows that abusive head trauma mortality in Sweden was at least 10 times lower than in other Western countries. *Acta Paediatr*, 107(3), 477-483. <https://doi.org/10.1111/apa.14138>
- Andur Pedersen, S. (1976). *Kriser i videnskaberne* (In Danish: Crises in the sciences) Københavns universitet. København.
- Azoulay, P., Fons-Rosen, C., & Graff Zivin, J. S. (2019). Does science advance one funeral at a time? *Am Econ Rev*, 109(8), 2889-2920. <https://doi.org/10.1257/aer.20161574>
- Barnes, P. (2017). Child abuse—Nonaccidental Injury (NAI) and Abusive Head Trauma (AHT) – Medical Imaging: Issues and controversies in the era of evidence-based medicine. *University of Michigan Journal of Law Reform*, 50(3), 679-692.
- Baum, R., & Sheehan W. (1997). *In Search of Planet Vulcan. The Ghost in Newton’s Clockwork Universe*. Plenum Trade, New York and London. <https://doi.org/10.1007/978-1-4899-6100-6>
- Brook, C. (2019). Is there an evidentiary basis for shaken baby syndrome? The conviction of Joby Rowe. *Austral J Forensic Sci*. <https://doi.org/10.1080/00450618.2019.1626483>.
- Caffey, J. (1972). On the theory and practice of shaking infants. Its potential residual effects of permanent brain damage and mental retardation. *Am J Dis Child*, 124, 161-169. <https://doi.org/10.1001/archpedi.1972.02110140011001>
- Choudhary, A. K. et al. (2018). Consensus statement on abusive head trauma in infants and young children. *Pediatr Radiol*, 48(8), 1048-1065. <https://doi.org/10.1007/s00247-018-4149-1>

- Cohen, M. C. (2009). Scheimberg I. Evidence of occurrence of intradural and subdural hemorrhage in the perinatal and neonatal period in the context of hypoxic Ischemic encephalopathy: An observational study from two referral institutions in the United Kingdom. *Pediatr Dev Pathol*, 12(3), 169-176. <https://doi.org/10.2350/08-08-0509.1>
- Cohen, M. C., Sprigg, A., & Whitby, E. H. (2010). Subdural hemorrhage, intradural hemorrhage and hypoxia in the pediatric and perinatal post mortem: Are they related? An observational study combining the use of post mortem pathology and magnetic resonance imaging. *Forensic Sci Int*, 200(1-3), 100-107. <https://doi.org/10.1016/j.forsciint.2010.03.036>
- Cowley, L. E., Maguire, S., Farewell, D. M., Quinn-Scoggins, H. D., Flynn, M. O., & Kemp, A. M. (2018). Acceptability of the predicting Abuse Head Trauma (PredAHT) clinical prediction tool: A qualitative study with child protection professionals. *Child Abuse & Neglect*, 81, 192-205. <https://doi.org/10.1016/j.chiabu.2018.04.022>
- De Leeuw, M. et al. (2013). History of an abusive head trauma including a lucid interval and retinal hemorrhage is most likely false. *Am J Forensic Med Pathol*, 34, 271-276. <https://doi.org/10.1097/PAF.0b013e3182a0a454>
- Donohoe, M. (2003). Evidence-based medicine and Shaken Baby Syndrome. Part I: Literature review, 1966-1998. *Am J Forensic Med Pathol*, 24, 239-242. <https://doi.org/10.1097/01.paf.0000083635.85457.97>
- Duhaime, A. C. et al. (1992). Head injury in very young children: Mechanisms, injury types, and ophthalmologic findings in 100 hospitalized patients younger than 2 years of age. *Pediatrics*, 90, 179-185.
- Duhaime, A. C., Gennarelli, T. A., Sutton, L. N., & Schut, L. (1988). "Shaken baby syndrome": A misnomer? *J Pediatr Neurosci*, 4, 77-86.
- Duhaime, A. C., Gennarelli, T. A., Thibault, L. E., Bruce, D. A., Margulies, S. S., & Wiser, R. (1987). The shaken baby syndrome. A clinical, pathological, and biomechanical study. *J Neurosurg*, 66(3), 409-415. <https://doi.org/10.3171/jns.1987.66.3.0409>
- Duncan, J. R., & Byard, R. W. (2018). Sudden Infant Death Syndrome: An overview. In J. R. Duncan, & R. W. Byard (Eds.). *SIDS Sudden infant and early childhood death: The past, the present and the future*. University of Adelaide Press. Barr Smith Library. Adelaide. <https://doi.org/10.20851/sids-02>
- Earman, J., & Glymour, C. (1981). Relativity and eclipses: The British Eclipse Expedition of 1919 and their predecessors. *Historical Studies in the Physical Sciences*, 11, 49-85. <https://doi.org/10.2307/27757471>
- Eddington, A. (2012). *The philosophy of physical science*. Cambridge University Press.
- Elinder, G., Eriksson, A., Hallberg, B., Lynøe, N., Sundgren, P. M., Rosén, M., ... Erlandsson, B. E. (2018). Traumatic shaking: The role of the triad in medical investigations of suspected traumatic shaking. *Acta Paediatr*, 107(Suppl 472), 3-23. <https://doi.org/10.1111/apa.14473>

