Evaluation of responses to risk situations in women and its

relation to the menstrual cycle from an evolutionary perspective

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Abstract

This thesis aimed to assess the hypothesis that women have evolved a rape avoidance mechanism that is particularly active during ovulation when chance of conception is highest. It assessed whether fertility-related differences in response to risk were specific to rape risk, or generalised to all threats. This is not known from previous research. In Study 1, fertility did not influence handgrip strength or subjective responses to scenarios that varied in the risk of rape. However, in Study 2, women increased their handgrip strength when fertile compared to nonfertile in response to all potentially threatening scenarios involving men, but not the female-perpetrated assault scenario, which involved danger but no immediate risk of rape. Women also felt at higher risk of rape and male-perpetrated assault when fertile compared to nonfertile. In Studies 3 and 4, fertility influenced attention to potential reproductive threats (angry versus neutral male and female faces), but not general threats (fear-relevant versus neutral animals). Against expectations, women were faster to detect neutral faces when fertile compared to nonfertile (Study 3). In Study 4, fertile women were slower to fixate on angry compared to neutral faces, but spent a higher proportion of time fixating on angry versus neutral faces. In Study 5, women were slower to categorise rape-related stimuli when fertile compared to nonfertile, while fertility did not influence categorisation of stimuli associated with robbery or consensual sex. In Studies 6 and 7, neither fear of crime nor perceived risk of victimisation differed in relation to fertility. Therefore, overall, the findings suggest fertility does not influence responses to threats in general, with some evidence that the mechanism is specific to situations with increased possibility of rape. However, hormonal influences on responses to risk appeared to manifest in visceral responses (e.g., physiology, attention, cognitive biases) rather than conscious feelings (e.g., fear).

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Declarations

Some work within this thesis has been published in an academic journal. The stimuli used in Study 6 of this thesis was used in Study 1 of the published paper, as well as some of the findings of Study 7. The reference is:

Ryder, H., Maltby, J., Rai, L., Jones, P., & Flowe, H. D. (2016). Women's fear of crime and preference for formidable mates: how specific are the underlying psychological mechanisms?. *Evolution and Human Behavior*, *37*(4), 293-302.

The study design was conceptualised by myself, Dr Heather Flowe, Dr John Maltby and Dr Phil Jones. The images used for Study 1 were taken by myself and Ms. Lovedeep Rai. The work has been re-analysed and re-written by myself for this thesis as the published paper took on a different primary focus.

Secondly, the work in Study 6 has been previously submitted for an MRes degree at the University of Leicester. Along with my supervisor, Dr Heather Flowe, I acted as co-supervisor to Ms. Lovedeep Rai during her Masters degree. The study was conceptualised by myself, Dr Heather Flowe and Ms. Rai, and programmed by myself. The photographs were taken by both Ms. Rai and myself, and Ms. Rai collected the data. I re-analysed the findings and the writing is my own work.

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1. Chapter 1: Literature review

Rape inflicts high psychological and physical costs to victims and could result in an unwanted and untimely pregnancy, and thus is undoubtedly costly to fitness (Perilloux, Duntley & Buss, 2012). Evidence suggests that women may have evolved rape avoidance mechanisms (e.g., McKibbin, Shackelford, Goetz, Bates, Starratt & Miner, 2009). However, rape during ovulation, when conception risk is highest would be particularly costly to reproductive fitness. As such, it has been theorised, and indeed evidence suggests that women increase their rape avoidance behaviours during ovulation, such as by avoiding going out alone late at night, avoiding dark and deserted areas (Chavanne & Gallup, 1998; Bröder & Hohmann, 2003), and showing increased strength when fertile in response to a scenario that depicts a dangerous situation (Petralia & Gallup, 2002). However, it is not clear from previous research whether women are avoiding rape specifically during ovulation due to the increased chance of conception, or whether women simply become more risk averse during this menstrual cycle phase. Research suggests differential responses to risk in other domains during ovulation, such as gambling and investment decisions (e.g., Ball et al. 2013, Kaighobadi & Stevens, 2013; Pearson & Lewis, 2005). Therefore, this thesis aims to further assess the fertility-related rape avoidance hypothesis, and show domain specificity in the response. Secondly, little is known about the cognitive and psychological mechanisms associated with the adaptation. Therefore, a second aim of this thesis is to examine the psychological and cognitive mechanisms that accompany, and possibly underlie rape avoidance.

Rape has been documented across history and cultures, and continues to be a problem in modern society (Sanday, 1981; McKibbin & Shackelford, 2011). Rape is defined as force by a male towards a female to accomplish penile-vaginal penetration that the female resists to the best of her ability without resulting in death or serious injury (Thornhill & Palmer, 2000). Due to the sensitive nature and underreporting, it is difficult to know the accurate prevalence of rape. However, it has been estimated that approximately 13% of females in Western samples have been victims of rape, with 37-57% of these women having experienced post-traumatic stress disorder, marking a

rate higher than for any other crime (Resnick, Kilpatrick, Dansky, Saunders & Best, 1993).

Our fundamental goals in evolutionary history are survival and successful reproduction. Successful reproduction involves providing offspring with the best resources, including high quality genetics such as physical attractiveness (Hunt, Bussiére, Jennions, Brooks, 2004). Consequently, at peak fertility when conception is most possible, women will aim to attract the best quality mate, in terms of the genes or resources he can provide (see Riebel, Holveck, Verhulst & Fawcett, 2010, see also the cycle-shift hypothesis; Gangestad & Thornhill, 1998, explained in section 1.1.6. of this thesis). However, due to the evolutionary costs of rape, including injury, psychological distress, and possible unwanted and untimely pregnancy (see Perilloux et al. 2012), it has been hypothesised that women may have evolved an adaptation to avoid rape, which is particularly accentuated during the phase of highest conception risk when rape could result in a pregnancy, and thus costs of rape are highest. This thesis will refer to 'costs' and 'benefits' in relation to reproductive fitness, with costs relating to reduced chances of successful reproduction, and benefits increasing the chances of successful reproduction (McKibbin, 2014). These terms relate only to biological functioning, with no moral or ethical implications, and should not be misinterpreted to mean costs and benefits to the individual or society more generally.

This thesis investigates the fertility-related rape-avoidance hypothesis, examining variations in women's risk-avoidance behaviours over the menstrual cycle, wherein 'risk-avoidance' is defined as behaviours that would decrease the chance of sexual assault. Hormones fluctuate over the menstrual cycle with fertility status and thus may drive the increased rape avoidance. Indeed, evidence suggest that hormones both drive and are influenced by reproduction and relationships, which in turn influences behaviour (Ellison & Gray, 2009). There is evidence to suggest that women may have evolved mechanisms to help reduce their risk of rape at peak fertility, such as avoidance of situations of increased risk of rape (Chavanne & Gallup, 1998; Bröder & Hohmann, 2003) or increased strength in response to a scenario that was designed to depict sexual assault (Petralia & Gallup, 2002). However, it is not clear from previous research whether women are avoiding rape specifically due to the increased

chance of conception, or whether women become risk averse more generally during ovulation. Secondly, whilst research demonstrates menstrual cycle-dependent changes in behaviour that could be indicative of rape-avoidance behaviours, research lacks focus on the psychological mechanisms underpinning avoidance behaviour. This thesis aims to test the assumptions of this apparent evolved adaptation, by determining the existence and specificity of behavioural and psychological mechanisms which may help to reduce women's risk of rape.

It is important to note here that studying rape, or women's rape avoidance from an evolutionary perspective in no way justifies this terrible crime, and it certainly does not shift the blame to the victims. As discussed by McKibbin, Shackelford, Goetz and Starratt (2008), regardless of accuracy, the increased understanding from new perspectives, such as evolutionary hypotheses about rape, increases understanding about why rape occurs and how women avoid it, which is central to reducing the prevalence of rape.

This chapter will present an overview of the main evolutionary theories of natural selection, mate preferences, rape avoidance, and the menstrual cycle, which form the theoretical perspective underpinning this work. Afterwards, methodological considerations will be discussed.

1.1. General introduction to Evolutionary theory and Parental Investment Theory

The primary goal for all species in evolutionary history is to reproduce genetics, making survival, mating and reproduction essential. However, for most species, including humans, the goals and associated costs of sexual reproduction differs between genders (Maynard-Smith, 1978; Halliday, 1994) due to differences in parental investment (Trivers, 1972). In evolutionary terms, for species wherein the female bears the offspring (all species but the Syngnathidae family), males generally have lower parental investment, and thus reproductive success is defined by the quantity of offspring for maximum regeneration (Bateman, 1948; Trivers, 1972). In contrast, females' reproductive success is determined by the quality of offspring. Whilst males have unlimited reproductive resources, females are limited both in their eggs and

time, generally being the primary care-giver, and thus have higher parental investment, particularly for humans. Therefore, females should be highly selective in whom they reproduce with, and will aim for a high quality mate for the best offspring to make their high reproductive efforts worthwhile. It has controversially been theorised that for species wherein males compete to mate with females, males may resort to rape as a means to overcome this challenge in gaining access to fertile females, whilst females have evolved a counter-adaptation, or 'anti-rape' mechanism, wherein they change their behaviour, specifically during peak fertility, to avoid conception as a product of rape, which would be a high cost to fitness (Thornhill & Palmer, 2000).

Psychology is largely concerned with understanding causes of behaviour. More specifically, Evolutionary Psychology relies on understanding proximate and ultimate causes of behaviour, as it is believed that "no aspect of life can be completely understood until both its proximate and its ultimate causation are fully known" (Thornhill & Palmer, 2000, p.5). *Proximate causes* of behaviour refer to forces that operate in the short term, immediately influencing behaviour. Hormones, brain structures and the environment are examples of proximate causes of behaviour. *Ultimate explanations* of behaviour, however, are concerned with why proximate mechanisms exist. An understanding of natural selection is first necessary to understand the proximate and ultimate explanations for changes in women's behaviour that could be seen as an evolved rape-avoidance mechanism.

1.1.1. Natural and Sexual selection

Darwin (1859, as cited in Confer, Easton, Fleischman, Goetz, Lewis, Perilloux & Buss, 2010) proposed the idea of natural and sexual selection, a process by which variants that benefit fitness and survival (natural selection) or reproduction (sexual selection) will become more frequent in future generations, whilst less beneficial traits do not replicate as the organism bearing them would reproduce at lower rates (Confer et al. 2010). This results in three possible outcomes. Firstly, inherited traits with an evolutionary benefit, such as overcoming environmental challenges to fitness, are known as *adaptations*. For example, people are fearful of snakes because they can be deadly. Secondly, *by-products* are intrinsically paired with adaptations, but serve no

adaptive function, such as fear of harmless snakes. Finally, *noise* refers to the variations in a given characteristic that are due to random environmental occurrences, such as irrational fears (Tooby & Cosmides, 1992, as cited in Confer et al. 2010).

1.1.2. Adaptations

Adaptations are solutions to environmental challenges faced by our ancestors in evolutionary history (Ridley, 1987, cited in Thornhill & Palmer, 2000; Williams 1966; Symons, 1979; Thornhill, 1997). According to Fodor (1983), an adaptation is categorised by domain specificity, informational encapsulation, obligatory firing, automaticity, shallow and simple outputs, limited accessibility, characteristic ontogeny and fixed neural architecture. Similarly, Williams (1996) states that an adaptation is identified as having special and complexity of design, reliability, precision, functionality, economy, efficiency and reliability. To show existence of an adaptation, evidence showing "special design", that the feature has evolved for a specific purpose which cannot be explained in any other account is necessary (Andrews, Gangestad & Matthews, 2002; Thornhill, 1990; 1997). Thus, to determine whether an adaptation has evolved, demonstration that the mechanism provides a solution to challenges to evolutionary fitness, which are unlikely to have evolved though more general learning processes, is necessary (see Andrews et al., 2002). This is a key aim of this thesis.

1.1.3. Animal adaptations to rape

The fact that forced copulation of a male onto a female occurs worldwide, and in many nonhuman species, including wildfowl, bottlenose dolphins and chimpanzees, has led some evolutionary theorists to suggest that rape may have evolved as a reproductive tactic for males to circumvent female mate choice and increase their chances of reproduction (e.g., Apostolou, 2013; Cox & Le Boeuf, 1977; Gowaty & Buschhaus, 1998; Smuts & Smuts, 1993; Thornhill, 1980; Thornhill & Thornhill, 1987). There is evidence of rape in the majority of known human societies worldwide (Palmer, 1989; Rozée, 1993), as well as across species (McKibbin & Shackelford, 2011). There are arguably signs of evolved rape mechanisms in many nonhuman species. For example, male bottlenose dolphins have been shown to work collectively to intimidate a female, and coerce her into intercourse (Connor, Smolker & Richards, 1992).

However, sexual coercion inflicts costs to females' reproductive fitness (Mesnick, 1997). Conception from rape denies a female of her choice in mate. Mating can be considered costly due to the time and resources necessary to both bear and raise offspring. Thus, it is of primary importance to a female to be selective, and choose the best mate to reproduce with.

Interestingly, amongst species wherein there is evidence of evolved mechanisms for forced copulation, there is also evidence of anti-coercion mechanisms in females. For example, it has been argued that drakes have evolved a mechanism to enable forced copulation with ducks (Brennan, Clark & Prum, 2010). Drake's penises extend in an anti-clockwise motion up to 20cm in less than half a second, and are lined with backward-pointing spikes to stay attached to the female during copulation, with soft 'dusters' on the end to remove other drake's sperm. However, as with any animal, ducks want to choose a desirable mate to pass quality genetics onto offspring. Interestingly, only a small 3% of 'duck rapes' actually result in fertilization (Burns, Cheng & McKinney, 1980). Female ducks appear to have developed counter-adaptations to protect themselves from insemination. For example, while a drake could easily project its penis into a straight test tube, or one that spirals anti-clockwise (i.e., in the same direction as its penis), it was much more difficult to insert into a tube bent at a sharp angle, or one that spirals in a clockwise direction (Brennan et al., 2007), as a duck's vagina does. This makes forced copulation extremely difficult for unwanted drakes (consenting females will relax their muscles to aid copulation with a desired mate). Additionally, inside ducks' vaginas there are many sharp turns, false passages and dead-ends, which are theorised to help prevent insemination from an undesired mate. Brennan et al. (2007) showed that female ducks belonging to the same species as drakes with the longest penises also have the most complex vaginas, which could be considered as evidence in support of the counter-adaptation. This was also true among other wildfowl species (Brennan et al. 2007). What's more, these features were only evident in the wildfowl species renowned for forced copulation.

The mating strategy of the Acilius genus species of water beetle also shows evidence of evolved rape, and anti-rape mechanisms. While the males engage in behaviours to enabled forced copulation, such as suffocation, females' body shapes

vary to prevent males' gripping onto them (Bergsten & Miller, 2005). Male waterstriders also show evidence of evolved rape mechanisms, such as by using a pair of ventral abdominal projections to hold onto females that resist intercourse (Rowe, Arnqvist, Sih & Krupe, 1994). However, female waterstriders have dorsal, as opposed to males' ventral abdominal spines, and have been seen to perform impressive manoeuvres to escape the grip of unwanted mates (Arnqvist & Rowe, 1995; Rowe, Arnqvist, Sih & Krupa, 1994; Watson, Stallman & Arnqvist, 1998). When male scorpion flies lack the resources (i.e., nuptial gifts) to be selected as mates, they have been shown to attempt forced copulation. However, the females made solid, and often successful, efforts to escape (Thornhill, 1980, 1984; Thornhill & Sauer 1991). In fact, inseminations only occurred in half of forced copulations, whilst copulations with males bearing nuptial gifts consistently achieved insemination. The overview of literature will now focus on rape, and anti-rape adaptations in humans.

1.1.4. Male adaptations to rape in humans

Extrapolation from research on animals to suggest the evolution of a rape adaptation in humans has been criticised (e.g., Coyne, 2003). It is possible that rape may not be an evolved adaptation, but rather a by-product of other evolved traits (Symons, 1979). For example, rape may be a by-product of men's evolved desire for sexual variety, their greater sex drive or aggressiveness. Nevertheless, Thornhill along with colleagues Thornhill (1983) and Palmer (2000) hypothesize that human rape is primarily an evolved mechanism whereby men who lack the necessary means to gain legitimate consensual access to women will rape as a way to reproduce their genetics. It is necessary to state that the following overview of evidence in support of, or against the evolution of a rape adaptation in no way justifies this terrible crime.

There is some evidence that could be considered to support this theory. For example, archival data of crime statistics shows the majority of rapists to be relatively low in socioeconomic status (Thornhill & Thornhill, 1983) and have more facial asymmetries (Krill, Lake & Platek, 2006 as cited by Ellsworth & Palmer), which may make it more difficult to find a consensual partner. However, alternatively, men lower in social economic status may have inadequate access to legal assistance and thus may be more likely to be convicted of rape compared to their wealthier counterparts. it is

also possible that women may be more likely to report a rape from a low socioeconomic status male perpetrator compared to one of a higher socioeconomic status.

Secondly, some research regarding the outcome of rape is argued to support the hypothesis that rape is an evolved reproductive tactic. For example, some evidence suggests that per-incident rate of conception after rape is higher than per-incident consensual pregnancy rates, even after controlling for use of birth control (Gottschall & Gottschall, 2003).

Third, it is argued that males who rape will preferentially target attractive, young females for their relatively higher reproductive value (Thornhill & Palmer, 2000; Thornhill & Thornhill, 1983). Reports suggest that rape victims are more likely to be young females, with the highest proportion of victims of sexual assault being between 16 and 19 years old (Office for National Statistics, 2013). However, it is important to note that a large proportion of rapes go unreported, meaning such reports may be inaccurate. Moreover, many rapes are not reproductive. At least a third of rape victims have no possibility of reproduction, being above or below reproductive age (e.g., Thornhill & Palmer, 2000), many rapes do not involve ejaculation in the vagina (see Thornhill & Thornhill, 1983) and often rape is committed on a victim of the same sex (see Coyne, 2003).

However, a study in Northern Ireland which assessed the prevalence of rape according to women's menstrual cycles over a 7-year period found that almost a fifth of rape victims were in the three-day window of peak fertility at the time of the assault, a rate higher than would be expected by chance (Beirne, Hall, Grills & Moore, 2011). This may be seen as lending support to the hypothesis that men have evolved mechanisms to detect fertility to increase chance of conception. Conversely, other studies have found that rape is not more common during the fertile phase of the menstrual cycle (Fessler, 2003). Nevertheless, the association between prevalence of rape and women's fertility is important to consider. Although traumatising and costly at any time, rape during ovulation could be argued to be exceptionally costly to a female's reproductive fitness, as chances of conception with an undesired male are

highest. If, like the aforementioned animal species, women have evolved mechanisms to prevent rape and the risk of conception, efforts to prevent rape may be particularly pronounced during peak fertility. It could be costly to consistently attend to, and behave in a way to avoid rape. For example, avoidance of situations of increased risk of rape, such as not going out late at night, could hinder mate-seeking opportunities and chances of attracting a potential mate. Therefore, such cognitions and behaviours may be particularly prominent when the benefits of these provisions outweigh any costs. Fessler (2003) argues that mechanisms that influence women's rape avoidance behaviours should coincide with women's conception risk. Evidence indeed shows cyclic- or more specifically hormonal-variations in behaviour, including behaviours which can reduce the risk of rape (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003; Guéguen, 2012a). To understand and assess women's rape avoidance over the menstrual cycle, it is first necessary to understand the menstrual cycle and associated fluctuations in hormone concentrations.

1.1.5. Hormones / the menstrual cycle

The menstrual cycle begins with the first day of menses, signifying the start of the follicular phase (Hampson & Young, 2007), see Figure 1. Conception risk is low at this point, particularly during the early follicular phase (see Figure 2). One follicle grows to be dominant from a larger body of antral follicles, forming the preovulatory follicle. Estradiol levels are initially slight, but this follicle secretes increasing levels of estradiol as it grows. When peak concentrations are reached and released, luteinizing hormone (LH) surges, leading to the release of the mature oocyte by the ovary 24-36 hours later, marking ovulation. Luteinising hormone levels are strongest immediately preceding ovulation (Thorneycroft, Mishell, Stone, Kharma & Nakamura, 1971, as cited in Hampson & Young, 2007). Ovulation occurs 12-14 days on average into a normal, regular menstrual cycle, and is the peak of fertility (Wilcox, Dunson, Weinberg, Trussel & Baird, 2001).

Succeeding ovulation, the remaining cells from the ovulatory follicle (the corpus luteum) secrete progesterone, estradiol and inhibin A (Hampson & Young, 2007). This, along with ovulation marks the beginning of the luteal phase, lasting approximately 13-15 days, and conception risk decreases again (see Figure 2). While

the follicular phase is characterised by high levels of estradiol, the luteal phase is characterised by high levels of progesterone (see Figure 1). Towards the end of the luteal phase, the corpus luteum degenerates, and estradiol, progesterone and inhibin A concentrations drop. The endometrium sheds, marking the beginning of menses, and the beginning of the next cycle (Hampson & Young, 2007). It is important to note that there are individual differences in timings of cycle phase and concentrations of hormones both between and within females.

In sum, the central sex steroids include progestins, androgens and estrogens, all which can affect, and can be affected by social behaviour, mood and cognition (Hampson & Young, 2007; Wallen & Hasset, 2009). These hormones carry information about the organism, such as its reproductive state to the central nervous system which in turn alters behaviour. Due to the fluctuating nature of hormones over the menstrual cycle, observing behavioural change in relation to cycle-phase aids understanding of the role of hormones. Indeed, a large body of research shows women's mating behaviours and motivations to shift in adaptive ways over the menstrual cycle, or more specifically, according to fertility status (Gangestad, Thornhill & Garver-Apgar, 2002).
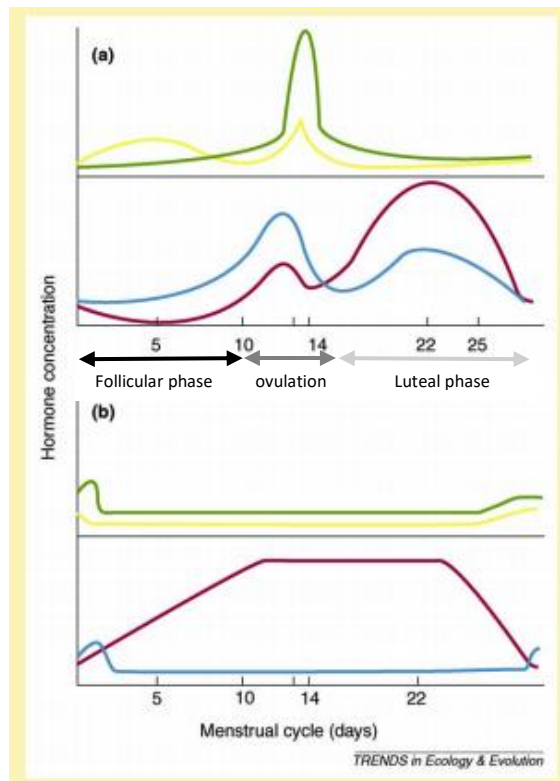
Figure 1. Fluctuation in hormone concentrations in naturally cycling women (a) and pill users (b) across the menstrual cycle, from Alvergne and Lummaa (2009) with cycle phases in naturally cycling women. Red lines show progestin and blue lines show oestrogen. Oral contraceptives prevent gonatropin-releasing hormone (GnRH) from the hypothalamus which prevents production of FSH (yellow lines) and luetenising hormone (green lines). Thus, while hormones flucatuate in naturally cycling women over the menstrual cycle, hormones remain relatively stable and no egg is released in hormonal contraceptive users.
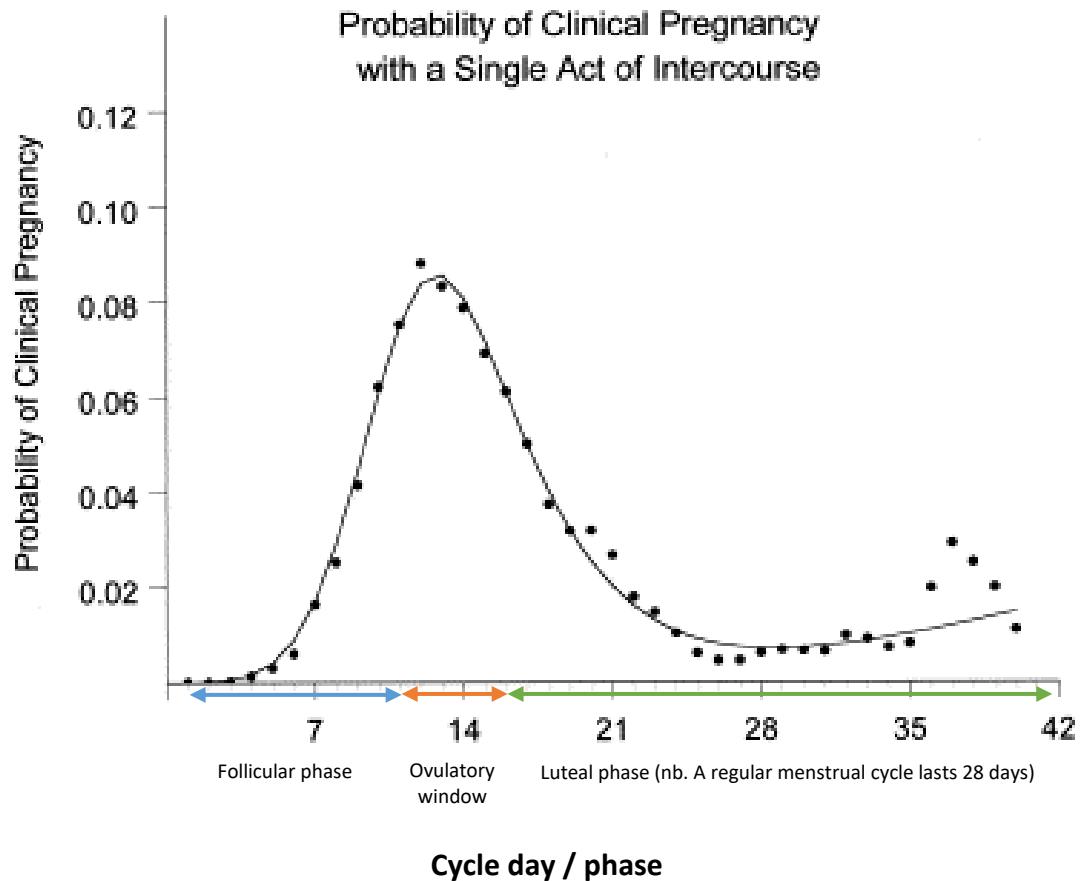
Figure 2. Conception risk by cycle day and cycle phases; follicular phase (blue arrows), ovulatory arrows) and the luteal phase (green arrows), adapted from Wilcox et al. (2001).

1.1.6. The Cycle-shift hypothesis

The cycle-shift hypothesis describes the process by which female mate preferences vary in relation to their cycle-phase. This theory argues that when fertile, females will prefer males with short-term reproductive benefits, including good quality genetics which is said to be indicated by attractive and masculine faces (Penton-Voak, Perrett & Castles, 1999; Penton-Voak & Perrett, 2000; Johnston, Hagel, Franklin, Fink & Grammer, 2001, though see Scott, Clark, Boothroyd & Penton-Voak, 2013). 'Attractiveness' can be explained by symmetry of the face which also signals good quality genetics and health (Møller & Swaddle, 1997). Offspring with better genetics will generally benefit from increased health and chance of survival. Women at peak fertility also prefer males that are tall (Pawlowski & JasienSka, 2005) with higher testosterone levels (Roney & Simmons, 2008) and masculine voices (Feinberg, Jones, Law Smith, Moore, DeBruine, Cornwell et al. 2006; Puts, 2005) and body shapes (Little,

Jones & Burriss, 2007). In contrast, preferences for male traits that signal a good long-term provider will be stable across the cycle (e.g., Gangestad, Simpson, Cousins, Garver-Apgar & Christianson, 2004). Reinforcing this hypothesis is the stability in attraction to men documented in women using hormonal contraceptives (Penton-Voak et al., 1999). Therefore, mate choice is a priority to women, to reproduce with a good quality mate to pass the best quality genetics possible onto her offspring.

1.2. Women's avoidance of rape

1.2.1. The costs of rape

It is argued that a female's reproductive success is based primarily on the circumstances associated with conception (Symons, 1979). Challenges to a woman's reproductive success include pregnancy without adequate resources to raise the offspring and anything that interferes with her ability to choose and keep a mate who can provide for her offspring (Symons, 1979). With this in mind, it is suggested that the freedom of mate choice is of foremost importance for many female animals in their reproductive behaviours (Wilson, Daly & Scheib, 1997). However, rape circumvents women's choice of mate, and as a consequence, has the potential to threaten women's reproductive success and ultimate fitness (Symons, 1979).

Unlike male's infinite sperm count, females only have a finite number of eggs and reproductive resources, which she would not want to expend in the wrong circumstances with the wrong male. Compared to males, reproduction is very costly and time consuming for a female, and thus females are very selective as to whom they reproduce with in order to pass good quality genetics onto their offspring. As well as quality genetics, females desire a mate who can invest in their offspring, and provide resources such as food, shelter and protection (Buss, 1989; Li, Bailey, Kenrick & Linsenmeier, 2002). Insemination from a rapist circumvents female's choice of mate, timing and circumstances for reproduction (Thornhill & Palmer, 2000). Moreover, she may face abandonment from a current partner, and chances of attracting future mates may decrease (Shields & Shields, 1983; Thornhill & Thornhill, 1983, 1990a). This is not to say that pregnancy is the only cost of rape. There are of course other significant physical and psychological costs of rape to consider, which are 'costly' at any point of

the menstrual cycle. However, considering the high parental investment women put into their offspring, and the importance of women's mate choice, pregnancy from rape can be considered a very high evolutionary cost to reproductive fitness, with the risk of conception being highest during ovulation.

The costs of rape, although always high, will likely differ according to the victim. For example, married women who had been victims of rape reportedly experienced more psychological pain compared to their single counterparts, despite there being no difference in reported violence (Thornhill & Thornhill, 1990a). If raped, those in a pair-bonded relationship could potentially face risk of abandonment and loss of resources and investment from their partner (Thornhill, 1999; Thornhill & Palmer, 2000; Thornhill & Thornhill, 1990a, 1990b, 1990c). What's more, pair-bonded females who suffer violence during the sexual assault purportedly feel less psychological pain due to the decreased likelihood of appearing as infidelity and risk of losing her mate (Thornhill & Thornhill, 1983; 1990c).

It has been found that victims that will face relatively higher costs to their future reproductive fitness will experience more psychological pain (Thornhill & Thornhill, 1983; 1990a; Thornhill & Palmer, 2000). For example, females of reproductive age are more fearful of sexual assault in particular due to their risk of conception, compared to older women who were more fearful of burglary in their homes (Pawson & Banks, 1993). One of the high costs involved with pregnancy as a result of rape is the inability to have a male father to provide resources. Interestingly, despite being less common, females fear stranger rape more than acquaintance rape (Thornhill & Thornhill, 1990b), supposedly because strangers are less likely to invest in the offspring than an acquaintance or partner. A father's absence in hunter-gatherer populations has been found to reduce the chance of offspring survival by 2.6 times (Hurtado & Hill, 1992, also see Geary, 2000). Thus, psychological anguish is highest for those experiencing the highest costs to reproductive fitness- those of a fertile age and in a pair-bonded relationship, and also when the act involves penile-vaginal penetration resulting in ejaculation in the reproductive tract where insemination is possible (Thornhill & Thornhill, 1990c). Taken together, these findings are best explained with evolutionary theory.

Thornhill and Thornhill (1989; 1990a, 1990b, 1990c, 1991) theorised psychological pain serves an evolutionary function to encourage adaptation of behaviour and cognitions to deal with and overcome the problem. They argue that the psychological pain experienced after being raped has an adaptive benefit to focus women's attention on the circumstances leading to the rape which motivates them to attend to, and avoid such situations in future. Watson and Andrews (unpublished manuscript, as cited by Thornhill & Palmer, 2000) suggest that during psychological pain, problem solving abilities are enhanced. Challenges to fitness and reproductive success, such as rape, will thus be dealt with by reducing the likelihood of experiencing such anguish again in the future. Natural selection may have favoured this trait, and thus reproduced through the generations for avoidance of the pain without ever experiencing it.

It is suggested that females adopt behaviours to reduce their risk of rape. For example, women make alliances with other females (Smuts & Smuts, 1993; Mesnick, 1997), and have a preference for physically strong partners and male friends due to the protection afforded, known as "the bodyguard hypothesis" (Wilson & Mesnick, 1997). Avoidance of certain males appears a common rape-avoidance behaviour. McKibbin et al. (2009) formulated the Rape Avoidance Inventory (RAI), composed of 69 behaviours reported to be employed by women to avoid being raped. These behaviours fell into four categories: avoiding strange men; avoid appearing sexually receptive; avoid being alone; and awareness of surroundings (defensive preparedness). Moreover, the Daughter-Guarding hypothesis (Perilloux, Fleischman & Buss, 2008) suggests that parents are more likely to control their daughters' mating decisions than their sons', to preserve their daughters' mate value and protect her from sexual victimisation. However, it is important to note that existing research appears to focus on mechanisms with regards to avoidance of stranger rape, as opposed to acquaintance or partner rape, despite being less common. One reason for this may be that the evolutionary costs of rape are arguably slightly higher for stranger, as opposed to acquaintance or partner rape, due to the absence of the male to provide for the offspring (e.g., Thornhill & Thornhill, 1990b). The mechanisms pertaining to avoidance of stranger versus acquaintance or partner rape would likely

differ. For example, avoiding strange men may benefit avoidance of stranger rape, but would not help to prevent acquaintance or partner rape.

However, rape avoidance behaviours inevitably limit activity, and thus may be maladaptive with regards to fulfilling other behaviours necessary for survival and reproduction, such as foraging and seeking out a mate. Therefore, as attentional and energy resources are limited, and there may be costs to fitness to continuously engage in rape avoidance behaviours, natural selection may have "favoured mechanisms that modulate behavioural prophylaxis as a function of the expectable fitness costs of rape" (Fessler, 2003, p.130). That is, although rape is always costly, the costs of rape are relatively higher during ovulation, when conception from rape is possible, meaning the benefits of rape avoidance behaviours would arguably also be higher during this menstrual cycle phase relative to phases of the menstrual cycle with lower risk of conception. Thus, the cost-benefit ratio of rape avoidance behaviours may vary according to fertility. For example, women of reproductive age may engage in more rape-avoidance behaviours than women who are menopausal. Similarly, as women's chance of conception is higher during ovulation, the benefits of rape avoidance behaviours will arguably be higher mid-cycle.

Chance of conception after a single act of intercourse can range from approximately 9% during peak fertility (around the time of ovulation) to zero chance in the early follicular phases (Wilcox et al. 2001). As such, there is a higher risk of insemination from rape during ovulation. Thus, it can be argued that although traumatising at any time, rape during peak fertility may be exceptionally harmful to a female's fitness. During this time, the benefits of rape-avoidance techniques are especially likely to outweigh any costs.

1.2.2. Studies documenting risk avoidance during ovulation

Chavanne and Gallup (1998) were first to explore the concept of increased rape-avoidance during ovulation. They asked 300 regularly-cycling female undergraduates information about their menstrual cycles, method of contraception and sexual activity. Participants completed a checklist of their activities in the last 24 hours (e.g., watching television, going to church, going on a date and walking in dimly

lit areas). The list had been developed by the researchers and previously rated and scored for their riskiness with regards to the risk of sexual assault. Each participant was assigned a composite risk-taking score according to their reported activities, which was analysed by cycle-phase. Whilst those using hormonal contraceptives (i.e., steady hormones and nonfertile) showed little variation in risk-taking behaviour, there was a significant decrease in risk-taking during the fertile phase compared to nonfertile phases for naturally cycling participants. However, while an interesting and novel finding, this study has been criticised for using the forward-cycle method (Grammer, 1993) of determining fertility because of the unreliability and inaccuracy in estimating cycle-phase when relying on retrospective memory and cycles that may deviate from the usual 28 days (Williams & Williams, 1982). Self-reports of behaviours may also be inaccurate due to retrospective remembering of activities and responding in a socially desirable way. Women may be hesitant to report instances wherein they went out alone, or on a date, for example. Moreover, Chavanne and Gallup (1998) did not make it clear how they developed their inventory of risk-taking behaviours. Their method of calculating risk-taking scores has also been criticised as someone who participated in many very low-risk activities (e.g., watching television) would receive a similar score to someone who had participated in one high-risk activity (e.g., walking in the dark, Bröder & Hohmann, 2003). Bröder and Hohmann (2003) also criticised their between-subjects design due to the variance between women. Nevertheless, Chavanne and Gallup's (1998) pioneering research showed that women selectively reduce their risk taking behaviours during ovulation, suggesting that women may have evolved a fertility-related rape avoidance mechanism.

In an attempt to replicate and improve their findings, Bröder and Hohmann (2003) used a within-subjects design and differentiated between risky and nonrisky activities. Each activity was assigned a mean risk-score, with the highest 20 being 'risky' (e.g., walking alone in the park/forest), and the lowest being 'nonrisky' (e.g., telephoning friends). Employing a longitudinal design, they recorded frequency of risky and nonrisky activities at four points of the menstrual cycle, which was estimated using both the forward and reverse cycling methods. They replicated the results of Chavanne and Gallup (1998); naturally cycling women showed a selective reduction in

risky behaviours and an increase in nonrisky ones during the ovulatory phase whilst women using hormonal contraceptives demonstrated stability in behaviour over the cycle. However, again these authors relied on the forward- and backward- cycling method of estimating cycle-phase, and their list of risk behaviours could be criticised for being too specific (e.g., going to a theatre/opera).

The aforementioned studies are self-report which raises problems with retrospective memory accuracy. Furthermore, Snyder and Fessler (2013a) argue that "an evolved rape-avoidance mechanism could conceivably operate without involving the conscious mind" (p550), suggesting self-report measures may not be appropriate for examining such mechanisms. They suggest it is possible that conscious awareness of such risks (what self-report measures) may not be involved in the cognitive processes associated with behavioural change. Nevertheless, one study employing a behavioural measure also found fertile females to avoid a dubious-looking male (Guéguen, 2012a). Heterosexual, naturally cycling females were asked to wait in a waiting room whilst the experimenter prepared the study. Also seated in the room was a male confederate manipulated to appear 'shady-looking', whom the participant believed to be also waiting for the study. The experimenter asked them both to place a narrow labial band strip on their tongue (to test luteinising hormone concentration), but were told it was to measure cortisol levels, before participating in a lexical decision task. Rape-avoidance behaviour was measured by the distance the participant sat from the male. Participants at peak fertility sat significantly further away from the confederate than those in the low fertile group, suggesting fertility-related avoidance of danger, or more specifically, a dangerous-looking male.

Also testing behavioural responses and luteinizing hormone directly, Petralia and Gallup (2002) employed a novel measure for testing reactions to sexual assault according to cycle-phase. Reproductive-aged females provided an initial test of handgrip strength using a hand-held dynamometer before completing a questionnaire regarding their menstrual cycle, and receiving one of two passages. Participants were either given a sexual assault scenario or a control scenario to consider whilst completing post-treatment tests of handgrip strength. The 192 whose cycle-phase could be tested were divided into one of four menstrual cycle-phases, or those using

hormonal contraceptives. Whilst there was no difference in baseline handgrip strength, only those in the ovulatory phase demonstrated an increase in handgrip strength relative to baseline in response to the sexual assault scenario. Fertile women exposed to a control scenario, and nonfertile women (including hormonal contraceptive users) showed a decline in strength from baseline, regardless of scenario. This was taken as support for the hypothesis that females have evolved an adaptation to prevent pregnancy resulting from rape.

One way females might avoid rape when conception is possible is through person evaluation, which may help them to infer the likely intentions of certain males and thus decide who to avoid. For example, Garver-Apgar, Gangestad & Simpson (2007) tested women's detection of male traits over the menstrual cycle. Women watched videotapes of men trying to attract a woman, and were asked to rate each man on the following traits: sexually coercive, frightening, creepy (these loaded on a single factor and collectively formed a 'sexually coercive' trait), as well as other global traits which are important in relationships: kind, committed, and faithful. The results showed that women were more sensitive to, and accurate at detecting males' sexual coercion near ovulation. It is suggested that this may represent a specially designed cognitive error management bias (see Haselton, Nettle & Andrews, 2005) to help females to determine the likelihood of sexual assault. Interestingly, the female participants' ratings of other traits including kindness, commitment and faithfulness did not vary over the cycle, suggesting a specifically designed mechanism for protection against sexually coercive males when most costly. In line with differential person evaluation around ovulation, Navarrete, Fessler, Fleischman and Geyer (2009) found white women in the fertile phase of their cycle to show more racial-bias, suggesting wariness of outgroup members. Walsh and DiLillo (2013), on the other hand, did not find direct effects of the menstrual cycle on risk recognition in response to a sexual assault vignette. Moreover, they actually found longer risk recognition latencies during ovulation when primed with a negative mood. However, use of oral contraceptives was not taken into account in this study, and thus analyses regarding fertility status may not have been accurate.

1.2.3. Evidence suggesting increased risk taking during ovulation

Section 1.1. provided an overview of research suggesting women reduce their risk taking behaviours during ovulation. However, despite these apparent adaptations to prevent rape at peak fertility, there is evidence to suggest that rape may actually be more prevalent during ovulation (Bierne, Hall, Grills & Moore, 2011). In addition, (though not implying a causal relationship), some research also suggests women may behave in ways that could put themselves at greater risk of encountering a sexually aggressive male during ovulation. It is important to note that exploration of the association between menstrual cycle phase and risk of sexual assault in no way justifies violence against women, and it does not shift the blame to the victims.