- Freudenthal, G. A. (2000). Rational controversy over compounding forces. In P. Machamer, M. Pera, & A. Baltas (Eds.), *Scientific controversies. Philosophical and historical perspectives*. Oxford University Press, Oxford.
- Gardner, H. B. (2007). A witnessed short fall mimicking presumed shaken baby syndrome. *Pediatr Neurosurg*, 43, 433-435. <https://doi.org/10.1159/000106399>
- Geddes, J. F., Vowles, G. H., Hackshaw, A., Nickols, C. D., Scott, I. S., & Whitwell, H. L. (2001). Neuropathology of inflicted head injury in children. II. Microscopic brain injury in infants. *Brain*, 124, 1299-1306. <https://doi.org/10.1093/brain/124.7.1299>
- Geddes, J. F., & Whitwell, H. L. (2004). Inflicted head injury in infants. *Forensic Science International*, 146, 83-88. [https://doi.org/10.1016/S0379-0738\(03\)00283-4](https://doi.org/10.1016/S0379-0738(03)00283-4)
- Geddes, J. F., Hackshaw, A. K., Vowles, G. H., Nickols, C. D., & Whitwell, H. L. (2001). Neuropathology of inflicted head injury in children. I. Patterns of brain damage. *Brain*, 124, 1290-1298. <https://doi.org/10.1093/brain/124.7.1290>
- Geddes, J. F., Tasker, R. C., Adams, G. G., & Whitwell, H. L. (2004). Violence is not necessary to produce subdural and retinal haemorrhage: A reply to Punt et al. *Pediatr Rehabil*, 7(4), 261-265. <https://doi.org/10.1080/13638490412331280435>
- Guthkelch, A. N. (1971). Infantile subdural haematoma and its relationship to whiplash injuries. *Br Med J.*, 2, 430-431. <https://doi.org/10.1007/BF01801276>
- Guthkelch, A. N. (2012). Problems of infant retino-dural hemorrhage with minimal external injury. *Houston J Health Law & Policy*, 201-208.
- Hansson, S. O. (2017). Science denial as a form of pseudoscience. *Stud Hist Philos Sci*, 63, 39-47. <https://doi.org/10.1016/j.shpsa.2017.05.002>
- Harvey, G. M. (1979). Gravitational deflection of light. A re-examination of the observations of the solar eclipse of 1919. *The Observatory*, 99, 195-198.
- Hettler, J., & Greenes, D. S. (2003). Can the initial history predict whether a child with a head injury has been abused? *Pediatrics*, 111(3), 602-607. <https://doi.org/10.1542/peds.111.3.602>
- Högberg, U., Lampa, E., Högberg, G., Aspelin, P., Serenius, F., & Thiblin I. (2018). Infant abuse diagnosis strongly associated with SBS/AHT criteria: Incidence increase in Sweden due to overdiagnosis? *Eur J Publ Health*, 28(4), 641-646. <https://doi.org/10.1093/eurpub/cky062>
- Hymel, K. P. (2019). Denying the abusive head trauma denialists their day in court, one step at a time. *Pediatr Radiol*, 49, 1710-1711. <https://doi.org/10.1007/s00247-019-04500-7>
- Jenny, C. (2014). Alternative theories of causation in abusive head trauma: What science tells us. *Pediatr Radiol*, 44(Suppl 4), S543-547. <https://doi.org/10.1007/s00247-014-3106-x>
- Johansson, I., & Ceteris Paribus Clauses, Closure Clauses and Falsifiability. (1980). *Zeitschrift für Allgemeine Wissenschaftstheorie*, 11(1), 16-22. <https://doi.org/10.1007/BF01801276>
- Johansson, I., & Lynøe, N. (2008). *Medicine & Philosophy—A Twenty-First Century Introduction*. Ontos Verlag, Frankfurt. <https://doi.org/10.1515/9783110321364>