Research shows that during ovulation, females have increased desire to attend social events with the possibility of meeting men (Haselton & Gangestad, 2006), would dress more provocatively for these social events (Durante, Li & Haselton, 2008), use more cosmetics (Guéguen, 2012c) and walk more sexily (Guéguen, 2012b). Furthermore, partnered women become more partial to sexual encounters and will more readily have sex with unfamiliar men during ovulation (Gangestad, Thornhill & Garver-Apgar, 2005). Likewise, Guéguen (2009a; 2009b) found that women in the ovulatory phase would respond more favourably to a romantic overture from an unknown male by giving her number out and agreeing to dance with an unknown male in a nightclub. As such, there are some contradictory findings regarding women's avoidance of situations of increased risk of encountering sexually coercive males during ovulation.

1.2.4. What moderates women's risk taking during ovulation?

Ellsworth & Palmer (2010) call for precision in testing the relationship between adaptations designed to seek good quality mates at peak fertility whilst balancing the costs of rape. Schipper (2014) suggests women may be predisposed during the most fecund phase of the menstrual cycle to behave in ways to maximise reproductive success. What seems plausible as a moderator is the type of male. The men that females agreed to dance with and gave their numbers to in Guéguen's (2009a; 2009b) studies were chosen for their high attractiveness, which may explain women's

willingness to engage with them. When the male was 'shady-looking', manipulated through his appearance and body language, this same researcher found women to distance themselves from the male confederate instead (Guéguen, 2012a). Participants may have automatically evaluated his appearance in an attempt to predict his likely intentions and thus chose to avoid him (Willis & Todorov, 2006; Zebrowitz, 2004). Similarly, in Durante et al.'s (2008) study showing ovulating women to have a desire to dress provocatively, the participants were told they would be attending a social event that evening where they could meet single, attractive males. Furthermore, whilst Flowe, Swords and Rockey (2012) found women to engage more with a male when fertile, this was only true if the male was masculine. On the other hand, fertile women in Guéguen's (2012a) study engaged in less nonverbal behaviour with a 'shady-looking' male than their nonfertile counterparts.

It appears that near ovulation women behave in ways that would benefit potential offspring; they may become more resource-oriented. For example, they engage in increased competitive bidding (Pearson & Schipper, 2012), which could secure higher resources for their offspring. Similarly, near ovulation, women are less likely to share a monetary prize with another woman (Lucas, Koff & Skeath, 2007). It may be that women will take risks if it will secure their offspring with resources. FMRI research also indicates an increased desire for immediate rewards near ovulation (Dreher et al., 2007). Similar to money, good quality genetics can be seen as a resource females seek when fertile. Research shows that during ovulation females will prefer dominant, masculine and symmetrical males (Penton-Voak & Perret, 2000; Penton-Voak et al. 1999), as it is assumed dominant men generally are of higher socio-economic status and thus have the ability to provide resources for his partner and offspring (Mueller & Mazur, 1997).

1.2.5. Domain specificity

An alternative explanation for the seemingly contradictory findings may be that female participants in the research documenting decreased risk-taking during ovulation are not avoiding rape specifically, but rather all danger. A debated, or arguably the central issue in Evolutionary Psychology is whether the mind is 'domain general' or 'domain specific' (Symons, 1987). Researchers have aimed to understand

whether the mind is composed of many modules, each with a specific purpose, or whether the mind is more 'domain-general', with problem-solving mechanisms that can be applied to a range of circumstances. It may be the case that the apparent evolved rape-avoidance mechanism is not adapted for avoidance of rape specifically, but rather women are risk-averse in a more domain-general sense, particularly during ovulation.

The 'sexual assault' passage used by Petralia and Gallup (2002) merely described a female walking to her car late at night through a deserted campus when she notices she is being followed by a male. She places her open handbag on the hood of the car to look for her keys. When she finds them, the scenario ends as she feels the man's hand on her shoulder. While suggestive of sexual assault, this scenario may have equally led participants to think about robbery of the handbag or car, or physical assault as a means of stealing the items, rather than specifically sexual assault. It may be that during ovulation, in order to maximise reproductive success, women become more risk-averse to protect themselves and their fertility. Survival is essential for reproduction. Alternatively, as previously suggested, females may become more protective to secure resources for potential offspring during this cycle phase and may have been responding to a mechanism of general protection of herself and her possessions rather than protection from rape. Similarly, the questionnaire-style methods that document a decrease in 'risky' behaviours during ovulation (e.g., Bröder & Hohmann, 2003; Chavanne & Gallup, 1998) did not refer to behaviours specifically associated with rape. They mention getting intoxicated, walking in dimly lit areas and dark corners of underground garages, all which are associated with danger and crime in general. It is therefore unclear whether this differential response to risk when fertile is a specific rape-avoidance mechanism to prevent pregnancy, or protects women from all threats. Females may simply be more receptive to danger during ovulation. Previous work has suggested that women were more attuned to traits associated with sexual coercion, including 'creepiness' and 'frightening', during ovulation in comparison to other traits (Garver-Apgar et al. 2007), which is seemingly the only study aiming to assess domain specificity in women's sexual risk perception over the menstrual cycle. Previous research has not demonstrated the specificity of the

response with regards to variations in women's risk avoidance over the menstrual cycle. Garver-Apgar et al. (2007) have argued that their results may reflect a general increase in fear mid-cycle, though this does not seem to be the case as fear and anxiety appear to be greater during the luteal phase (Solis-Oritz & Cabrera, 2002; Vandermolen, Merckelbach, & Vandenhout, 1988), or there may even be a dip in anxiety mid-cycle (Gottschalk, Kaplan, Gleser Winget, 1961). Nevertheless, the concept of differential responses to risk as an explanation for the existing findings has not been examined. Coyne (2003) states, "What moves science forward is… the testing of alternative theories with observations and experiments." (p.223). To be able to conclude that ovulatory declines in risky behaviour represent an evolved rape-avoidance adaptation to prevent pregnancy resulting from rape, evidence showing "special design" for performing a specific function which cannot be explained with other accounts is necessary (Andrews et al. 2002; Thornhill 1990; 1997). Garver-Apgar et al. (2007) call for further research assessing specificity of design in women's sensitivity to sexual coercion over the menstrual cycle.

1.2.5. Evidence showing fertility-related risk avoidance in other domains

There is evidence of decreased risk-taking during ovulation in other domains, which may suggest that women become more risk avoidant in general during ovulation. For example, ovulating women became less impulsive during a gambling task when viewing images of attractive men, compared to nonfertile women, or when primed with images of attractive landscapes (Kaighobadi & Stevens, 2013). Similarly, women have been shown to become less trusting of strangers, and take less risks in an investment task during ovulation (Ball, Wolf, Ocklenburg, Herrman, Pinnow, Brüne, Wolf & Güntürkün, 2013). Ovulating women have also been shown to have enhanced detection of faces showing fear (Pearson & Lewis, 2005), which may suggest an overall increased response to images signalling threat. Neural evidence also suggests that women may process risk differently when fertile; ovulating women showed increased activation in the brain areas for risk evaluation when viewing images of masculine males (Rupp, James, Ketterson, Sengelaub, Janssen & Heiman, 2009). Such findings suggest a more general change in perception and evaluation of risk over the menstrual cycle. Indeed, research has also shown women to perceive risk differently during the

fertile compared to nonfertile periods of the menstrual cycle (Šukolová & Sarmány-Schuller, 2011). However, in this study, fertile women were willing to take more risks than nonfertile women. These findings therefore highlight the possibility that fertile women may be more attuned to risk in general, rather than specifically avoiding rape due to increased chance of pregnancy.

1.2.6. Psychological mechanisms

One way to assess whether an adaptation has evolved for a specific purpose is to link physiological characteristics with psychological processes that show specificity of design (Garver-Apgar et al. 2007). Physical and psychological responses to the environment are not separate (Palmer, 1991; 1992). Similar to physiological traits that have evolved to enhance survival and reproduction, such as the immune system, it is suggested that psychological adaptations also exist to help overcome challenges to fitness (Confer et al. 2010). To understand the development of a domain-specific adaptation, it is necessary to assess and understand the interaction between biology (e.g., hormones) and the environment (which acts as cues) (Thornhill & Palmer, 2000). Therefore, along with the primary aim of assessing domain-specificity in women's responses to risk over the menstrual cycle, a second aim of this thesis is to assess the psychological mechanisms that may be associated with women's rape avoidance behaviours.

Possible psychological mechanisms associated with women's rape avoidance could be differences in emotional arousal. Research suggests that emotions, including negative affect and anxiety, fluctuate over the menstrual cycle as hormones fluctuate (Moos, Kopell, Melges, Yalom, Lunde, & Raymond, 1969). Moreover, while measures of affect, such as anxiety and hostility, have been shown to vary over the menstrual cycle, such fluctuations in affect were not consistent among women (Gottschalk et al. 1962). Both anxiety and negative affect are associated with fear of crime (Beaulieu, Leclerc & Dubé, 2004) which may underlie avoidance behaviour that is documented in existing research (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003). Therefore, to assess for any influence in variation in mood, the Positive and Negative Affect Schedule (PANAS; Watson, Clark & Tellegen, 1988) was used to measures women's affect during each testing session.

It is argued that fear is an evolutionary response to threats (Öhman, Flykt & Esteve, 2001). Öhman & Mineka (2001) suggested the idea of an evolved fear module, encompassing a behavioural, mental and neural system which has evolved to overcome evolutionary challenges. They argue that the system can be activated either consciously or unconsciously. This is a concept that was considered throughout this thesis. Previous research has shown increases in handgrip strength during the fertile phase in response to a sexual assault scenario, which was suggested to be evidence in support of a fertility-related rape avoidance mechanism (Petralia & Gallup, 2002). Research suggests that increased handgrip strength is associated with fear (Flykt, Lindeberg & Derakshan, 2012) and threat (Elliot & Aarts, 2011). Handgrip strength was assessed in Studies 1 and 2 of this thesis. Fear of rape, or more specifically, heightened fear of rape during ovulation, may motivate the increases in rape avoidance mid-cycle. Moreover, physiological responses, such as skin conductance and heart rate acceleration have been documented in response to feared stimuli (e.g., Globisch, Hamm, Esteves, & Öhman, 1999). Therefore, fertility-related differences in response to threats may also be apparent in physiological responses, which were assessed in Study 2.

Heart rate, specifically decelerations in heart rate, are associated with increased attention (Graham, 1992, as cited by Flykt, 2005). Fear draws attention to the feared stimuli (e.g., Flykt, 2005; Soares, Esteves, Flykt, 2005) through realisation of the importance of the situation and vigilance (Öhman & Mineka, 2001). Fear of rape has been associated with cognitive vigilance and increased rape-prevention behaviours (Krahé, 2005). A possible psychological mechanism that may be associated with a rape avoidance mechanism may be biased cognition or attention towards situations of increased risk of rape during ovulation. Increased attention and detection of threats would allow faster defensive action, such as avoidance (Armony & LeDoux, 2000; Calder, Lawrence, & Young, 2001; Flykt, 2006, Öhman, 1996; LeDoux, 1996). Alternatively, increased fear may be characterised by attentional avoidance (e.g., Tolin, Lohr, Lee & Sawchuk, 1999), as a way to avoid the anxiety caused by feared stimuli. Thus, stimuli that causes anxiety will either result in increased attention (vigilance) or withdrawal of attention (Baumeister, Dale, & Summer, 1998). Attention

to threats was assessed in Studies 3 and 4 (Chapter 3), and biased cognitions were examined in Study 5 (Chapter 4).

Vigilance is associated with higher probability estimates for negative events, such as being burgled (Myers & Brewin, 1996). Therefore, women may also be more vigilant to threats, such as rape, and attribute higher probability to threats occurring when they are fertile. Women may perceive their risk of rape, or criminal victimization, to be higher during ovulation, which in turn motivates avoidance. Risk perceptions vary over the menstrual cycle (Šukolová & Sarmany-Schuller, 2011), and are associated with avoidance behaviour (Ferraro, 1995). This may act as a cognitive bias, in line with Error Management Theory (Haselton & Buss, 2000), which acts to reduce costs whilst maximizing benefits during judgment and decision making. Therefore, there may be variations in risk perceptions as a psychological mechanism underlying differences in risk avoidance. Perceived risk that a negative event is going to occur may lead to preventative behaviours, such as avoiding going out late at night. Therefore, risk perceptions of negative events may be heightened specifically during ovulation, when the costs of negative events to reproductive fitness are most significant. Risk perceptions were assessed in Chapter 2 (Study 2) and Chapter 5 (Study 7).

The more psychological mechanisms that the nervous system appears to possess, the more probable it is that the adaptive trait that is designed to overcome evolutionary challenges has evolved (Hagen, 2005). Therefore, multiple methodologies, combining physiology, behaviour and psychological mechanisms are necessary to fully understand whether a rape avoidance adaptation, which is heightened during ovulation, has indeed evolved.

1.3. Rationale development

It is important to note that while an adaptation should be a reliable inherent characteristic, adaptations benefit reproduction on average. The presence of an adaptive trait that benefits reproduction will be dependent on the costs and alternative designs available for selection (Buss et al. 1998). As discussed by McDonald, Donnellan, Cesario and Navarrete (2015), there will inevitably be costs

involved with a mechanism that causes avoidant behaviour, including time, energy, attention and missed opportunities. As such, an adaptive system is likely to be calibrated so that avoidant behaviours are employed when there would be the most adaptive benefit, whilst simultaneously minimising the costs to fitness. They suggest that a mechanism that works to protect reproductive fitness should be attuned to when sexual coercion would pose the highest threats to fitness, such as during peak fertility, and for situations in which there is the highest risk of threat.

However, there is a difference between current and ancestral environments. For example, modern contraception means that human behaviour is poorly adapted to current conditions (Thornhill & Palmer, 2000). Such delays in evolution have led to criticisms that humans have a Stone Age brain that is designed to deal with ancient adaptive problems, but are living in a modern world wherein these problems may no longer exist (Allman, 1994). Moreover, the existence of a trait amongst species may not necessarily signal an adaptation. "It is both necessary and sufficient to show that the process [or trait] is designed to serve the function" (Williams, 1966 p. 209) to be able to conclude the existence of an adaptation. As such, this thesis aims to assess the existence and specificity of a fertility-related rape avoidance mechanism in women. It aims to determine whether fertility-related changes in behaviour that have been documented in previous research have evolved to specifically prevent conception following rape by assessing for domain specificity. Secondly, it aims to examine physiological as well as psychological aspects of the mechanism. In sum, both behavioural (including physiological) and cognitive changes over the menstrual cycle in response to stimuli varying in its depiction of risk will be assessed.

1.3.1 Research questions and aims

To summarise, the evolutionary costs of rape to reproductive fitness are high for women. Rape could result in untimely pregnancy with a mate that is not of her choosing, and offspring that she may not have the resources to raise. Moreover, women could lose support from an existing mate, or have difficulty attracting mates in the future. Evolutionary theory suggests that adaptive traits evolve to overcome challenges to reproductive fitness and survival. Indeed, previous research suggests

that women have evolved adaptations to reduce their risk of rape, which is particularly active during ovulation when conception risk is highest. For example, self-report surveys have reported that women selectively reduce risky behaviours, such as going out alone late at night (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003). Moreover, fertile compared to nonfertile women have demonstrated increased handgrip strength after exposure to a scenario which depicted a dangerous scenario which could have resulted in a rape (Petralia & Gallup, 2002), whilst handgrip strength did not differ according to fertility status for a control scenario. However, domain specificity has not been demonstrated. The activities in the self-report surveys, and the scenario used by Petralia and Gallup (2002), are associated with danger and crime more generally, rather than rape specifically. Therefore, it is not clear whether women reduce their risk-taking during ovulation to prevent pregnancy resulting from rape, or become more risk averse in general during ovulation. Garver-Apgar et al. (2007) showed that women over-estimate men's sexual intent during ovulation, whilst ratings of other positive traits, such as kindness, did not differ according to fertility status. This is the only published study to have assessed specificity of response in women's rape avoidance mechanisms. Previous research has also documented decreased risk taking during ovulation in other domains, such as gambling or investment tasks. Therefore, throughout this thesis, I aim to discover whether cycle-dependent shifts in behaviour, such as avoidance of certain people and situations, are the result of an evolved mechanism to protect females from rape, or a general danger avoidance mechanism that is most sensitive during ovulation.

Specificity of purpose can be assessed through examining psychological mechanisms that may be associated with an adaptation (Garver-Apgar et al. 2007). For example, women may show higher fear of rape, higher perceived risk of rape, or attend more to stimuli associated with rape during ovulation compared to nonfertile women. Evidence of fertility-related differences in response to rape risk across psychological, physiological and behavioural measures would lend support for the rape avoidance hypothesis. Therefore, as a second aim of this thesis, I also aim to ascertain the mechanisms underlying this apparent behavioural change, such as whether there

are cycle-dependent differences in the perception of risk in general, or specifically in relation to rape risk.

Ellsworth and Palmer (2010) suggest the need for further research within this field through employing new methods. It is argued that testing hypotheses regarding the evolution of adaptive traits gives rise to the selective pressures that may have led to the trait's evolution (Thornhill, 1990). As such, as with the general aims of evolutionary psychology, this thesis aims to understand the mechanisms of the mind that drive behaviour (Campbell, 2013).

1.4. Methodological Considerations

This section will focus on considerations and experimental approaches that will be prioritised in the research used throughout this thesis.

1.4.1. Individual differences

Chance of conception and hormone levels fluctuate over the menstrual cycle, between menstrual cycles and between women. The menstrual cycle does not affect all women in the same manner (Moos & Leiderman, 1978). Factors associated with hormonal fluctuations, such as mood changes across the menstrual cycle, are not consistent among women. Some women experience more intense changes in mood, such as more negative affect and anxiety, during premenstrual tension (Gottschalk, Kaplan, Gleser & Winget, 1962). This suggests that manipulation of fertility within-subjects is preferable to a between-subjects manipulation to control for individual differences in affect, which may influence responses to threatening stimuli. The Positive and Negative Affect Schedule (Watson, Clark & Tellegen, 1988) was used to assess fertility-related differences in affect.

Secondly, it is suggested that the psychological pain caused by rape, which encourages avoidance, varies according to individual differences, including marital status, children and age (Thornhill and Thornhill research 1990a; 1990b; 1990c). Factors such as age and marital status were assessed using the pre-screening questionnaires for each study (explained in section 1.5.2.). To reduce the impact of extraneous variables, where possible, a within-subjects design was prioritised,

assessing responses to risk across the menstrual cycle, or more specifically, across women's fertility-status. Indeed, it is argued that menstrual cycle phase is inherently a within-subjects concept (Laeng & Falkenberg, 2007).

1.4.2. Hormonal contraceptives

The aim of this thesis is to assess responses to risk stimuli as hormones, or more specifically fertility, fluctuates across the menstrual cycle. If fertility and hormone levels drive changes in behaviour or cognition, these changes should be apparent across the menstrual cycle. However, hormones and fertility should only fluctuate in naturally cycling women. In contrast, hormonal contraceptives provide a steady release of the same hormones, and prevent women from being fertile (Fleischman, Navarrete & Fessler, 2010). For example, the combined pill, which contains similar hormones to the estrogen and progesterone produced in naturally cycling women, is characterised by steady hormone concentrations, and thus no mid-cycle surges in luteinising hormone. As such, hormonal contraceptive users should not fluctuate in their hormonal or fertility status and thus serve as an adequate control to naturally cycling females. Thus, it was important to assess information such as use of hormonal contraceptives and cycle regularity using a pre-screening questionnaire, to be able to select eligible participants.

1.5. Assessment of hormonal and fertility status

1.5.2. Pre-screening Questionnaire

Pre-screening questionnaires are essential with menstrual cycle research to assess eligibility criteria, and so participation can be arranged during the appropriate menstrual cycle phase. Online questionnaires were used to pre-screen potential participants for each study, and also administered during participation for up to date information regarding participants' menstrual cycles (see Appendix A). It became apparent after study 3 that it was also important to ask about cycle length as well as regularity, as it is possible to have a regular cycle wherein menses occurs consistently, but with a shorter or longer amount of time between menses than the regular 28 days. Pre-screening questionnaires are also useful for obtaining information on participants' demographics, including age, marital and cohabiting status. These, along with

additional questions regarding health, sleep and social behaviours also served as distractor questions to avoid disclosing the aims of the research. Although the research advertisements called for females aged 18-35 years, the questionnaire enabled confirmation of participants' exact age. It is suggested that women from mid-20s to mid-30s are ideal participants for ovulatory research (Hampson & Young, 2007).

1.5.3. Verification and assessment of fertility

While questionnaires are useful for collecting preliminary information regarding menstrual cycles, such as use of hormonal contraceptives, retrospective self-reports of menstrual cycles as the sole measure of fertility status could lack accuracy. While the forward-count method can help to estimate menstrual cycle phase, direct, objective measurements of hormones are considered the best method to confirm hormonal status (Hampson & Young, 2007). Self-administered ovulation tests which measure the levels of luteinising hormone present in urine were used to verify fertility. The tests used had a sensitivity of 30 miu/ml (http://www.homehealth-uk.com/medical/ovulation-tests.htm). Positive ovulation results are indicated if the test band and control band are of equal intensity in colour. If the test strip is lighter than the control strip, the surge in luteinising hormone is not currently in progress (see Figure 3).
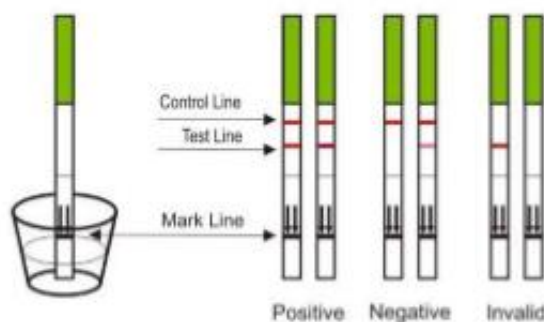
Figure 3. Assessment of ovulatory status using urine-based ovulation tests

Ovulation tests accurately predict ovulation day by identifying the participant's luteinising hormone (LH) surge in the urine (Paz et al. 1990) that occurs approximately 18 to 24 hours before ovulation. However, the surge can occur between 16 and 48 hours prior to ovulation (Hampson & Young, 2007), and the LH elevation can last from 48 to 58 hours after the surge (Fritz et al. 1992). Nevertheless, the presence of a surge

in LH is considered a reliable and accurate marker for the onset of ovulation (Behre et al. 2000). However, despite following advice regarding the circumstances for the most accurate results, and arranging participation during peak fertility based on information in the pre-screening questionnaire, ovulation tests for women participating in the 'fertile' condition were sometimes negative. As such, as a further verification of menstrual cycle phase during participation, participants were asked to contact when their next menstrual cycle began proceeding participation. Estimating fertility by counting backwards from date of menstrual cycle onset to the date of participation is more accurate than the forwards count method, as the luteal phase is relatively constant. Ovulation occurs 13-15 days prior to the onset of next menstruation (Hampson & Young, 2007). However, despite reminders to participants, this information was not always volunteered.

1.5.4. Organisation of participation

As ovulation occurs approximately 14 days prior to menses, participation sessions usually occurred 2 weeks apart, with cycle days 1-3 most commonly being the nonfertile phase (including day 21-23 in Studies 1, 3 and 5) and day 14 (backward count) or 12-16 (forward-count) being used for the fertile phase. Days 1-3 were chosen as the nonfertile phase as conception risk and hormone concentrations are lowest (as used by Macrae, Alnwick, Milne & Schloerscheidt, 2002). Previous research has often also included day 21 (the luteal phase) as the nonfertile phase, and indeed the mid-luteal phase was used as the nonfertile condition in some participants in studies 1, 3 and 5. However, it is important to note that the hormonal profiles for the menstrual and mid-luteal phase differ, that is, the menstrual (also known as early-follicular) phase is characterised by high estrogen, while the luteal phase involves high progesterone levels (see Figure 1). As the participants in both the menstrual and luteal phase were combined for the 'nonfertile' condition, there was variation in the hormone profiles within the nonfertile participants. Progesterone and estrogen may have affected responses differentially. For example, attention to faces and emotions has been shown to be influenced by progesterone (e.g., Miller, 2011, as cited in Fleischman, Fessler & Cholakians, 2015). Unrelated to the aims of this thesis, I was interested in the effect progesterone would have in this regard. However, after further

research, it was decided that the luteal phase may not be appropriate for a nonfertile condition. Aside from the hormonal profiles differing to the follicular phase, research has indicated fear and anxiety to be highest during the luteal phase (e.g., Glover et al., 2013; Steiner, Peer, Macdougall, & Haskett, 2011). For example, the luteal phase is known as a vulnerability period for re-experiencing stressful stimuli (Bryant et al. 2011; Ferree & Cahill, 209; Ferree, Kamat & Cahill, 2011; Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999; Soni, Curran & Kamboj, 2013), and likelihood of intrusions due to the high progesterone strengthening memory representations (Pitman, Shalev, & Orr, 2000). Consequently, as participants were exposed to threat-related and potentially stress-inducing stimuli, the interaction between progesterone and fear may have caused unnecessary additional stress to participants, and may have influenced the responses. For example, women that experienced a sexual assault scenario during their luteal phase may have shown increased fear and physiological responses that were not related to fear of conception specifically but rather higher anxiety during this phase more generally.

Conception risk is continuous. However, as this thesis was interested in fertility specifically, and the luteal phase could be considered problematic due to the high progesterone levels, fertility was conceptualised as a dichotomous variable. The phase in which first participation occurred was always counterbalanced across participants. Assuming cycle days were calculated accurately; naturally cycling participants would fluctuate in hormonal and fertility status across the two testing sessions, and therefore, if there is an evolved adaptive trait to aid rape-avoidance particularly when fertile, physiological and cognitive responses to risk should differ across the two testing sessions.

1.6. Experimental Approaches: Problems with existing research

1.6.1. Self-report

Questionnaires are useful for collecting information about participants, such as their demographics and for administering scales, but could be argued to be problematic when used as the sole source of data collection. Existing research on rape avoidance behaviour over the menstrual cycle is largely based on self-report (e.g.,

Chavanne & Gallup, 1998; Bröder & Hohmann, 2003). This may lack accuracy due to retrospective remembering of activities and responding in a socially desirable way. Women may be hesitant to report instances wherein they went out alone, or on a date, for example. As such, this thesis focused on methodologies that give insight into cognitions, emotions, perceptions, motivations and physiology to assess variations according to fertility and risk stimuli.

An evolved trait should affect all aspects of an organism including behaviour, physiology and cognitions (e.g., attention, fear). Therefore, a variety of methodologies were used to assess whether the adaptive trait is apparent in all aspects. For example, physiological measures (heart rate, hand grip, eye movements), cognitive measures (attention, dichotomous categorisation task), self-report (perceptions, rating scales) and behaviours (reaction speed) were examined. To conclude that females have evolved a fertility-related rape avoidance mechanism, there should be fertility-related differences in all aspects.

1.6.2. Domain specificity

The main research question of this thesis is specificity of the adaptation. Previous research has not yet shown specificity in risk avoidance behaviours across the menstrual cycle. It has instead focused on stereotypical markers of crime or sexual assault such as alleyways and night time (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003; Petralia and Gallup, 2002). Therefore, previous research may not actually be measuring 'rape-avoidance' behaviours per se, but rather general danger avoidance. Therefore, this thesis aimed to assess responses to rape risk specifically in comparison to risk and danger more generally. One way to do this is by comparing responses to the physical versus sexual aspects of crimes. However, this may be difficult due to the assumptions of the Shadow of Sexual Assault Hypotheses (Ferraro, 1995; 1996; Warr, 1985).

1.6.3. The shadow of Sexual Assault Hypothesis

It is difficult to separate women's fear of sexual assault from their fear of crime in general. This is explained by the 'Shadow of Sexual Assault Hypothesis' (SSAH; Ferraro, 1995; 1996; Warr, 1985). Despite their lower overall risk of victimisation,

females are consistently reported as having greater fear of crime than males (e.g., Akers, LaGreca, Sellers & Cochrane, 1987; Liska, Lawrence & Sanchirico, 1982, Roman & Chalfin, 2008; Warr 1984). Arguably, this may be due to men's underreporting (Smith & Torstensson, 1997; Sutton & Farrall, 2005). Nevertheless, females are more likely to become victim to sexual assault than men (Fox, Nobles, & Piquero, 2009) and have increased associated costs, such as risk of conception. The SSAH suggests that a female's fear of sexual assault is so pronounced that it 'shadows' fear of all other crimes, as any crime could potentially escalate into sexual assault (Warr, 1984). Indeed, after controlling for fear of sexual assault, fear of nonsexual assault became equal between the sexes (Hilinski, 2009). This hypothesis has been tested and successfully replicated across many situations and populations (e.g., Dobbs, Waid & Shelley, 2009; Ferraro, 1996; Fisher & Sloan, 2003; May, 2001; Wilcox, Jordan & Pritchard, 2006), but is still believed to lack extensive empirical testing (Cook & Fox, 2012).

Recent contradictory findings by Cook & Fox (2012) however, suggest that fear of physical harm has a significantly greater impact on women's fear of crime than sexual assault. Furthermore, some females reported that their fear of some crimes did not prompt thoughts of the crime accelerating into sexual assault (Hilinski, Pentecost, Neeson & Andrews, 2011). For example, the female participants in Hilinski et al.'s (2011) research believed that theft was to satisfy a financial need whereas rape was a sexual need. However, it may be that these women were not in the fertile phase of the cycle. More research is needed to refine SSAH in terms of physical versus sexual aspects of rape (Lane & Meeker, 2003), and how these assumptions might vary according to fertility. This thesis considered the assumptions of the SSAH when designing experiments, and consequently also examined the SSAH in relation to cycle-phase. To test the specificity of response it is necessary to compare reactions to rape to those of other dangerous crimes. Studies were designed to further test the assumptions of SSAH by differentiating between physical and sexual assault. An adequate control, which is not present in previous research, is to assess responses to female-perpetrated crimes. Female-perpetrated crimes involve danger, whilst controlling for the risk of rape and thus conception that is present in male-perpetrated

crimes. As such, responses to male versus female stimuli were compared. This should help to understand whether fertility-related differences in responses reflect danger avoidance or rape avoidance.

2. Chapter 2: Physiological responses

2.1. Introduction

Recent research has documented that there are significant changes in women's social behaviour across the menstrual cycle. For example, women have self-reported avoiding situations that should theoretically increase their risk of rape, including coming home alone late at night, and walking in dimly lit areas and dark corners of underground garages, particularly during the phase of peak fertility in their menstrual cycle (Chavanne & Gallup, 1998; Bröder & Hohmann, 2003). This finding holds both when fertility is measured between-subjects (Chavanne & Gallup, 1998) and within-subjects (Bröder & Hohmann, 2003), highlighting the impact of the menstrual cycle on rape-avoidance behaviours. However, self-reports rely on retrospective memory and may therefore lack accuracy. Behavioural research has also demonstrated ovulating females to keep more distance from a 'shady-looking' male (Guéguen, 2012a), be more sensitive to, and accurate at detecting the sexual coercion of males (Garver-Apgar, Gangestad & Simpson, 2007) and demonstrate increased strength in response to a sexual assault scenario compared to their nonfertile counterparts (Petralia & Gallup, 2002).

Petralia and Gallup's (2002) novel study used handgrip strength to operationalise women's physiological reactions to a sexual assault scenario according to menstrual cycle phase in order to assess evolved mechanisms associated with the fertility-related rape-avoidance hypothesis. One hundred and ninety-two females of reproductive age were asked to provide an initial test of handgrip strength using a hand-held dynamometer before completing a questionnaire regarding their menstrual cycle, and reading (whilst also listening to the experimenter read) one of two passages. Participants received either a control (i.e., neutral everyday scenario in daylight) or a sexual assault scenario to consider whilst completing posttreatment tests of handgrip strength. Menstrual cycle phase was estimated using the forward cycle method (Grammer, 1993) as well as a self-administered urine-based ovulation stick to test for luteinizing hormone (LH) levels. Participants were categorised into one of four menstrual cycle phases, or those using hormonal contraceptives. There were no differences in pre-treatment handgrip strength between females in the five

different hormonal categories. However, only those in the ovulatory phase increased their handgrip strength relative to baseline after exposure to the sexual assault scenario, whilst fertile women exposed to a control scenario, and nonfertile women (including hormonal contraceptive users) exposed to the sexual assault or control scenario gripped with equal intensity to baseline (Petralia & Gallup, 2002). This was taken as showing increased ability to thwart off a sexual attacker, and support for the hypothesis that women may have evolved a counter-adaptation to prevent pregnancy resulting from rape. Their finding supports that of Elliot and Aarts (2011), who demonstrated increased strength in response to threat. However, it is important to note that cycle-dependent fluctuations in handgrip strength have been reported more generally (e.g., Phillips, Gopinathan, Meehan, Bruce & Woledge, 1993). However, research has also found handgrip strength to decrease mid-cycle (Phillips, Sanderson, Birch, Bruce & Woledge, 1996) without involving threat of sexual assault. Other studies including handgrip strength (e.g., Allen & Bailey, 1982) and knee extension (Dibrezzo, Fort & Brown, 1988) have however shown no fluctuations over the menstrual cycle.

However, Petralia and Gallup's (2002) findings may simply reflect menstrual cycle-related increases in risk-avoidance or risk perception more generally. First, their 'sexual assault' scenario did not explicitly depict rape, but rather alluded to the possibility of a sexual assault occurring. It described a girl walking alone to her car late at night through a wooded area when she realises she is being followed by a man. She fumbles for her car keys, and places her bag down to look for them. The scenario ends as she finally finds her keys and inserts them into the door, and she feels the man's hand on her shoulder. Although suggestive of rape, participants may have alternatively thought that the scenario would end in a physical assault or robbery. It may be the case that women increase their risk aversion more generally during ovulation to maximise reproductive success. Secondly, Petralia and Gallup (2002) concluded from their study that women's increase in handgrip strength when fertile is representative of the increased ability to thwart off a sexual attack when it would have the most reproductive costs. However, whilst this may be the case, it is not entirely clear what increased handgrip strength in response to the likelihood of sexual assault occurring

was operationalising. Adaptations work to increase reproductive fitness through psychological and physiological mechanisms. Buss (2010) states that psychological adaptations can be apparent in physiological activity. An adaptation that could help women to avoid rape at peak fertility could influence both psychological and physiological mechanisms. While increased strength may help to successfully fend off an attacker, there may be alternative, or additional underlying mechanisms resulting in the increased grip strength during peak fertility.

For example, increased handgrip strength may have resulted from, or could be accompanied by: fear, desire to defend oneself, perceived ability to resist, overall physiological arousal, emotion, or perceived risk. McKibbin, Shackelford, Goetz & Starratt (2008) argue that, whilst previous research does not inform us about the specific behaviours women perform to avoid rape, the findings suggest that women do have evolved mechanisms that allow them to assess the risk inherent in certain situations. As such, risk assessment may differ according to fertility, when risk of sexual assault would have more evolutionary costs. Therefore, both the physiological and psychological mechanisms that women may have evolved that underlie the apparent increased rape avoidance during ovulation were explored. Multiple and converging methodological approaches were used. Furthermore, it was assessed whether such mechanisms were specific to situations associated with sexual assault, or were related more generally to different types of dangers (e.g., physical assault by a female) besides sexual assault.

Other related research on rape risk avoidance across the menstrual cycle has similar limitations with respect to behavioural specificity. The self-report surveys (e.g., Bröder & Hohmann, 2003; Chavanne & Gallup, 1998) did not refer to behaviours specifically associated with rape-avoidance. They mention being intoxicated, walking in dimly lit areas and dark corners of underground garages, all which may have primed thoughts of danger in general rather than rape specifically. It is, therefore, unclear whether the changes in behaviour and strength vary across the menstrual cycle in order to avoid rape and decrease the chance of conception with an undesired mate, or whether women become risk averse more generally during ovulation. Indeed, there is evidence of decreased risk-taking during ovulation in other domains, such as gambling

(Kaighobadi & Stevens, 2013) and investment tasks (Ball et al. 2013). Ovulating women also have enhanced detection of fearful expressions (Pearson & Lewis, 2005), become less trusting of strangers (Ball et al. 2013) and show increased activation in the brain areas for risk evaluation, with regards to risk of sexually transmitted infections (Rupp et al. 2009). Research has also shown women to perceive risk differently during the fertile compared to nonfertile periods of the menstrual cycle (Šukolová & Sarmány-Schuller, 2011). These findings, therefore, highlight the possibility that women may be more attuned to risk in general, rather than specifically avoiding situations that increase their risk of rape in particular when conception is possible. Given that the evidence for a rape-specific adaptation is to a large extent indirect, Study 1 aimed to examine whether a fertility-related rape avoidance adaptation, as suggested by previous research, is specific to rape or extends to other situations depicting risk.

To test whether women are altering their behaviour to avoid rape specifically, it is necessary to compare the responses of women to various types of danger (e.g., physical assault versus sexual assault) across the menstrual cycle. However, the shadow of sexual assault hypothesis (Ferraro, 1995; 1996; Warr, 1984) theorises that women's heightened fear of crime relative to men arises because women fear that any crime has the potential to escalate into a sexual attack. Because of the associated costs of sexual assault, women are disproportionately fearful of crime. Therefore, to control for this possibility, two different types of scenarios were included, including a male- and a female- perpetrated physical assault scenario. In line with the shadow of sexual assault hypothesis, women should demonstrate greater reactivity in response to a depiction of physical assault by a male compared to a female assailant. Furthermore, an explicit rape scenario in which the perpetrator was male was included. Women should demonstrate the highest levels of reactivity to the rape scenario compared to the control (physical assault) scenarios.

To understand whether self-report measures, as used in previous research (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003), accurately correspond to physiological reactions, subjective responses towards each of the scenarios were also collected. For example, to corroborate actual physiological responses, women were asked questions about their perceived responses and subjective feelings. Previous

research has found that women feel physically stronger when conception risk is relatively high (Prokop, 2013). As such, to understand whether cognitive changes in relation to the scenario corresponded to physiological changes, subjective questions about self-perceived strength were asked. Therefore, this study assessed reactivity to various threats across multiple modalities.

Reactivity was assessed during each scenario, immediately post-scenario and during a 1-minute rumination period post-scenario using physiological and subjective measures. Research suggests that physiological reactivity to stressors is informative both during the stressor, and when people ruminate about a stressor whilst recovering from it (Glynn, Christenfeld & Gerin, 2002; 2007). Replicating Petralia and Gallup's (2002) method, handgrip strength was tested at baseline and post-scenario, as well as after a 1-minute rumination period. Subjective responses to the scenarios were measured after the rumination period.

2.2.1. Study 1: Handgrip strength and subjective responses according to risk of rape and fertility

Study 1 assessed whether physiological (handgrip strength) and subjective responses to scenarios vary across women's menstrual cycle and use of hormonal contraceptives (HC). The aim was to distinguish whether the findings of increased physiological reactivity (handgrip strength) when fertile in previous research signifies women's reactions to the reproductive or physical injury costs of rape in particular. Therefore, reproductive and physical injury costs portrayed in the scenarios to which fertile and nonfertile participants were exposed were varied. Women experienced a scenario portraying a woman being sexually assaulted by a male, physically assaulted by a male, or physically assaulted by a female. This female scenario depicted a physically dangerous situation in which there were no reproductive costs. Further, in Study 1, fertility (fertile, nonfertile, or hormonal contraceptive users) and scenario type (rape, male-perpetrated physical assault or female-perpetrated physical assault) were manipulated between subjects.

To assess convergence in women's psychological and physiological responses to the scenarios, converging methodologies were used. Handgrip strength was

assessed as a physiological measure, as well as subjective responses, including women's self-perceived emotional and physiological responses to the scenarios. Perceptions of risk were addressed to examine whether fertility influences risk perceptions, as would be suggested by previous research (e.g., Šukolová & Sarmány-Schuller, 2011).

Based on the findings of Petralia and Gallup (2002), and the premise of the shadow of sexual assault hypothesis (Ferraro, 1995; 1996), it was hypothesised that fertile women would show greater reactivity (as measured by increased handgrip strength, and more negative responses on the subjective perceptions e.g., higher perceived risk and physiological arousal) for the rape scenario and the male-perpetrated physical assault scenario only compared to nonfertile women, including hormonal contraceptive users (Hypothesis 1). That is, there would be no differences in reactivity in response to the female-perpetrated physical assault scenario according to fertility.

2.2.2. Method

2.2.2.1. Participants

Participants responded to an advertisement that was placed on the University bulletin and research participation scheme. The advertisement called for women aged between 18-35 years to participate in a study assessing their reactions to criminal scenarios. One hundred and eighty-five women signed up, and gave their informed consent before completing a pre-screening questionnaire that assessed their eligibility for participation. The pre-screening questionnaire was primarily used to gather information regarding women's menstrual cycles. The questionnaire asked about use of hormonal contraceptives at present, or in the past 6 months. If participants stated they had been using hormonal contraceptives in the past 6 months, they were followed up via email to assess when they stopped taking hormonal contraceptives and if their cycle had returned to normal since. The pre-screening questionnaire also asked whether participants would class their cycle as regular, defined as menstruation consistently occurring every 28 days, or irregular, and the date of onset of their most recent menstruation. The pre-screening questionnaire was also used to obtain

information on participants' demographic characteristics, including their age, marital and cohabitation status. In addition, questions regarding health, sleep and social behaviours also served as distractor questions to avoid disclosing that the research was particularly interested in studying women's reactions across their menstrual cycle. Although the research advertisements called for females aged 18-35, the questionnaire enabled confirmation of participants' exact age. It is suggested that women from mid-20s to mid-30s are ideal participants for ovulatory research (Becker, Berkley & Geary, 2007).

Women who were aged between 18 and 35 years and using hormonal contraceptives or had been naturally cycling for more than 5 months were contacted via email and recruited for participation. Naturally cycling (NC) participants were asked to state the average length of their menstrual cycle to estimate menstrual cycle phase. NC participants were arranged to participate during either a fertile (days 12-16) or nonfertile (days 1-3, and 21-23) phase of their menstrual cycle. Hormonal contraceptive (HC) users were not arranged to participate on any specific day. This was calculated based on the information women provided in the pre-screening questionnaire regarding their menstrual cycles using the forward count method (Grammer, 1993; Wideman, Montgomery, Levine, Beynnon, & Shultz, 2013). Ovulation tests, which measure levels of luteinising hormone at a sensitivity of 30 miu/ml, were administered to all naturally cycling participants to verify fertility (http://www.homehealth-uk.com/medical/ovulation-tests.htm). A positive ovulation result was indicated if the test band was of equal, or greater intensity in colour than the control band. In contrast, if the test strip was lighter in colour than the control strip, this indicated that the surge in luteinising hormone was not present.

A total of 115 female participants participated in the study. Participants ranged in age from 18 to 34 years (M = 20.96, SD = 3.61 years). For the fertile phase, 15 participants completed the rape and female-perpetrated physical assault (FPA) scenario, and 14 completed the male-perpetrated physical assault (MPA) scenario. For the nonfertile phase, there were 12 in each of the three scenarios. For the hormonal contraceptive users, there were 14 in the SA condition, 11 in the male-perpetrated assault condition and 10 in the female-perpetrated assault scenario.

2.2.2.2. Design

A 3 fertility (fertile, nonfertile, hormonal contraceptive) x 3 scenario (sexual assault, male-perpetrated physical assault, female-perpetrated physical assault) x 2 time (handgrip change from baseline to post-scenario, handgrip change from baseline to post-rumination) mixed design was employed, with time as the only within-subjects factor. Handgrip strength was measured at baseline, post-scenario and after a 1-minute rumination period. The independent variables were fertility and scenario, whilst the dependent variables were handgrip change from baseline to post-scenario and baseline to post-rumination, as well as subjective reactions and perceptions.

2.2.2.3. Materials and procedure

The study received full ethical approval from the University of Leicester ethics committee. Participants were randomly assigned to one of the three scenarios (see Appendix B). These scenarios were written in a similar structure and length to those by Petralia and Gallup (2002). The scenarios were approximately two and a half minutes long when presented auditorily via a recorded description and written in a similar style (e.g., third person) but they varied in substantive content. Each scenario was identical for approximately the first two thirds. The scenarios involved a woman walking alone home from work when she realises she is being followed. However, the endings differed. The sexual assault scenario involved the woman being followed by a man and ending in a completed rape. The male-perpetrated physical assault scenario described a woman being followed by a man, who physically assaults her before leaving. Finally, the female-perpetrated physical assault scenario involved a woman being followed by another woman, who physically assaults her before leaving. It was important to make it clear that the perpetrator had left following the crime, given the shadow of sexual assault hypothesis (Ferraro, 1995; 1996), which posits that women are aware that a nonsexual crime can escalate into a sexual crime. An audio recording was made of a female actor reading each of the scenarios, which participants listened to on headphones whilst they read the scenario. The same female recorded all three scenarios in the same tone.

On arrival, participants were made aware of what their participation would involve before providing full informed consent via a consent form (see Appendix C),

but were not aware of the aims of the research. A Vernier International handheld dynamometer was placed upright, attached to the table in front of the participant, next to their dominant hand. Participants completed preliminary assessments, with questions similar to those in the pre-screening questionnaire for up to date information regarding their demographics and menstrual cycles.

The study began with participants completing a baseline test of handgrip strength, wherein they were instructed to squeeze the handheld dynamometer with their dominant hand as hard as possible for 3s. Afterwards, to allow the handgrip to return to baseline and to assess differences in mood according to fertility, participants completed the Positive and Negative Affect Schedule (the PANAS; Watson et al. 1988).

Participants listened to the recording of the scenario to which they had been randomly assigned whilst reading the written form of the scenario on a computer monitor. Immediately after the scenario had finished, participants were instructed to squeeze the handheld dynamometer to the best of their ability with their dominant hand again. Afterwards, participants were asked to think about the scenario vividly with their eyes closed for 1 min before completing a final post-rumination test of handgrip strength. After this, participants completed questions about their subjective emotional and physiological reactions to the scenario. This included the extent to which, on a scale of 1 (Not at all) to 7 (Completely), that the scenario made them feel negative emotions, physiologically aroused, running from the attacker, physically fighting the attacker, they could successfully fend off the attacker, they could emotionally cope with the situation, and the perceived risk of the situation happening to them that day. Participants were fully debriefed as to the aims of the study. Naturally cycling participants completed self-administered ovulation tests (1 participant refused) to verify ovulatory status.

2.2.2.4. Data analysis

Maximum handgrip strength (N) for baseline, post-scenario and post-rumination measurements were recorded. To calculate the effect of the scenario on handgrip strength, the score for baseline handgrip was subtracted from the post-scenario handgrip measurement. Likewise, to calculate the effect of rumination,

baseline handgrip was subtracted from the post-rumination handgrip measurement. There were missing values for the rumination period; for the fertile participants there were 2 missing measurements for the female-perpetrated assault scenario and 1 for the rape scenario. For the nonfertile participants, there was 1 measurement missing from the rape scenario, and one from the female-perpetrated assault scenario. Little's MCAR test suggested that data were missing completely at random, $\chi^2(1) = 2.126$, $p = .145$. As such, missing data were replaced using the expectation maximisation method (Dempster, Laird & Rubin, 1977). This widely applicable iterative method uses an algorithm to compute the maximum likelihood estimates from incomplete data, with each iteration of the algorithm comprising an expectation step before a maximisation step (Dempster et al. 1977).

2.2.3. Results

2.2.3.1. Preliminary results

As can be seen in Table 1, there was no difference in baseline handgrip across fertile, nonfertile, or hormonal contraceptive using women, $F(2, 106) = .34$, $p = .71$. Descriptively speaking, for naturally cycling women, regardless of fertility, baseline handgrip was highest for those in the rape scenario condition, and lowest for the female-perpetrated assault scenario condition. Neither positive affect, $F(2, 109) = .728$, $p = .49$, nor negative affect, $F(2, 109) = .53$, $p = .59$ differed by fertility.

Table 1. Baseline mean (±1 SEM) handgrip by fertility and scenario.

Fertility	Rape		Male-perpetrated assault		Female-perpetrated assault	
	M	SEM	M	SEM	M	SEM
Fertile	165.80	11.37	148.33	11.77	141.63	11.37
Nonfertile	176.14	12.71	163.34	12.71	140.65	12.71
HC	144.03	11.77	160.64	13.28	159.17	13.93

2.2.3.2. Handgrip

Figure 4 shows handgrip change from baseline to post-scenario, while Figure 5 shows handgrip change from baseline to post-rumination. Figure 6 shows the mean

change in handgrip strength from baseline to post-scenario handgrip measures (post-scenario and post-rumination combined). Relative to baseline, there was a general pattern of a decrease in handgrip strength, with a small increase in strength for the rape scenario in nonfertile participants.

The handgrip strength data were submitted to a 3 fertility (fertile, nonfertile, hormonal contraceptive [HC]) x 3 scenario (rape, male-perpetrated physical assault, female-perpetrated physical assault) x 2 time (handgrip change from baseline to post-scenario, handgrip change from baseline to rumination) mixed ANOVA, with fertility and scenario as between-subjects' factors and time within-subjects. There was no main effect of fertility, $F(2, 106) = 1.08$, $p = .34$, scenario, $F(2, 106) = .36$, $p = .69$, or time, $F(1, 106) = 1.25$, $p = .27$. Overall, with post-scenario and post-rumination measures combined, fertility and scenario did not significantly interact, $F(4, 106) = 1.51$, $p = .2$ on women's change in handgrip strength (See Figure 6 and Table 2). Time did not interact with fertility, $F(2, 106) = .07$, $p = .93$, or scenario, $F(2, 106) = .73$, $p = .49$, and the three-way interaction for time, fertility and scenario was not statistically significant, $F(4, 106) = 1.23$, $p = .3$. Therefore, the hypothesis was not supported.
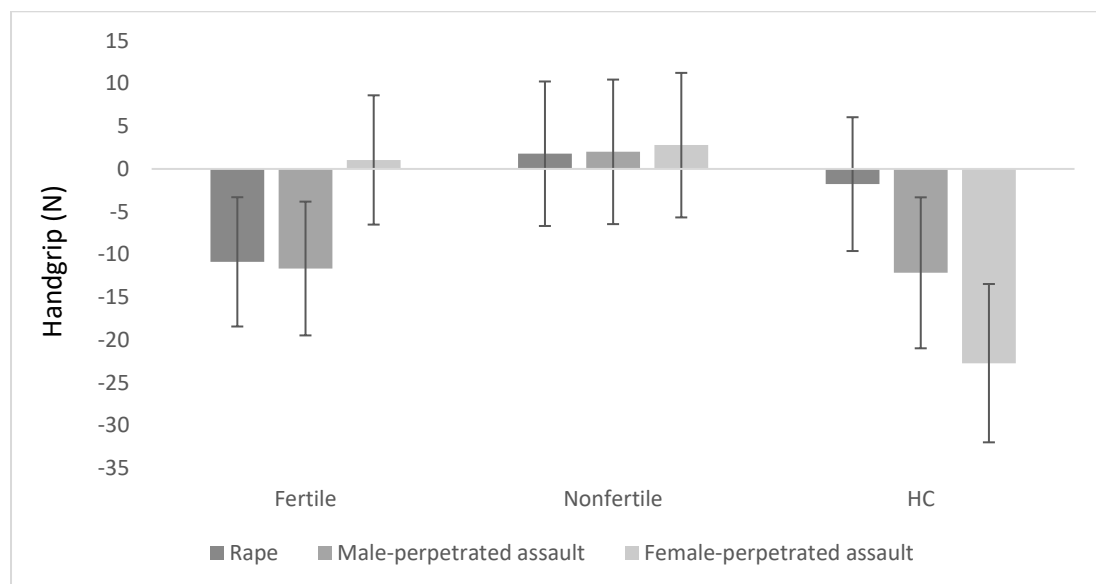
Figure 4. Mean (±1 SEM) change in handgrip from baseline to post-scenario, by scenario and fertility
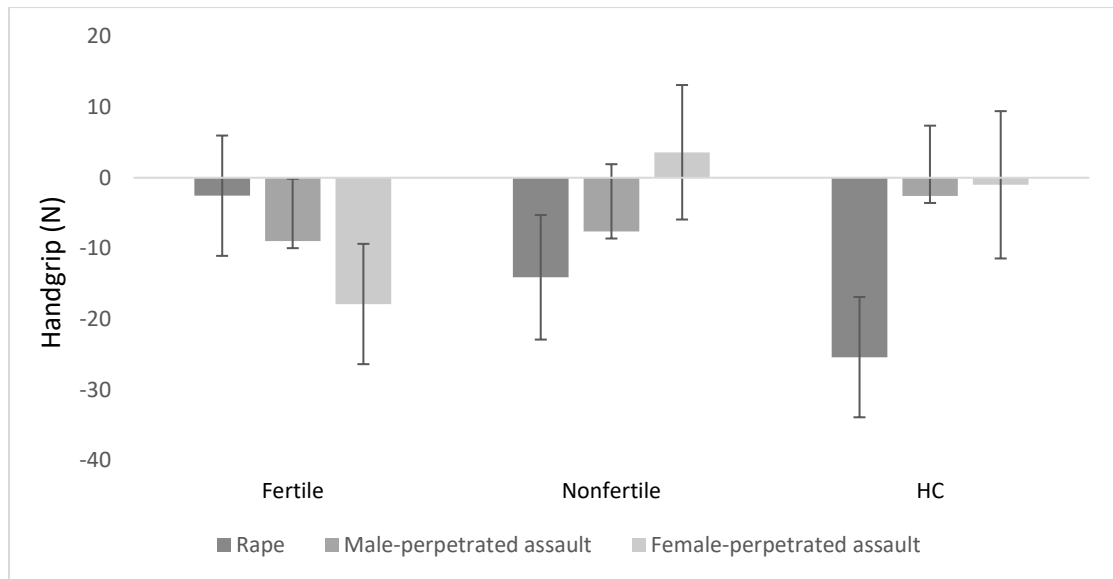
Figure 5. Mean (±1 SEM) change in handgrip from baseline to post-rumination, by scenario and fertility.
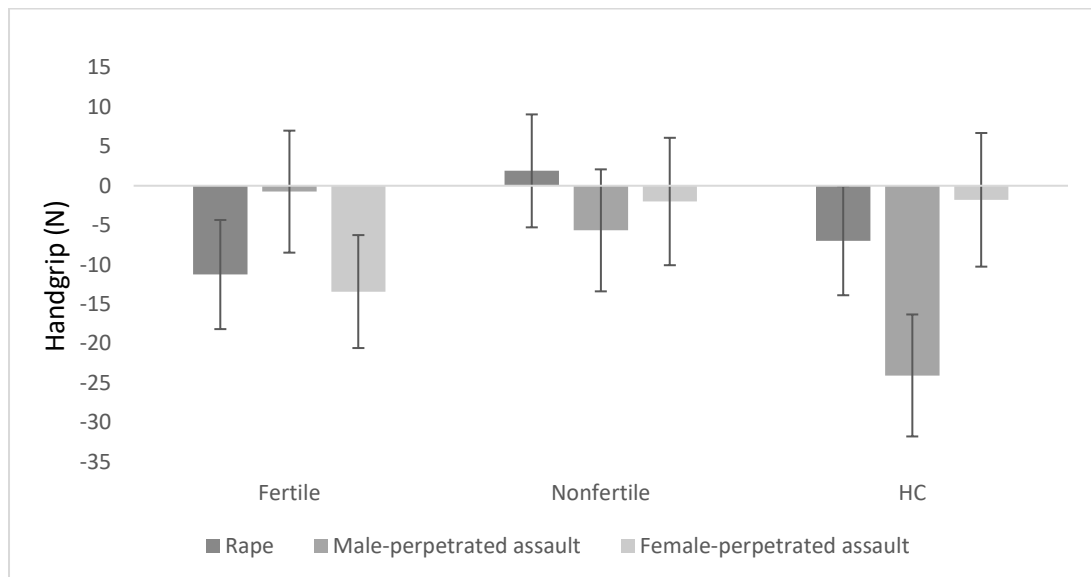
Figure 6. Mean (±1 SEM) change in handgrip from baseline to post-scenario and post-rumination combined, by scenario and fertility

Table 2. Descriptive statistics for mean (+ 1 SEM) change in handgrip from baseline to post-scenario, and from baseline to post-rumination by fertility and scenario

| | Post-scenario | | | | | | Post-Rumination | | | | | |
| | Rape | | Male-perpetrated Assault | | Female-perpetrated Assault | | Rape | | Male-perpetrated Assault | | Female-perpetrated Assault | |
	M	SEM	M	SEM	M	SEM	M	SEM	M	SEM	M	SEM
Fertile	-10.87	7.56	-11.65	8.45	1.05	7.82	-2.54	8.51	-8.97	9.52	-17.87	8.81
Nonfertile	1.78	7.82	1.99	8.45	2.78	8.83	-14.09	8.81	-7.60	9.52	3.60	9.94
HC	-1.78	7.56	-12.15	8.45	-22.72	9.26	-25.39	8.51	-2.57	9.52	-1.0	10.43

2.2.3.3. Subjective responses

As seen in Table 3, negative responses (e.g., higher negative emotions, more physiological arousal, less perceived ability to emotionally cope) were highest for the rape scenario, and lowest for the female-perpetrated physical assault scenario. However, descriptively speaking, negative responses were slightly lower for fertile participants compared to nonfertile participants and hormonal contraceptive users. Therefore, the hypothesis was not supported.

Table 3. Mean (+1 SEM) ratings for subjective reactions by scenario type across all participants

Subjective perception	Fertility	Rape		Male-perpetrated assault		Female-perpetrated assault	
		M	SEM	M	SEM	M	SEM
Negative Emotions	Fertile	5.64	0.41	5.21	0.38	4.64	0.32
	Nonfertile	5.73	0.36	5.08	0.38	4.77	0.46
	HC	5.79	0.28	5.45	0.41	5.70	0.21
	Total	5.72	0.20	5.25	0.22	5.04	0.22
Physiological Arousal	Fertile	3.43	0.52	3.57	0.42	3.14	0.42
	Nonfertile	4.07	0.28	3.77	0.43	3.69	0.43
	HC	4.71	0.29	4.45	0.47	4.90	0.31
	Total	4.07	0.22	3.93	0.24	3.91	0.24
Run	Fertile	5.14	0.51	4.86	0.56	3.93	0.41
	Nonfertile	5.87	0.41	4.69	0.58	4.23	0.56
	HC	5.93	0.29	5.27	0.63	4.80	0.39
	Total	5.65	0.27	4.94	0.29	4.32	0.30
Physically fight	Fertile	4.50	0.56	3.93	0.51	4.57	0.49
	Nonfertile	4.93	0.56	4.15	0.64	4.85	0.55
	HC	5.07	0.37	3.64	0.54	4.70	0.45
	Total	4.83	0.29	3.91	0.31	4.71	0.32
Successfully fend	Fertile	3.07	0.41	3.07	0.50	4.64	0.50
	Nonfertile	3.27	0.50	3.62	0.37	4.31	0.44
	HC	3.14	0.42	2.73	0.47	4.30	0.33
	Total	3.16	0.25	3.14	0.27	4.42	0.27
Emotionally Cope	Fertile	2.71	0.42	3.71	0.50	4.29	0.37
	Nonfertile	2.27	0.36	4.38	0.47	3.92	0.49
	HC	2.71	0.40	3.64	0.41	3.40	0.48
	Total	2.57	0.24	3.91	0.26	3.87	0.26
Risk	Fertile	3.29	0.45	2.71	0.44	2.50	0.37
	Nonfertile	3.00	0.40	3.38	0.43	3.15	0.41
	HC	3.71	0.50	3.09	0.48	3.10	0.50
	Total	3.33	0.24	3.06	0.26	2.92	0.27

A 3 fertility (fertile, nonfertile, hormonal contraceptive [HC]) x 3 scenario (rape, male-perpetrated physical assault, female-perpetrated physical assault) MANOVA was carried out to analyse the 7 subjective responses (negative emotions, physiological arousal, likelihood of running, physically fighting, ability to successfully defend, ability to emotionally cope and perceived risk). Overall, there was a main effect of scenario. $F(14, 206) = 3.25$, $p < .001$, Wilk's $\Lambda = .67$. However, the overall MANOVA did not reach significance for fertility, $F(14, 206) = 1.2$, $p = .28$, Wilk's $\Lambda = .86$, or for the interaction between fertility and scenario, $F(28, 372.794) = .4$, $p = .99$, Wilk's $\Lambda = .9$.

To examine the significant scenario effect, univariate ANOVAs were conducted on each of the dependent variables. Scenario affected women's reported likelihood of running from the attacker, $F(2, 109) = 5.49$, $p = .005$, $\eta p^2 = .09$. Women were more likely to run from the rape scenario compared to the female-perpetrated assault scenario (mean difference = 1.33, $SEM = .42$, $p = .004$), but all other pairwise comparisons were nonsignificant (p's > .24). Scenario also affected perceived ability to successfully fend off the attacker, $F(2, 109) = 20.07$, $p = .001$, $\eta p^2 = .12$. Women felt more able to successfully fend off the attacker in the female-perpetrated physical assault scenario compared to the rape scenario (mean difference = 1.26, $SEM = .37$, $p = .003$) and male-perpetrated assault scenario (mean difference = 1.28, $SEM = .38$, $p = .003$). Finally, scenario also affected the perceived ability to emotionally cope with the situation, $F(2, 109) = 23.89$, $p < .001$, $\eta p^2 = .15$. Women felt less able to cope with the rape scenario compared to the male-perpetrated assault scenario (mean difference = 1.35, $SEM = .35$, $p = .001$) and female-perpetrated assault scenario (mean difference = 1.31, $SEM = .36$, $p = .001$). Ability to emotionally cope did not differ between the male- and female-perpetrated assault scenario (mean difference = .04, $SEM = .37$, $p = 1.0$).

2.2.4. Discussion

Study 1 aimed to assess fertility-related differences in response to scenarios that vary in rape risk. A scenario that explicitly depicted rape was included to reduce any ambiguity about what was being portrayed, as well as a male-perpetrated physical assault (MPA) scenario to assess responses to physical rather than sexual costs of rape, and a physical assault perpetrated by a female (FPA) to reduce the risk of rape, or pregnancy resulting from rape.

Scenario appeared to influence some subjective responses. The rape and female-perpetrated physical assault scenario differed in the extent to which they produced negative emotions, perceived ability to successfully fend off the attacker, and ability to emotionally cope. Compared to the female-perpetrated physical assault scenario, the rape scenario made women feel more negative emotions, lowered their perceived ability to fend off the attacker and emotionally cope with the situation. This suggests that the scenarios were effective in manipulating feelings of threat, with

respect to participants being more concerned about rape than physical assault by a female and that women were discriminating between them.

Fertility did not influence responses to the scenarios. This is against expectation, as evolutionary theory predicts that women would feel more physiologically aroused, or report higher hypothetical avoidance behaviours (e.g., running from or physically fighting the attacker) during ovulation, owing to the higher costs of criminal victimisation when women are fertile (e.g., Fessler et al. 2015). As such, it was hypothesised that handgrip strength and subjective responses would indicate heightened anxiety for fertile women compared to their counterparts. However, ovulation is characterised by a surge in oestrogen, while hormonal contraceptive users remain stable in their hormone levels. Oestrogen has been shown to reduce feelings of fear (e.g., Glover et al. 2013). Accordingly, it is suggested that women are more prone to anxiety during the luteal phase of the menstrual cycle. Moreover, Ossewaarde, Hermans, van Wingen, Koojiman, Johansson, Bäckström & Fernández (2010) showed that stress induction had a more pronounced effect on heart rate and negative affect during the late luteal compared to late follicular phase of the menstrual cycle. They concluded that women are more sensitive to stressors during the luteal phase. In the current study, participants were arranged to participate during the early follicular or luteal phase for the naturally cycling 'nonfertile' condition. As women have been shown to be more vulnerable to fear and anxiety during the luteal phase, women who participated during the luteal phase may have shown pronounced physiological (increased handgrip strength) and more negative subjective responses to the scenarios. This may explain the null findings for fertility in reactions to threats. That is, while it was expected that physiological and subjective responses to threats would be higher when fertile due to the higher costs of criminal victimisation during ovulation, such fear responses may have increased in nonfertile participants during the luteal phase too.

Handgrip changes from baseline to post-scenario or post-rumination did not differ according to scenario type or fertility, including hormonal contraceptive users. Therefore, participants' subjective feelings towards the scenarios were not reflected in the physiological response. The findings of Petralia and Gallup (2002), that women's

handgrip strength increased when fertile in response to the risk of sexual assault, were therefore not replicated. One reason for this could have been low statistical power. The total sample size was 115 participants. However, a between-subjects design limited the number of participants per condition, which ranged from 12 to 15. A power analysis using G-Power suggested that the study had a power of .215. Cohen (1988) suggested that power should be around 80%, showing that the study was underpowered. A priori tests on Gpower to assess the effect of fertility, with power set at .8, the ndf as 8 (9 groups minus 1; 9 groups being 3 levels to fertility and 3 levels to scenario) suggests 1510 participants were needed to find a small effect size of .1. The effect size for the interaction between fertility and scenario was very small ($\eta p^2 =$ .054). Alternatively, considering just fertility alone (i.e., 3 groups or an ndf of 2), 967 participants would be needed to detect a small effect size of .10. The effect size of the current study turned out to be quite small. Given the size of the psychology participant panel, recruiting a sample of this size is not possible.

Another reason that Study 1 may not have replicated the findings of Petralia and Gallup (2002) could be due to demographic differences across samples. Petralia and Gallup (2002) tested American students, while this study tested students in the UK. There may be differences in the risk or feelings of risk regarding criminal victimisation, which may have affected women's responses to crime scenarios. However, statistics from the home office (UK) and FBI (US) suggest that prevalence of rape of a female are almost equal in the US compared to the UK[1]. Therefore, this is unlikely to account for the differences in response to a rape scenario.

The precise conditions in which participants participated in Petralia and Gallup's (2002) study are not clear from their paper. For example, while this study used an audio recording of a female reading the scenario to ensure standardisation in the portrayal of the scenario across participants, Petralia and Gallup (2002) had a live experimenter read the scenario aloud to the participant. Their paper did not specify the sex of the experimenter. The experimenter who read the scenario may have been

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[1] https://dispellingthemythukvsusguns.wordpress.com

male. The presence of a male experimenter reading the scenario may have influenced responses, in comparison to the female experimenter and recording in the current study. Past research shows that an experimenter's sex can affect participant responses (e.g., Fisher, 2007; Galla, Frisone, Jeffrey & Gaer, 1981; Huddy, Billig, Bracciodieta, Hoeffler, Moynihan et al. 1997; Kane & Macauley, 1993). Moreover, Petralia and Gallup (2002) did not give precise details of how handgrip strength was measured, other than a handgrip measurement was taken for each hand. This study used maximum handgrip strength from participants' dominant hand only.

Study 1 aimed to differentiate between the physical versus sexual aspects of rape to assess whether fertility-related differences in women's responses to rape risk reflected their desire to avoid rape specifically, or whether women become more averse to physical danger more generally during ovulation. To distinguish between these two possibilities, scenarios that depicted sexual assault, and male- and female-perpetrated physical assault were used. However, this meant that all scenarios in Study 1 depicted some level of risk, which may explain why women's handgrip responses did not vary across scenario type. There may have been ceiling effects due to criminal victimisation always being costly regardless of crime type, and regardless of fertility. However, some handgrip measurements actually decreased from baseline after exposure to the scenario, which is in opposition with the concept of ceiling effects. Nevertheless, had there have been a control scenario for comparison, as Petralia and Gallup did, there may have been differences in handgrip strength across scenarios. Alternatively, it may simply be the case that fertility does not influence handgrip strength altogether. Study 2 aimed to answer these questions.

2.3.1. Study 2: Physiological and subjective responses to scenarios that vary in the risk of rape within women's menstrual cycles

Due to the problems with lack of statistical power in Study 1, fertility and scenario were manipulated within-subjects rather than between-subjects in Study 2. Due to differences in hormonal fluctuations and individual differences across women, manipulation within-subjects is preferable for menstrual cycle research (e.g., Laeng &

Falkenberg, 2007, also see section 1.4.1. in chapter 1 of this thesis). One of these differences across participants could be mood. Mood has been shown to fluctuate over the menstrual cycle (Backstrom, Sanders, Leask, Davidson, Warner & Bancroft, 1983). For example, negative moods gradually increase following ovulation until menstruation, with positive moods being strongest during preovulatory peaks in estradiol (Backstrom et al. 1983). Some women experience more intense changes in mood than others, such as more negative affect and anxiety during premenstrual tension (Gottschalk, Kaplan, Gleser & Winget, 1962). Accordingly, in Study 2, as well as administering the PANAS (Watson, Clark & Tellegen, 1988) to assess positive and negative affect, the influence of scenario and fertility was measured within participants.

Study 2 assessed women's psychological and physiological reactions to scenarios that differ in their depiction of rape risk at two specific points of their menstrual cycle (i.e., fertile versus nonfertile). If fertility and hormonal status influence perceptions of and responses to rape risk, then naturally cycling women should show heightened reactivity to depictions of rape when they are fertile compared to nonfertile, while hormonal contraceptive users should remain stable in their responses across time. Moreover, when women are fertile, they should show heightened reactivity to physical assault if it is perpetrated by a male as opposed to a female.

Research suggests that women have an enhanced period of vulnerability to intrusive and distressing thoughts after exposure to stressful stimuli during the luteal phase (approx. days 16-20, Soni et al. 2013). As such, to help eliminate potential extraneous variables that may have influenced the feelings of fear in response to the scenarios in Study 1, and to avoid the possibility of providing additional stress to participants, the follicular phase rather than the luteal phase was used for the nonfertile phase in Study 2.

Another aim of Study 2 was to replicate Petralia and Gallup's (2002) findings. Accordingly, their original two scenarios were included in Study 2. The three new scenarios designed for Study 1 were also included (female-perpetrated physical assault, male-perpetrated physical assault and the explicit rape scenario) to test the

shadow of sexual assault hypothesis (Ferraro, 1995; 1996). Therefore, each participant was exposed to all five scenarios, the order of which was randomised across participants and testing session.

In Study 2, an additional measure of physiological reactivity, heart rate variability, was assessed. Heart rate has been associated with a fear response (e.g., Globisch et al., 1999 cited in Carlsson et al., 2004). Heart rate was converted into heart rate variability (HRV), which is the variation in the interval between consecutive heart beats (The Task Force, 1996). HRV is related to emotion (e.g., Beevers, Ellic & Read, 2011; Friedman, 2007; Kreibig, 2010). Experimental manipulations of anxiety, worry and fear have been shown to decrease HRV, which is indicative of increased heart rate and emotional arousal (Fabes & Eisenberg, 1997; Hansen, Johnson & Thayer, 2003; Kreibig, 2010; Palomba, Sarlo, Angrilli, Mini, Stegagno, 2000; Thayer, Friedman & Borkovec, 1996). For example, HRV was decreased during intense parts of a story (Wallentin et al., 2011). HRV thus appears to be associated with sensitivity to threat (Elliot, Payen, Brisswalter, Cury & Thayer, 2011; Johnson et al., 2003; Thayer & Lane, 2009), and thus served as an additional measure of response to threat in Study 2. Scenarios that signal threat should be associated with decreased HRV. Similarly, if fertile women are more fearful of situations with higher evolutionary costs, such as rape and male-perpetrated physical assault, they should show decreased HRV in comparison to when nonfertile. However, while attention to threat is heightened in those with low HRV, high HRV is characterised by more effectively responding to environmental challenges (Jahfari et al., 2011). Therefore, it may be more adaptive for women to have higher HRV when fertile for more effective response to environmental threats. Moreover, as in Study 1, Study 2 aimed to show convergence between modalities. For example, events that are perceived to be less likely to occur (as assessed through risk perceptions) are associated with higher HRV (Epstein & Roupenian, 1970). Furthermore, increased HRV has been associated with increased handgrip strength (Napadow, Dhond, Conti, Makris, Brown & Barbieri, 2008). As such, the various dependent variables may be associated.

Participants participated at two points during their menstrual cycle. Participants listened to all five scenarios (Petralia and Gallup's control and sexual

assault scenarios, as well as the three additional scenarios created for study 1). Similar to Study 1, reactivity was assessed during each scenario, immediately post-scenario and in response to a 1-minute rumination period post-scenario using physiological and subjective measures. Participants had their heart rate measured throughout the study and completed baseline handgrip strength tests, as well as post-scenario and post-rumination tests of handgrip strength and subjective responses after each of the 5 scenarios.

Based on existing findings, it was hypothesised that firstly, women would show heightened physiological reactivity (increased handgrip strength and decreased HRV) and heightened psychological reactivity (higher negative emotions, perceived risk and predicted avoidance behaviours) for the rape and male-perpetrated assault scenarios (Hypothesis 1). Secondly, for naturally cycling participants, physiological and psychological reactivity should be higher for the rape scenario when fertile compared to nonfertile (Hypothesis 2). However, there should be no difference in reactivity across the scenarios or between the two testing conditions for those on hormonal contraceptives, due to the stability in hormones and fertility.

2.3.2. Method

2.3.2.1. Participants

Female participants (N = 34) aged between 18 and 44 years (M = 24.42, SD = 6.16) participated in return for monetary compensation. Of these women, 20 were naturally cycling and 14 were using hormonal contraceptives.

Participants were selected from a wider sample of 59 women who responded to an advertisement for women to participate in a study 'assessing reactions to various scenarios'. Interested participants were provided with a link to an online pre-screening questionnaire that measured demographic variables and women's use of hormonal contraceptives, as well as regularity, length and current position of their menstrual cycle. Questions about general health and lifestyle were also included to prevent disclosing the aims of the research. Inclusion criteria for participation included a regular menstrual cycle (i.e., menses consistently occurring, and cycle length being

between 26 and 32 days long), and being aged between 18 and 45 years old[2]. Two participants failed to attend the second testing session, resulting in a total sample of 30 participants (naturally cycling n = 20; hormonal contraceptive users = 12) for analysis.

Information from the pre-screening questionnaire enabled calculation of approximate cycle-phase using the forward-count method (Grammer, 1993; Wideman, Montgomery, Levine, Beynnon, & Shultz, 2013), which involves counting forward from the date of most recent menses onset to the appropriate cycle day. Depending on cycle length, women were arranged to participate during days 1 to 3 of their cycle when fertility is at its lowest, and again during ovulation (days 12-16, Wilcox et al. 2001). Whether the first testing session occurred during the nonfertile phase, or during ovulation was determined for each participant via random assignment. Hormonal contraceptive users were also arranged to participate 2 weeks apart. However, as the majority of hormonal contraceptive users did not have regular 'withdrawal bleeds', they were not arranged to participate on any specific day. Participants were not aware of the aims, and were only told that they would participate on two occasions two weeks apart. As in Study 1, ovulation tests were administered to all naturally cycling participants to verify fertility, with a sensitivity of 30 miu/ml (http://www.homehealth-uk.com/medical/ovulation-tests.htm).

2.3.2.2. Design

The study used a 2 hormonal contraceptive use (users or naturally cycling) x 2 fertility (fertile, nonfertile) x 2 session (session 1, session 2) x 5 scenario (rape, male-perpetrated assault [MPA] female-perpetrated assault [FPA], Petralia & Gallup's sexual assault scenario [PG sexual assault], Petralia and Gallup's control scenario [Control]) x 2 time (post-scenario, post-rumination) mixed design, with hormonal contraceptive use as the only between-subjects factor. Hormonal contraceptive use (users or naturally cycling) was measured between subjects, with fertility (fertile, nonfertile) as

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[2] The study aimed to recruit participants aged 18-35 as before. However, one participant that was interested in signing up was 44, but had a very regular and consistent menstrual cycle, and thus was included in this study. Her fertility status was verified using an ovulation test.

a variable nested within naturally cycling participants, and session (first or second) nested within hormonal contraceptive users.

2.3.2.3. Materials and Procedure

The study received full ethical approval from the University of Leicester's ethics committee. The study was conducted using online survey software (surveymonkey.com), which presented all questionnaires, the distractor tasks and scenario text along with the scenario audio recordings.

Participants began by reading the consent form (see Appendix E), which provided information about what participation in the study would involve, and informed participants that the study could involve themes of physical and/or sexual assault. Once informed consent was given, the physiological sensors were arranged. All physiological equipment was manufactured by Vernier international (http://www.vernier.com/). Handgrip was measured using a hand dynamometer. Heart rate was monitored and recorded using a Polar 'Exercise Heart Rate Monitor', consisting of a chest belt and transmitter. Whilst heart rate was collected continuously, handgrip was recorded at specific time points throughout the study. Each test of handgrip was measured using the participant's dominant hand, and participants were instructed to squeeze the dynamometer to the best of their ability for three seconds. Baseline handgrip was taken at the beginning of the study. Thereafter, handgrip was measured immediately after each scenario, and following a 1 min rumination period after each scenario.

Preliminary assessments involved questions pertaining to age, relationship and cohabiting status, as well as information regarding menstrual cycles (hormonal contraceptive use, date of onset of previous menses, cycle regularity and length). The Positive and Negative Affect Schedule (Watson, Clark & Tellegen, 1988) was administered during the preliminary assessments to test for differences in mood.

Once the preliminary assessments were complete, the study began. The first of the five scenarios was then presented. The scenarios included Petralia and Gallup's original 'sexual assault' (PG sexual assault) and 'control' scenarios (see Petralia & Gallup, 2002, and Appendix D), along with three new scenarios in which the risk of

sexual assault varied (see Appendix D). The additional scenarios included female-perpetrated physical assault (FPA), male-perpetrated physical assault (MPA) and a more obvious rape scenario, compared to the scenario used by Petralia and Gallup (2002). The scenarios were of similar length (approximately 2 and a half min) and structure to those designed by Petralia and Gallup (2002). For example, the scene was set in the first half the scenario, with the attack occurring towards the end of the scenario. Due to the within-subjects design, 3 versions of each of the 3 new scenarios were created. Whilst the attack remained the same, the settings varied to prevent habituation to the scenario across the two testing sessions. It was ensured that participants received a different version of each of the 3 new scenarios on their second testing session. However, Petralia and Gallup's two scenarios remained the same for each testing session to test for within-subject replication of their findings. Each scenario was read and recorded by a female in a consistent manner. Participants listened to the scenarios using headphones whilst reading the written version of the scenario on-screen. During each session, all participants received each of the five scenarios. Nine different scenario presentation orders were created for each session 1 and session 2 by using a random number generator to randomise the order that scenarios would be presented to control for any potential order effects. Participants were randomly assigned to one of the 9 links depending on their testing session (i.e., 9 links for session 1 and 9 links for session 2). Therefore, the presentation order was different across testing sessions 1 and 2. The experimenter, who was female, was blind to the scenario the participants were experiencing at any given time.

Immediately after the scenario had finished, participants completed a post-scenario test of handgrip strength using their dominant hand. A rumination period followed whereby participants were asked to think about the scenario vividly with their eyes closed for 1 min, after which they completed a post-rumination test of handgrip strength. After the rumination period, participants answered questions about their subjective physiological and emotional reactions regarding the scenario. They were asked to give an open-ended response stating which type of situation they had just experienced as a manipulation check to ensure that participants had interpreted the scenario in the manner intended. They were asked to state the extent

to which the scenario made them feel negative emotions on a scale of 1 (Not at all) to 7 (Completely). On this same scale, participants were also asked to report the extent to which the scenario make them feel physiologically aroused (e.g., sweating, increased heart rate); how likely they would be to run from the attacker and feel like physically fighting the attacker; the extent to which they felt they could successfully fend off the attacker and emotionally cope with the scenario; and finally to estimate their risk of someone trying to attack them that day in the way described in the scenario.

Distractor tasks were administered between scenarios as a means of returning participants' cognitions and physiology to baseline levels and preventing additional rumination and other carry-over effects. These included five versions of the original trail-making task (Reitan, 1958) and mathematical equations of a moderate difficulty. This procedure was then repeated for the next 4 scenarios, the order of which was randomised and counterbalanced across participants. Participants then completed the same procedure approximately two weeks later, depending on cycle length. The study concluded by debriefing participants as to the true aims of the research, before participants completed a self-administered urine-based ovulation test.

2.3.2.4. Data analysis

Time and signal data from the heart rate monitor was converted into heart rate variability (HRV) using Matlab, by assessing the standard deviation of interbeat intervals (e.g., Delaney & Brodie, 2000). Handgrip strength was assessed as the change in handgrip from baseline to post-scenario (post-scenario handgrip) and from baseline to post-rumination (post-rumination handgrip), by subtracting baseline handgrip scores from post-scenario and post-rumination handgrip measurements (N).

Two hormonal contraceptive using participants did not attend the second session, and as such these participants were removed from the analysis. One hormonal contraceptive user stopped taking hormonal contraceptives just before her second session and thus was removed from the analysis. One naturally cycling participant gave conflicting menstrual cycle information, and had a negative ovulation test during her fertile phase, and thus was removed from the analysis.

2.3.3. Results

Due to sample size disparities, data from naturally cycling women and hormonal contraceptive users were analysed separately. Moreover, fluctuations in reactivity according to scenario type, and hormonal fluctuations within participants were of particular interest.

2.3.3.1. Preliminary Analyses

2.3.3.1.1. Mood

First, it was important to assess whether there were differences in mood across the two testing sessions which may account for any differences in reactivity. A 2 fertility (fertile, nonfertile) x 2 affect (positive affect, negative affect) repeated measures ANOVA carried out for naturally cycling women on the positive and negative affect schedule (PANAS) ratings showed that women felt more positive affect ($M = 27.83$, $SEM = 1.55$) than negative affect ($M = 12.13$, $SEM = .74$), $F(1,19) = 108.14$, $p < .001$, a main effect for affect. There was no main effect of fertility, $F(1,19) = .11$, $p = .75$, nor did fertility interact with affect, $F(1,19) = .44$, $p = .52$. As such, any differences in reactivity could not be attributed to differences in mood over the menstrual cycle. For hormonal contraceptive users, women overall felt more positive ($M = 27.46$, $SEM = 1.93$) than negative affect ($M = 10.79$, $SEM = .83$), $F(1,11) = 89.72$, $p < .001$. There was no main effect of session, $F(1,11) = .03$, $p = .85$. Session did not interact with affect, $F(1,11) = .38$, $p = .55$. As such, affect will not be analysed further.

2.3.3.1.2. Manipulation check

Questions following each scenario began by asking participants to state which type of scenario they thought was being portrayed. 98.33% reported that the new explicit rape scenario indeed depicted rape, whilst only 5% described Petralia and Gallup's sexual assault scenario as potentially escalating to sexual assault. Other descriptions included 'following' or 'stalking', 'potential for assault' and 'beginning of maybe a robbery or worse'. Furthermore, none of the participants reported that either physical assault scenario depicted rape, but rather 'violent assaults' and 'robbery', and all participants believed the control scenario did not involve any danger, reporting it as depicting a 'normal everyday scenario' which was 'relaxing' with 'no feelings of

potential attackers'. However, it is important to note that when asked 'which part of the scenario provoked the most negative emotions or feelings of physiological arousal', participants oftentimes responded that although it was a normal situation, they anticipated another attack occurring 'when she sees a tall figure ahead of her'. Therefore, despite distractor tasks, previous scenarios may have impacted upon the depiction of the control scenario.