- Kadom, N., Khademian, Z., Vezina, G., Shalaby-Rana, E., Rice, A., & Hinds, T. (2014). Usefulness of MRI detection of cervical spine and brain injuries in the evaluation of abusive head trauma. *Pediatr Radiol*, *44*, 839-848. <https://doi.org/10.1007/s00247-014-2874-7>
- Kemp, A. M., Stoodley, N., Copley, C., Coles, L., & Kemp, K. W. (2003). Apnoea and brain swelling in non-accidental head injury. *Arch Dis Child*, *88*(6), 472-476. <https://doi.org/10.1136/adc.88.6.472>
- Kempe, C. H., Silverman, F. N., Steele, B. F., Droegemueller, W., & Silver, H. K. (1962). The battered-child syndrome. *JAMA*, *181*, 17-24. <https://doi.org/10.1001/jama.1962.03050270019004>
- Kennefick, D. (2019). *No Shadow of a Doubt. The 1919 Eclipse That Confirmed Einstein's Theory of Relativity*. Princeton University Press. Princeton and Oxford. <https://doi.org/10.1007/BF01801276>
- Kuhn, T. S. (1970). *The Structure of Scientific Revolutions*. University of Chicago Press, Chicago.
- Lakatos, I. (1970). Falsification and the Methodology of Scientific Research Programmes. In I. Lakatos, & A. Musgrave (Eds.), *Criticism and the Growth of Knowledge*. Cambridge University Press. Cambridge. <https://doi.org/10.1017/CBO9781139171434.009>
- Levin, A. V. (2009). Vitreoretinal traction is a major factor in causing the haemorrhagic retinopathy of abusive head injury?—yes. *Eye*, *23*, 1758-1760. <https://doi.org/10.1038/eye.2009.199>
- Levinson, T. (2015). *The Hunt for Vulcan: How Albert Einstein destroyed a planet and deciphered the universe*. Random House, New York.
- Lynøe, N. (n.d.). Waney Squier's ordeal and crisis of the shaken baby paradigm. *Prometheus. Researcher.One*. Retrieved from <https://www.researchers.one/article/2019-03-3>
- Lynøe, N., & Eriksson A. (2019). In order to ensure that evidence is unbiased it is sometimes necessary to retreat to the scientific ivory tower. *Forensic Sci Med Pathol*, *15*(1), 164. <https://doi.org/10.1007/s12024-018-0037-0>
- Lynøe, N., & Eriksson, A. (2018). A diagnostic test can prove anything if you use incorrect assumptions and circular reasoning. *Acta Paediatr*, *107*(12), 2051-2053. <https://doi.org/10.1111/apa.14503>
- Lynøe, N., & Eriksson, A. (2018). Is focusing on the triad really irrelevant and of no practical use? *Acta Paediatr*, *107*(10), 1675-1676. <https://doi.org/10.1111/apa.14442>
- Lynøe, N., & Eriksson, A. (2019). Hidden clinical values and overestimation of shaken baby cases. *Clin Ethics*, *14*(3), 151-154. <https://doi.org/10.1177/1477750919851048>
- Lynøe, N., & Eriksson, A. (2020). Can burnout among Child Abuse Clinicians be caused by doubt that they are doing the right thing? *Perm J*, *24*:20.011. <https://doi.org/10.7812/TPP/20.011>
- Lynøe, N., & Eriksson, A. (2020). Is there a common denominator for Brief Resolved Unexplained Events, Sudden Infant Death Syndrome, and alleged Shaken Baby Syndrome? *Med Hypotheses*, *144*, 109939. <https://doi.org/10.1016/j.mehy.2020.109939>
- Lynøe, N., Elinder, G., Hallberg, B., Rosén, M., Sundgren, P., & Eriksson, A. (2017). Insufficient evidence for “shaken baby syndrome”—a systematic review. *Acta Paediatr*, *106*(7), 1021-1027. <https://doi.org/10.1111/apa.13760>