2.3.3.2. Handgrip strength
Order effects analysis

Although the presentation of scenarios was counterbalanced, due to the within-subjects design, one potential concern is a carry-over effect, whereby participants differentially react to subsequent scenarios after having read the rape scenario. The influence of order of presentation of the rape scenario would be most apparent in response to the control scenario, which should not elicit any negative responses or physiological arousal (e.g., handgrip strength). To assess this possibility, order effects were assessed to see whether handgrip strength differed according to the order in which the rape scenario relative to the control scenario was presented. Order could not be assessed within participants as the order of scenarios differed in participants' fertile and nonfertile session. Therefore, a 5 scenario (rape, male-perpetrated physical assault, female-perpetrated physical assault, Petralia and Gallup's sexual assault, control) x 2 time (handgrip change from baseline to post-scenario, handgrip change from baseline to post-rumination) x 2 order (rape before control, control before rape) mixed ANOVA on handgrip data was computed for fertile and nonfertile trials separately, with scenario and time assessed within-subjects and order assessed between-subjects. For the fertile trials, there were 9 instances wherein the control scenario came before the rape scenario, and 10 where the rape scenario was presented before the control scenario. There was no main effect of order, $F(1, 17) = 1.74$, $p = .205$, and it did not interact with scenario, $F(4, 68) = .69$, $p = .6$. Similarly, assessing instances wherein the control scenario comes before ($n = 5$) or after ($n = 14$) scenarios involving a threatening male for fertile participants, there was no main effect of order $F(4, 68) = .63$, $p = .44$, and no interaction with scenario, $F(1, 17) = .78$, $p = .55$. For nonfertile trials, there was again no effect of order (control before [$n = 10$]

or after [n = 9] rape) on handgrip overall, $F(1, 17) = .24$, $p = .63$, and it did not interact with scenario, $F(4, 68) = 2.43$, $p = .075$. For the control versus dangerous male scenarios, there were 5 instances wherein the control scenario came before the dangerous male scenarios, and 14 where it came after. There was no main effect of order, $F(1, 17) = 1.16$, $p = .3$, and order did not interact with scenario, $F(4, 68) = 1.32$, $p = .27$. As such, order will not be considered in any further analyses.

2.3.3.2.2. Naturally cycling participants

Table 4. Mean (±1 SEM) change in handgrip strength from baseline to post-scenario and post-rumination, and total (average of post-scenario and post-rumination) for naturally cycling participants

Fertility	Scenario	Post-scenario		Post-rumination		Total	
		M	SEM	M	SEM	M	SEM
	Rape	3.65	6.89	-2.73	6.94	0.46	6.60
	Male-perpetrated assault	3.75	6.43	-2.77	5.23	0.49	5.23
Fertile	Female-perpetrated assault	-5.02	6.83	-5.33	6.67	-5.18	6.28
	PG sexual assault	-4.37	5.66	-1.66	6.65	-3.02	5.67
	Control	-1.95	5.97	-4.53	7.35	-3.24	6.38
	Rape	-14.95	4.99	-17.27	5.55	-16.11	4.85
	Male-perpetrated assault	-17.08	6.11	-14.88	7.09	-15.98	5.91
Nonfertile	Female-perpetrated assault	-8.29	4.30	-9.20	4.90	-8.75	4.39
	PG sexual assault	-20.53	4.70	-25.77	6.80	-23.15	5.47
	Control	-20.92	5.39	-27.67	6.91	-24.29	5.89

As shown in Table 4, most handgrip measurements decreased from baseline to post-scenario (see Figure 7) and post-rumination (see Figure 8). However, there were slight increases in handgrip strength from baseline to post-scenario for the rape and male-perpetrated physical assault scenarios in fertile women only. On average, nonfertile women's handgrip strength decreased more from baseline to post-scenario and post-rumination than fertile participants. There was missing data due to equipment failure. Little's MCAR test suggested the data was missing completely at, random, $\chi^2(82) = 73.77$, $p = .73$, and thus was replaced using the expectation maximisation method.
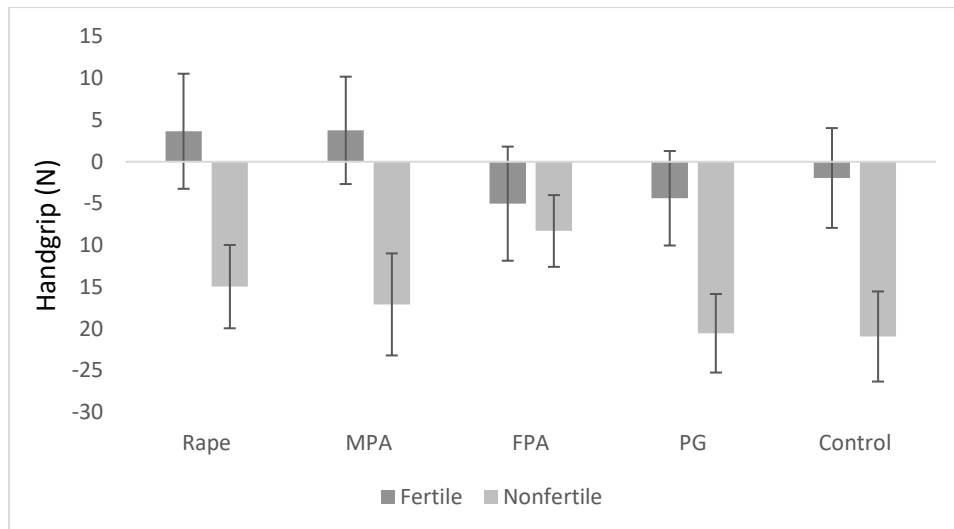
Figure 7. Mean (±1 SEM) change in handgrip strength from baseline to post-scenario by fertility and scenario type (*rape, male-perpetrated assault [MPA], female-perpetrated assault [FPA], PG sexual assault [PG], control*)
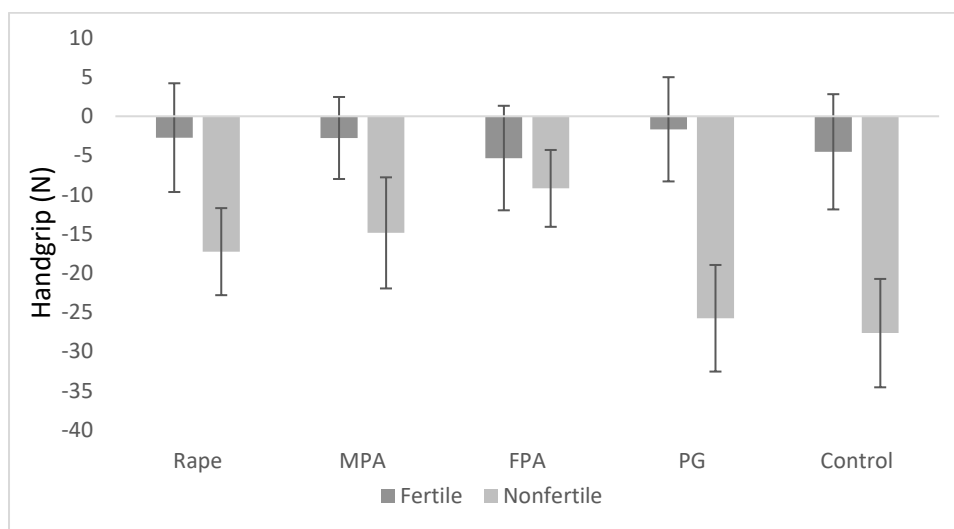
Figure 8. Mean (±1 SEM) change in handgrip strength from baseline to post-rumination by fertility and scenario type (*rape, male-perpetrated assault [MPA], female-perpetrated assault [FPA], PG sexual assault [PG], control*).

Handgrip data were entered into a 2 fertility (fertile, nonfertile) x 5 scenario (rape, male-perpetrated physical assault [MPA], female-perpetrated physical assault [FPA], Petralia & Gallup's sexual assault [PG sexual assault], Petralia & Gallup's control [control]) x 2 time (handgrip change from baseline to post-scenario, handgrip change from baseline to post-rumination) repeated measures ANOVA. Fertile women showed less of a decrease in handgrip strength from baseline than nonfertile women, a main effect of fertility, $F(1, 18) = 5.53$, $p = .03$, $\eta p^2 = .24$. The main effect of scenario approached significance, $F(4, 72) = 2.37$, $p = .06$, $\eta p^2 = .116$. There was no main effect

of time, $F(1, 18) = 1.85$, $p = .19$. There was a significant interaction between fertility and scenario, $F(4, 18) = 2.79$, $p = .03$, $\eta p^2 = .13$ (see Figure 9). Bonferroni-adjusted t-tests showed there were significant fertility-related differences for all scenarios (all p's < .04) except for the female-perpetrated assault scenario ($p = .65$). That is, women gripped relatively harder when fertile compared to nonfertile for all scenarios featuring a male. For scenario, all pairwise comparisons adjusted with the Bonferroni corrections were nonsignificant (p's < .36). Therefore, Hypotheses 1 and 2 were supported.
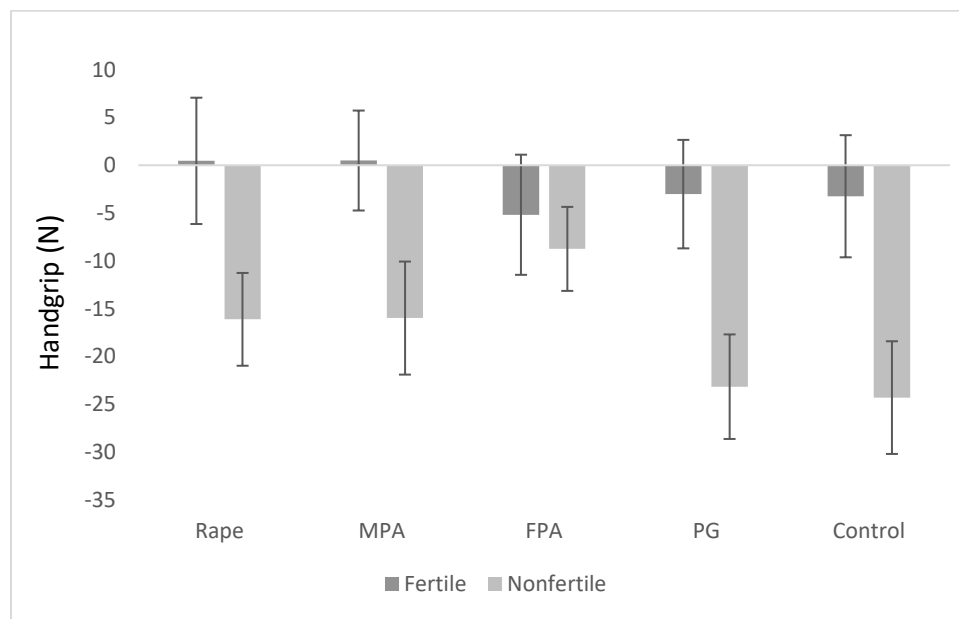
Figure 9. Mean (±1 SEM) change in handgrip strength from baseline to post-scenario and post-rumination combined by fertility and scenario type (rape, male-perpetrated assault [MPA], female-perpetrated assault [FPA], PG sexual assault [PG], control).

2.3.3.2.3. Hormonal contraceptive users

Table 5. Mean (±1 SEM) change in handgrip strength from baseline to post-scenario and post-rumination for hormonal contraceptive users

Session	Scenario	Post-scenario		Post-rumination		Total	
		M	SEM	M	SEM	M	SEM
	Rape	-9.56	7.44	-16.68	5.78	-13.12	6.16
	Male-perpetrated assault	-16.75	8.82	-9.20	5.68	-12.98	6.90
Session 1	Female-perpetrated assault	-18.76	8.58	-18.98	7.97	-18.87	7.89
	PG sexual assault	-13.91	9.68	-24.55	7.00	-19.23	7.90
	Control	-26.17	9.16	-32.89	11.94	-29.53	10.47
Session 2	Rape	-7.28	6.12	-16.59	6.76	-11.93	5.51

Male-perpetrated assault	-23.78	7.29	-22.86	8.31	-23.32	7.58
Female-perpetrated assault	-11.10	6.82	-12.27	5.95	-11.69	5.93
PG sexual assault	-20.03	4.88	-21.60	11.90	-20.82	7.01
Control	-15.83	5.89	-31.14	8.52	-23.48	6.97

Table 5 shows mean (± 1 *SEM*) change in handgrip strength from baseline to post-scenario (also see Figure 11) and post-rumination (also see Figure 12), and the total mean change in handgrip from baseline to post-scenario measures (average of post-scenario and post-rumination). As can be seen, there was a consistent pattern of a decrease in handgrip strength from baseline for all measurements. The decrease was smaller for the rape scenario compared to the other scenarios, and generally larger for post-rumination measures compared to post-scenario measures.

A 2 session (session 1, session 2) x 5 scenario (rape, male-perpetrated physical assault [MPA], female-perpetrated physical assault [FPA], Petralia & Gallup sexual assault [PG sexual assault], Petralia & Gallup control [control]) x 2 time (handgrip change from baseline to post-scenario, handgrip change from baseline to post-rumination) repeated measures ANOVA was carried out on the handgrip scores. There was a significant main effect of scenario, $F(4,40) = 2.27$, $p = .04$, $\eta p^2 = .22$. There was no main effect of session, $F(1,10) = .002$, $p = .96$ or time, $F(1,10) = 2.77$, $p = .13$ and no significant interactions between day and scenario, $F(4,40) = 1.14$, $p = .35$ or session and time, $F(1,10) = .26$, $p = .62$. The scenario by time interaction was significant $F(4, 40) = 2.95$ $p = .03$, $\eta p^2 = 23$. The three-way interaction for day, scenario and time was not significant $F(4,40) = .57$, $p = .68$.

T-tests adjusted for multiple comparisons with the Bonferroni correction showed that the interaction between scenario and time arose as the difference in handgrip strength according to time (post-scenario versus post-rumination) was larger for the rape (mean difference = 8.21, *SEM* = 2.9, $p = .018$) and control scenarios (mean difference = 11.01, *SEM* = 2.5, $p = .001$) (see Figure 10). That is, the decrease in handgrip from baseline to post-scenario was smaller than the decrease in handgrip from baseline to post-rumination for the rape and control scenarios only.
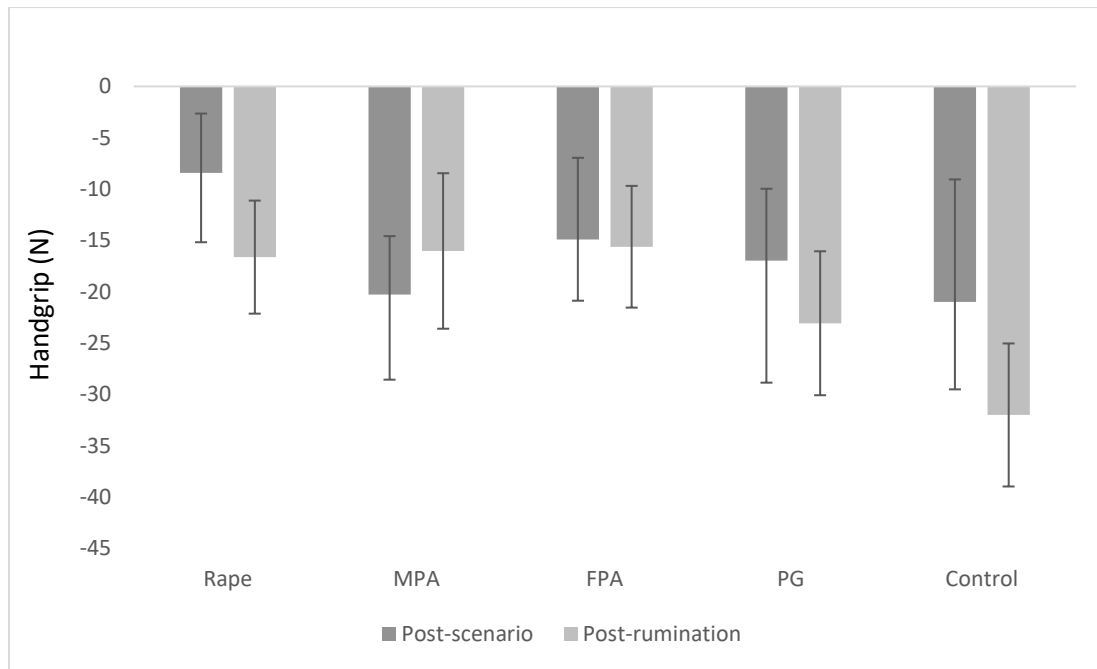
*Figure 10. Mean (+1 SEM) change in handgrip strength from baseline by scenario type (*rape, male-perpetrated assault [MPA], female-perpetrated assault [FPA], PG sexual assault scenario [PG], control) and time (*post-scenario and post-rumination)*
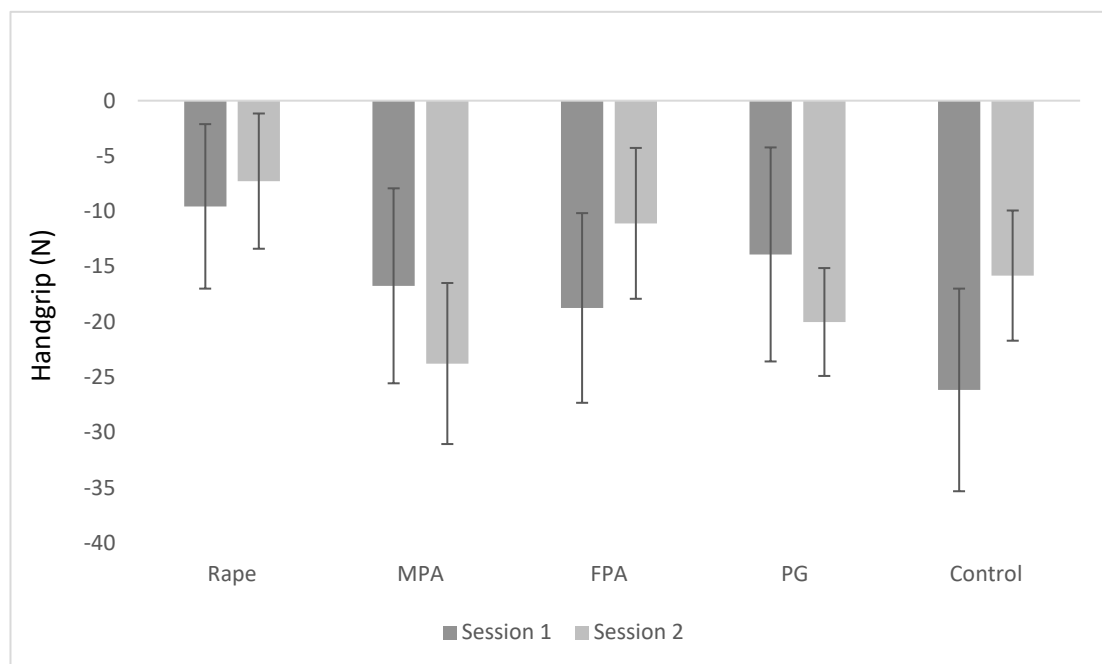
*Figure 11. Mean (+1 SEM) change in handgrip strength from baseline to post-scenario by scenario type (*rape, male-perpetrated assault [MPA], female-perpetrated assault [FPA], PG rape scenario [PG], control)*
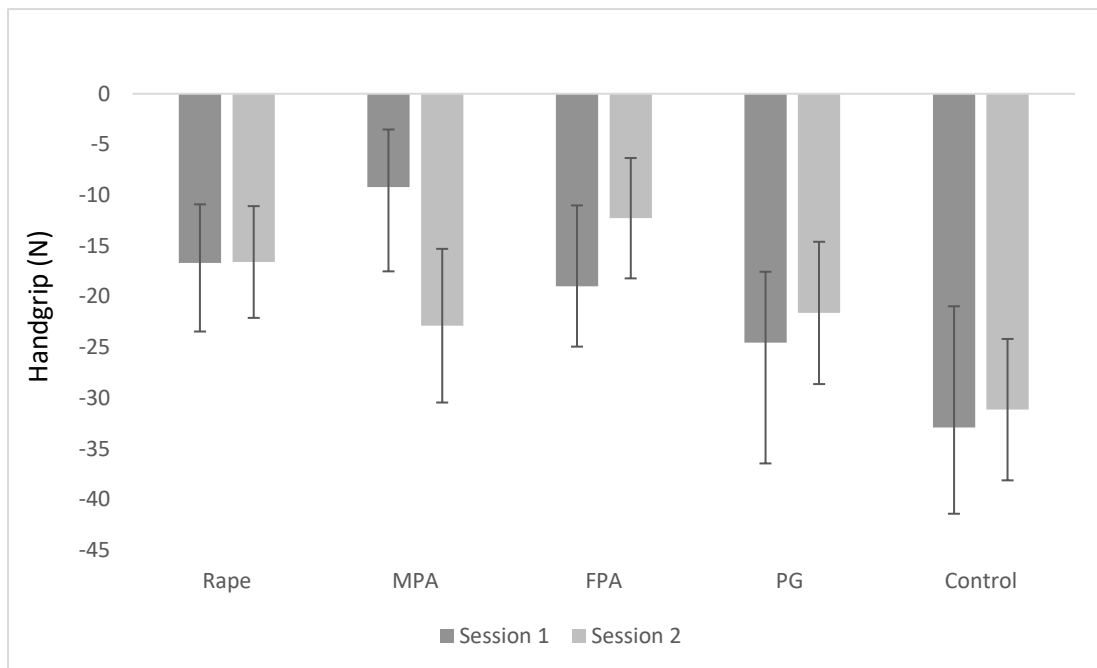
Figure 12. Mean (±1 SEM) change in handgrip strength from baseline to post-rumination by scenario type (rape, male-perpetrated assault [MPA], female-perpetrated assault [FPA], PG sexual assault [PG], Control)

2.3.3.3. Heart Rate Variability (HRV)

2.3.3.3.1. Naturally cycling participants

For naturally cycling fertile participants, HRV analysis was unable to be computed for one participant in the rumination portion of the male-perpetrated assault scenario, for two participants for the whole of Petralia and Gallup's sexual assault scenario, and one additional participant for the rumination portion of Petralia and Gallup's sexual assault scenario. For naturally cycling nonfertile participants, HRV analysis could not be conducted for two participants for all of the sexual assault and control scenarios, or for one participant for the male-perpetrated assault, female-perpetrated assault and Petralia and Gallup's sexual assault scenario, and an additional participant for the rumination portion of the new rape scenario. Little's MCAR test showed that the data were likely to be missing at random, $\chi^2(149) = 97.21$, $p = 1.00$. Accordingly, missing values for each variable with missing data were replaced using the expectation maximisation method.

Table 6. Mean (±1 SEM) heart rate variability (HRV) by scenario, fertility and time of scenario for naturally cycling participants

Scenario	Fertility	Start		Attack		Rumination	
		M	SEM	M	SEM	M	SEM
Rape	Fertile	0.76	0.03	0.78	0.03	0.77	0.03
	Nonfertile	0.77	0.02	0.72	0.05	0.79	0.02

Male-perpetrated assault	Fertile	0.75	0.02	0.76	0.02	0.77	0.02
	Nonfertile	0.77	0.02	0.76	0.02	0.78	0.02
Female-perpetrated assault	Fertile	0.76	0.02	0.76	0.02	0.77	0.02
	Nonfertile	0.76	0.02	0.76	0.02	0.80	0.04
PG sexual assault	Fertile	0.73	0.02	0.75	0.02	0.74	0.02
	Nonfertile	0.78	0.02	0.78	0.02	0.81	0.03
Control	Fertile	0.76	0.03	0.74	0.02	0.77	0.03
	Nonfertile	0.77	0.02	0.77	0.02	0.77	0.02

Table 6 shows the mean (± 1 SEM) HRV score, with a higher score indicating more variability. As can be seen, HRV did not seem to differ according to scenario or fertility, or the part of the scenario (start, attack or rumination portions). To further assess the influence of the factors on HRV, a 2 fertility (fertile, nonfertile) x 5 scenario (rape, male-perpetrated assault, female-perpetrated assault, PG sexual assault, PG control) x 3 time (start of the scenario, attack, rumination) repeated measures ANOVA was carried out on the HRV data. There was no main effect of fertility, $F(1,19) = .45$ $p = .51$, and the main effect of scenario was nonsignificant, $F(4,76) = .11$, $p = .98$. Therefore, Hypothesis 1 was not supported. There was a significant main effect of time, $F(2, 38) = 6.99$, $p = .003$, $\eta p^2 = .269$. Pairwise t-tests adjusted with the Bonferroni correction suggested that there was more heart rate variability during the rumination portion of the scenarios ($M = .78$, $SEM = 0.19$) compared to during the start of the scenario ($M = .76$, $SEM = .02$, mean difference = .02, $SEM = .01$, $p = .011$) and attack portions ($M = .76$, $SEM = .02$, mean difference = .02, $SEM = .01$, $p = .02$).

There were no significant interactions (p's > .078). Thus, Hypothesis 2 was not supported. However, descriptively speaking, there was an interesting data pattern for the attack portion of the scenario, wherein although fertile women consistently showed slightly lower HRV, they showed a higher HRV for the rape scenario only (see Figure 13).
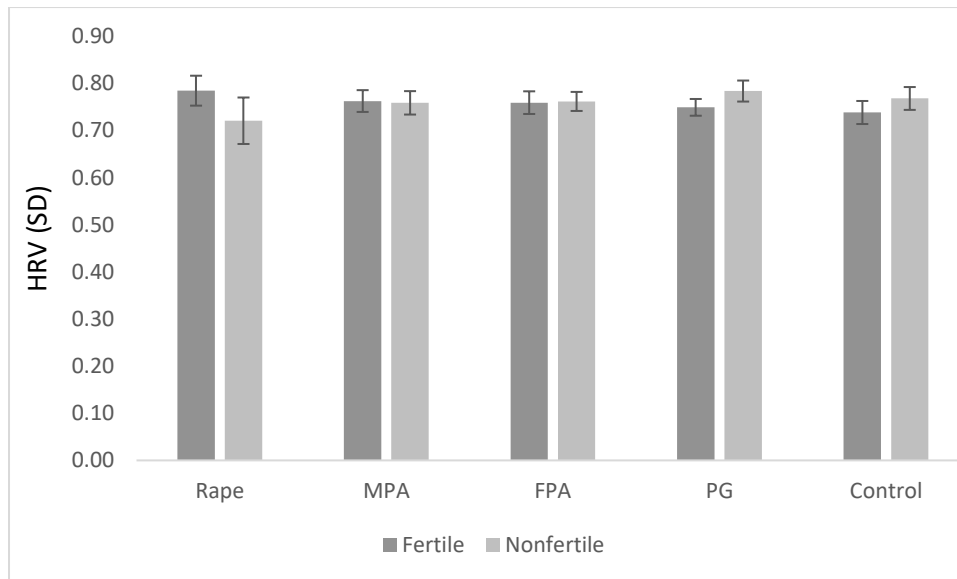
Figure 13. Mean (±1 SEM) HRV by scenario and fertility in naturally cycling participants during the attack portion of the scenario

2.3.3.3.2. Hormonal contraceptive Users

For session 1, one participant's data was missing for the whole session, plus the start of the female-perpetrated assault scenario for another participant. For data collected in session 2, three participants' data were missing for all scenarios. One participant had data missing for the female-perpetrated assault scenario and another for the control scenario. Little's MCAR test suggested that the missing data points were missing completely at random, $\chi^2(113) = 48.89$, $p = 1.00$. Therefore, the missing data was able to be replaced using the expectation maximisation method.

Table 7. Mean (±1 SEM) HRV by scenario, session and time of scenario for hormonal contraceptive users

		Start		Attack		Rumination	
		M	SEM	M	SEM	M	SEM
Rape	Session 1	0.79	0.03	0.79	0.04	0.78	0.03
	Session 2	0.82	0.03	0.81	0.03	0.82	0.04
Male-perpetrated assault	Session 1	0.81	0.04	0.80	0.03	0.81	0.04
	Session 2	0.83	0.04	0.90	0.06	0.83	0.04
Female-perpetrated assault	Session 1	0.80	0.03	0.79	0.03	0.80	0.04
	Session 2	0.81	0.03	0.82	0.03	0.83	0.04
PG rape	Session 1	0.80	0.04	0.78	0.03	0.78	0.04
	Session 2	0.81	0.03	0.80	0.03	0.82	0.03
PG control	Session 1	0.81	0.04	0.81	0.04	0.81	0.04
	Session 2	0.80	0.03	0.82	0.03	0.82	0.04

A 2 session (session 1, session 2) x 5 scenario (rape, male-perpetrated assault, female-perpetrated assault, PG rape, PG control) x 3 time (start of the scenario, attack, rumination) repeated measures ANOVA was carried out on the HRV data. The Greenhouse Geisser correction was applied for instances wherein sphericity was violated.

There was no main effect of session, $F(1,12) = 1.66$, $p = .22$, scenario, $F(1.92, 23.02) = 2.51$, $p = .11$, or time, $F(2,24) = .15$, $p = .87$. There were no significant interactions between session and scenario, $F(2.17, 26.06) = 1.09$, $p = .35$, session and time, $F(2,24) = 2.88$, $p = .08$, scenario and time, $F(2.32, 27.84) = 1.28$, $p = .3$, or session, scenario and time, $F(2.43, 29.15) = 1.46$, $p = .18$ (see Table 7).

2.3.3.4. Subjective reactions

2.3.3.4.1. Naturally cycling participants

Subjective responses were analysed as an additional measure of reactivity to the scenarios. The pattern of findings was as expected. In general, women reported more negative reactions towards the rape and male-perpetrated physical assault scenario compared to the female-perpetrated assault and control scenario, including higher physiological arousal, negative emotions, likelihood of running and physically fighting, less able to emotionally cope, and higher negative emotions. However, there was not a consistent pattern across the subjective reactions with regards to fertility. For example, while fertile women felt slightly higher physiological arousal in response to the rape scenario, they reported slightly lower negative emotions (see Table 8).

For each subjective response, a 2 fertility (fertile, nonfertile) x 5 scenario (rape, male-perpetrated physical assault, female-perpetrated physical assault, Petralia and Gallup's sexual asssault, control) repeated measures ANOVA was performed for each subjective response. Scenario influenced most subjective responses, including physiological arousal, $F(4, 76) = 53.06$, $p < .001$, $\eta p2 = .74$, likelihood of running, $F(4, 76) = 73.02$, $p < .001$, $\eta p2 = .794$, and physically fighting, $F(4, 76) = 34.49$, $p < .001$, $\eta p2 = .65$, ability to emotionally cope, $F(4, 76) = 15.71$, $p = < .001$, $\eta p2 = .45$, perceived risk, $F(4, 76) = 8.33$, $p < .001$, $\eta p2 = .31$, and the extent to which the scenario elicited negative emotions, $F(4, 76) = 91.3$, $p < .001$, $\eta p^2 = .83$. Thus, Hypothesis 1 was supported.

Scenario did not influence perceived ability to successfully fend off the attacker, $F(4, 76) = 1.02$, $p = .4$.

Fertile women felt more able to emotionally cope compared to nonfertile women, $F(1, 19) = 4.37$, $p = .05$, $\eta p^2 = .19$. Perceived risk differed by fertility. Fertile women felt more at risk overall compared to nonfertile women, $F(1, 19) = 6.69$, $p = .02$, $\eta p^2 = .26$. Thus, Hypothesis 2 was partially supported. The main effect of fertility was not significant for physiological arousal, $F(1, 19) = .18$, $p = .67$, likelihood of running from the attacker, $F(1, 19) = 2.08$, $p = .12$, or fighting the attacker, $F(1, 19) = .5$, $p = .49$, ability to successfully fend off the attacker, $F(1, 19) = .002$ $p = .96$ or the extent to which the scenarios elicited negative emotions, $F(1, 19) = .12$, $p = .73$.

There were no significant interactions regarding fertility and scenario (all p's > .116). However, Wilcox (1987, p.36) suggests that "most multiple comparison procedures should be used regardless of whether the F test is significant". Wilcox states that this includes the Bonferroni t-test, which was used in this analysis[3]. Wilcox (1987, p.36) states that the reason for doing so is that "most multiple comparison procedures are not designed under the assumption that a significant F test has already been obtained. Furthermore, O'Brien (1983) states that the statistical analysis should be decided according to the hypothesis, that is, what the experimenter wants to know from the data, and the Type 1 error probability permitted. As such, these pairwise comparison procedures were carried out to assess the main hypotheses regarding fertility-related differences in response to risk, whilst controlling for Type 1 errors appropriately. Moreover, Howell (2002) states that a significant overall F is not always required before proceeding with appropriately corrected multiple comparison

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[3] Pairwise comparisons, adjusted for multiple comparisons using the bonferonni correction, were assessed for each interaction throughout this thesis, regardless of the significance of the overall F test. In this instance, for example, pairwise comparisons were assessed despite the overall fertility by scenario interaction on risk perceptions not reaching significance. Wilcox (1987, p.36) suggests that "most multiple comparison procedures should be used regardless of whether the F test is significant". Wilcox states that this includes the Bonferroni t-test, which was used in this analysis. This suggestion is supported in other statistics text book e.g., Howell (2002).

procedures. The only instance in which a significant overall F is required is when using Fisher's Least Significant Difference Test (LSD).

Pairwise comparisons adjusted with the Bonferroni correction showed that fertile compared to nonfertile women felt more at risk of the situations depicted in the rape (mean difference = .6, *SEM* = .23, *p* = .019) and male-perpetrated physical assault scenarios (mean difference = .8, *SEM* = .33, *p* = .025). Moreover, the likelihood of running from the attacker in the scenario differed by fertility for the male-perpetrated assault scenario (mean difference = .75, *SEM* = .35, *p* = .044). Fertile women were more likely to run from the attacker compared to nonfertile women. The effect of fertility on perceived ability to successfully fend off the attacker in the female-perpetrated physical assault scenario approached significance, (mean difference = .75, *SEM* = .36, *p* = .052). Women felt more able to successfully fend off the female attacker when fertile compared to nonfertile.

Table 8. Mean (+ 1 SEM) ratings for subjective reactions by scenario and fertility in naturally cycling participants

Subjective Reaction	Scenario	Fertile		Nonfertile	
		M	SEM	M	SEM
	Rape	5.05	0.42	5.00	0.34
	MPA	4.65	0.32	4.75	0.36
Physiological Arousal	FPA	4.70	0.33	4.45	0.29
	PG sexual assault	4.60	0.37	4.35	0.34
	Control	1.60	0.22	1.60	0.13
	Rape	5.75	0.33	5.90	0.36
	MPA	6.15	0.26	5.40	0.43
Run	FPA	5.45	0.38	4.90	0.46
	PG sexual assault	5.10	0.36	5.05	0.43
	Control	1.25	0.16	1.20	0.12
	Rape	5.00	0.39	4.85	0.40
	MPA	3.75	0.40	3.55	0.37
Physically Fight	FPA	4.40	0.40	3.90	0.40
	PG sexual assault	3.30	0.38	3.40	0.29
	Control	1.05	0.05	1.15	0.60
	Rape	3.80	0.40	3.85	0.40
	MPA	3.05	0.41	3.10	0.37
Successfully Fend	FPA	3.65	0.41	2.90	0.40
	PG sexual assault	3.30	0.37	3.50	0.29
	Control	3.05	0.50	3.45	0.60
Emotionally Cope	Rape	3.00	0.36	2.80	0.34

	MPA	3.65	0.36	3.35	0.36
	FPA	3.95	0.37	3.55	0.38
	PG sexual assault	3.70	0.33	3.75	0.31
	Control	5.80	0.46	5.40	0.57
	Rape	2.85	0.42	2.25	0.35
	MPA	3.25	0.40	2.45	0.34
Perceived Risk	FPA	2.90	0.38	2.50	0.39
	PG sexual assault	2.80	0.40	2.50	0.37
	Control	1.70	0.27	1.30	0.16
	Rape	6.00	0.28	6.05	0.29
	MPA	5.65	0.30	5.55	0.37
Negative Emotions	FPA	5.35	0.35	5.55	0.37
	PG sexual assault	5.20	0.36	4.95	0.30
	Control	1.60	0.24	1.45	0.20

2.3.3.4.2. Hormonal contraceptive users

As shown in Table 9, negative reactions (e.g., greater physiological arousal and negative emotions, and decreased ability to emotionally cope) to the scenarios were highest for the rape and male-perpetrated assault scenarios, and lowest for the control scenario. Subjective responses were similar across the two testing sessions for hormonal contraceptive users.

Table 9. Mean (±1 SEM) ratings for subjective reactions by scenario and session in hormonal contraceptive users

Subjective Reaction	Scenario	Session 1		Session 2	
		M	SEM	M	SEM
	Rape	4.75	0.45	4.83	0.49
	MPA	4.00	0.58	3.83	0.53
Physiological Arousal	FPA	3.92	0.53	3.92	0.56
	PG sexual assault	3.33	0.50	3.67	0.47
	Control	1.33	0.14	1.58	0.29
	Rape	5.50	0.54	5.92	0.47
	MPA	5.50	0.50	5.33	0.56
Run	FPA	5.17	0.55	5.17	0.58
	PG sexual assault	4.75	0.66	5.08	0.58
	Control	1.17	0.11	1.00	0.00
	Rape	5.17	0.63	5.17	0.52
	MPA	3.42	0.69	4.08	0.66
Physically Fight	FPA	2.67	0.26	3.92	0.57
	PG sexual assault	3.42	0.69	4.00	0.69

	Control	1.58	0.50	1.58	0.50
	Rape	3.42	0.50	3.17	0.49
	MPA	2.42	0.31	3.25	0.54
Successfully Fend	FPA	2.25	0.45	2.75	0.45
	PG sexual assault	3.33	0.56	3.92	0.50
	Control	2.83	0.69	2.17	0.64
	Rape	2.67	0.47	2.42	0.45
	MPA	3.42	0.34	4.08	0.42
Emotionally Cope	FPA	5.75	0.54	4.83	0.60
	PG sexual assault	3.83	0.34	4.25	0.35
	Control	4.50	0.65	6.00	0.39
	Rape	3.00	0.62	3.25	0.54
	MPA	3.75	0.45	3.67	0.59
Perceived Risk	FPA	3.08	0.50	3.17	0.42
	PG sexual assault	3.33	0.59	3.17	0.53
	Control	1.58	0.34	1.83	0.47
	Rape	5.75	0.41	5.92	0.47
	MPA	4.92	0.47	4.92	0.50
Negative Emotions	FPA	4.83	0.53	4.75	0.57
	PG sexual assault	4.25	0.49	4.25	0.48
	Control	1.17	0.11	1.17	0.11

For each subjective response, a 2 session (session 1, session 2) x 5 scenario (rape, male-perpetrated physical assault, female-perpetrated physical assault, Petralia and Gallup's sexual assault [PG sexual assault], control) repeated measures ANOVA was performed.

Overall, subjective responses did not differ according to session (all p's > .195), apart from for the likelihood of physically fighting, $F(1, 11) = 8.68$, $p = .013$, $\eta p^2 = .44$. Women rated that they would be less likely to physically fight the attacker in session 1 compared to session 2. Session did not interact with scenario (p's > .148). As the main aim of assessing hormonal contraceptive users was to assess differences in reactions across the two testing sessions as hormones are stable (hormonal contraceptive users) or fluctuate (naturally cycling participants), the main effects regarding scenario type will be briefly summarised.

As with naturally cycling participants, scenario type affected subjective responses to all scenarios (*p*'s < .001), apart from the perceived ability to successfully fend off the attacker, $F(1.95, 12.22) = 2.32$, *p* = .12. Pairwise t-test comparisons adjusted with the Bonferroni correction showed the results to be in the expected direction; the control scenario evoked less physiological arousal, less likelihood of running, less likely to physically fight, more able to emotionally cope and less negative emotions than the other four scenarios (*p*'s < .05). The rape scenario elicited higher physiological arousal than Petralia and Gallup's sexual assault scenario (mean difference = 1.29, *SEM* = .23, *p* = .001), and women were more likely to physically fight the attacker in the rape scenario compared to the female-perpetrated physical assault scenario (mean difference = 1.88, *SEM* = .5, *p* = .03). For the perceived ability to emotionally cope, all pairwise comparisons were significantly different (all p's < .045; least able to emotionally cope with rape, then male-perpetrated assault, Petralia and Gallup's sexual assault scenario, then the control scenario, with women most able to emotionally cope with the female-perpetrated assault scenario), apart from between male-perpetrated physical assault and Petralia and Gallup's sexual assault scenario (mean difference = .29, *SEM* = .2, *p* = 1.0) and between the female-perpetrated physical assault scenario and the control scenario (mean difference = .04, *SEM* = .3, *p* = 1.0).

Women perceived lower risk of the control scenario happening to them that day compared to the rape scenario (mean difference = 1.42, *SEM* = .37, *p* = .03), male-perpetrated assault scenario (mean difference = 2.0, *SEM* = .35, *p* = .001), and Petralia and Gallup's sexual assault scenario (mean difference = 1.54, *SEM* = .42, *p* = .039). Finally, Petralia and Gallup's sexual assault scenario elicited lower negative emotions than the rape scenario (mean difference = 1.58, *SEM* = .28, *p* = .002) and the male-perpetrated physical assault scenario (mean difference = .67, *SEM* = .19, *p* = .046).

2.3.3.5. Convergence

It was assessed whether the findings showed convergence by assessing correlations between DVs. The average was calculated for post-scenario and post-rumination handgrips (change from baseline), the average HRV for attack and post-rumination, and the scores from each subjective measurement for each participant.

The correlations between the dependent variables were assessed within fertility and scenario. Handgrip strength was correlated with HRV for nonfertile participants in the rape scenario only, $r(19) = .595$, $p = .007$. All other correlations across scenario and fertility were nonsignificant.

2.3.4. Discussion

Study 2 aimed to examine the underlying psychological and physiological mechanisms that might underlie an evolved adaptation to avoid rape, particularly during ovulation when chances and costs of conception are highest. Secondly, this study aimed to assess whether such mechanisms were specific to rape, or whether women's reactivity to all risk was higher during ovulation. Women's psychological and physiological reactivity to scenarios that varied in their depiction of rape was assessed. Overall, women's risk perception and handgrip strength increased during the phase of peak fertility. Moreover, fertile compared to nonfertile women demonstrated increased handgrip strength relative to baseline for scenarios involving a male but not a threatening female. Therefore, reactions to threatening scenarios appeared to differ as hormones fluctuated, in support of Hypothesis 2. In contrast, while scenario affected reactions in hormonal contraceptive users, their responses in general did not differ across the two testing sessions. Therefore, reactions appeared to remain consistent with stability in hormones.

Firstly, it is important to note that the different scenarios elicited the appropriate responses. Qualitative responses demonstrated that women indeed felt that Petralia and Gallup's sexual assault scenario was ambiguous, and depicted a stalking situation, whereas the vast majority believed the new explicit rape scenario pertained to rape. This finding supports one of the aims of this study, due to the ambiguity of the risk situations used in previous research. Similarly, the physical assault scenarios were believed to depict assault or robbery. While participants were aware that the control scenario did not actually involve danger, it was often mentioned that a similar attack to one they had experienced in a previous scenario was anticipated. However, order effects analysis showed that the order in which the control scenario appeared did not influence reactivity.

Further evidence for the validity of the scenarios comes from the finding that scenario type significantly influenced perceived risk, negative emotions, perceived physiological arousal, the extent to which women would be likely to run from or physically fight the attacker, emotionally cope and handgrip strength, in support of Hypothesis 1. Furthermore, mood did not vary by fertility for naturally cycling women and therefore differences in reactivity to the scenarios could not be assumed to be due to differences in affect. Therefore, it can be suggested that differences in emotions do not underlie the risk avoidance behaviour during ovulation that has been documented in previous research (e.g., Bröder & Hohmann, 2003; Chavanne & Gallup, 1998).

One possible reason for fertile women's increased avoidance of situations of rape risk, such as dark and deserted areas (e.g., Bröder & Hohmann, 2003; Chavanne & Gallup, 1998) could be women's increased perception of risk when fertile. Women reported that they felt more at risk of the situations depicted in the scenarios occurring to them when fertile compared to nonfertile. Šukolová and Sarmány-Schuller (2011) also found differences in risk perception according to fertility. They found that fertile women attributed a higher score than nonfertile women to the 'likelihood of a negative outcome', and fertile women judge risk based on the severity of a negative outcome. Follow up analyses suggested fertility-related differences in risk perceptions were for the rape and male-perpetrated physical assault scenarios specifically, in support of Hypothesis 2. Indeed, McKibbin et al. (2008) state that previous research suggests that women have evolved mechanisms that motivate them to assess the risk of sexual coercion. If sexual coercion is more costly during ovulation, it makes evolutionary sense to have enhanced risk assessment during this cycle phase, especially for situations with high risk of rape. Similarly, Fessler, Holbrook and Fleischman (2015) refer to 'asset risk', which relates to the ability to prevent an attack, and the costs likely to be suffered in the event of an attack, with 'costs' referring to evolutionary costs in relation to reproduction or survival. They argue that, as the fitness costs of sexual assault are arguably higher during ovulation due to the increased chance of conception, women's asset risk is higher during ovulation.

Hormonal contraceptive users did not differ in their risk perception according to session.

For the physiological measures, heart rate variability (HRV) did not differ according to fertility or scenario type, thus not supporting Hypothesis 1 or 2. It was hypothesised that women would show decreased HRV when fertile compared to when nonfertile due to the higher fear the scenarios were presumed to elicit. However, while descriptively speaking this was the case; that is women's HRV was lower when fertile compared to when nonfertile, this did not differ significantly.

Research has suggested individual differences in physiological responses to threat. For example, Hare (1972) found that while some participants demonstrated increased heart rate in response to images of homicide victims, others showed decreased heart rate or only moderate deceleration. This seems to be due to individual differences in fear. Indeed, it has been suggested that whether heart rate accelerates or decelerates in response to fear stimuli is determined by individual differences (Klorman, Wiesenfeld & Austin, 1975). A follow-up study by Hare (1973) showed that participants with a specific fear of spiders showed heart rate acceleration while those who were not fearful of spiders showed heart rate deceleration. Therefore, although spiders are an established evolutionary threat to fitness, physiological response depended on self-perceived feelings of fear. While rape is undoubtedly an evolutionary threat, particularly so at peak fertility, it is possible that conscious feelings of fear of rape do not change over the menstrual cycle.

However, HRV also did not differ by scenario type. Scenario influenced subjective measures and the main effect of scenario on handgrip strength was close to significance, which suggests that the stimuli were effective in eliciting differences in response. One reason HRV may not have differed according to scenario type is due to the scenarios being less than 5 minutes long. It is suggested that HRV should ideally be analysed for periods longer than 5 minutes (Malik, 1996). HRV in this study was assessed during a 3-and-a-half-minute period, which was separated into the start, attack and rumination periods. As such, it is possible that the HRV measurement was not as accurate or informative as it could have been had heart rate signal been

collected for longer. It may also be the case that the sample size was too small in comparison to previous research finding heart rate to be influenced by emotional stimuli (e.g., Krypotos, Jahfari, van Ast, Kindt & Forstmann, 2011). Alternatively, it is possible that HRV is not affected by threatening stimuli. While some find HRV to be associated with processing threatening stimuli (e.g., Appelhans & Luecken, 2006; Johnsen et al., 2003; Krypotos, et al. 2011; Melzig, Weike, Hamm & Thayer, 2009) others have found that HRV is related to emotions elicited by positive stimuli only (e.g., Fujimura & Okanoya, 2012), and thus may explain the lack of effect of threatening scenarios on HRV. This is an area of research that would benefit from further research.

However, HRV did vary according to the start, attack and rumination portions of the scenarios. HRV was consistently higher during rumination compared to the start or attack. This may be explained by the fact the handgrip measurement immediately preceded rumination. Physical movement, such as handgrip measurements, have been shown to influence HRV (Lehrer et al., 2010; Luft, Takase & Darby, 2009), due to an increase in sympathetic stimulation.

Unlike HRV, handgrip strength was affected by the interaction between fertility and scenario type. However, the only increases in handgrip strength from baseline were for the rape and male-perpetrated assault scenarios, supporting Hypothesis 1. This is not surprising considering there were 11 tests of handgrip strength within a 40-minute period. This may explain the lack of effect regarding rumination; post-rumination handgrip measurements may have occurred too soon after post-scenario tests of handgrip to allow hand muscles to return to baseline. Indeed, for hormonal contraceptive users, handgrip was significantly weaker during rumination than post-scenario, regardless of scenario type. Nevertheless, fertility interacted with scenario, and follow up analyses showed women's handgrip strength to be greater when fertile compared to nonfertile for the rape, male-perpetrated assault, Petralia and Gallup's sexual assault and control scenarios; that is, all scenarios involving a male, thus partially supporting Hypothesis 2. Interestingly, the only scenario to elicit no difference in handgrip according to fertility was for the female-perpetrated physical assault scenario, where danger was still present, but there was no immediate risk of rape. This

was the only scenario that did not mention a male figure approaching. Therefore, it could be suggested that women were not simply more responsive to general risk during ovulation. The female-perpetrated physical assault scenario involved danger, yet fertile women responded equally to nonfertile women in terms of physical strength, which was not the case for the other scenarios. The findings therefore may also lend support for the shadow of sexual assault hypothesis (Ferraro, 1995; 1996). Scenarios involving a male may have primed women to believe the scenario could potentially escalate into a sexual attack.

The shadow of sexual assault hypothesis may also help to explain the fertility-related difference for the control scenario. Although all participants showed an average decline in handgrip from baseline to post-scenario and post-rumination for the control scenario, there was a significantly smaller decline in handgrip from baseline for fertile compared to nonfertile trials. This was an unexpected finding as there was no danger implied, but the scenario did mention the shadow of a tall man approach, which then reaches for a football. This may be due to the within-subjects design, which in this regard could be considered a limitation of the current study as handgrip strength inevitably weakened over time and carry-over effects were unavoidable despite including distractor tasks. Participants may have heard the control scenario after previously hearing the sexual assault scenario, for example, and anticipated a similar situation occurring when the male figure appeared. Indeed, participants mentioned in their open-ended responses that they were expecting a similar attack to one they had previously experienced. However, the scenarios were counterbalanced across participants, and analyses suggested that the order in which the control scenario was presented in relation to scenarios portraying threatening males or rape did not influence handgrip strength. Therefore, Petralia and Gallup's (2002) findings were not replicated regarding the control scenario using a within-subjects design.

The subjective responses also did not lend support to the hypothesis that women would be more likely to avoid situations of increased rape when fertile compared to nonfertile (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003). Handgrip measurements did not correlate with any other DV overall. Women did not

report that they would be more likely carry out avoidance behaviours (run from or fight the attacker) in response to scenarios with increased risk of rape when fertile compared to nonfertile. However, women reported they would be more likely to run from the male-perpetrated assault scenario only when fertile compared to nonfertile, which arguably is associated with risk of rape due to the SSAH. The relative increase in handgrip strength when fertile compared to when nonfertile does not seem to be a result of increased willingness to fight, nor does it make fertile women feel they are more capable of successfully fending off the attacker. However, this finding approached significance for the female-perpetrated physical assault only. Thus, the findings of Prokop (2013) were replicated; that women felt more physically capable during ovulation. Therefore, it may be the case that the behavioural and physiological changes documented as rape avoidance behaviours are unconscious and instinctual (i.e., system 1 processes, e.g., Kahneman, 2003) rather than a deliberate and conscious decision driven by cognition (i.e., system 2 processes). System 1 processes are fast, automatic, subconscious thought processes, while System 2 processes are slow, rational and conscious. It is possible that avoidant behaviour can be present without changes in cognition (Gabriel & Greve, 2003). Correspondingly, Snyder and Fessler (2013a) argue that "an evolved rape-avoidance mechanism could conceivably operate without involving the conscious mind" (p544). This is an avenue that would be interesting to research further.

In sum, this study aimed to find domain specificity in women's avoidance behaviours. Women overall felt more at risk when fertile compared to when nonfertile, particularly for the rape and male-perpetrated assault scenarios. Further, women's handgrip strength increased more when fertile compared to when nonfertile in response to scenarios that featured a male, but not a female actor. As such, it cannot be concluded that the evolved mechanism which has been suggested by previous research is rape-specific. However, fertile women do not appear to simply be responding differentially to danger more generally when fertile as handgrip strength, amongst other measures of reactivity, was not affected by fertility in response to female-perpetrated physical assault, where danger is present but risk and costs of rape are controlled. Handgrip strength was strongest for scenarios involving a male

attacker (rape and male-perpetrated assault). Against expectations, there were also fertility-related differences for the control scenario which featured the appearance of a male, but not in a threatening manner. This finding may be explained by subjective responses, showing that women had anticipated an attack to occur when the male appeared. As there were no fertility-related differences for the female-perpetrated assault scenario, it could be argued that the results are in line with the shadow of sexual assault hypothesis, which appears to be influenced by fertility.

3. Chapter 3: Attentional biases

This chapter reports the results of two studies (Study 3 and Study 4) examining the cognitive mechanisms associated with fertility-related risk avoidance that have been documented in previous research. During exploratory analyses for heart rate in Study 2, it was found that heart rate (bpm) appeared to decrease during the attacks compared to other parts of the scenario, especially for fertile women. Decreased heart rate is associated with the orienting response (Bradley, 2008). Although bpm was not included in the final analyses, and these differences were not significant, it brought consideration of the underlying cognitive processes that may be associated with fertility-related responses to risk situations. For example, women may differentially attend to risk stimuli according to fertility.

3.1. Introduction

Previous research suggests that women reduce risk-taking behaviours to decrease their risk of rape, particularly during ovulation when rape could result in a pregnancy (Chavanne & Gallup, 1998; Bröder & Hohmann, 2003). Research to date regarding fertility-related rape avoidance has focused largely on behavioural changes, documenting an increase in behaviours that may help a person avoid being raped (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003; Guéguen, 2012a; Petralia & Gallup, 2002). The precise psychological mechanisms underlying such changes, however, are not clear.

It is argued that psychological mechanisms evolved to overcome specific adaptive challenges (Pinker, 2007) such as to protect oneself from threats or to attract mates (Buss, 1995; Buss, 2008; Cosmides & Tooby, 1992; Plotkin, 1998). Buss (1995) argues that psychological mechanisms underlie all behaviour, and fluctuate according to circumstances (Kaplan, 1992), which consequently drives behavioural change. Thus, if women's reductions in risk-taking behaviour during ovulation reflect an adaption to avoid rape (e.g., Chavanne & Gallup, 1998; Bröder & Höhmann, 2003), such behavioural changes might be mediated by cognitive mechanisms that vary across the cycle, such as attention. Indeed, it is argued that the mind enables detection of physical cues that affect reproductive success (Thornhill & Gangestad, 1996).

Considering these arguments, consideration of the psychological mechanisms that underlie rape avoidance behaviours is fundamental to understanding the fertility-related rape avoidance hypothesis.

Navarrete and colleagues examined a cognitive mechanism that may aid rape avoidance by assessing bias towards outgroup members over the menstrual cycle (Navarrete et al. 2009; McDonald, Asher, Kerr & Navarrete, 2011). Outgroup members are believed to have been a threat to our ancestors (Daly & Wilson, 1988, as cited in Navarrete et al. 2009) and therefore due to lack of social controls that are likely to be present with ingroup members, may pose a greater threat of sexual assault (Navarrete et al. 2009). As such, the authors theorised that women may have evolved a psychological mechanism to be biased towards ingroup compared to outgroup members during ovulation, when behaviour, socialisation and mate choice has the most reproductive consequences. Navarrete et al. (2009) examined attitudes, attractiveness and rated 'scariness' of outgroup members (defined by race) across the menstrual cycle. Ovulation was associated with elevated race bias, fear of male targets, and decreased attraction to outgroup members. McDonald et al. (2011) showed the bias towards outgroup members extended beyond race using an implicit association test. These findings suggest the presence of a psychological mechanism that varies over the menstrual cycle in a way to predispose fertile women to evaluate and avoid potential threats to reproductive fitness.

However, it cannot be concluded from Navarrete and colleagues' research that bias towards outgroup members evolved for rape avoidance specifically. To conclude the evolution of an adaptive trait, the evolved mechanism should be domain-specific. Behavioural and cognitive changes should have a specialised function, tailored to overcome a specific adaptive problem (Buss, 2008; Cosmides & Tooby, 1994; Pinker, 2007; Tooby & Cosmides, 2007). Therefore, if the mechanism indeed reflects rape avoidance to prevent pregnancy, rather than avoidance of all danger more generally, fertile women should show psychological biases towards stimuli that are specifically associated with an increased risk of rape.

Garver-Apgar et al. (2007) argue that to establish speciality of design, it is necessary to show that the findings cannot be attributed to other, more general processes. They endeavoured to examine domain specificity in women's perceptions of male traits over the menstrual cycle. They found fertile compared to nonfertile women were more attuned to, and even over-estimated males' sexual coerciveness. However, perceptions of more positive traits, including perceived kindness, commitment or faithfulness did not differ by fertility. Fertility-related sensitivity to male traits thus appeared specific to cues associated with coercion. However, this does not rule out the possibility that women are more attuned to risk more generally. Indeed, Garver-Apgar et al. (2007) mention that it is possible that sensitivity to coercion could be due to increased fear and anxiety more generally during ovulation. However, they contend that fear has not been shown to increase mid-cycle, but rather that fear increases specifically during the luteal phase (Solis-Oritz & Cabrera, 2002; Vandermolen, Merckelbach, & Vandenhout, 1988, as cited in Garver-Apgar et al. 2007, also see Soni et al. 2013; Glover et al. 2013). However, previous research does show enhanced sensitivity to fear during ovulation (Pearson & Lewis, 2005). Thus, to fully establish that the purpose of the mechanism is specifically to avoid rape due to increased risk of pregnancy during ovulation, rather than a general increase in risk-aversion, fear or anxiety more generally, the specificity of response within risk situations needs to be demonstrated. Previous research has not yet adequately considered this.

Avoidance behaviours are associated with anxiety, as are physiology, and cognitive biases that prioritise the processing of threat (for reviews, see Eysenck, 2014; Mogg & Bradley, 1999). For example, high trait-anxious individuals are faster to detect threatening stimuli (e.g., Lipp & Derakshan, 2005). This is also the case for phylogenetically prepared stimuli. Threats to evolutionary fitness, such as dangerous animals, are detected faster than neutral stimuli, such as neutral animals or flowers (e.g., Flykt, 2006; Lipp & Derakshan, 2005; Mogg & Bradley, 2006; see Öhman & Mineka, 2001 for a review). This mechanism is even present in very young children (LoBue & DeLoache, 2008), and supported by event-related potential studies showing that there are attentional processes that seem to prioritise both threat- and

evolutionary-relevant stimuli (van Hooff, Crawford & Van Vugt, 2011). Recurrent threats over evolutionary history are believed to have acted on the emergence of psychological mechanisms to facilitate fear learning for these threats (Öhman & Mineka, 2001).

There are evolutionary benefits to the rapid detection of danger (Fox, Lester, Russo, Bowles, Pichler & Dutton, 2000), such as efficient response and defensive action, which could increase the chance of survival (Armony & LeDoux, 2000; Calder, Lawrence, & Young, 2001; Flykt, 2006, Öhman, 1996; LeDoux, 1996). Faster detection of snakes, for example, would allow for faster avoidance. Thus, rapid detection of threats, or biased attention, has adaptive benefits. For example, faster detection of stimuli associated with increased risk of rape, may enable faster defensive action, such as avoidance behaviours.

3.2. Study 3: Attentional biases to threats over the menstrual cycle

Study 3 assessed whether there are fertility-linked differences in attentional bias to dangerous stimuli using a dot-probe paradigm (Macleod, Mathews & Tata, 1986). A dot-probe paradigm typically involves two words or images appearing on the screen briefly, with one being emotionally or evolutionarily salient and the other neutral. After the stimuli disappear, a small dot-probe appears in the position of one of these stimuli. If attention is directed towards the threat, probes that replace threatening words or images would be responded to more quickly than if the probe appears in place of the neutral stimuli, where attention is not directed. Faster detection of the dot-probe would also indicate faster preparation to respond to threat (Flykt, 2006).

Research suggests processing biases are the result of the stimuli used, rather than general anxiety (Lipp & Derakshan, 2005). Research using a dot-probe paradigm has also found faster detection of threatening facial expressions, such as angry faces, compared to neutral or happy faces (e.g., Cooper & Langton, 2006; Hansen & Hansen, 1988; Öhman, Lundqvist, & Esteves, 2001; Staugaard, 2009), which is also true in children (LoBue, 2009). An angry facial expression signals aggressive intent (Sell,

Cosmides & Tooby, 2014) and is associated with perceptions of criminality (Flowe, 2012). Anger is argued to motivate violence (Fessler, 2010, as cited in Galperin et al. 2013), and thus is a source of threat (Becker & Detweiler-Bedel, 2009). Face perception is important for inferring intentions, and making approach or avoid decisions (McArthur & Baron, 1983). Prioritised processing of angry faces allows efficient response selection, namely a fight or flight response (LeDoux, 1996).

Fertility-linked differences in threat responses have been documented. For example, research has shown variations in attentional biases, interpreted as variations in the activity of the fear module, over the menstrual cycle (Masataka & Shibasaki, 2012). Using a visual search paradigm, Masataka and Shibasaki (2012) found slightly faster detection of snakes compared to flowers during the late follicular phase (approaching ovulation) compared to the early follicular phase of the menstrual cycle, though this did not reach significance. However, women in the luteal phase were significantly faster to find the snake than women in both the early and late follicular phases. This was taken as evidence for an adaptive mechanism for avoidance of threat during the phase of possible early pregnancy. However, their sample of only 29-30 year olds was limited, and they did not directly or intentionally test for fertility. Furthermore, the use of an inanimate neutral comparison (i.e., flowers) has been criticised as an inadequate control (see Lipp, Derakshan, Waters & Logies, 2004; Quinlan, 2013), and visual search paradigms have been criticised for being unable to demonstrate cognitive biases to threat in the general population (see Tipples, Young, Quinlan, Broks, & Ellis, 2002).

Evidence also suggests fertility-related differences in processing of social stimuli. Marečková et al. (2014) found more neural activation in the fusiform face area in response to faces during mid-cycle. Similarly, Derntl, Windischberger, Robinson, Lamplmayr, Kryspin-Exner et al. (2008) found stronger amygdala activation and enhanced performance in an emotion recognition task during the follicular phase compared to the luteal phase. Hormones may affect neural processes that influence women's responses to reproductively relevant stimuli (Dreher, Schmidt, Kohn, Furman, Rubinow & Berman, 2007). For example, Krug, Plihal, Fehm & Born's (2002) and Macrae et al.'s (2002) findings of faster categorisation of male stereotypes during

ovulation are interpreted as suggesting that there is an enhanced sensitivity to stimuli of reproductive relevance when conception is most possible. Indeed, research shows increased activation in the right medial orbitofrontal cortex (Rupp et al. 2009), and increased attention (Anderson et al. 2010) in response to male faces during the follicular compared to the luteal phase, which may suggest a hormonally mediated increase in appetitive motivation. Fertility-related enhancements in attention may reflect more thorough cognitive assessment of reproductively significant stimuli (Anderson et al. 2010). Pearson and Lewis (2005) suggest that it "makes evolutionary sense to have an enhanced sensitivity to reproductively relevant stimuli during ovulation" (p.267, also see Pilarczyk, Schwertner & Kunieki, 2015).

Previous research shows enhanced detection of stimuli that benefits reproductive fitness during ovulation, such as attractive males (e.g., Anderson et al. 2010), with little research on attention to threats to reproductive fitness over the menstrual cycle. Pearson and Lewis (2005) found better detection of fearful expressions during ovulation, compared to during menstruation. No fertility-related differences were found for recognition of other emotions, including sad, happy, angry, disgust or surprise. This may suggest enhanced sensitivity to fear-relevant stimuli at peak fertility. However, this study focused on the accuracy of emotion judgments, rather than the speed, which may be more important for efficient avoidance. Threatening situations (e.g., an attacker) often impose time constraints, and as such, a rapid response to danger would have clear adaptive advantage. In such situations, speed is prioritised over accuracy (e.g., LeDoux, 1996; Öhman, 2000). However, detection of threats to reproductive fitness over the menstrual cycle has not been examined. Therefore, Study 3 was conducted.

Study 3 had two primary aims. Firstly, it aimed to assess whether women have attentional biases towards threat, particularly when fertile, which may provide evidence for an evolved psychological mechanism underlying rape-avoidance behaviours. The second aim of the study was to determine domain specificity in attention to threat. Attention to phylogenetically-relevant stimuli (animals) and social stimuli (faces) was assessed using a dot-probe paradigm across two experiments. One experiment consisted of face stimuli, that is, angry versus neutral male and female

faces. Angry faces signal aggressive intent (Sell et al. 2014), and men are more likely to commit criminal violence (Kruttschnitt, 1994; Simon & Baxter, 1989, as cited in Campbell, 2013). Moreover, the shadow of sexual assault hypothesis (Ferraro, 1995; 1996) suggests that women's higher fear of crime relative to men's and their actual victimisation rate is due to the assumption that any crime could potentially escalate into a sexual crime. Therefore, angry and neutral female faces, which could inflict danger but controls for the risk of rape, were also used. The faces also varied in their rated dominance and trustworthiness (see Flowe, 2012 for ratings), which may also influence approach or avoid decisions, and thus attention (Oosterhof & Todorov, 2008). Another experiment consisted of animal stimuli, which was used to assess fertility-related differences in detection of more general threats (e.g., snakes and spiders) compared to neutral animals (e.g., dogs and sheep). Fertility-related differences in attention should be apparent for facial stimuli, but not for animals, as animals are not relevant to reproductive fitness. Women participated in both experiments in both testing sessions.

It was predicted that, in general, reaction times (RTs) would be faster towards dot-probes replacing threatening (i.e., angry, low trustworthy or high dominant faces and fear-relevant animals) compared to neutral stimuli (i.e., neutral, high trustworthy, low dominance faces, neutral animals) (Hypothesis 1). Moreover, fertility-related differences would be apparent for face stimuli only (Hypothesis 2). In particular, women would be faster to detect probes that replaced angry male faces, compared to angry female faces or neutral faces regardless of gender when fertile compared to nonfertile (Hypothesis 3), and faster RTs to faces that are rated low in trustworthiness and high in dominance when fertile compared to nonfertile (Hypothesis 4).

3.2.1. Method

3.2.1.1. Participants

Ethical approval was received from the University of Leicester's ethics committee. The study advertised for females aged 18-35 years on the University's student participation system, along with a link to an online pre-screening questionnaire, which 133 women completed. The pre-screening questionnaire

informed participants what the questionnaire involved, and once consent was given, participants answered questions about their demographics (e.g., age, relationship status) and menstrual cycles (e.g., use of hormonal contraceptives, cycle regularity and length, and the date of their most recent menstruation), along with questions about their general health and lifestyle to avoid disclosing the aims of the research (e.g., frequency of illness and exercise). For accurate estimation of menstrual cycle phase, it was important that naturally cycling participants had regular menstrual cycles (i.e., menses occurring every 26-32 days). Eligible participants were contacted via email, and the first testing session was arranged for either a high fertility (days 12-16) or low fertility phase (days 1-3 or 21-23). The phase in which first participation occurred was counterbalanced. Testing sessions occurred approximately 2 weeks apart. Hormonal contraceptive users also participated two weeks apart. Hormones would fluctuate in naturally cycling participants, while hormonal contraceptive users would remain stable in their hormone profiles across the testing sessions (Fleischman, Navarrete & Fessler, 2010). Therefore, any differences in reaction time within naturally cycling participants but not in hormonal contraceptive using participants could be assumed to be due to fluctuations in hormones and fertility.

Fifty-eight eligible women (30 hormonal contraceptive users, 28 naturally cycling) participated in return for monetary compensation[4]. Women ranged in age from 18-23 years (M = 19.3875, SD = 1.065). Each woman participated in two experiments, one for faces and one for animals in each testing session. However, due to software issues[5], only 54 women participated in the experiment using face stimuli (27 naturally cycling and 27 hormonal contraceptive users).

3.2.1.2. Design

The study used a dot-probe paradigm. The dependent variable, attentional bias, was measured by reaction time (RT, in ms) for the participant to find the dot-probe following its onset.

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[4] Funded by the European Evolution and Human Behaviour Association (EHBEA).
[5] On the first day of participation, the face experiment did not run correctly. These four participants therefore only participated in the animal experiment.

The study used a 2 hormonal contraceptive use (users or naturally cycling) x 2 fertility (fertile, nonfertile) x 2 session (session 1, session 2) x 2 stimuli (fear-relevant [angry faces, fear-relevant animals], neutral [neutral faces, neutral animals]) mixed design, with hormonal contraceptive use as the only between-subjects factor.

Hormonal contraceptive use (users or naturally cycling) was measured between subjects, with fertility (fertile, nonfertile) as a variable nested within naturally cycling participants, and session (first or second) nested within hormonal contraceptive users. For the face stimuli, the independent variables were emotion (neutral, angry) and gender (male, female) of the target face (i.e., that the probe replaces). The influence of trustworthiness (high, low) and dominance (high, low) were also assessed. For the animal stimuli, the independent variables were the types of animal (neutral, fear-relevant) that were presented. All variables were measured within-subjects, apart from hormonal contraceptive use.

3.2.1.3. Materials

An online questionnaire was used to provide information about what the study would involve, along with a consent form which informed participants of their right to withdraw from the research at any point. The questionnaire also included questions similar to those in the pre-screening questionnaire, including the date of onset of most recent menstruation, use of hormonal contraceptives and cycle regularity. Spider- and snake-phobia questionnaires (SPQ and SNAQ, Klorman et al., 1974) were also included. Eighteen items assessed fear of snakes, and 20 items assessed fear of spiders[6] to ensure that no participants were phobic (e.g., Lipp & Waters, 2007). Participants were asked to respond 'True' or 'False' to each item, with sum of 'True' items being the dependent measure.

The animal dot-probe task employed stimuli from Flykt (2006), see Figure 14 for examples (also see Appendix F). There were 8 pictures of each type of animal,

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[6] Items from the original SNAQ and SPQ to assess fear only (i.e., the 'True' items, see Klorman et al. 1974) were used. scales that were specific to the US (where the scale was developed) such as "I would not want to travel 'down south' or in tropical countries because of the greater prevalence of snakes" were not included.
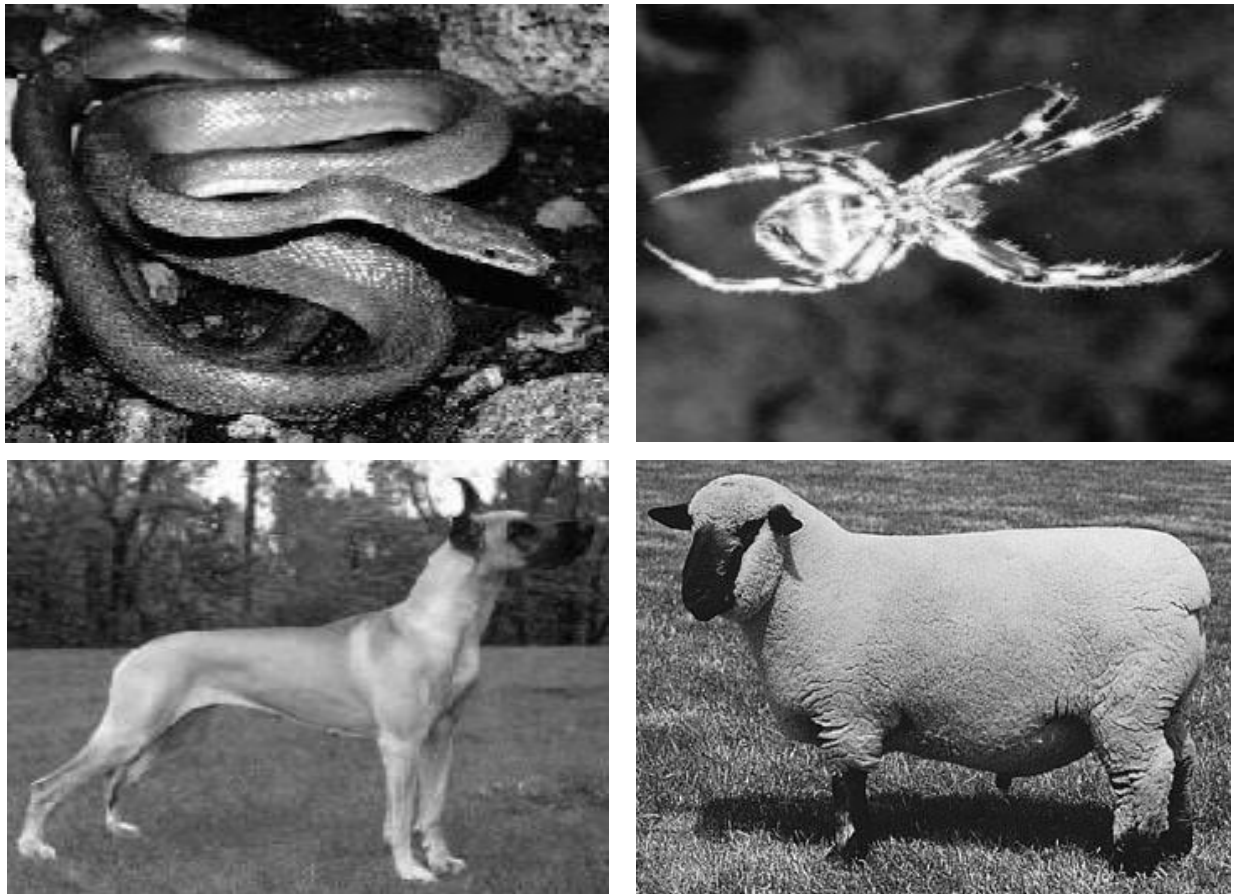
Figure 14. Example images of fear-relevant animals (top row) and neutral animals (bottom row).

which were converted to grayscale to control for any influence of colour contrast sensitivity (see Turatto & Galfano, 2000; Johnson & Petersik, 1987). For practice trials, pictures of mushrooms and flowers from Flykt (2006) were employed; these were also converted to grayscale.

For the face dot-probe task, Caucasian male (*N* = 20) and female (*N* = 19) faces were used with permission from the Radboud database (Langner, Dotsch, Bijlstra, Wigboldus, Hawk & van Knippenberg, 2010). All photographs were taken from a frontal view, with angry and neutral expressions (see Figure 15 and Appendix G). Each actor was trained by a FACS (Facial Action Coding System) coder, to ensure they were portraying the correct emotion. It was ensured that the photos did not show the actor's teeth, as such properties can influence attention over and beyond the emotional valence (see Blagrove & Watson, 2014). Photographs were cropped to show just the face, hair and neck, and were against a white background. Actors wore a plain black t-shirt. Photographs were in colour. Each of the faces had previously been rated on trustworthiness and dominance (see Flowe, 2012).

The images for both experiments were placed in the centre of the left and right side of the screen, with the centre of the photo being at 25% along the y-axis for the left image, and 75% along the y-axis for the right image. The width and height of the images were both 3cm. Responses were collected using keys 'A' and 'L' on a keyboard. The keyboard had a time delay of 30-50ms, but, importantly, the same keyboard was used for each participant.

Figure 15. Examples of the neutral (left) and angry (right) female (top) and male (bottom) faces

3.2.1.4. Procedure

Participants were told they would be completing a questionnaire that was similar to the pre-screening questionnaire. Once consent was given (see Appendix H), participants completed the questionnaire before the dot-probe study began. Whether participants completed the animal or face dot-probe task first was counterbalanced

across participants. Both experiments began with detailed instructions, before delivering 10 practice trials using mushrooms and flowers as stimuli. Any questions that participants had were answered after the practice trials.

The images were presented as pairs. For the faces, stimulus-pairs consisted of a neutral and an angry version of the same face (as per the methodology of Bradley, Mogg & Millar, 2000; Mather & Carstensen, 2003). Thus, gender was manipulated between trials rather than within trials. The side in which the angry face appeared, as well as the side in which the probe appeared was counterbalanced across trials. There were 156 trials in total, separated into 3 blocks of 52 trials with a break (approx. 1 minute) after each block. For fear-relevant trials, the probe appeared in the location of the angry face, and for neutral trials the probe replaced the neutral face. For the animal experiment, trials consisted of control and experimental trials. There were two types of control trials, wherein both pictures were neutral (e.g., dog and sheep), or both pictures were fear-relevant (e.g., snake and spider). In contrast, experimental trials consisted of a fear-relevant and neutral stimulus pair (e.g., snake and dog or sheep and spider). The animal within a given category (e.g., the dog in dog versus snake trials) was randomly drawn from 8 images. There were 144 animal trials in total, separated into 3 blocks of 48 trials with a break after each block.

The dot-probe programme was created and presented using E-Prime. All trials, including practice trials, involved seeing a fixation cross in the centre of the screen for 1000ms, which was followed by pairs of stimuli appearing concurrently, either side of the screen. The images were shown for 200ms, after which they disappeared and a dot-probe appeared for 50ms on a blank screen in place of one of the images.
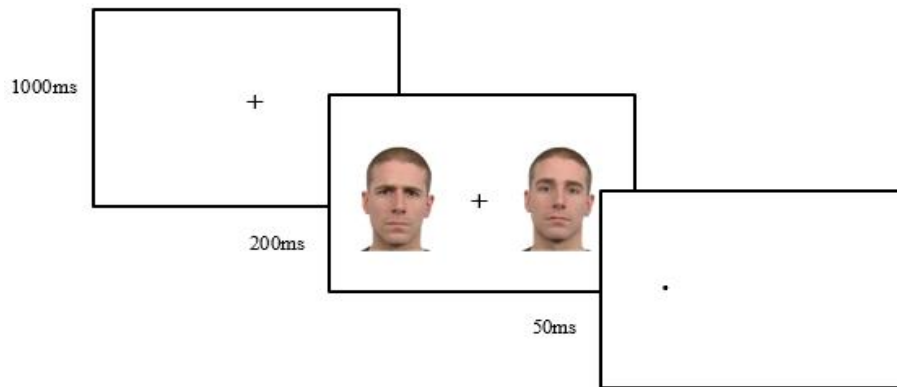
Figure 16. The procedure for the dot-probe paradigm

Participants sat approximately 90cm from the computer display. Participants were asked to respond as quickly and accurately as possible to the probe by pressing 'A' if the probe appeared on the left, or 'L' if it appeared on the right (see Figure 16). Participants frequently responded too quickly for the response to register, and thus needed to press any key to proceed to the next trial. They completed both experiments during each testing session. On completion of both experiments, participants took a self-administered urine-based ovulation test to assess luteinising hormone levels with a sensitivity of 30 miu/ml (http://www.homehealth-uk.com/medical/ovulation-tests.htm). A positive test was indicated by the test and control line being equal in colour. Participants then completed the same procedure in a second testing session that took place approximately two weeks later, depending on cycle phase and length. Participants were debriefed as to the aims of the study after participation in both testing sessions was complete.

3.2.1.5. Data analysis

Participants whose fertile phase could not be verified as being a phase of high fertility (i.e., via ovulation tests and/or conception risk calculation via backwards count method) were removed from the analysis (n = 10). Data were analysed separately for naturally cycling and hormonal contraceptive participants to assess the influence of hormonal fluctuations (i.e., fertility) within naturally cycling participants. Due to software issues with the face experiment, one naturally cycling participant and three hormonal contraceptive users only completed the animal experiment. For the face experiment, 7 participants' fertile phase was in the first session and 10 in the second.

For the animal experiment, 8 participants' fertile phase was in the second session and 10 in the first session. RT was measured in ms, and corresponded to the time taken to respond to the probe according to the stimuli the probe replaced.

Data from the face and animal experiment were analysed separately (e.g., Mogg, Holmes, Garner & Bradley, 2008). The sum of 'true' responses on the SNAQ and SPQ scales were representative of fear, with a higher score indicating a higher fear. Some RTs were extraordinally high. For example, sometimes a participant responded too quickly for the software to register the keyboard press, and thus the next trial would not begin until a key was pressed. As such, RTs were as high as 15s. Therefore, all incorrect trials and RTs over 1500ms were removed from the analysis to account for these errors. Subsequently, as per the methodology of previous studies (e.g., Masataka & Shibasaki, 2012), all RTs that fell 2 SD from the mean were removed from the analysis. The Greenhouse-Geisser correction was applied where necessary.

3.2.2. Results

3.2.2.1. Preliminary results

A 2 fertility (fertile, nonfertile) x 2 session (session 1, session 2) repeated measures ANOVA assessed whether session and fertility had an interactive effect on reaction times in each of the face and animal experiments. Although session 2 was faster than session 1 for the faces, $F(1, 6) = 54.32$, $p < .001$, $\eta p^2 = .90$ and for the animals, $F(1, 7) = 15.45$, $p = .006$, $\eta p^2 = .69$, fertility and session did not interact for either experiment (p's < .73). Hence, session will not be discussed any further.

3.2.2.2. Face stimuli- Naturally cycling participants

As seen in Table 10, descriptively speaking, average reaction time (RT) to find the probe was faster for fertile compared to nonfertile trials. Against expectations, RTs were slightly faster for neutral compared to angry faces. A 2 fertility (fertile, nonfertile) x 2 emotion (angry, neutral) x 2 gender (male, female) repeated measures ANOVA was carried out on the response time data. RTs were consistently faster when women were fertile compared to nonfertile, though the main effect of fertility only approached significance, $F(1, 16) = 4.03$, $p = .06$, $\eta p^2 = .2$. There was no significant main effect of

gender, $F(1, 16)$ = .05, p = .84, and mean RT did not vary for angry compared to neutral faces, $F(1,16)$ = 1.27, p = .28. Thus, Hypothesis 1 was not supported.

There was no interaction between fertility and gender of the target face, $F(1,16)$ = .34, p = .568 or between emotion and gender, $F(1, 16)$ = .13, p = .72, but the interaction between fertility and emotion of the target face only approached significance, $F(1, 16)$ = 4.17, p = .058, ηp^2 = .21, in line with Hypothesis 2 (see Figure 17). The three-way interaction between fertility and emotion and gender of the target face was not significant, $F(1, 16)$ = .27, p = .61.

Table 10. Mean (±1 SEM) RT to find the probe by fertility, emotion and gender

Fertility	Emotion	Gender	RT (ms)	SEM
Fertile	Angry	Male	185.68	8.83
		Female	185.83	8.94
	Neutral	Male	182.44	7.90
		Female	183.12	7.99
Nonfertile	Angry	Male	205.83	13.57
		Female	206.33	14.81
	Neutral	Male	216.69	14.45
		Female	214.21	15.29

Pairwise mean comparisons (t-tests) adjusted with the Bonferroni[7] correction indicated that nonfertile women showed faster detection of angry compared to neutral faces (mean difference = -9.36, *SEM* = 3.88, p = .028). However, fertile women showed the opposite pattern, with slightly faster RTs towards neutral compared to angry faces, but this difference was not statistically significant (mean difference = 2.97, *SEM* = 4.40, p = .51). RTs towards neutral faces differed significantly according to fertility, with fertile women responding to neutral targets faster than nonfertile women (mean difference = 32.67, *SEM* = 12.6, p = .02). There was no fertility-related

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[7] Wilcox (1987, p.36) suggests that "most multiple comparison procedures [including Bonferroni t-test] should be used regardless of whether the F test is significant" (see also Howell, 2002).

difference for angry faces (mean difference = 20.33, *SEM* = 14.44, *p* = .18). Thus, Hypothesis 3 was not supported.
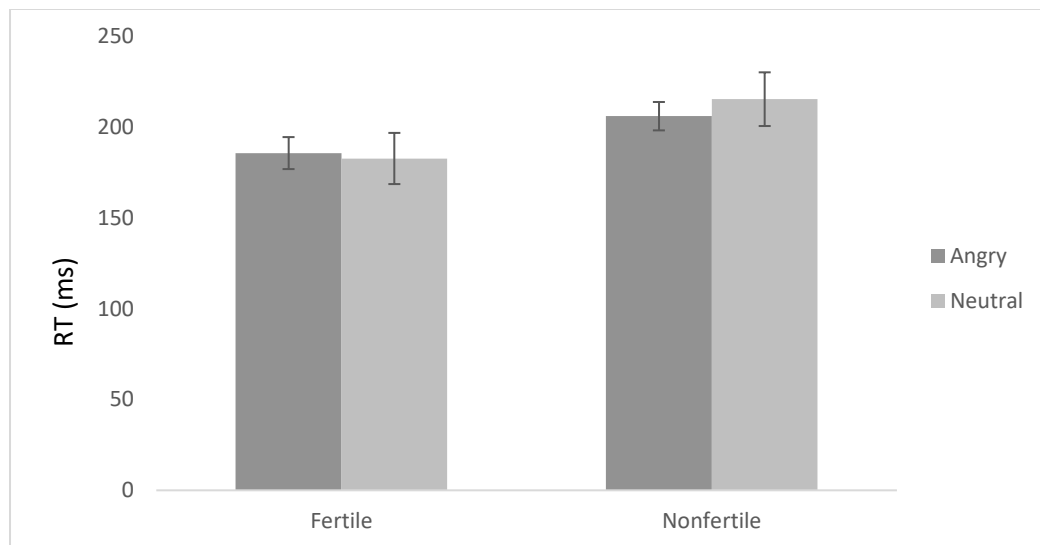
Figure 17. Mean (±1 SEM) RTs (ms) by fertility and emotion of the target face. The interaction approached significance (p = .058).