- Lynøe, N., Juth, N., & Eriksson, A. (2019). From child protection to paradigm protection—The genesis, development and defence of a scientific paradigm. *J Medicine & Philosophy*, *44*(3), 378-390. <https://doi.org/10.1093/jmp/jhy015>
- Mack, J., Squier, W., & Eastman, J. T. (2009). Anatomy and development of the meninges: Implications for subdural collections and CSF circulation. *Pediatr Radiol*, *39*(3), 200-210. <https://doi.org/10.1007/s00247-008-1084-6>
- Maguire, S. A., Kemp, A. M., Lumb, R. C., & Farewell, D. M. (2011). Estimating the probability of abusive head trauma: A pooled analysis. *Pediatrics*, *128*, 550-664. <https://doi.org/10.1542/peds.2010-2949>
- Matshes, E. W., Evans, R. M., Pinckard, J. K., Joseph, J. T., & Lew, E. O. (2011). Shaken infants die of neck trauma, not of brain trauma. *Acad For Path*, *1*, 82-91919191. <https://doi.org/10.23907/2011.009>
- Oehmichen, M., Schleiss, D., Pedal, I., Saternus, K. S., Gerling, I., & Meissner, C. (2008). Shaken baby syndrome: Re-examination of diffuse axonal injury as cause of death. *Acta Neuropathol*, *116*(3), 317-329. <https://doi.org/10.1007/s00401-008-0356-4>
- Parks, S. E., Kegler, S. R., Annest, J. L., & Mercy, J. A. (2012). Characteristics of fatal abusive head trauma among children in the USA, 2003-2007: An application of the CDC operational case definition to national vital statistics data. *Inj Prev*, *18*(3), 193-199. <https://doi.org/10.1136/injuryprev-2011-040128>
- Parks, S., Sugeman, D., Xu, L., & Coronado, V. (2012). Characteristics of non-fatal abusive head trauma among children in the USA, 2003-2008: Application of the CDC operational case definition to national hospital inpatient data. *Inj Prev*, *18*(6), 392-398. <https://doi.org/10.1136/injuryprev-2011-040234>
- Passmore, S., Hemming, E., Chancellor McIntosh, H., & Hellman, C. M. (2020). The relationship between hope, meaning in work, secondary traumatic stress and burnout among Child Abuse Clinicians. *Perm J*, *24*, 19.087. <https://doi.org/10.7812/TPP/19.087>
- Piteau, S. J., Ward, M. G., Barrowman, N. J., & Plint, A. C. (2012). Clinical and radiographic characteristics associated with abusive and non-abusive head trauma: A systematic review. *Pediatrics*, *130*, 315-323. <https://doi.org/10.1542/peds.2011-1545>
- Prange, M. T., Coats, B., Duhaime, A. C., & Margulies, S. S. (2003). Anthropomorphic simulations of falls, shakes, and inflicted impacts in infants. *J Neurosurg.*, *99*(1), 143-150. <https://doi.org/10.3171/jns.2003.99.1.0143>
- Punt, J., Bonshek, R. E., Jaspán, T., McConachie, N. S., Punt, N., & Ratcliffe, J. M. (2004). The “unified hypothesis” of Geddes et al. is not supported by the data. *Pediatr Rehabil*, *7*(3), 173-184. <https://doi.org/10.1080/13638490410001711515>
- Reece, R. M., & Sege, R. (2000). Childhood head injuries: accidental or inflicted? *Acta Paediatr Adolesc Med*, *154*(1), 11-15.