3.2.2.2.1. Trustworthiness

Study 3 also assessed whether attention would differ according to the perceived trustworthiness of a face and fertility. The main effects for fertility, gender and emotion are as above. Rather, this analysis will focus on trustworthiness only. Figure 18 and Table 11 show RTs to respond to the probe when it replaces a high or low trustworthy face by fertility. As shown, trustworthiness influenced attention more when women were fertile compared to nonfertile, such that fertile women were faster to detect probes replacing a face low in trustworthiness compared to high trustworthiness.

Table 11. Mean (±1 SEM) RTs by fertility, trustworthiness and gender of the target face

Trustworthiness	Gender	Fertile		Nonfertile	
		M	SEM	M	SEM
High	Female	183.83	8.58	209.89	15.05
	Male	180.54	7.95	211.03	13.88
Low	Female	185.29	7.97	210.20	14.73
	Male	187.64	8.28	212.15	14.14

To assess this finding, a 2 fertility (fertile, nonfertile) x 2 trustworthiness (high, low) x 2 gender (male, female) repeated measures ANOVA was carried out. The main effect of trustworthiness approached significance, $F(1, 16) = 3.88$, $p = .067$, with faster RTs to high trustworthy faces, against Hypothesis 1. Trustworthiness did not interact with gender, $F(1, 16) = 1.16$, $p = .298$ or fertility, $F(1, 16) = 2.53$, $p = .13$, thus Hypothesis 4 was not supported. However, t-tests adjusted for multiple comparisons with the Bonferroni correction showed differences in RT to low versus high trustworthy faces during the fertile phase (mean difference = 4.28, *SEM* = 1.77, *p* = .028), but not during the nonfertile phase (mean difference = .71, *SEM* = 1.62, *p* = .667)[8], supporting Hypothesis 2 (see Table 11).
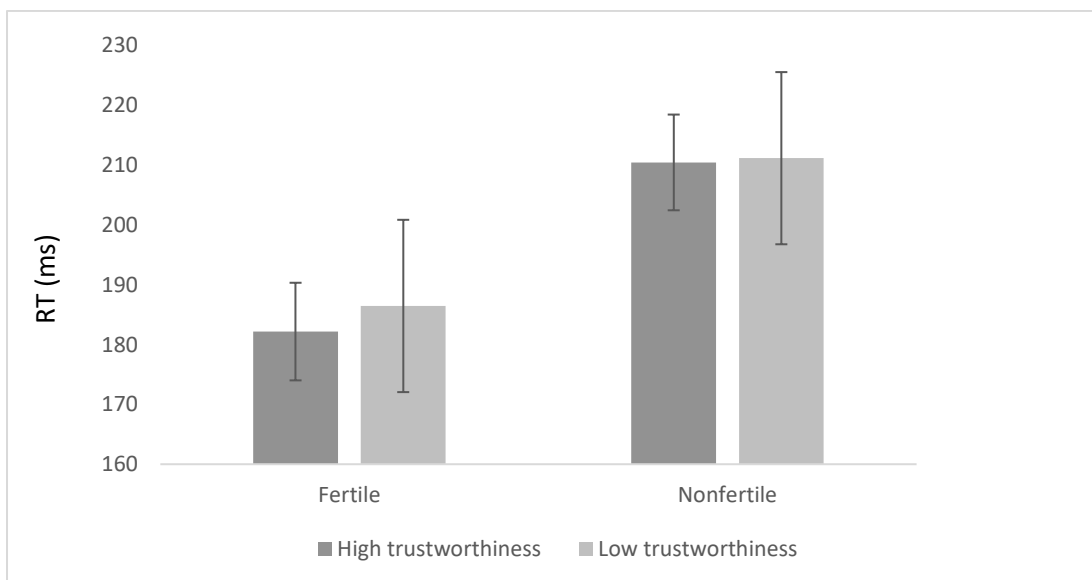
Figure 18. Mean (+1 SEM) RTs by fertility and trustworthiness of the target face. The trustworthiness effect on RT (i.e., faster to high trustworthy faces) was significantly different during the fertile phase, but not during the nonfertile phase.

3.2.2.2.2. Dominance

Table 12 shows RTs according to whether the probe replaces a high or low dominant face by fertility. Main effects for fertility, emotion and gender are as above, so this analysis will focus on dominance only. As shown, RTs did not differ according to

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[8] Pairwise comparisons were assessed despite the interaction between fertility and trustworthiness not reaching significance. Wilcox (1987, p.36) suggests that "most multiple comparison procedures [including Bonferroni t-test] should be used regardless of whether the F test is significant". This suggestion is supported in other statistics text book e.g., Howell (2002).

the gender or dominance of the face. A 2 fertility (fertile, nonfertile) x 2 dominance (high, low) x 2 gender (male, female) repeated measures ANOVA confirmed these observations. RTs did not differ according to the dominance of the face, $F(1, 16) = 1.41$, $p = .252$, and dominance did not interact with gender, $F(1, 16) = .004$, $p = .953$, or fertility, $F(1, 16) = .94$, $p = .346$. Therefore, Hypotheses 1 and 4 in relation to dominance were not supported.

Table 12. Mean (±1 SEM) RTs by fertility, dominance and gender of the target face

Dominance	Gender	Fertile		Nonfertile	
		M	SEM	M	SEM
High	Female	185.94	8.23	210.26	15.64
	Male	185.68	8.08	211.38	13.73
Low	Female	183.46	8.24	209.75	14.05
	Male	182.46	8.05	211.29	14.35

3.2.2.3. Face stimuli- Hormonal contraceptive users

As seen in Table 13, RTs were faster during session 2 with smaller standard errors, compared to session 1 in hormonal contraceptive users. RTs were also faster for female compared to male targets. A 2 session (session 1, session 2) x 2 emotion (angry, neutral) x 2 gender (male, female) repeated measures ANOVA conducted on the RT data confirmed these findings. There was a significant main effect of session, $F(1, 24) = 29.7$, $p < .001$, $\eta p^2 = .55$. RTs were faster in session 2 compared to session 1. There was also a main effect of gender, $F(1, 24) = 6.46$, $p = .018$, $\eta p^2 = .21$. RTs were faster towards female compared to male faces. There was no main effect of emotion, $F(1, 24) = .09$, $p = .769$, and it did not interact with gender, $F(1, 24) = .32$, $p = .577$. Session did not interact with emotion, $F(1, 24) = 1.72$, $p = .203$ or gender, $F(1, 24) = 2.01$, $p = .17$, and there was no three-way interaction between emotion, gender and session, $F(1, 24) = .76$, $p = .393$. Thus, Hypothesis 1 was not supported.

Table 13. Mean (±1 SEM) RT by emotion, gender and session for hormonal contraceptive users

Session	Emotion	Gender	RT (ms)	SEM
Session 1	Angry	Male	248.76	17.18
		Female	220.84	11.68

	Neutral	Male	234.16	11.45
		Female	221.38	11.20
	Angry	Male	178.10	8.94
		Female	171.32	7.49
Session 2	Neutral	Male	190.17	9.77
		Female	179.63	8.75

3.2.2.3.1. Trustworthiness

Table 14 shows RTs to respond to the probe when it replaces a high or low trustworthy face by session. Main effects for session, emotion and gender are as above, so this analysis will focus on trustworthiness only. Trustworthiness did not seem to influence RTs. To assess this finding, a 2 session (session 1, session 2) x 2 trustworthiness (high, low) x 2 gender (male, female) repeated measures ANOVA was carried out on the RT data. RTs for high trustworthy and low trustworthy faces did not differ, $F(1, 24) = .00$, $p = .99$. Thus, Hypothesis 1 was not supported. Trustworthiness did not interact with session, $F(1, 24) = .001$, $p = .97$, or gender, $F(1, 24) = 1.67$, $p = .21$, and there was no 3-way interaction, $F(1, 24) = .00$, $p = .99$.

Table 14. Mean (±1 SEM) RT by trustworthiness, gender and session for hormonal contraceptive users

Trustworthiness	Gender	Session 1		Session 2	
		M	SEM	M	SEM
High	Female	205.04	9.41	164.74	6.69
	Male	204.56	8.82	165.82	7.02
Low	Female	203.02	9.07	162.81	6.72
	Male	206.49	9.57	167.85	6.63

3.2.2.3.2. Dominance

The main effect of session and gender is as above. As such, this section focuses on the influence of dominance only. As seen in Table 15, RTs to respond to probes replacing faces low in dominance were faster than for faces high in dominance. A 2 session (session 1, session 2) x 2 dominance (high, low) x 2 gender (male, female) repeated measures ANOVA conducted on the RT data indicated no main effect of dominance, $F(1, 24) = 1.79$, $p = .19$. Thus, Hypothesis 1 was not supported. Dominance

did not interact with gender, $F(1, 24) = .43$, $p = .52$, or session, $F(1, 24) = .02$, $p = .88$. There was no 3-way interaction, $F(1, 24) = .16$, $p = .69$.

Table 15. Mean (+1 SEM) RTs by dominance and session in hormonal contraceptive users

Dominance	Gender	Session 1		Session 2	
		M	SEM	M	SEM
High	Female	206.53	9.09	171.75	8.33
	Male	204.09	9.14	170.07	8.36
Low	Female	200.38	9.82	161.35	6.47
	Male	200.64	8.02	168.31	7.25

3.2.2.4. Animal stimuli- Naturally cycling participants

<u>Fear of snakes of spiders</u>

A repeated measures t-test assessed fear of snakes and fear of spider scores by fertility (see Table 16). Fear did not differ according to fertility for either fear of snakes, $t(17) = .72$, $p = .48$, or spiders, $t(17) = -.74$, $p = .47$. There were no anomalies or phobic participants.

Table 16. Mean (+1 SEM) number of 'True' responses to fear of snakes (SNAQ) and spiders (SPQ) by fertility. A higher score indicates higher fear

	Fertile		Nonfertile	
	M	SEM	M	SEM
Snake	5.22	.8	5.56	0.89
Spider	7.06	1.38	6.78	1.33

Figure 19 and Table 17 both represent descriptive statistics for trial type and fertility. As shown, women were faster to respond when they were fertile as opposed to nonfertile. Against expectations, RTs were faster towards neutral compared to fear-relevant targets. The fastest RTs were towards neutral control trials, and neutral experimental trials, compared to fear-relevant control trials and fear-relevant experimental trials. These findings were assessed with a 2 fertility (fertile, nonfertile) x 2 trial type (neutral, control fear-relevant, experimental neutral, experimental fear-relevant) repeated measures ANOVA, where control trials refer to the two stimuli

being of the same category, and experimental trials being where the stimuli are fear relevant and neutral.

There was no main effect of fertility, $F(1, 17) = .16$, $p = .69$, but there was a significant main effect of trial type, $F(3, 51) = 27.88$, $p < .001$, $\eta p^2 = .62$. However, the interaction between fertility and trial type, $F(3, 51) = .6$, $p = .619$, was nonsignificant.

To further examine the main effect obtained for trial type, pairwise mean comparisons (t-tests) adjusted for multiple comparisons with the Bonferroni correction showed that RTs to control and experimental neutral trials were significantly faster than fear-relevant control trials and fear-relevant experimental trials (all p's < .001). All other pairwise comparisons were nonsignificant (p's = 1.00). Thus, Hypothesis 1 was not supported.

Table 17. Mean (±1 SEM) RTs by trial type, animal the probe replaces and fertility

Trial type	Probe replaces	Fertile		Nonfertile	
		M	SEM	M	SEM
Control	Neutral	300.67	17.26	310.16	18.16
	Fear-relevant	324.36	20.66	339.23	18.51
Experimental	Neutral	304.94	18.96	310.96	18.12
	Fear-relevant	322.44	19.67	333.39	20.85
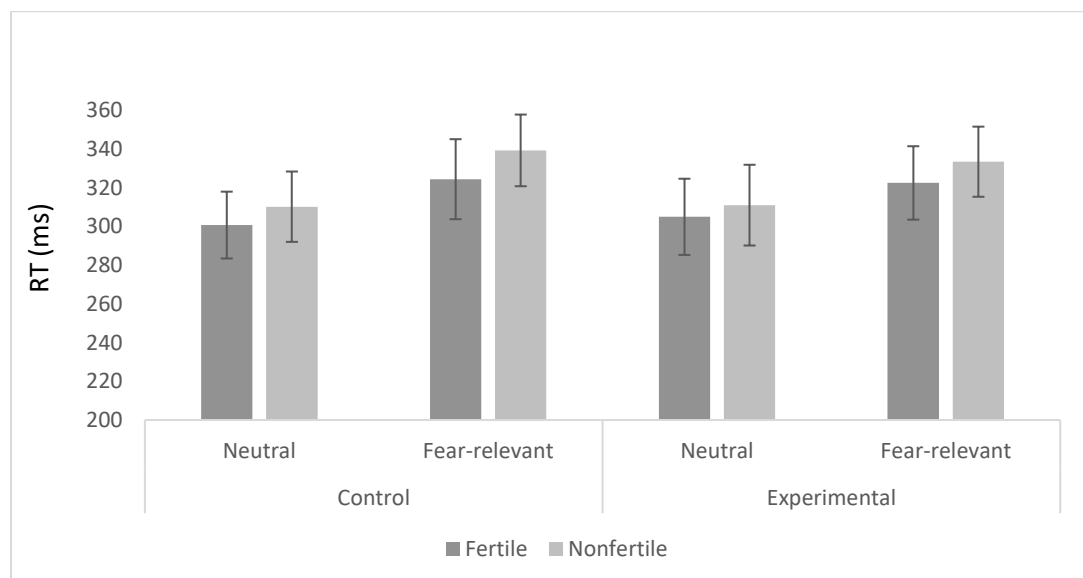
Figure 19. Mean (±1 SEM) RTs (ms) for trials wherein (from left to right), both stimuli are neutral, both stimuli are fear-relevant, experimental trials with the probe replacing the neutral and fear-relevant (far right)

3.2.2.5. Animal stimuli- Hormonal contraceptive users

Fear of snakes and spiders

Session did not influence fear of snakes, $t(26) = -.2$, $p = .846$. However, the effect of session approached significance for fear of spiders, $t(26) = 1.99$, $p = .057$, with women fearing spiders less on the second session (see Table 18). There were no anomalies or phobic participants.

Table 18. Mean (+1 SEM) number of 'True' responses to fear of snakes (SNAQ) and spiders (SPQ) by session in hormonal contraceptive users. A higher score indicates higher fear

	Session 1		Session 2	
	M	SEM	M	SEM
Snake	2.56	0.59	2.59	.64
Spider	7.19	1.17	6.44	1.20

Table 19 and Figure 20 shows that, descriptively speaking, for hormonal contraceptive users, RTs were faster during session 2, and for trials wherein the probe replaced neutral animals compared to fear-relevant animals. The RT data were analysed with a 2 session (session 1, session 2) x 4 trial type (control neutral, control fear-relevant, experimental neutral, experimental fear-relevant) repeated measures ANOVA. RTs were faster during session 2 compared to session 1, a significant main effect for session, $F(1, 26) = 35.82$, $p < .001$, $\eta p^2 = .58$. There was also a significant main effect of trial, $F(1.91, 49.67) = 40.99$, $p < .001$, $\eta p^2 = .61$. Session and scenario did not interact, $F(1.95, 50.61) = 2.21$, $p = .093$.

Table 19. Mean (+1 SEM) RT (ms) by trial type and session in hormonal contraceptive users

Trial Type	Animal	Session 1		Session 2	
		M	SEM	M	SEM
Control	Neutral	298.77	8.35	264.27	7.21
	Fear-relevant	328.86	9.75	295.93	10.31
Experimental	Neutral	309.99	9.23	269.13	8.17
	Fear-relevant	339.60	10.94	294.05	10.67

To further examine the significant main effect of trial, t-tests adjusted for multiple comparisons with the Bonferroni correction were conducted, and the results indicated that RTs to the control neutral trials were faster compared to all other trials

(p's < .031). RTs to the neutral experimental trials were also significantly faster compared to the control fear-relevant trials (p < .001), and the fear-relevant experimental trials (p < .001). The only trials that did not differ were the control fear-relevant and experimental fear-relevant trials (p = .622). Thus, Hypothesis 1 was not supported.
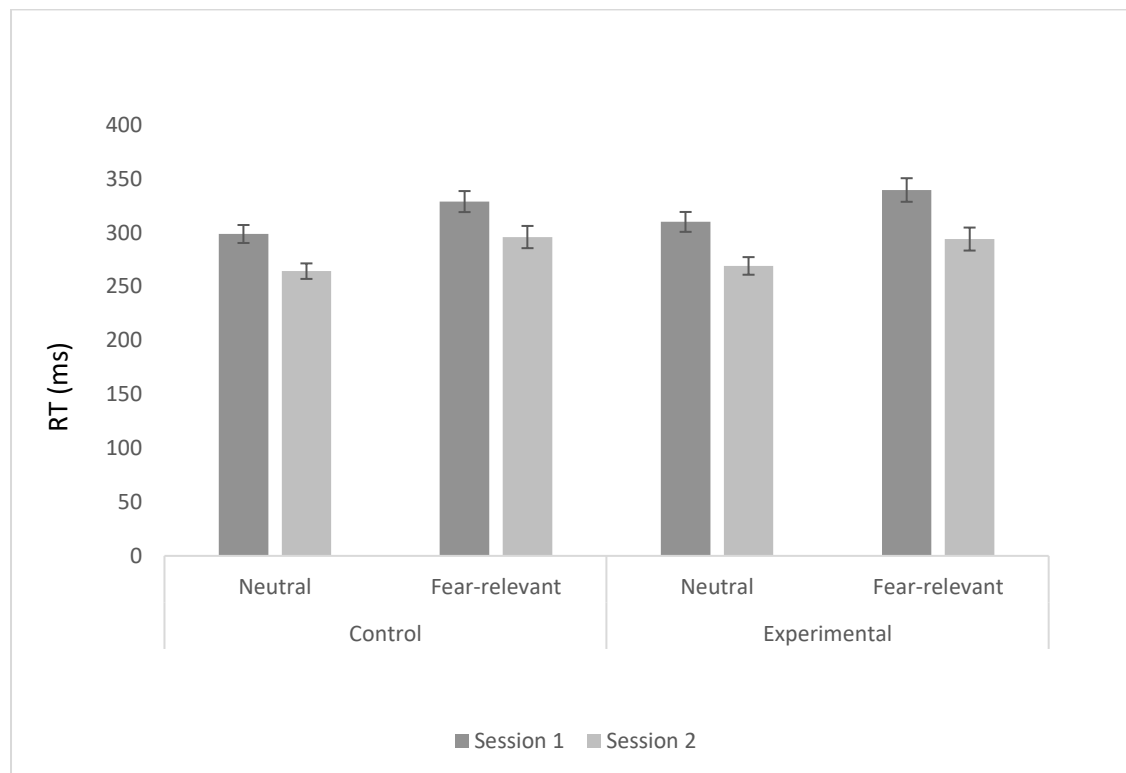
Figure 20. Mean ($\pm$1 SEM) RT (ms) by session and trial type in hormonal contraceptive users. Session 2 was faster than session 1, and neutral trials were faster than fear-relevant trials.

3.2.3. Discussion

The aim of the study was to assess whether fertility-related differences existed in attention to threats, and if so, if this was for threats to reproductive fitness, or all evolutionary threats. Overall, reaction times were faster in women's second session compared to their first, in both naturally cycling participants and hormonal contraceptive users. This finding may be indicative of practice effects, with women becoming faster at the task with practice. It was ensured that fertility was counterbalanced according to session in naturally cycling participants, and thus this

should not have accounted for the faster detection speeds during peak fertility. Fertility and session did not have an interactive effect on RTs. Emotion of the target face did not influence reaction times in naturally cycling or hormonal contraceptive using women.

Hypothesis 1 predicted that women would be faster to detect threats, including angry faces, untrustworthy faces, dominant faces and fear-relevant animals compared to neutral faces, trustworthy faces, low dominant faces, and neutral animals. Generally, trustworthiness and dominance did not influence attention overall. Moreover, neutral animals were responded to more quickly than fear-relevant animals. Therefore, Hypothesis 1 was not supported. For the faces, consistent with the literature (e.g., Cooper & Langton, 2006), and Hypothesis 1, nonfertile women were significantly faster to respond to probes following angry compared to neutral faces. However, when women were fertile, they were faster, but not significantly so, to respond to neutral compared to angry faces. Thus, there was some limited evidence that emotional facial expressions were influencing attention more so during the nonfertile compared to fertile phase, though not in the expected direction. However, descriptively speaking, women were faster to respond to probes overall when fertile compared to nonfertile, which may suggest overall increased vigilance during ovulation, regardless of stimuli.

Women were significantly faster to attend to neutral faces when fertile compared to nonfertile, while there were no fertility-related differences for angry faces. This is against expectations, but may be explained by repression or attentional avoidance (Krahé, 2005). Threatening stimuli may have led to avoidance and attentional withdrawal from threat, particularly when fertile, resulting in attentional engagement and thus faster reaction time to neutral stimuli (e.g., Frewen, Dozois, Joanisse & Neufeld, 2008). Walsh and DiLillo (2013) also found slower detection of sexual assault risk during ovulation, possibly to avoid the feelings of anxiety such stimuli might impose (e.g., Fox, 1993). Indeed, avoidance behaviours that have been documented in previous research (e.g., Chavanne & Gallup, 1998) are associated with repression (i.e., withdrawal of attention from threat) and anxiety (Asendorpf & Scherer, 1983).

The apparent trustworthiness of a given face did not influence reaction times in naturally cycling or hormonal contraceptive using women overall. However, while the overall interaction was not significant, pairwise comparisons suggested that trustworthiness influenced attention in naturally cycling women during their fertile, but not their nonfertile session. Fertile women were faster to respond to high trustworthy compared to low trustworthy faces, again which may be indicative of attentional avoidance (Krahé, 2005). Thus, Hypothesis 2 was supported, that fertility influenced responses to faces. However, this was not in the expected direction of faster response to low trustworthy faces when fertile, as predicted in Hypothesis 4. Nevertheless, this finding supported previous research showing fertility-related differences in perceptions of trustworthiness (e.g., Ball et al. 2013). Dominance did not influence reaction times in naturally cycling participants or hormonal contraceptive users.

It is important to note that both the main effect of fertility (faster when fertile) and the interaction between fertility and emotion only approached significance. One reason for this could have been due to lack of power. Post-hoc power analyses using GPower suggested that the power for the effect of fertility was .49, and for the interaction between fertility and emotion was .62. This suggests the study may have been underpowered (e.g., Cohen, 1988), and had a larger sample been used, these findings may have reached statistical significance.

For the animal stimuli, against expectations, reaction times were overall faster towards neutral compared to fear-relevant images, supporting the findings of Fox (1993) and Miltner et al. (2004), who also found RTs were faster towards neutral stimuli. Reaction times were fastest when both stimuli were neutral animals, and slowest when both stimuli were fear-relevant animals. This suggests that participants react more slowly to more threatening stimuli that are present in their visual field. In line with the suggestions of Koster, Crombez, Verschuere & De Houwer (2004), control neutral trials gave insight into the underlying mechanism. That is, overall detection speed was faster for neutral stimuli than for fear-relevant stimuli. This pattern may reflect avoidance or difficulty with disengagement (e.g., Koster et al. 2004). Fear can lead to threat and attentional avoidance, meaning faster reactions to neutral stimuli

(Frewen et al. 2008; Krahé, 2005). Similarly, negative stimuli have been shown to involve more processing and longer reaction times compared to positive stimuli (Cacioppo & Berntson, 1994; Ito, Larsen, Smith & Cacioppo, 1998; Ito & Cacioppo, 2000). Crucially, however, for the animal stimuli, there was no influence of fertility. This could, again, possibly be due to low power as a result of low sample size. Masataka & Shibasaki, for example, found hormonal status to influence attention to fear-relevant animals using a sample size more than 3 times the size of that used in the present study. However, their findings were driven by an increase in attention in the luteal phase of the menstrual cycle, rather than assessing attention according to fertility status specifically. Moreover, fertility appeared to influence attention to emotion in the present study using the same sample. Therefore, it can be assumed that fertility does not seem to influence attention to general threats to fitness, but appeared to influence attention to stimuli which was socially relevant. However, against expectation, women attended to neutral faces faster when they were fertile, rather than angry faces.

It was predicted that women would respond to threats more quickly, especially when fertile, as this may allow for more efficient avoidance. Inconsistent with previous research, women were faster to respond to probes following neutral compared to fear-relevant animals. Similarly, women were faster when fertile compared to nonfertile to respond to neutral as opposed to angry faces, and showed slightly faster detection of neutral compared to angry faces when fertile. As suggested, these findings may be explained by attentional avoidance, or difficulty with disengagement (e.g. Koster et al. 2004) as opposed to vigilance (Frewen et al. 2008). Alternatively, the cognitive resources required to respond to the probe efficiently may be hindered in response to negative stimuli. Research has shown that unpleasant stimuli is identified less rapidly than pleasant stimuli (Fazio, 2001).

On the other hand, the findings may be explained by Cooper and Langton's (2006) findings. They found attentional biases towards threat at exposures of 100ms, but not at 500ms. They explain attentional bias as acknowledgement and inhibition of the relatively least threatening stimulus rather than attentional bias towards threat. That is, faster detection of threat may not reflect vigilance to threat, but rather that

they have noticed the neutral stimulus quickly, and realised that it does not require attention, and so shifted attention to the threat. An exposure duration of 200ms may have allowed for multiple shifts in attention, and thus the response to the probe may not be indicative of initial allocation of attention, especially as women might be particularly efficient at threat evaluation due to their higher asset risk when fertile (Fessler et al. 2015). Therefore, eye tracking was employed in Study 4 to provide more accurate measurement of attention allocation in response to threats across the fertile compared to nonfertile phase of the menstrual cycle.

3.3. Study 4: Occulomotor behaviour in response to threats over the menstrual cycle

Reaction times in dot-probe experiments may not offer accurate information as to the initial allocation of attention (e.g., Fox, Russo, Bowles & Dutton, 2001; Weierich, Treat & Hollingworth, 2008) and are not indicative of actual eye movements (Stevens, Rist & Gerlach, 2011). Stevens et al. (2011) found that eye movements were, however, related to anxiety, and therefore eye tracking may be a better measure of visual response to threats compared to the dot-probe paradigm.

If the probe appears quickly following stimulus onset, and responses are correct, this may give accurate indication of attention allocation. That is, when stimuli are rapidly presented in dot-probe paradigm, reaction time measures immediate bottom-up attentional processes. However, with increased stimulus exposure time there is opportunity for top-down attentional processes. It is important to assess both immediate bottom-up attention to threats, as well as how people distribute their attention in response to threats during stimulus exposure (top down processing). Eye movements show the time course of initial orienting and visual engagement, which are argued to be more closely related to attentional processes than reaction times (Nummenmaa et al., 2006; Rosa, Gamito, Oliveira, Morais, 2011). Therefore, in Study 4, attention to threats across the menstrual cycle was assessed using eye tracking as a direct measurement of fixation patterns.

3.3.1. Introduction

Fixation patterns can reflect motivational state or stimuli of significance. For example, longer time spent fixating and higher proportion of fixations can signal interest in, or attention to that stimulus (Võ, Smith, Mital & Henderson, 2012; Balcetis and Dunning, 2006; Henderson, 2003; Isaacowitz, 2006; Mogg, Bradley, Field, & De Houwer, 2003), and are valid measures of sexual interest (Harris, Rice, Quinsey, & Chaplin, 1996; Quinsey, Ketsetzis, Earls, & Karamanoukian, 1996). The order in which people make their fixations also varies according to the interest in the stimuli (Rizzo, Hurtig & Damasio, 1987; Isaacowitz, 2006). Therefore, fixation patterns may give insight into differences in attention to, and relative significance of evolutionarily-relevant stimuli over the menstrual cycle.

There is reason to believe that eye movements will vary according to menstrual cycle phase, as hormones fluctuate. Miyahira et al. (2000) found that gender differences in eye movements emerged during puberty, and disappeared after menopause, suggesting that sex hormones may drive visual processing. Indeed, eye movement patterns differ over the menstrual cycle, and thus may be influenced by top-down processes (Pilarczyk, Schwertner & Kunieki, 2015). Cognitions are influenced in functional ways, which may benefit reproductive success (Ackerman et al., 2009; Becker et al. 2007; Maner et al., 2005).

Research has shown that during peak fertility, women increase their attention, as measured by time spent fixating, to attractive men. Fertile women paid more attention to male compared to female faces, while gender did not influence attention in nonfertile women (Anderson et al. 2010). Rupp and Wallen (2007) found differences in attention to sexual stimuli between naturally cycling and hormonal contraceptive using women, suggesting hormonal influences on attention to reproductively relevant stimuli. For example, naturally cycling women focused their first looks, time spent fixating and proportion of fixations at genitals, which was not found in hormonal contraceptive users. However, they did not find menstrual cycle phase to influence looking patterns in regards to sexual stimuli.

Eye movements have also been shown to vary in response to threat. Research indicates a higher proportion of first fixations to threat, which is indicative of vigilance (Felmingham, Rennie, Manor & Bryant, 2011). Stimuli of particular relevance or significance, such as stimuli relevant to reproductive fitness or survival, are likely to be attended to first, and rapidly so. This processing bias ensures that important stimuli are selected early for further processing, thus allowing efficient response, such as avoidance behaviours (Nummenmaa et al. 2006). Thus, faster orienting to potentially threatening stimuli may aid fitness.

Emotional stimuli have been shown to influence attention. For example, proportion of first fixations, number of fixations and time spent fixating were higher for both emotionally pleasant and unpleasant compared to emotionally neutral stimuli (Calvo & Lang, 2004, Nummenmaa et al. 2006). Thus, unpleasant (i.e., threatening) stimuli may attract attention. While some researchers have found this is the case, with high-anxious individuals directing their fixations more towards angry faces (e.g., Mogg, Garner & Bradley, 2007), some eye tracking studies have shown attentional avoidance in response to angry faces (e.g., Becker & Detweiler-Bedell, 2009). Furthermore, some researchers have found anxiety to be related to vigilance to threat (i.e., rapid and initial orienting to threat), with difficulties disengaging from the threat, as measured by dwell time, or the proportion of time fixating on the threat stimulus (Schofield, Johnson, Inhoff & Coles, 2012). Thus, fixation patterns differ according to emotional valence, which suggests that oculomotor behaviour differs in response to threat. Specifically, the presentation of fear-relevant or anxiety-provoking stimuli is associated with faster first fixations, increased number of first fixations, more total fixations and longer time spent fixating on threat.

Research to date has focused on assessing eye movements to threat stimuli according to specific phobias or anxiety levels. Moreover, hormonal influences on fixation patterns have focused on attention to sexual stimuli over the menstrual cycle. However, there is very little research on eye movements in relation to threats over the menstrual cycle. Pilarczyk, Schwertner and Kuniecki (2015) presented their findings at a conference in 2015, assessing eye movements to various stimuli during the follicular and luteal phase. They found more first fixations, and more overall fixations on threat

images (e.g., an aggressor) during the luteal compared to the follicular menstrual cycle phase. However, this appears the only research to assess eye movements to threats over the menstrual cycle.

Therefore, Study 4 assessed attention to evolutionarily-relevant stimuli in naturally cycling women during a fertile and a nonfertile phase of their menstrual cycle. There was no influence of threat on attention in hormonal contraceptive users in Study 3, and thus they were not recruited in Study 4. Women viewed the same stimuli as in Study 3, but for a longer duration, whilst their eye movements were tracked. Thus, fixation patterns in response to threatening versus neutral faces and animals were assessed according to fertility. Threatening faces, particularly angry males, represented possible reproductive threats, while threatening animals represented general threats to fitness. Measures of attention included first fixation location, time to first fixation (TTFF) and the proportion of time spent fixating (PTSF) on stimuli. The location and speed of first fixation will give rise to bottom-up processes, while the proportion of time spent fixating on stimuli will provide information about top-down attentional processing.

Another improvement on Study 3 was the inclusion of control neutral and control fear-relevant stimulus-pairs for the faces. In a dot-probe paradigm, it is not possible to tell whether faster responses to fear-relevant versus neutral stimuli are due to vigilance, or difficulty with disengagement from threat (e.g., Fox et al. 2001, see Koster et al. 2004). Similarly, slower responses to fear-relevant versus neutral stimuli may be due to attentional avoidance, or neutral stimuli attracting attention. Therefore, in addition to assessing eye movements directly, Study 4 also included control trials for both face and animal stimuli. Control trials consist of either two neutral stimuli (e.g., two of the same neutral face), or two fear-relevant stimuli (e.g., two of the same angry face). In contrast, experimental trials consist of one neutral and one fear-relevant stimulus appearing on the screen concurrently. Experimental trials allow assessment of attention when there is competition for attention between a threatening and neutral stimulus. If threats attract attention, attention should be directed towards threatening stimuli, resulting in faster TTFF compared to for a neutral stimulus. However, if threats result in attentional avoidance, attention would be

directed away from threats and towards a neutral stimulus, resulting in slower TTFF for threats. However, this cannot rule out the possibility that attention is being attracted to a neutral stimulus, rather than avoiding threat. Thus, control trials allow understanding of fixation speed towards neutral or threat stimuli, when there is no competition for attention. Therefore, if women are avoiding threats, they will be slower (i.e., longer TTFF) to fixate on threatening compared to neutral stimuli in control trials. On the other hand, if women are vigilant to threat, they will be faster to make their first fixation on fear-relevant compared to neutral stimuli in control trials.

If women are more sensitive to threats at peak fertility due to relatively higher costs of rape (e.g., Fessler et al. 2015), fertility-related differences in attention should be apparent for reproductive threats (i.e., angry male faces), whilst there would be no fertility-related differences in attention to general threats (i.e., fear-relevant animals). Specifically, it was predicted that, in response to both faces and animals, women would make a higher proportion of first fixations, faster first fixations and spend a longer proportion of time fixating on threatening, compared to neutral stimuli (Hypothesis 1). In relation to fertility, it was predicted that women would make a higher proportion of first fixations, faster first fixations and spend a longer proportion of time during the trial fixating on angry faces, particularly angry male faces compared to neutral faces, when fertile compared to nonfertile (Hypothesis 2).

3.3.2. Method

3.3.2.1. Participants

The study was approved by the University of Leicester's ethics committee. Advertisements were placed around campus and on the University's student participation system. Women interested in participating were asked to complete an online pre-screening questionnaire to check their eligibility, including use of hormonal contraceptives, cycle regularity, and cycle length. The pre-screening questionnaire also included questions about their eyesight and need for glasses, and questions about health, sleeping patterns and physical activity to avoid disclosing the aims of the research. Selection criteria included being aged between 18-35 years, and having a natural and regular cycle (i.e., menstrual cycle consistently occurring every 26-32

days). For purposes of recording eye movements, it was also important that participants who needed glasses could wear regular glasses rather than contact lenses, and that the glasses did not have an anti-reflective coating. Eligible participants were contacted via email to arrange a date for participation. Of the 118 women who were pre-screened, 31 women participated. Participants ranged in age from 18-34 years (M = 23.19, SD = 5.04).

Women were arranged to participate during a nonfertile (days 1-3) and fertile phase (days 12-16, depending on cycle length). Women participated in both the face and animal experiment during each testing session. Before participating, participants were reminded to wear regular glasses if needed, and to avoid wearing eye makeup which could affect reading of the pupil.

3.3.2.2. Design

The study used an Eyelink 1000 eye tracker to assess attention to evolutionarily-relevant stimuli according to fertility. The dependent variables were proportion of first fixations, time to first fixation (TTFF), and proportion of time spent fixating the stimuli (PTSF) during the trial, all conditioned by stimuli and fertility. These factors will be explained in the data analysis section.

The study used a 2 fertility (fertile, nonfertile) x 2 stimuli (face, animal) x 2 threat (angry versus neutral faces, fear-relevant versus neutral animals) repeated measures design. For the face stimuli, the independent variables were emotion (angry, neutral) and gender (male, female). For the animal stimuli, the independent variable was the type of animal (fear-relevant, neutral). All variables were measured within-subjects.

3.3.2.3. Materials and procedure

Face stimuli consisted of angry and neutral male and female faces from the Radboud database (Langner et al. 2010, see Appendix G). Animal stimuli were adapted from Flykt (2006), and included fear-relevant (snakes and spiders) and neutral animals (dogs and sheep) which were converted to greyscale (for full description of materials used with examples, see materials for Study 3 and Appendix F). For experimental trials, faces were arranged in pairs, so that an angry and neutral version of the same face

was presented on the screen (as in Mather & Carstensen, 2003). Control trials were also included in which two of the same neutral or angry faces appeared on the screen concurrently. For the animal stimuli, experimental trials consisted of a fear-relevant animal (i.e., a snake or spider) and a neutral animal (i.e., a sheep or dog) appearing on the screen together, and for control trials two fear-relevant or two neutral animals appeared on the screen.

Women participated during a fertile and nonfertile phase of their menstrual cycle; the fertility status in which first participation occurred was randomised and counterbalanced across participants. On arrival at the lab, participants were informed of all that their participation in the study would involve (though not the aims of the research) before signing the consent form (see Appendix I). A pre-testing questionnaire was used to verify age, relationship and living status, sexual orientation, use of hormonal contraceptives, date of onset of most recent menstrual cycle, cycle regularity and cycle length, along with distractor questions. This also contained the shortened version of the state and trait anxiety questionnaire (STAI short, Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) and the fear of snakes (SNAQ) and spiders (SPQ) questionnaires (Klorman et al. 1974), to ensure there were no significant fears (see Study 3). The STAI short consisted of 6 statements, e.g., "I am worried" to which participants stated their agreement, from 1 (Not at all) to 4 (Very much). The SNAQ and SPQ consisted of 18 items to assess fear of snakes, and 20 items to assess fear of spiders[9]. Participants were asked to respond 'True' or 'False' to each item, with the sum of 'True' items indicating fear.

Participants were asked to sit comfortably, approximately 90cm from the computer, and were positioned in a head mount to ensure their head remained stable. An Eyelink1000 eye tracker was used to examine fixation information. The camera was

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[9] Items from the original SNAQ and SPQ to assess fear only (i.e., the 'True' items, see Klorman et al. 1974) were used. scales that were specific to the US (where the scale was developed) such as "I would not want to travel 'down south' or in tropical countries because of the greater prevalence of snakes" were not included.

set to a sample rate of 1000 Hz. The lights were turned off to improve recording accuracy.

Each experiment began with instructions, informing the participant that they would see two images appear on the screen at the same time, after which a small dot would appear on either the right or left side of the screen. They were told to indicate the side in which the dot appeared using 'A' (left) or 'L' (right), as quickly and accurately as possible using a keyboard. Participants' eyes were calibrated and validated using a 9-point matrix calibration grid. Once participants' eyes had been successfully calibrated and validated, they completed 6 practice trials using flowers and mushrooms as stimuli. Any questions were answered after the practice trials. Eyes were re-calibrated and validated after the practice trials.

The order in which participants completed the face and animal experiment was randomised and counterbalanced across participants. Both experiments consisted of 144 trials separated into two blocks of 72 trials to allow for a break and re-calibration. For the face experiment, there were 36 control angry trials (18 male, 18 female), 36 control neutral trials (18 male, 18 female), 36 experimental trials for male faces, and 36 experimental trials for female faces. The position in which the angry face appeared in experimental trials was counterbalanced. The position in which the dot-probe appeared was also counterbalanced across trials. For the animal experiment, there were 24 control neutral trials, 24 control fear-relevant trials, and 96 experimental trials. Within the experimental trials, the location in which the fear-relevant animal appeared was counterbalanced.

For each trial, a fixation cross appeared for 1000ms, after which two images appeared (e.g., an angry and neutral face, or a fear-relevant and neutral animal if it was an experimental trial). The images remained on the screen for 2000ms[10], after

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[10] Stimulus exposure duration was initially 200ms. However, preliminary analyses suggested that 200ms exposure produced insufficient eye-movement data; the majority of the trials failed to show any evidence of fixations. Previous research also failed to find detailed fixation data under 500ms (Bradley et al. 2000; Veenstra et al. 2010). Thus, exposure time was increased to 2000ms. Reaction time data for the pilot study and Study 3 was compared, and found not to differ. However, for the face stimuli, the

which a small dot-probe appeared in place of one of the images for 50ms on a blank screen. Participants indicated the position of the probe using 'A' and 'L' keys. Participants had a break for approximately 2 minutes in between the two blocks of 72 trials. After participants had completed all trials for the face and animal experiments, they took a self-administered ovulation test, as in Study 3.

Participants completed the same procedure approximately 2 weeks later, depending on menstrual cycle day. On completion of both sessions, participants were given a full debrief, and were asked to contact the experimenter when their next menses began for calculation of menstrual cycle phase using the backwards count method. Participants either received course credit, or were paid £6.

3.3.2.4. Data analysis

Participants whose ovulatory status could not be verified through the ovulation tests, the forward count method or the backwards count method (n = 5), or did not attend their second session (n = 3) were not included in the analyses. Likewise, participants with poor fixation data due to calibration difficulties were removed from the analyses (n = 5). This left 18 participants who had completed both sessions and had their fertile phase verified. One participant only completed the face experiment due to a spider phobia, leaving 17 for the animal experiment.

An interest period was created to capture fixations from stimulus onset until appearance of the probe. The dot-probe component of the study was used for methodological consistency with Study 3. Therefore, it was important to hold constant any parameters of the dot-probe paradigm that may influence attention. The dot-probe task also gave participants a task to focus their attention on the screen. Responses to stimuli that appear rapidly gives rise to bottom-up attentional processes. However, increases in exposure duration allow for top-down processes to occur. Therefore, while speeded responses, such as TTFF and location of first fixation show immediate, bottom up attentional processes, the pattern of fixations within longer

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interaction between fertility and emotion, which was previously reported as approaching significance, became significant, $F(1, 21) = 4.593$, $p = .044$.

exposure times, such as the PTSF on stimuli during the trials gives rise to bottom-up attentional processes. The 2000ms exposure duration would therefore not be informative of the initial allocation of attention. As such, accuracy or response time of key-presses, were not analysed. Rather, fixation data was used to assess attention to the stimuli. Specifically, the dependent measures included: the proportion of trials in which the threat compared to the neutral stimulus was fixated first, the time to first fixation (ms), and the proportion of time spent fixating on a threatening versus neutral stimulus out of the total time spent fixating per trial. All dependent measures were assessed according to stimulus threat and fertility, for both the face and animal stimuli.

In assessing the proportion of trials in which the first fixation was directed towards a threatening versus neutral stimulus, experimental trials only were assessed. For this dependent measure, fixations directly on each stimulus, as well as fixations around the stimulus, were used to measure attention. For example, if an angry female appeared on the left and a neutral female on the right, and a fixation fell in the left interest area but not directly on the image itself, this was still included as attention towards the angry female[11]. However, as a fixation cross was presented before stimulus onset, participants' first fixation was typically focused on the centre of the screen. Therefore, as per the methodology of Rupp and Wallen (2007), the second fixation was used to better reflect participants' attention immediately after stimulus onset. However, this will still be referred to as the 'first fixation' as it represents the subject's volitional eye movement (see Rupp & Wallen, 2007). The proportion of trials in which participants first fixated on the threatening and neutral stimulus was calculated (e.g., Bradley, Mogg & Millar, 2000). For example, for the face experiment, there were 36 experimental trials for male faces. To assess whether first fixation was more often directed towards angry versus neutral male faces, the number of times in which the first fixation was directed on the angry face was divided by the sum of first fixations towards angry and neutral male faces (i.e, not considering fixations that fell in

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[11] Many of the first fixations (and second as assessed here) were not directed on the image directly but towards one image or another. This was still taken as directing attention towards the given stimulus. Fixations that fell in the centre, or on the outer edges of the screen were not included.

the centre). Thus in the majority of cases, the denominator was 36 (i.e., 36 experimental male trials). Likewise, to assess the proportion of first fixations on neutral male faces, the number of times the first fixation was directed towards the neutral face was divided by the sum of all first fixations on angry and neutral male faces. Proportions of first fixations were calculated within male and female trials separately (gender did not vary within trials). This gave a proportion of first fixation locations towards angry versus neutral male faces, and angry versus neutral female faces. Similarly, for the animal stimuli, the number of first fixations towards fear-relevant animals (or neutral animals) was divided by the sum of all first fixations towards fear-relevant and neutral animals.

To assess whether speed of orienting differs according to threat and fertility, the time to first fixation (though as above, was measured as the second fixation) was assessed in experimental and control trials. Experimental trials assess the allocation of attention when there is competition for attention between a threatening and neutral stimulus. As such, if women have a bias towards or away from threat, this will be apparent in TTFF in the experimental trials. Control trials allow for baseline fixation speed, to assess how threatening and neutral stimuli influence fixation speed when there is no competition for attention. For each participant, the mean time taken (ms) to make their first fixation was assessed, and conditioned by fertility, trial type and stimulus type. As before, fixations directed on and towards the stimuli were included in the analysis.

Finally, the distribution of attention during the trials was assessed. Experimental trials only were analysed, when there is competition for the distribution of attention. For each trial, the proportion of time that the participant fixated directly on each stimulus was assessed by calculating the time (ms) spent fixating on the face or animal divided by the total amount of time women were fixated on the screen during the trial. The mean proportion of time spent fixating (PTSF) on stimuli across trials was calculated for each participant, conditioning the data on fertility and stimulus type (i.e., animal type, or gender and emotion in faces).

Any missing data was checked using Little's MCAR test to ensure data was missing at random, and replaced using the expectation maximisation method (Dempster et al. 1977).

3.3.3. Results

The results section will proceed as follows. Preliminary analyses will report results for the STAI and fear of snakes and spiders, to ensure participants were not phobic. The main analyses will focus on the three dependent variables, and assess the fixation data for the face and animal experiment separately for each measure. The main analyses begin by assessing the location in which the first fixation occurred, to assess whether proportion of first fixation differs by threat and fertility. Secondly, the time to first fixation is examined to assess whether fixation speed differs according to stimulus threat and fertility. Finally, the proportion of time spent fixating on each stimulus type (i.e., fear-relevant versus neutral) is assessed according to fertility.

3.3.3.1. Preliminary results

There was no significant difference according to fertility in state or trait anxiety (STAI) scores, $t(17) = .22$, $p = .831$. However, while there were no phobic participants (highest mean score was 6.5 out of 20), when women were fertile as opposed to nonfertile, they reported a greater fear of snakes, $t(17) = 2.17$, $p = .044$ and spiders, $t(17) = 2.12$, $p = .049$.

3.3.3.2. First fixation location

Analyses began by assessing the proportion of trials in which the first fixation[12] was directed towards the threat compared to the neutral stimulus according to fertility. Experimental trials were assessed, where there was competition for first fixation. That is, participants could either fixate on the threat or neutral stimulus first. As such, the proportion of first fixations towards both the fear-relevant and neutral stimulus will be analysed.

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[12] Measure of first fixation was actually second fixation, as explained in the data analysis

3.2.3.2.1. Faces

Figure 21 shows the proportion of first fixations directed towards angry versus neutral faces by fertility, for both male and female faces. Overall, there were fewer first fixations to angry compared to neutral faces. For male faces, fertile women made fewer first fixations on angry compared to neutral faces, while nonfertile women did not differ in their proportions of first fixations. For female faces, women made a higher proportion of first fixations on angry faces, and a lower proportion of first fixations on neutral faces when fertile compared to nonfertile. For fertile women, distribution of first fixations (i.e., smaller proportion on angry compared to neutral) differed more for male compared to female faces.
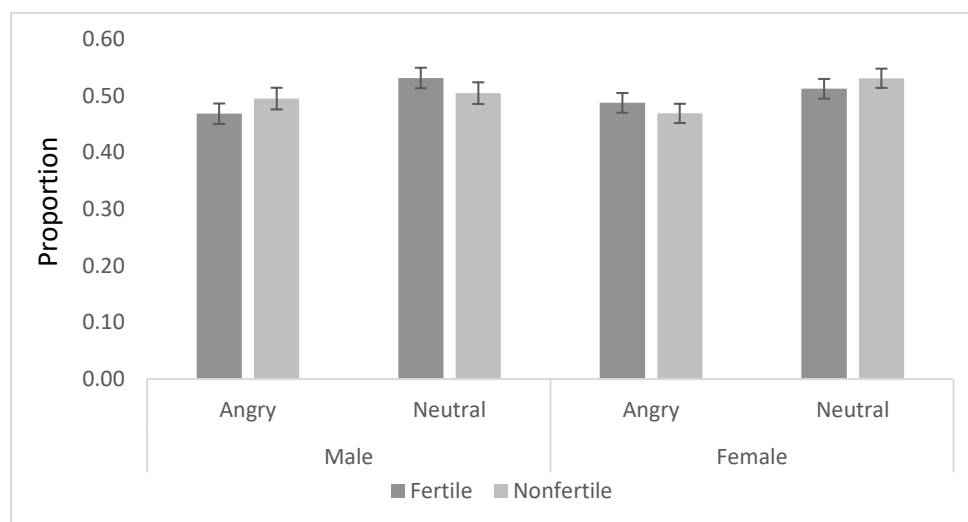
Figure 21. Mean (±1 SEM) proportion of first fixations by emotion and fertility for male and female faces in experimental trials. Emotion varied within each trial only, meaning there was competition for attention according to emotion, but not gender.

To assess the proportion of location of first fixations according to emotion in male and female faces, a 2 fertility (fertile, nonfertile) x 2 emotion (angry, neutral) x 2 gender (male, female) repeated measures ANOVA was carried out on proportion data. Main effects for fertility and gender were not included in the ANOVA output as proportions equated to 1. That is within trials, women made a first fixation regardless of gender or fertility; there was only competition for attention according to emotion. Thus, proportions would only be able to differ according to emotion. Indeed, there was a main effect of emotion, $F(1,17) = 5.25$, $p = .035$, $\eta p^2 = .24$, with fewer first fixations towards angry compared to neutral faces. However, emotion did not interact with fertility or gender (all p's > .286). Thus, Hypotheses 1 and 2 were not supported.

3.2.3.2.2. Animals

Proportion of first fixation location was also assessed for the animal stimuli. Figure 22 displays the proportion of first fixations directed towards each animal type by fertility. As shown, overall, all women directed a higher proportion of first fixations to fear-relevant animals, particularly during their nonfertile compared to their fertile phase. In contrast, women directed a lower proportion of first fixations to fear-relevant animals when fertile compared to nonfertile.
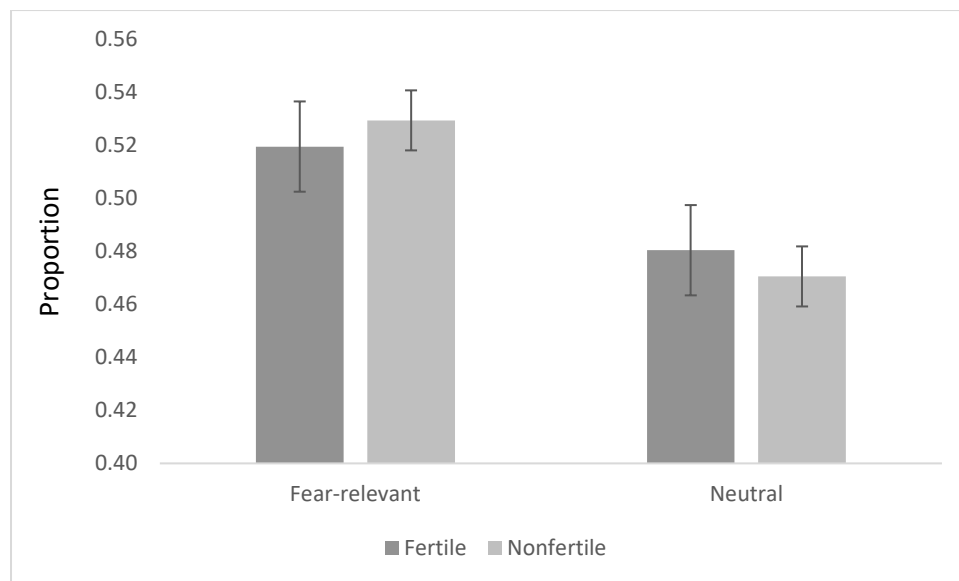
Figure 22. Mean (±1 SEM) proportion of first fixations by animal and fertility

These findings were assessed with a 2 fertility (fertile, nonfertile) x 2 animal (fear-relevant, neutral) repeated measures ANOVA on the proportion of first fixations. The main effect of fertility was not included in the ANOVA output as the values equated to 1 (i.e., all women made a first fixation regardless of fertility). However, proportions of first fixations were slightly higher towards fear-relevant versus neutral animals; the main effect of animal approached significance, $F(1, 16) = 3.73$, $p = .07$, $\eta p^2 = .19$, thus supporting Hypothesis 1. Fertility and animal did not interact, $F(1, 16) = .51$, $p = .49$.

3.3.3.3. Time to first fixation (TTFF)

Next, it was assessed whether speed of first fixation differed by threat and fertility, by analysing mean time to first fixation (TTFF). Both experimental and control

trials were anlaysed, to assess for vigilance to threat versus attentional avoidance of threat.

3.2.3.3.1. Faces

As shown in Table 20, women were faster to make their first fixations when fertile compared to nonfertile, particularly for neutral males in control trials. TTFF did not appear to differ by emotion or gender. However, the influence of emotion on TTFF appeared to differ more for male, compared to female faces, such that TTFF was longer for angry compared to neutral males, while emotion did not influence TTFF as much for female faces. During the fertile phase, the influence of emotion on TTFF was greater (i.e., slower for angry versus neutral faces) in experimental compared to control trials, suggesting neutral faces attracted attention when there was competition for attention. However, during the nonfertile phase, emotion influenced attention to male faces more in control trials compared to experimental trials, such that TTFF was faster for control angry versus control neutral trials, suggesting vigilance when nonfertile. Emotion did not influence attention to male faces in experimental trials.

Table 20. Mean (+1 SEM) time to first fixation (ms) by trial type, gender, emotion and fertility

Trial type	Gender	Emotion	Fertile		Nonfertile	
			M	SEM	M	SEM
Experimental	Male	Angry	348.84	68.35	359.42	47.94
		Neutral	320.01	43.15	359.19	38.88
	Female	Angry	325.56	40.11	348.58	45.43
		Neutral	317.53	48.12	364.27	52.38
Control	Male	Angry	316.36	37.71	348.87	40.94
		Neutral	302.03	28.92	390.38	49.28
	Female	Angry	317.43	38.89	358.64	48.09
		Neutral	316.67	51.21	357.06	40.49

The findings were assessed with a 2 trial type (experimental, control) x 2 fertility (fertile, nonfertile) x 2 emotion (angry, neutral) x 2 gender (male, female) repeated measures ANOVA on TTFF. There was no main effect of trial type, $F(1, 17) =$

.2, *p* = .658, fertility, $F(1, 17)$ = 1.17, *p* = .295, gender, $F(1, 17)$ = .4, *p* = .535, or emotion, $F(1, 17)$ = .01, *p* = .91. Thus, Hypothesis 1 was not supported.

All interactions were nonsignificant (p's > .163), apart from the interaction between fertility and emotion, $F(1, 17)$ = 5.12, *p* = .033, ηp^2 = .23. T-tests adjusted with the Bonferroni correction suggested that the interaction between fertility and emotion arose due to the influence of emotion in fertile women only. Women were overall slower to make their first fixation on an angry face compared to a neutral face during their fertile phase (mean difference = 12.98, *SEM* = 6.28, *p* = .054), see Figure 23. All other pairwise comparisons were nonsignificant (*p* = .09). Thus, Hypothesis 2 was not supported. However, t-tests adjusted for multiple comparisons with the Bonferroni correction[13] suggested that for control trials, fertile women were significantly faster than nonfertile women to make their first fixation on a neutral male (mean difference = 88.35, *SEM* = 37.06, *p* = .029). This pattern seems to be driven by both particularly fast TTFF on male faces in control neutral trials when fertile, and particularly slow TTFF on male faces in control neutral trials when nonfertile.
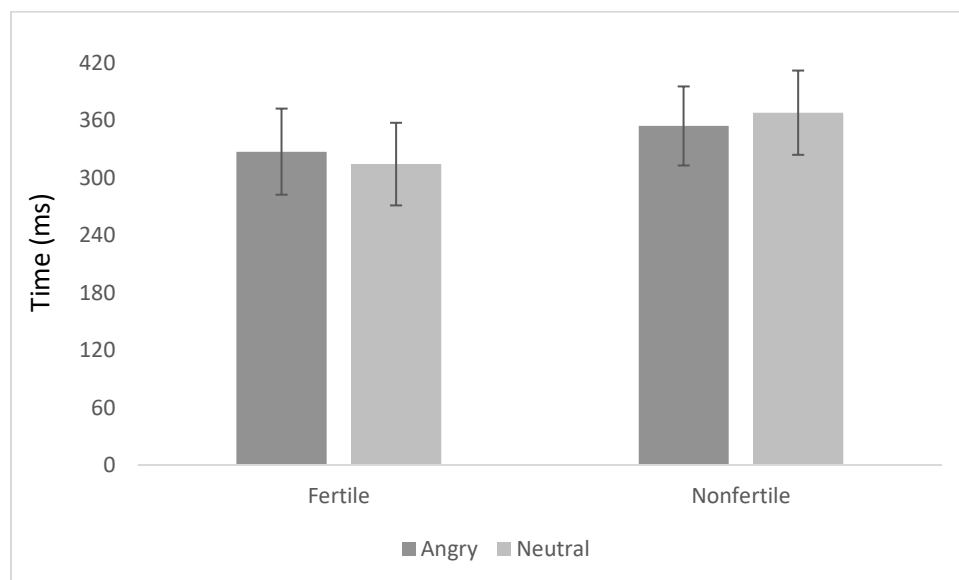
Figure 23. Mean (±1 SEM) TTFF (ms) by emotion and fertility. Fertility and emotion interacted on TTFF.

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[13] Wilcox (1987, p.36) suggests that "most multiple comparison procedures [including Bonferroni t-test] should be used regardless of whether the F test is significant" (see also Howell, 2002).

3.2.3.3.2. Animals

Time to first fixation on threatening versus neutral animals was also assessed according to trial type and fertility. As shown in Figure 24, women were overall faster to make their first fixation when fertile compared to when nonfertile. Regardless of fertility, for experimental trials, TTFF was faster to fear-relevant compared to neutral animals. However, in control trials, TTFF was slower for fear-relevant compared to neutral animals, which may suggest attentional avoidance patterns.
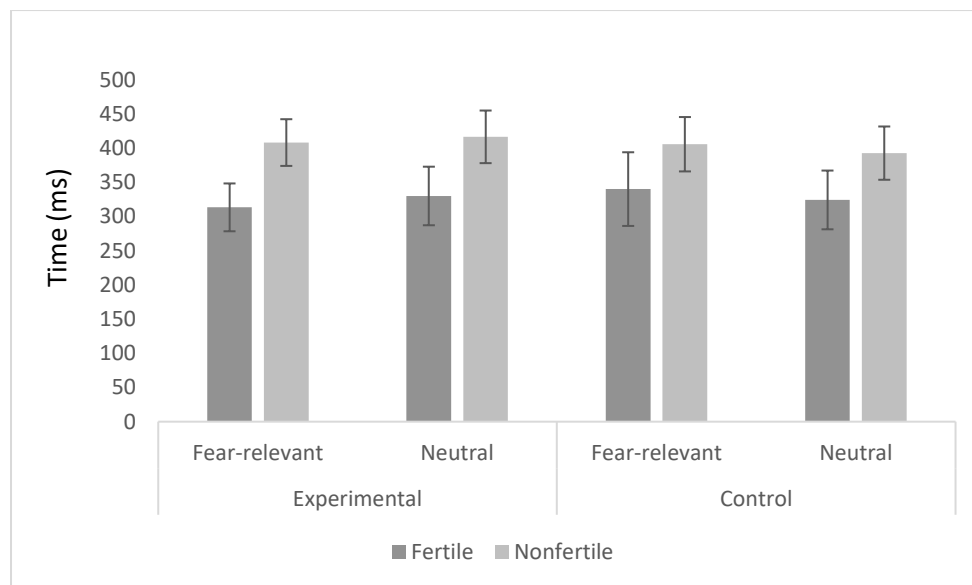
Figure 24. Mean ($\pm$1 SEM) TTFF (ms) by trial type, animal and fertility. Women were faster to make their first fixation when fertile compared to nonfertile

TTFF was assessed with a 2 trial type (experimental, control) x 2 animal (fear-relevant, neutral) x 2 fertility (fertile, nonfertile) repeated measures ANOVA (see Table 21 for descriptive statistics). There was no main effect of trial type, $F(1, 16) = .02$, $p = .89$, or animal, $F(1, 16) = .02$, $p = .9$. Thus, Hypothesis 1 was not supported. However, there was a main effect of fertility, $F(1, 16) = 7.9$, $p = .013$, $\eta p^2 = .331$ such that fertile trials were faster than nonfertile trials. However, all interactions were nonsignificant (p's > .119).

Table 21. Mean ($\pm$1 SEM) TTFF (ms) by trial type, animal and fertility

Trial type	Animal	Fertile		Nonfertile	
		M	SEM	M	SEM
Experimental	Fear-relevant	313.44	34.97	408.21	34.15

	Neutral	330.11	42.81	416.59	38.47
Control	Fear-relevant	340.15	53.86	405.76	39.76
	Neutral	324.31	42.96	392.76	38.96

3.3.3.4. Proportion of time spent during the trial fixating on stimuli (PTSF)

To assess how women distributed their attention during the trials, the proportion of time spent fixating (PTSF) on threatening and neutral stimuli out of the total fixation time per trial was assessed in experimental trials, when there is competition for the distribution of fixation time. This analysis focuses on fixations made directly on the stimuli, rather than around the regions of interest more generally.

3.2.3.4.1. Faces

To assess how women distributed their attention according to threat, PTSF on angry versus neutral male faces, and angry versus neutral female faces out of total fixation time per trial was assessed, and conditioned by fertility. As seen in Figure 25, women spent a higher PTSF on the faces, as opposed to around the regions of interest, during their fertile compared to nonfertile phase. PTSF was higher on angry compared to neutral faces, particularly when fertile compared to nonfertile.
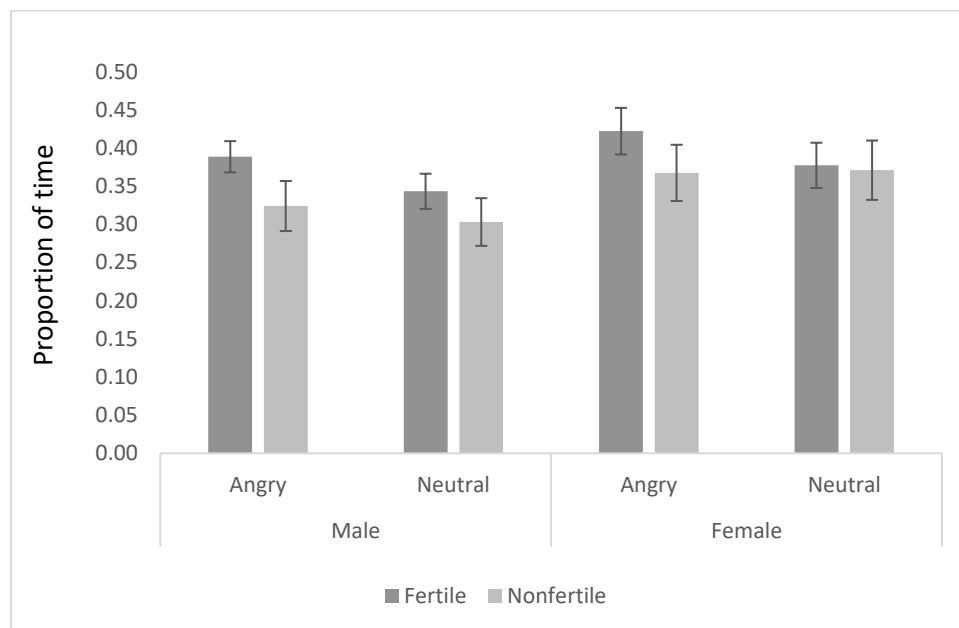
Figure 25. Mean (±1 SEM) proportion of time spent fixating (PTSF) on angry versus neutral male and angry versus neutral female faces by fertility in experimental trials

These findings were assessed with a 2 fertility (fertile, nonfertile) x 2 gender (male, female) x 2 emotion (angry, neutral) repeated measures ANOVA. There was no main effect of fertility, $F(1, 17) = 2.17$, $p = .16$, or emotion, $F(1, 17) = .83$, $p = .38$. Thus, Hypothesis 1 was not supported. However, women spent a higher proportion of time looking at female compared to male faces, a main effect for gender, $F(1, 17) = 13.25$, $p = .002$, $\eta p^2 = .44$. The interaction between fertility and emotion was significant, $F(1, 17) = 4.47$, $p = .049$, $\eta p^2 = .21$, see Figure 26. All other interactions were nonsignificant (p's > .235).

T-tests adjusted for multiple comparisons with the Bonferroni correction assessed the interaction between fertility and emotion, which appeared to arise due to women having a higher PTSF on angry faces when fertile compared to nonfertile (mean difference = .06, SEM = .03, $p = .043$). Similarly, the mean difference in PTSF on angry versus neutral faces approached significance for fertile trials (mean difference = .05, SEM = .03, $p = .086$) but not nonfertile trials (mean difference = .01, SEM = .04, $p = .81$), with longer PTSF on angry faces.
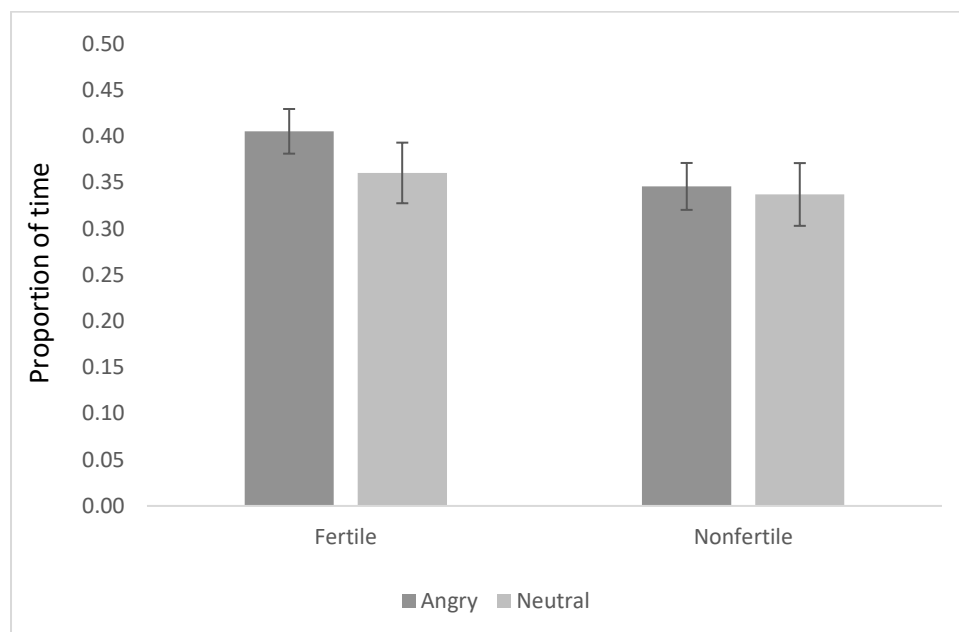
Figure 26. Mean (±1 SEM) proportion of time spent fixating (PTSF) on angry versus neutral faces by fertility

3.2.3.4.2. Animals

PTSF on threatening and neutral animals out of total fixation time per trial was also assessed in experimental trials, when there is competition for distribution of

attention. Figure 27 displays mean (±1 SEM) PTSF on fear-relevant versus neutral animals by fertility. As shown, women spent longer fixating on the stimuli itself (as opposed to around the screen more generally) during their fertile phase compared to their nonfertile phase. However, PTSF did not appear to differ according to animal.
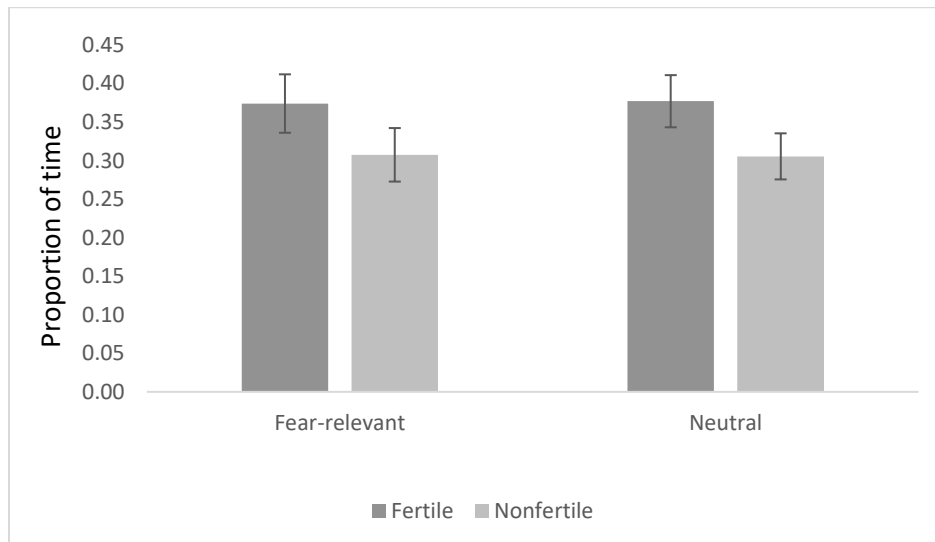
Figure 27. Mean (±1 SEM) proportion of time fixating on fear-relevant versus neutral animals by fertility in experimental trials

These observations were assessed with a 2 fertility (fertile, nonfertile) x 2 animal (fear-relevant, neutral) repeated measures ANOVA on the PTSF on each animal. There was a main effect of fertility, $F(1, 16) = 6.89$, $p = .018$, $\eta p^2 = .3$, with women fixating on the animals for a higher proportion of time during their fertile phase compared to their nonfertile phase. PTSF per trial did not differ by animal, $F(1, 16) = .00$, $p = .99$, thus Hypothesis 1 was not supported. There was no interaction between fertility and animal, $F(1, 16) = .02$, $p = .9$.

3.3.4. Discussion

Study 4 assessed women's fixation patterns in response to evolutionarily-relevant stimuli, including reproductive threats and general threats to fitness, over the menstrual cycle. It was predicted that, in response to both faces and animals, women would make a higher proportion of first fixations, faster first fixations and spend a longer proportion of time fixating on threatening, compared to neutral stimuli. Moreover, it was predicted that there would be differences in fixation patterns towards threats, angry males in particular, when fertile compared to nonfertile, as

shown by a higher proportion of first fixations, faster first fixations and a higher proportion of time spent fixating on threatening compared to neutral stimuli.

Firstly, although anxiety did not differ according to fertility, women reported a higher fear of snakes and spiders when fertile compared to nonfertile. Garver-Apgar et al. (2007) suggested increased sensitivity to sexual coercion at mid-cycle is unlikely to be explained by a general increase in fear. However, women's increase in fear of dangerous animals when fertile may be evidence to suggest that women's fear module (e.g., Öhman & Mineka, 2001) is more active in general during ovulation.

In relation to eye movements, overall, the pattern of first fixations was not consistent across face and animal experiments. For the faces, there was a smaller proportion of first fixations on angry versus neutral faces, whilst there were more first fixations on fear-relevant as opposed to neutral animals. Therefore, while there is partial support for Hypothesis 1, as first fixations were directed towards threat in the animal experiment (though this main effect approached significance), first fixations were directed away from threat for the face experiment. It may be possible that neutral female faces are perceived as threatening (e.g., Yoon & Zinbarg, 2008). Malatesta, Fiore and Messina (1987) found that neutral female faces that looked angry scored high on a hostile personality dimension. However, in comparison to angry faces, neutral faces are rated as lower on perceived criminality (Flowe, 2012). Therefore, the reason for the faster fixations to neutral compared to angry faces when fertile is not clear.

It may be possible that angry faces are perceived as being less attractive due to the negative emotion. More positive emotions are associated with higher attractiveness ratings (Mueser, Grau, Sussman & Rosen, 1984). Moreover, women with high eyebrows are seen as more attractive (e.g., Deutsch, LeBaron & Fryer, 1987). Eyebrows are higher in neutral compared to angry female faces, due to the emotional expression of anger resulting in furrowed eyebrows. Therefore, neutral faces may have been perceived as relatively more attractive than angry faces, which has been shown to influence attention (e.g., Anderson et al. 2010).

Alternatively, the findings may represent attentional avoidance. Women may be avoiding the threat, and instead attending to the neutral stimulus (e.g., Frewen et al. 2008). On the other hand, Cooper and Langton (2006) have explained women's attentional biases in response to threat as inhibition of the relatively least threatening stimulus. This first fixation may represent women's acknowledgment of the least threatening stimulus in the visual field, which does not require attending to, before focusing attentional resources on the threat. This will be discussed further in response to PTSF below. However, importantly, fertility did not interact with threat on the proportion of first fixations in either the face or animal experiments, thus Hypothesis 2 was not supported.

Women were faster to make their first fixations when fertile compared to nonfertile, particularly for the animal experiment. This suggests that overall, women may be more vigilant in general during peak fertility. Faster detection, allows more efficient response generation (e.g., Hommel, Müsseler, Aschersleben, & Prinz, 2001; Nummenmaa et al. 2006), and thus may be adaptive, particularly during ovulation when behaviour has the most reproductive consequences (Chavanne & Gallup, 1998). However, against the predictions of Hypothesis 2, women were slower to fixate on angry compared to neutral faces during the fertile phase. This may be suggestive of attentional avoidance, by fixating more quickly on neutral stimuli. Time to fixate on angry versus neutral faces did not differ when women were nonfertile. Therefore, while this finding suggests that women are more sensitive to facial emotion, and possibly threat, when fertile compared to nonfertile, women may not possess cognitive biases that enable better detection of threat for more efficient avoidance during peak fertility. The faster first fixation of neutral faces when fertile may again represent inhibition of the relatively least threatening stimulus (e.g., Cooper & Langton, 2006), and thus more efficient threat evaluation when fertile compared to nonfertile. Control trials were employed to understand whether fixation patterns reflected vigilance to threat, attraction to neutral stimuli or avoidance of threat, for example. However, trial type did not interact with any variables on TTFF, and emotion did not affect TTFF within control trials. Although, women were significantly faster to make their first fixation on neutral males in control trials when fertile compared to

nonfertile. This may suggest fertility-related attraction to male stimuli when fertile. This is a finding that is found in the literature (e.g., Anderson et al. 2010), and may explain the overall faster detection of neutral faces when fertile.

Women spent a higher proportion of time fixating (PTSF) on faces and animals (as opposed to the surrounding areas) when fertile compared to nonfertile; however, this fertility difference did not reach significance for faces. For the face experiment, PTSF was lower for male compared to female faces. Moreover, women spent a higher PTSF per trial on angry faces during the fertile compared to nonfertile phase. As with TTFF, emotion appeared to have more of an influence on PTSF (i.e., longer time spent fixating on angry faces) during women's fertile compared to nonfertile phase. Thus, although women do not initially orient to threats faster when fertile, when they do attend to threat they may have difficulty disengaging their attention, particularly when fertile. Schofield et al. (2012) found that high anxious individuals show difficulties disengaging from threatening stimuli. Therefore, it is possible that angry faces are a source of anxiety for fertile women. Alternatively, as suggested, the faster fixations to neutral compared to angry faces when fertile, followed by dwelling on angry faces, may be explained with Cooper and Langton's (2006) suggestion that attentional biases to threat are characterised by rapid inhibition of the relatively least threatening stimulus, allowing attentional resources to focus on the threat. As this was the case when fertile compared to nonfertile, for face stimuli only, this may suggest women indeed have an attentional bias to social (and possibly reproductive) threats at peak fertility.

However, interestingly, gender and emotion did not interact on time to first fixation, or proportion of time spent fixating on stimuli, showing that women were slower to fixate on angry faces, but spent a higher proportion of time fixating on angry faces, regardless of gender. It was predicted that women would show increased attention to angry male faces when fertile compared to nonfertile. Angry male faces may signal aggressive intent, and may lead to violence (e.g., Sell et al. 2014). Violence by males could lead to sexual victimisation (e.g., the shadow of sexual assault hypothesis; Ferraro, 1995; 1996), and thus, due to the costs of victimisation being relatively higher when fertile (e.g., Fessler et al. 2015), women should be relatively

more vigilant to aggressive males during peak fertility. While angry faces held women's attention for longer during ovulation, this did not differ by gender of the face. Thus, it may be suggested that the findings do not reflect domain specificity in women's attention to threat over the menstrual cycle. However, it may be possible that the mechanism of an enhanced vigilance to angry male faces has generalised to all angry faces. The generalisability of the mechanism in response to angry versus neutral male and female faces is an area that would benefit from further research.

For the animal experiment, during the nonfertile phase, women showed the general pattern in the literature of fixating for a higher proportion of time on threatening versus neutral animals (e.g., Schofield et al. 2012), suggesting threats attract attention. However, while women's PTSF was higher overall when fertile, this did not differ by threat. On the one hand, this finding, along with overall faster fixation speed when fertile, may suggest an increase in attentional vigilance more generally when fertile compared to nonfertile. On the other hand, as fertility did not interact with threat for animal stimuli, this may lend some support to the domain specificity argument. That is, in response to animal stimuli, women appear to be more attentive in general when fertile, rather than specifically in relation to threatening animals. In contrast, for the face stimuli, there appeared to be fertility-related differences in fixation patterns according to potential threat.

One limitation of this study is a general limitation of eye tracking. While eye tracking apparatus allowed evidence of where the participants were looking, it cannot provide understanding of why attention is directed to that stimulus (Rupp & Wallen, 2007). Thus, explanations for the reasons underlying any fertility-related differences in attention to threat are speculative, based on previous theoretical evidence. Future research could further assess the fixation patterns to various types of threat over the menstrual cycle.

A second limitation with the current study concerned attentional biases according to gender of the face. Gender was manipulated between- rather than within trials. Therefore, the influence of fertility on attention to angry male versus female faces, for example, could not be assessed within trials. It would be interesting to see in

future how gender and threat would influence fixation patterns within trials according to fertility.

Attention to angry male faces was used as a way to assess attention to reproductive threats. It is suggested that an angry male face may represent aggression (e.g., Sell et al. 2014), and thus potential for victimisation. However, an angry male face may not have been directly specific enough to rape, and may have primed thoughts of any type of victimisation or danger. Similarly, the fertility-related differences in fixation patterns according to emotion may have reflected an enhanced sensitivity to emotional expression during ovulation, when oestrogen is highest (e.g., Pearson & Lewis, 2005). It would be interesting to see how cognitive biases towards stimuli that are more specific to rape would vary over the menstrual cycle. This is something that was considered in Study 5.

In sum, Studies 3 and 4 aimed to assess attentional biases to threats according to women's fertility, and whether any attentional biases would be specific to situations of increased risk of rape (e.g., an aggressive male) or extended to all threats to fitness. Study 3 showed that women differed in their attention to reproductively relevant stimuli, according to fertility. Against expectations, women were faster to respond to neutral faces when fertile compared to nonfertile. However, as predicted, there were no fertility-related differences in attention to animals, thus suggesting fertility-related differences may be specific to social, or reproductively relevant stimuli. This was further assessed in Study 4 through oculomotor evidence. Overall, for the animal experiment, consistent with Hypothesis 1, women made a higher proportion of first fixations towards threatening compared to neutral animals, though this only approached significance. With regards to fertility, women were faster to make their first fixations when fertile compared to nonfertile, and they fixated on the animals for a higher proportion of time. However, importantly, fertility did not influence attention according to fear-relevance in animals. However, for the face experiment, women directed a smaller proportion of first fixations on angry compared to neutral faces, which is against the predictions of Hypothesis 1. Regarding fertility, women were slower to make their first fixations on angry compared to neutral faces when fertile, whilst emotion did not influence first fixation speed when nonfertile. Following this,

fertile women spent a higher proportion of time per trial fixating on angry versus neutral faces. During the fertile phase specifically, women appear to initially attend to neutral faces, possibly reflecting acknowledgment for inhibition of the relatively least threatening stimulus (e.g., Cooper & Langton, 2006) and proceed to spend a longer proportion of time fixating on the threat versus neutral stimulus, which may represent difficulty disengaging attention from threat. Thus, fertility influenced both top-down and bottom-up attentional processes in relation to facial emotion. Importantly, fertility differences in regards to the animal experiment reflected a more general increase in attention during the fertile phase, whilst fertility differences in response to faces were more specific to the emotion, and thus potential threat, of the face. Thus, the findings of both Study 3 and Study 4 appear to suggest fertility-related differences in attention are specific to reproductively relevant stimuli. However, more research is needed to assess cognitive biases to threats relating to rape more specifically according to fertility.

4. Chapter 4: Cognitive biases to reproductively relevant, and threat-related stimuli over the menstrual cycle

4.1. Introduction

Study 5 tested whether women demonstrate cognitive biases indicative of heightened sensitivity to rape-related stimuli during the fertile phase. Evolutionary theorists have hypothesised that women have evolved a psychological adaptation to prevent rape and associated costs to reproductive fitness, such as unwanted pregnancy with an undesired and absent mate (e.g., Perilloux, Duntely & Buss, 2011). Rape is arguably more costly during ovulation, when conception risk is highest. As such, it has been theorised, and indeed evidence suggests, that rape avoidance behaviours increase during ovulation. For example, ovulating women appear to selectively reduce behaviours that could increase their risk of sexual assault (Bröder & Hohmann, 2003; Chavanne & Gallup, 1998), keep a further distance away from a male who appears 'shady looking' (Guéguen, 2012a) and show increased strength in response to a sexual assault scenario (Petralia and Gallup, 2002; see also Study 2 in this thesis). However, whilst these studies demonstrate fertility-related differences in women's responses to risk situations, they do not necessarily provide evidence that behaviour is differentially varying to avoid rape specifically. The situations included in these studies, such as walking alone late at night, are arguably associated with an increased risk of danger more generally rather than rape specifically. Research has demonstrated differential responses to risk in other domains during ovulation, including gambling tasks and investment decisions (Kaighbodi & Stevens, 2013; Ball et al. 2013), fear detection (Pearson & Lewis, 2005) and are less trusting of strangers (Ball et al. 2013). Therefore, the findings of previous research may simply reflect sensitivity to risk more generally during ovulation. Therefore, investigations of fertility-related rape avoidance mechanisms should focus on stimuli specific to rape, rather than stimuli associated with danger more generally. Secondly, evidence for the fertility-related rape avoidance hypothesis is based primarily on self-reports of behaviour, with relatively few studies providing behavioural and physiological evidence. Further, even fewer studies have investigated the potential cognitive processes that might be associated with the proposed adaptation.