- Richards, P. G. et al. (2006). Shaken baby syndrome. *Arch Dis Child*, 91(3), 205-206.
<https://doi.org/10.1136/adc.2005.090761>
- Riggs, J. E., & Hobbs, G. R. (2011). Infant homicide and accidental death in the United States, 1940-2005: Ethics and epidemiological classification. *J Med Ethics*, 37, 445-448.
<https://doi.org/10.1136/jme.2010.041053>
- Scheimberg, I. et al. (2013). Nontraumatic intradural and subdural hemorrhage and hypoxic ischemic encephalopathy in fetuses, infants, and children up to three years of age: Analysis of two audits of 636 cases from two referral centers in the United Kingdom. *Pediatr Dev Pathol*, 16(3), 149-159.
<https://doi.org/10.2350/12-08-1232-OA.1>
- Squier, W. (2011). The “Shaken Baby” syndrome: Pathology and mechanisms. *Acta Neuropathologica*, 122, 519-542. <https://doi.org/10.1007/s00401-011-0875-2>
- Squier, W. S. (n.d.). baby syndrome: Causes and consequences of conformity. *Researcher.One*. Prometheus Shaken Baby Debate. Retrieved from <https://www.researchers.one/article/2019-03-3>
- Squier, W., & Mack, J. J. (2016). Infants dying suddenly and unexpectedly share demographic features with infants who die with retinal and dural bleeding. *Dev Med Child Neurol*, 58(12), 1223-1234.
<https://doi.org/10.1111/dmcn.13202>
- Strouse, P. J. (2016). Child Abuse: We have problems. *Pediatr Radiol.*, 46, 587-590.
<https://doi.org/10.1007/s00247-016-3551-9>
- Supreme Court of Judicature Court of Appeal (Criminal Devision)*. (n.d.). Neutral Citation Number: [2005] EWCA Crim. 1980 Case Nos. 200403277. 200406902. 200405573. 200302848. Approved Judgement. Paragraph 68. 69.
- Thiblin, I., Andersson, J., Wester, K., Wikström, J., Högberg, J., & Högberg, U. (2020). Medical findings and symptoms in infants exposed to witnessed or admitted abusive shaking: A nationwideregistrystudy. *PLoS ONE*, 15(10), e0240182.
<https://doi.org/10.1371/journal.pone.0240182>
- Thorne, K. S. (1995). *Black Holes & Time Warps: Einstein's Outrageous Legacy*. WW. Norton & Co.
- Vinchon, M., de Foort-Dhellemmens, S., Desurmont, M., & Delestret, I. (2010). Confessed abuse versus witnessed accidents in infants: Comparison of clinical, radiological, and ophthalmological data in corroborated cases. *Child Nerv Syst*, 26, 637-645.
<https://doi.org/10.1007/s00381-009-1048-7>
- Zahl, S. M., Wester, K., & Gabaeff, S. (2020). Examining perinatal subdural haematoma as an aetiology of extra-axial hygroma and chronic subdural haematoma. *Acta Paediatr*, 109(4), 659-666.
<https://doi.org/10.1111/apa.15072>

Note. List of abbreviations:

AHT—Abusive Head Trauma

OUNG theory—Original Unrestricted Newtonian Gravitational theory

OUAHT theory—Original Unrestricted Abusive Head Trauma theory

RH—Retinal Hemorrhages

SBS—Shaken Baby Syndrome

SDH—Subdural Hemorrhage

WWII—World War II

Box 1. Definitions of certain concepts used in the present paper (theory, *ceteris paribus* clauses, auxiliary hypotheses, initial conditions, closure clauses and *ad hoc* hypotheses).

A **theory** is one or a number of assumptions which are internally connected and has been made explicit. In this sense a theory makes clear in which manner the different assumptions/rules/laws are related to each other.

A ***ceteris paribus* clause** tells us that a theory cannot be directly empirically tested because the theory takes for granted that other factors might interact with factors in the theory.

An **auxiliary hypothesis** is one or a number of statements which is/are presupposed in order to test a theory empirically. Several such hypotheses are always presupposed.

Initial conditions are needed in order to describe, e.g., the instrumental conditions for measurement and to ensure that the observations actually function as expected. Hence, auxiliary hypotheses can be associated with both a theory and the experimental (initial) conditions.

A **closure clause** tells us that when performing a certain test (and an observation) we have considered all relevant auxiliary hypotheses and initial conditions.

An ***ad hoc* hypothesis** is an assumption which completely without empirical support might transform falsification of a theory to verification. This transformation is achieved by claiming that one or more auxiliary hypotheses, initial conditions or closure clauses are false and replaced with an *ad hoc* hypothesis. Accordingly, an *ad hoc* hypothesis can become a kind of auxiliary hypothesis, initial condition or closure clause.

Theories, auxiliary hypotheses, initial conditions and closure clauses might be true, truth-like, or false (Johansson & Ceteris Paribus Clauses, Closure Clauses and Falsifiability, 1980).

Box 2. The use of “paradigm” and “research program”.

We refer to Thomas Kuhn’s philosophy of science and his use of the concept “scientific paradigm” defined as a hierarchy of 1) basic assumptions or symbolic generalizations, 2) basic research values, 3) group obligations and rationality criteria, 4) methodological preferences, and 5) tacit knowledge. In this context we can also refer to Imre Lakatos’ concept “research program” which is narrower than Kuhn’s “paradigm concept”. Lakatos’ programs might be changed or adjusted without scientific revolution,

even though he describes phases of crisis similar to the pre-revolutionary phase provided by Kuhn. When describing scientific development the “paradigm concept” is sometimes more applicable than “research program” and sometimes “research program” is more adequate. In the present context we find that “paradigm” is slightly more applicable than “research program” but we are aware that the “Vulcan paradigm” might also be described merely as a sub-paradigm under the Newtonian mechanic-paradigm (Johansson & Lynøe, 2008).