Macrae, Alnwick, Milne and Schloerscheidt (2002) hypothesised that cognitive processing and sensitivity to reproductively relevant stimuli might vary over the menstrual cycle. They examined women's categorisation of reproductively relevant stimuli, namely male and female faces, according to gender of the face, over the menstrual cycle. Categorisation speed was faster for male faces during peak fertility, whilst categorisation of female faces did not vary over the menstrual cycle. Thus, the results suggest faster categorisation of reproductively relevant stimuli, rather than enhanced perceptual processing, during ovulation. Similarly, categorisation of words relating to men were categorised more quickly when conception risk was high. These results, therefore, suggest a fertility-related enhancement in access to categorical information that is relevant to reproductive success. Moreover, neuropsychological evidence has shown greater activation in the late-positive component of the event-related potential for sexual stimuli during ovulation (Krug, Plihal, Fehm & Born, 2000). Therefore, as there are fertility-related differences in processing of stimuli that enhances reproductive fitness, there may also be a fertility-related enhancement in processing of threats to reproductive fitness, such as rape. However, women may be more sensitive to all threats when fertile, rather than rape specifically. There is very little evidence with respect to domain specificity in fertility-related cognitive biases to reproductive threats.

Garver-Apgar et al. (2007) attempted to assess domain specificity in psychological biases to sexual coercion according to fertility. Women watched videotaped interviews of men trying to attract women. Female participants rated the males on traits associated with sexual coercion, as well as positive traits (e.g., kind, committed, faithful). Fertile compared to nonfertile women over-estimated males' sexual coerciveness, whilst their ratings of positive traits did not differ according to menstrual cycle phase. This suggests an evolved cognitive bias (see error management theory; Haselton & Buss, 2006), wherein it is less costly to over-estimate a male's sexual intent and make a type I error (a false positive), than underestimate it, which may result in a type II error (a false negative). Therefore, there may be fertility-related differences in cognitive processing, which would provide evidence towards another dimension of the rape-avoidance adaptation. Hormones can influence information

processing and response generation (Erlanger, Kutner & Jacobs, 1999), with research documenting, as reviewed above, increased sensitivity, as evidenced by faster categorisation speed, to reproductively relevant stimuli at peak fertility (Macrae et al. 2002). Therefore, fertile women may also have an enhanced sensitivity, or biased cognitive processing, towards stimuli associated with threats to reproductive fitness.

Study 5 extended previous research by examining speed of categorisation of stimuli (images and words) relevant to reproductive success (i.e., consensual sex) as well categorisation speed for stimuli relating to threats to reproductive fitness (i.e., rape). Images and words relating to robbery were also included to assess biases to danger more general. If the rape-avoidance hypothesis is correct, especially when fertile as opposed to nonfertile, women should differentially process rape compared to other stimuli, as explained below. Further, given the shadow of sexual assault hypothesis (SSAH; Ferraro, 1995; 1996), women should differentially process rape and robbery stimuli compared to consensual sexual intercourse stimuli.

Cognitive processing was measured using a speeded binary classification task to assess information processing (e.g., Nickerson, 1973). Incoming stimuli are coded in such a way to prepare for action or response (Hommel et al. 2001). During cognitive processing, stimuli are often grouped into categories. Categorical thinking assists judgment and decision making (Proctor & Cho, 2006) and has endless adaptive benefits (Macrae et al. 2002), including efficient information processing and responses to situations (Bodenhausen & Lichtenstein, 1987; Bodenhausen & Wyer, 1985; Macrae, Milne & Bodenhausen, 1994). Cognitive categorisation can be studied with a binary classification task, wherein participants are asked to state which category, out of two, to which a given stimulus belongs. If the stimuli to be sorted are conceptually similar, categorisation speed will be slower (Bruce, 1981). In the present study, it was predicted that women will be slower to categorise stimuli as being related to rape compared to robbery. This prediction arises from the shadow of sexual assault hypothesis (SSAH), which proposes that any crime has the potential to escalate into a sexual crime. Based on this logic, robbery and rape are conceptually similar. Moreover, as women's 'asset risks' and thus the costs of rape are relatively higher during ovulation (e.g., Fessler et al. 2015), the potential for robbery to escalate into a sexual

attack may be particularly costly during peak fertility. Thus, as a cognitive bias, the conceptual overlap between robbery and rape may be of higher significance during ovulation, resulting in longer categorisation times when women are sorting rape and robbery categories when fertile compared to nonfertile. This proposition is also in line with error management theory (Haselton & Buss, 2006). It would be less evolutionarily costly to err by overestimating the likelihood that robbery could escalate into rape (i.e., make a type I error), as this could increase avoidance behaviours, than it would be to err by underestimating the risk (i.e., make type II error). Indeed, evidence suggests that fertile women believe negative events or risky situations are more likely to occur than nonfertile women (see Study 2 in this thesis).

The emotional valence of the stimuli may also influence response time. Negative stimuli have been shown to involve more processing compared to positive stimuli (Cacioppo & Berntson, 1994; Ito, Larsen, Smith & Cacioppo, 1998; Ito & Cacioppo, 2000), and therefore, negative stimuli may take longer to categorise than positive stimuli. Arguably, this serves an adaptive purpose with regards to the selection of an appropriate response in order to avoid thus threats to fitness (Cacioppo & Berntson, 1994; Crites & Cacioppo, 1996; Pratto & Bargh, 1991). Adverse stimuli automatically activate vigilance and protective behaviours at the expense of cognitive resources (Becker, Kenrick, Neuberg, Blackwell & Smith, 2007). Moreover, rape or robbery stimuli have a more negative valence when women are fertile, due to increased costs of victimisation, and therefore, stimuli associated with rape and robbery may take longer to categorise when fertile compared to nonfertile.

It was predicted that categorisation speed would be slowest for negative stimuli (i.e., rape and robbery) compared to positive stimuli (i.e., consensual sex; Hypothesis 1). Secondly, as rape is arguably more negative when fertile, due to the higher threats to reproductive fitness, categorisation of rape stimuli will be particularly slow during the fertile compared to nonfertile phase in naturally cycling participants (Hypothesis 2). Finally, due to the possibility of increased conceptual overlap between robbery and rape during the fertile compared to nonfertile phase, response speed for categorising rape versus robbery should be particularly slow when fertile, compared to when nonfertile (Hypothesis 3).

4.2. Method

4.2.1. Participants

The study advertised for female participants aged 18-35 years on the University's experimental participant scheme, along with a link to an online pre-screening questionnaire. The pre-screening questionnaire informed participants what the questionnaire and study would involve. Once consent was given, participants were asked questions about their demographics (e.g., age, relationship status), menstrual cycles (e.g., use of hormonal contraceptives, cycle regularity, and the date of their most recent menstruation), and questions about their general health and lifestyle to avoid disclosing the aims of the research (e.g., frequency of illness and exercise). For accurate estimation of menstrual cycle phase, it was important that naturally cycling participants had regular menstrual cycles (i.e., menstruation consistently occurring every 28 days). Respondents who did not meet these criteria were not eligible to participate. Eligible participants were contacted via email, and the first testing session was arranged for either a high fertility (days 12-16) or low fertility phase (days 1-3 or 21-23) in naturally cycling participants. All naturally cycling participants completed two testing sessions that were approximately two weeks apart. One session occurred during a fertile phase and the other occurred during a nonfertile phase, with session order vis a vis fertility, being counterbalanced across participants. Hormonal contraceptive users participated twice, with testing sessions occurring two weeks apart.

Thirty-nine women participated for course credit. Women ranged in age from 18-22 years (M = 19.47 years, SD = 1.22). Naturally cycling women (n = 16 completed the word categorisation task, n = 14 completed the image categorisation task) were recruited, as were hormonal contraceptive using women (n = 23 completed the word categorisation task, n = 24 completed the image categorisation task), who thus had stable hormone profiles across testing sessions, which allowed for measuring the effects of repeated testing.

4.2.2. Design

The study used a 2 hormonal contraceptive use (users or naturally cycling) x 2 fertility (fertile, nonfertile) x 2 session (session 1, session 2) x 2 stimuli (images, words) x 3 category (rape, robbery, consensual sex) mixed design, with hormonal contraceptive use as the only between-subjects factor.

The independent variables were hormonal contraceptive use (users or naturally cycling), target stimulus type (images and words) and category (rape, robbery or consensual sex). Fertility (fertile versus nonfertile) was nested within naturally cycling participants, and session (first or second) was nested within the hormonal contraceptive users group. The dependent variable was response time (ms). The study employed a mixed design, with hormonal contraceptive use as the only between-subjects factor. The study received full ethical approval from the University of Leicester's Ethics Committee.

4.2.3. Materials and Procedure

There were 10 images for each category (see Figure 28, Appendix J). Images related to rape (e.g., a man following a woman in the dark), robbery (e.g., a balaclava) and consensual sex (e.g., man and woman kissing) were obtained from Internet searches. Images were selected that corresponded to the words. For the word sorting task, there were 19 words, with each relating to rape (e.g., force, alley), robbery (e.g., steal, vault) and consensual sex (e.g. couple, cuddle, see Appendix K). The words were obtained through pilot tests in which participants (n = 30) named words that related to each category. An additional 30 participants rated each word with respect to how representative it was of the given category, and the most highly ranked words were selected as the words used in the study. Word usage frequency analyses (http://corpus.byu.edu/) suggested that frequency did not vary across the categories, $F(2, 36) = .162$, $p = .851$.

On arrival, participants were told they would be completing a short questionnaire that was similar to the pre-screening questionnaire. It asked participants about their most recent menstruation date, use of hormonal contraceptives, cycle regularity, and included questions about the participant's health and lifestyle in an

effort to prevent participants from guessing the aims of the research. The pre-study questionnaire also provided information about what participation would entail, and gave examples of the images and words for each category. Participants were also given a consent form which informed them about their right to withdraw from the study at any point without consequence (See Appendix L) and the opportunity to ask questions about their participation. Once the participant had completed the pre-study questionnaire and consented to participate, the experiment commenced.

The experiment was programmed and presented using E-prime. Participants completed 12 experimental blocks, including 6 blocks for images and 6 blocks for words. For the image blocks, two blocks entailed participants sorting images into the categories rape or robbery. For example, in the first block of 24 trials, the category 'rape' appeared on the left and 'robbery' on the right, with 12 stimuli relating to rape, and 12 to robbery. In the second block, 'robbery' appeared on the right and 'rape' on the left. Similarly, two blocks involved participants categorising images as relating to rape or consensual sex, and two blocks as robbery or consensual sex. For the word blocks, two blocks consisted of rape or robbery, two as rape or consensual sex, and two blocks as robbery or consensual sex. Participants completed a total of 288 trials, with 24 trials in each block. The word and image blocks were counterbalanced, such that some participants completed the image blocks first, and some participants completed the word blocks first.

Figure 28. Examples of images depicting rape (left), robbery (centre), and consensual sex (right).

Each block proceeded as follows: A fixation cross appeared onscreen for 500ms before a stimulus (an image or word) appeared in the centre of the screen and two

category labels appeared on the left- and right hand side of the screen. Figure 29 provides an example from the image sorting blocks. Participants were asked to indicate as quickly and accurately as possible to which category the image or word belonged by pressing 'A' if the stimuli belonged to the category presented on the left side of the screen, and 'L' if the stimuli belonged to the category on the right side of the screen. There was no response deadline. The image/word and the categories remained onscreen until the participant made a response. A fixation cross appeared for 500ms before the next trial began. Prior to the experiment commencing, participants were given two example trials. Instructions were given verbally as well as in writing.
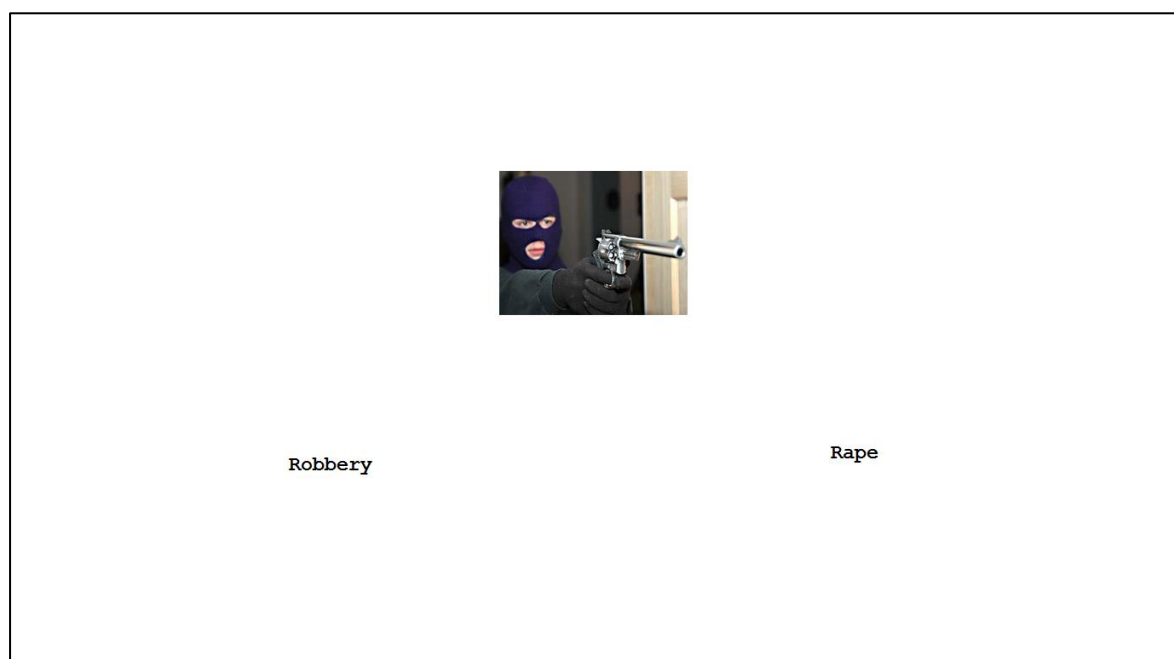
Figure 29. Example of a rape versus robbery trial in the image sorting trials. The correct response would be 'a' for robbery

After the experiment was completed, urine-based ovulation sticks that measured levels of luteinising hormone were given to verify ovulatory status, with a sensitivity of 30 miu/ml (http://www.homehealth-uk.com/medical/ovulation-tests.htm). A positive test was indicated by the test and control line being of equal colour intensity. Participants were debriefed as to the aims of the study at the end of their second testing session.

4.2.4. Data analysis

For each type of stimulus, mean response time was calculated across participants, collapsing across session and fertility. For each participant, for each type of stimulus, data from trials in which the response time was ±2 SD from the group mean were removed from the analysis following other research (e.g., Masataka & Shibasaki, 2012; Macrae et al. 2002). Data for naturally cycling versus hormonal contraceptive users were analysed separately. This is because the primary aim was to assess differences in responses to threats according to fertility within subjects, as hormonal status fluctuates, which is the case for naturally cycling participants but not hormonal contraceptive users. Reaction time did not differ according to the side that the target category was presented on the screen, which was nevertheless counterbalanced across trials. Greenhouse Geisser corrections were applied to the degrees of freedom as necessary.

4.3. Results

4.3.1. Naturally cycling

Table 22 shows mean (±1 SEM) response time (in ms) by category (rape, robbery or consensual sex), stimulus type and fertility. As shown, descriptively speaking, women were fastest to categorise stimuli relating to consensual sex, and slowest to categorise stimuli relating to rape. Women were slower to categorise words compared to images. Fertile women were slightly slower than nonfertile women to categorise the stimuli, particularly stimuli relating to rape.

Table 22. Mean (±1 SEM) time taken to categorise stimuli by stimulus type, category and fertility

Stimuli type	Category	Fertile		Nonfertile	
		M	SEM	M	SEM
	Rape	999.70	78.21	914.40	58.40
Image	Robbery	779.27	42.24	755.41	43.73
	Consensual Sex	739.53	38.73	703.39	39.03
	Rape	1025.44	39.51	1004.83	47.26
Word	Robbery	1004.53	37.88	1029.03	50.73
	Consensual Sex	917.16	27.79	902.02	35.03

The hypotheses were tested with a 2 stimulus type (image, word) x 2 fertility (fertile, nonfertile) x 3 category (rape, robbery, consensual sex) repeated measures ANOVA. Categorisation speed was faster for images (M = 815.28, SEM = 44.32) compared to words (M = 980.50, SEM = 31.90), a main effect for stimulus type, $F(1, 12)$ = 45.85, $p < .001$, ηp^2 = .793. There was also a main effect of category, $F(2, 24)$ = 33.62, $p < .001$, ηp^2 = .74. The main effect of fertility approached significance, $F(1, 12)$ = 3.20, p = .099. Fertility did not interact with stimulus type, $F(1, 12)$ = .46, p = .51, or category, $F(2, 24)$ = 2.45, p = .108. Stimulus type interacted with category, $F(1.38, 26.59)$ = 18.65, $p < .001$, ηp^2 = .61. There was no 3-way interaction, $F(2, 24)$ = .26, p = .78.

T-tests adjusted for multiple comparisons using the Bonferroni correction showed that for the main effect of category, all pairwise comparisons were significant, with categorisation of stimuli being slowest for rape, followed by robbery and consensual sex (see Table 23). Thus Hypothesis 1 was supported. For the interaction between stimulus type and category, for image sorting, all pairwise comparisons were significant (p's < .018). However, for the word sort, all pairwise comparisons were significant (p's < .001) apart from the pairwise comparison for time taken to categorise rape versus robbery (p = 1.0). Moreover, the stimulus type difference was significant for categorising stimuli relating to robbery (mean difference = 249.44, SEM = 22.14, $p < .001$) and consensual sex (mean difference = 188.13, SEM = 18.8, $p < .001$), but not for stimuli relating to rape (mean difference = 58.09, SEM = 44.34, p = .215).

Table 23. Mean (±1 SEM) difference between categorisation time according to stimuli

Stimuli	Stimuli	Mean difference	SEM	p
Rape	Robbery	94.04*	23.95	.006
	Consensual Sex	170.57*	23.43	.000
Robbery	Consensual Sex	76.54*	13.42	.000

T-tests comparisons adjusted with the Bonferroni correction[14] showed that, overall, the fertility-related difference was significant for rape stimuli (mean difference = 52.95, *SEM* = 13.09, *p* = .002), but not for robbery (mean difference = .318, *SEM* = 24.16, *p* = .99), or consensual sex (mean difference = 25.64, *SEM* = 21.5, *p* = .26), see Figure 30. Thus, Hypothesis 2 was supported.
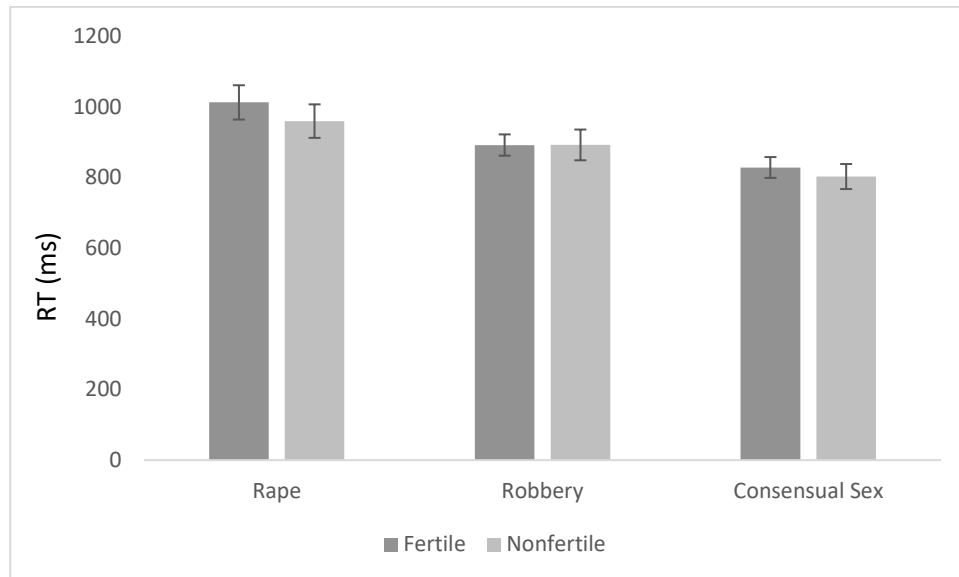
Figure 30. Mean (+1 SEM) RT to categorise stimuli by fertility, with categorisation of words and images combined. RT to categorise stimuli associated with rape was slowest, and stimuli associated with consensual sex was fastest to categorise.

4.3.1.1. Conceptual overlap

It was assessed whether conceptual overlap influenced categorisation speed, particularly when fertile. Arguably, rape and robbery are more conceptually similar than robbery and consensual sex or rape and consensual sex. The assumptions of the shadow of sexual assault hypothesis suggest that any crime, such as robbery, may escalate into rape. This may be more costly and significant during ovulation. As such, there may be greater conceptual overlap, as indicated by relatively slower RT to categorise rape versus robbery stimuli compared to robbery versus consensual sex, or rape versus consensual sex, particularly when fertile. As shown in Figure 31, women

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[14] Pairwise comparisons were assessed despite the interaction between fertility and category not reaching significance. Wilcox (1987, p.36) suggests that "most multiple comparison procedures [including Bonferroni t-test] should be used regardless of whether the F test is significant". This suggestion is supported in other statistics text book e.g., Howell (2002).

were faster to categorise stimuli when the category options were between robbery versus consensual sex, when there is arguably the least conceptual overlap, and slowest when the categories were rape versus robbery, when there is arguably the most conceptual overlap.
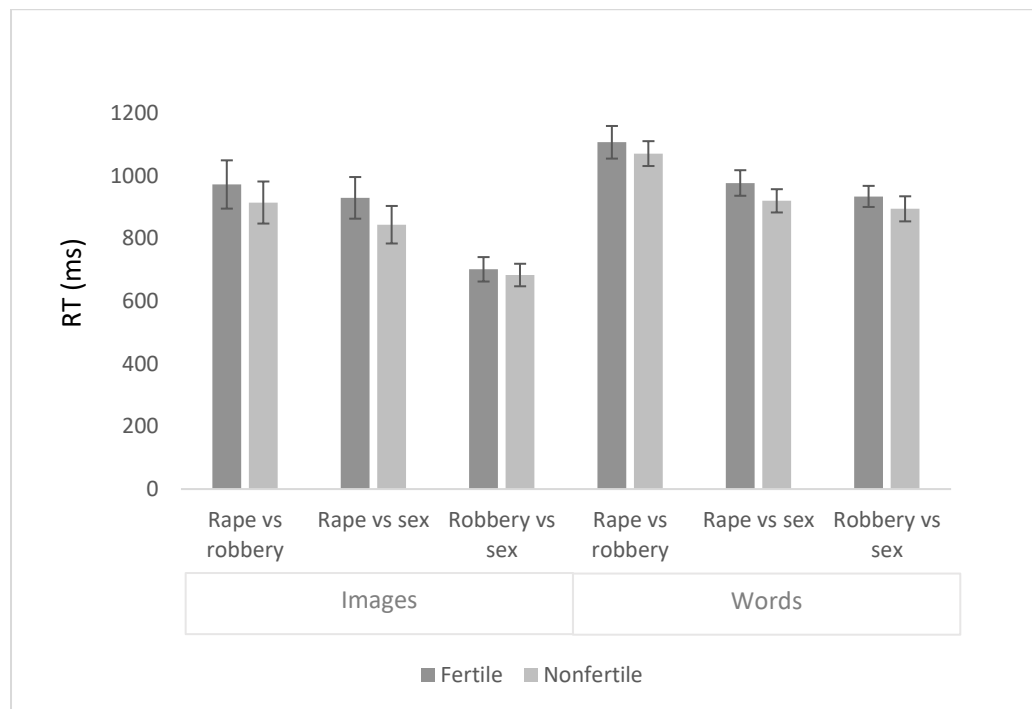
Figure 31. Mean (±1 SEM) time taken to categorise stimuli by category, stimuli type and fertility. Categorisation speed was fastest for robbery versus sex, which arguably has the least conceptual overlap, and slowest for rape versus robbery, which likely has the most conceptual overlap.

This was assessed with a 2 stimulus type (image, word) x 2 fertility (fertile, nonfertile) x 3 category (rape versus robbery, rape versus consensual sex, robbery versus consensual sex) repeated measures ANOVA on the time taken to categorise the stimuli. There was a significant main effect of category, $F(2, 24) = 44.39$, $p < .001$, $\eta p^2 = .79$. However, category did not interact with fertility, $F(2, 24) = 1.24$, $p = .307$, and thus Hypothesis 3 was not supported. However, category interacted with stimulus type, $F(2, 24) = 14.11$, $p < .001$. There was no three-way interaction between stimulus type, category and fertility, $F(2, 24) = .3$, $p = .74$.

Pairwise t-test comparisons adjusted with the Bonferroni correction were used to assess the signficant effect of category and the interaction between category and stimulus type. Women were faster to categorise robbery versus consensual sex compared to rape versus robbery (mean difference = 212.86, *SEM* = 25.89, *p* < .001)

and rape versus consensual sex (mean difference = 114.27, *SEM* = 21.33, *p* = .001). Women were faster to categorise rape versus consensual sex compared to rape versus robbery (mean difference = 98.59, *SEM* = 20.2, *p* = .001).

The interaction between category and stimulus type appeared to arise because the stimulus effect (i.e., faster for images than words) was significant for the rape versus robbery category (mean difference = 145.47, *SEM* = 46.82, *p* = .009) and for robbery versus consensual sex (mean difference = 222.01, *SEM* = 20.5, *p* < .001), but was not significant for rape versus consensual sex, (mean difference = 71.38, *SEM* = 30.74, *p* = .067).

Interestingly, pairwise comparisons adjusted with the Bonferroni correction showed that overall, women were slower to categorise stimuli relating to rape versus consensual sex when fertile versus nonfertile (mean difference = 71.38, *SEM* = 30.98, *p* = .04). Fertility-related differences for the rape versus robbery (mean difference = 46.86, *SEM* = 42.69, *p* = .29) and robbery versus consensual sex categories (mean difference = 28.91, *SEM* = 23.46, *p* = .24) were nonsignificant. Thus, Hypothesis 3 was not supported.

4.3.2. Hormonal contraceptive users

Next, categorisation speed in hormonal contraceptive users was assessed. As shown in Table 24, women were faster to categorise stimuli in session 2 compared to session 1. Moreover, women were faster to categorise stimuli associated with consensual sex, and slowest to categorise stimuli associated with rape. Categorisation speed was slower for words compared to images.

Table 24. Mean (±1 SEM) RT (ms) by stimulus type, category and session in hormonal contraceptive users

Stimuli type	Category	Session 1		Session 2	
		M	SEM	M	SEM
	Rape	870.18	26.69	772.28	23.94
Image	Robbery	776.33	24.02	698.90	19.89
	Consensual Sex	756.88	20.21	663.00	21.31
Word	Rape	955.76	19.11	913.55	26.83
	Robbery	952.10	25.32	896.29	23.70

	Consensual Sex	877.22	25.24	848.97	27.73

These findings were assessed with a 2 stimulus type (image, word) x 2 session (session 1, session 2) x 3 category (rape, robbery, consensual sex) repeated measures ANOVA on mean categorisation speed. For descriptive statistics, see Table 24. Session 2 was faster than session 1, resulting in a main effect for session, $F(1, 22) = 38.41$, $p <$ .001, $\eta p^2 = .34$. Categorisation speed was faster for images compared to words, a significant main effect of stimulus, $F(1, 22) = 77.66$, $p < .001$, $\eta p^2 = .78$. There was a main effect of category, $F(2, 44) = 53.93$, $p < .001$, $\eta p^2 = .71$. Session did not interact with category, $F(2, 44) = .23$, $p = .79$, but the interaction between stimulus and session approached significance, $F(1, 22) = 3.17$, $p = .089$. Stimulus interacted with category, $F(2, 44) = 7.91$, $p = .001$, $\eta p^2 = .26$. There was no 3-way interaction, $F(2, 44) = 1.57$, $p = .22$.

Pairwise t-test comparisons adjusted with the Bonferroni correction were used to assess significant main effects and interactions regarding category. For the main effect of category, categorisation speed was faster for consensual sex compared to rape and robbery. Categorisation of stimuli related to rape was slower compared to robbery (see Table 25).

Table 25. Pairwise comparisons (t-tests) adjusted with the Bonferroni correction for the main effect of category

Stimuli	Stimuli	Mean difference	SEM	p
Rape	Robbery	47.04[*]	9.50	.000
	Consensual Sex	91.43[*]	8.89	.000
Robbery	Rape	-47.04[*]	9.50	.000
	Consensual Sex	44.39[*]	7.96	.000
Consensual sex	Rape	-91.43[*]	8.89	.000
	Robbery	-44.39[*]	7.96	.000

For the significant interaction between session and category, all pairwise comparisons were significant (all p's < .017), apart from for the difference between categorisation speed of rape versus robbery words only (*p* = 1.0).

4.4. Discussion

In the present study, participants (contraceptive users and nonusers) viewed stimuli (images and words) that were related to rape, robbery or consensual sex, and categorised them into one of two categories. The study aimed to assess cognitive biases in processing of stimuli related to reproductive success, reproductive threats or general threats across fertile and nonfertile phases.

Overall, for both naturally cycling and hormonal contraceptive using women, categorisation speed was faster for images compared to words. This is in line with Rosch's (1975) suggestion that pictures are responded to more quickly than words. Hormonal contraceptive users differed in their categorisation speed across the two testing sessions. Women were faster to categorise stimuli during their second testing session compared to their first. This may be indicative of practice effects, with women becoming faster at the task with increased practice.

Response times also differed depending on the category of the target stimuli. In both naturally cycling women and hormonal contraceptive users, response times were the longest for stimuli associated with rape, which is arguably the most threatening stimulus due to rape having high costs to reproductive fitness (Perilloux, Duntley & Buss, 2012). Participants were fastest to categorise stimuli associated with consensual sex. Therefore, the findings supported Hypothesis 1, which predicted that more negative stimuli would take longer to process (e.g., Cacioppo & Berntson, 1994; Ito et al. 1998; Ito & Cacioppo, 2000). However, it is possible that women are particularly fast to respond to sexual stimuli due to the reproductive relevance, especially considering the relatively young age of the sample. However, women also took longer to process rape images compared to robbery images, suggesting that with increased threat, categorisation speed is slower. Arguably, this is adaptive as it allows for the appropriate response to a potentially threatening situation to be selected (see Cacioppo & Berntson, 1994). This finding, therefore, suggests that stimuli related to

reproductive success versus reproductive threats are differentially processed. However, it is difficult to assess whether the faster categorisation speed found for consensual sex stimuli arose because of its association with reproductive success, or because it is positive in valence more generally. The addition of a positive control condition, which is unrelated to reproductive fitness, would be beneficial in future research.

Although there was some evidence that categorisation speed varied for rape stimuli in relation to fertility, fertility did not influence categorisation of stimuli associated with robbery or consensual sex. Previous research has demonstrated faster categorisation of stimuli of reproductive relevance during peak fertility (Macrae et al. 2002). It is possible that the overall main effects and interactions regarding fertility and its interaction with category did not reach statistical significance due to lack of power. Post-hoc power analysis in GPower suggested that the study was underpowered at .38 for the main effect of fertility and .31 for the interaction between fertility and category. This study used a small sample of 13 participants. Macrae et al. (2002), however, also used a relatively small sample size of 18 participants and managed to find significant effects of fertility on categorisation of socially relevant stimuli. However, Macrae et al. (2002) used social stimuli (i.e., male and female faces). They suggest that women are more sensitive to social stimuli, particularly males, during peak fertility. Males are of highest reproductive significance to women at peak fertility, when conception is possible. While some of the images in Study 5 included people, this was not a key feature that was intentionally manipulated. Some images simply showed hands rather than faces. This could explain the null findings with regards to fertility in comparison to Macrae et al.'s (2002) findings, and is something that could be improved upon in future research. Indeed, Study 3 in this thesis found fertility-related differences in attention to faces, but no fertility-related differences in attention to animals. However, Macrae and colleagues also found that women were faster to categorise words relating to reproductive success at peak fertility. The present study also assessed categorisation speed of words, but did not find any fertility-differences in categorisation speed of words

related to reproductive success (consensual sex), reproductive threats (rape) or general threats (robbery).

Women were slower at categorising rape stimuli when fertile compared to nonfertile, with no fertility-related differences for categorisation of robbery or consensual sex. This may lend some support for domain specificity in fertility-related cognitive biases. It can be argued that although always costly and negative, due to the chance of conception during ovulation, rape would be particularly costly. Thus, the slower response to rape stimuli when fertile compared to nonfertile is in keeping with the finding that the more negative the stimuli, the longer the processing and response time (e.g., Caccioppo & Berntson, 1994; Ito et al. 1998; Ito & Cacioppo, 2000).

Previous research suggests that conceptual overlap results in longer categorisation time (e.g., Bruce, 1981). It was predicted that there would be greater conceptual overlap between rape and robbery stimuli compared to rape versus consensual sex or robbery versus consensual sex, resulting in longer response times, particularly when fertile due to the assumptions of the SSAH, and the relatively higher costs of robbery escalating into rape during ovulation. Overall, women took longer to categorise stimuli belonging to rape versus robbery compared to rape versus consensual sex or robbery versus consensual sex, suggesting conceptual overlap. This may represent an evolved cognitive error bias (Haselton & Buss, 2006) wherein it is less costly to assume the possibility of robbery escalating into a rape (e.g., Ferraro, 1995; 1996) than to assume they are entirely separate possibilities. However, time taken to catgeorise rape versus robbery stimuli did not differ by fertility, thus not supporting Hypothesis 3. However, pairwise comparisons showed that fertile women took longer than nonfertile women to categorise stimuli as belonging to rape versus consensual sex. Rape and consensual sex both have significance to reproductive fitness, particularly when fertile, which may be indicative of conceptual overlap.

In sum, the findings of Study 5 may suggest that women differ in their processing of stimuli associated with reproductive success, reproductive threats and general threats. Moreover, longer categorisation speeds were found for more negative stimuli. Future research should employ an additional positive control condition to

assess whether the relatively faster categorisation of consensual sex stimuli compared to threats is due to the association with reproductive success, or the general positive valence of the stimuli. Women took longest to differentiate between stimuli associated with rape versus robbery, suggesting that conceptual overlap is associated with longer processing speed. However, conceptual overlap between rape and robbery did not differ by fertility. Therefore, the assumption that any crime, such as robbery, may escalate into a sexual crime (the SSAH; Ferraro, 1995; 1996) may not differ by fertility. Nevertheless, fertile compared to nonfertile women were particularly slow to categorise rape stimuli, which suggests rape is especially negative when fertile, and may lend some support to domain specificity in cognitive biases to rape threat when fertile.

5. Chapter 5: Vulnerability to criminal victimisation

5.1. Introduction

Traits that benefit successful reproduction and survival are increased in prevalence via the process of natural selection (Dobzhansky, 1956). Criminal victimisation, particularly sexual assault, can signficantly reduce a female's fitness, as well as reduce her relatives' and close allies' fitness (e.g., Duntley & Shackelford, 2012). There are multiple costs to criminal victimisation (Perilloux, Duntley & Buss, 2012), including both physical and psychological pain (Thornhill & Palmer, 2000), such as depression (Atkeson, Calhoun, Resick, & Ellis, 1982), untimely pregnancy with an undesired mate (Gottschall & Gottschall, 2003), or even death (Duntley & Shackelford, 2012), which results in additional costs such as loss of future reproduction and harm to existing offspring. As such, evolutionary theorists (e.g., Duntley & Shackelford, 2012; Smuts, 1992) have argued that due to the prevalence of violence in ancestral history, women may have evolved adaptations that are designed to reduce the chance and costs of criminal victimisation.

Criminal victimisation is undoubtedly costly at any time. However, it can be argued that victimisation, specifically sexual assault, would be particularly costly to evolutionary fitness during peak fertility when conception risk is highest. Moreover, according to the shadow of sexual assault hypothesis (Ferraro, 1995; 1996), any crime has the potential to escalate into a sexual crime. This means that all criminal victimisation, particularly by a male perpetrator, would be relatively more costly during ovulation. Therefore, women should feel more vulnerable to all criminal victimisation during ovulation, when costs are higher.

Fessler, Holbrook and Fleischman (2015) argue that as the fitness costs of sexual assault are arguably higher during ovulation due to the increased chance of conception with an undesired mate, women's asset risk is higher during ovulation. 'Asset risk' refers to women's ability to prevent an attack, and the costs likely to be suffered from victimisation. It is suggested that women alter their cognitions and behaviour in a way that reduces their likelihood of being sexual assaulted, particularly during ovulation (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003; Fessler et

al. 2015; McKibbin et al. 2011; Petralia & Gallup, 2002). For example, fertile compared to nonfertile women are more avoidant of dimly lit and deserted areas (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003), arguably due to the increased risk of rape in such situations. However, the psychological mechanism, and thus the cognitions, which may drive this avoidant behaviour is not known from previous research.

Avoidant and protective behaviour is associated with fear of crime, perceptions of risk and vulnerability (Gabriel & Greve, 2003; Killias & Clerici, 2000; Rader, 2004; Rader, May & Goodrum, 2007), and thus, fear may drive avoidant behaviour. Öhman & Mineka (2001) suggested that fear enables effective prevention of danger through avoidance, freezing or fighting. They propose that humans have an evolved fear module to help to overcome challenges to evolutionary fitness. Criminal victimisation is a challenge to fitness (Duntely & Shackelford, 2012; Perilloux, Duntley & Buss, 2012). Therefore, theoretically, women should feel fearful of criminal victimisation. Moreover, women are hypothesised to feel particularly fearful of crime due to the likelihood of sexual assault occurring (Ferraro, 1995; 1996, Warr, 1985). Arguably, there are relatively higher costs of criminal victimisation, specifically sexual assault, during peak fertility due to increased chance of conception and thus higher costs to reproductive fitness. Therefore, as both avoidant behaviour and costs of criminal victimisation, specifically sexual assault, are relatively higher during ovulation, fear of crime may also be higher during ovulation.

5.2. Study 6: Fear of crime

Study 6 examined women's fear of crime according to fertility. To manipulate feelings of fear of crime, photographs were taken in a city centre at daytime and night time, which portrayed crime hotspots (e.g., alleyways and backstreets), safe spots (e.g., open and well-lit areas, markets and shopping centres), as well as images of a shadowy male figure in crime hotspots. Women participated in either a fertile or nonfertile phase of their menstrual cycle, and upon viewing the photographs, they were asked to rate their fear with regards to their personal safety if they were in the situation depicted in the photograph.

It was predicted that fear ratings would be higher in response to images depicting a shadowy male figure and crime hotspots compared to crime safe spots, particularly for fertile compared to nonfertile women (Hypothesis 1). This is because women should fear and avoid situations that are associated with an increased risk of criminal victimisation, specifically sexual assault, particularly when they are fertile. Additionally, due to the higher risk of criminal victimisation at night time compared to daytime, it was predicted that fear ratings would be higher in response to images taken at night time compared to the daytime, particularly for fertile compared to nonfertile women (Hypothesis 2).

5.2.1. Method

5.2.1.1. Participants

Women who were interested in participating completed an online pre-screening questionnaire that assessed their eligibility to participate. Participants included Psychology students and women recruited from the public. The pre-screening questionnaire assessed use of hormonal contraceptives, cycle length and cycle regularity so that participants who were naturally and regularly cycling were recruited. The pre-screening questionnaire also asked for participant demographics, including age, relationship and living status, along with filler questions regarding health and general lifestyle to avoid disclosing the aims of the research. Women who reported that they were naturally cycling, with regular menstrual cycles that lasted a consistent length of 26-32 days were contacted via email to arrange participation. Participation was arranged for either a fertile (cycle days 12-16) or nonfertile (days 1-3) phase. The forward cycle method was used to determine the date on which participants should participate by counting forward from the date of last menses as reported on the prescreening questionnaire. The nonfertile phase was calculated by counting forward the number of days they reported their cycle length to be. The fertile phase was calculated as being 14 days before the predicted date their next menses was due to begin.

Thirty-two eligible females participated for course credit (students at the University of Leicester), or for £3 (public). Participants ranged in age from 18 to 26

years (M = 20.97, SD = 2.62 years). Seventeen women participated in the fertile phase of the menstrual cycle and 15 in the nonfertile phase. The study received full ethical approval from the University of Leicester's ethics committee.

5.2.1.2. Design

A 3 risk situation (crime hotpots, safe spots, shadowy male figure) x 2 time of day (daytime, night time) x 2 fertility (fertile, nonfertile) mixed design was used, with risk situation and time of day manipulated within subjects and fertility between subjects. The dependent variable was women's fear rating score, measured on a scale from 0% (no fear) to 100% (absolutely fearful).

5.2.1.3. Materials and Procedure

Images were taken in Leicester city centre at daytime and night time to manipulate perceptions of risk. There were 30 images in total; 10 for each risk situation. Within each risk situation, 5 images were taken in the day with the same 5 images taken at night. The crime hotspots consisted of images of alleyways, backstreets and dark, deserted areas. In the male presence condition, the images were taken in the same locations, but featured a lone shadowy male figure. Finally, images of busy, well-lit open spaces and shopping areas were used to depict the safe spots (see Figure 32 and Appendix M).

On arrival to the lab, participants gave their full informed consent (see Appendix N) before completing a questionnaire that verified their menstrual cycle status. They then began the experiment. The experiment was administered via E-Prime. The programme began with an instruction screen, which told participants all that the study would involve. Participants were told that they would be viewing images of locations in a city centre and would be asked to rate their fear with regards to their personal safety in response to the images. They were told they would be asked questions about themselves which may be considered personal (e.g., about their menstrual cycle) and may be asked to take a self-administered urine-based ovulation test. However, they were not told the aims of the study, and questions were included to avoid disclosing the aims of the research. Following the instruction screen, and in between each trial, a fixation cross appeared for 1s in the centre of the screen. Each of

the 30 images were programmed to appear for 2s in a randomised order. Participants were asked to view the images and rate their feelings of fear with regards to their personal safety as if they were alone in the situation depicted. A novel 'fear slider' was used as a means of allowing the participants to respond with their gut reaction. The fear slider involved participants pressing the arrow keys, which moved an arrow from left to right, with left indicating 0% (no fear) and the right indicating 100% (absolutely fearful). Once participants had rated their fear, they were told to press the 'Enter' key to submit their response, which showed participants their fear rating. Upon pressing 'Enter' again, a fixation cross would appear for 1s to initiate the next trial. Participants completed 30 trials, one for each image, the order of which was randomised. The experiment took approximately 15 minutes.
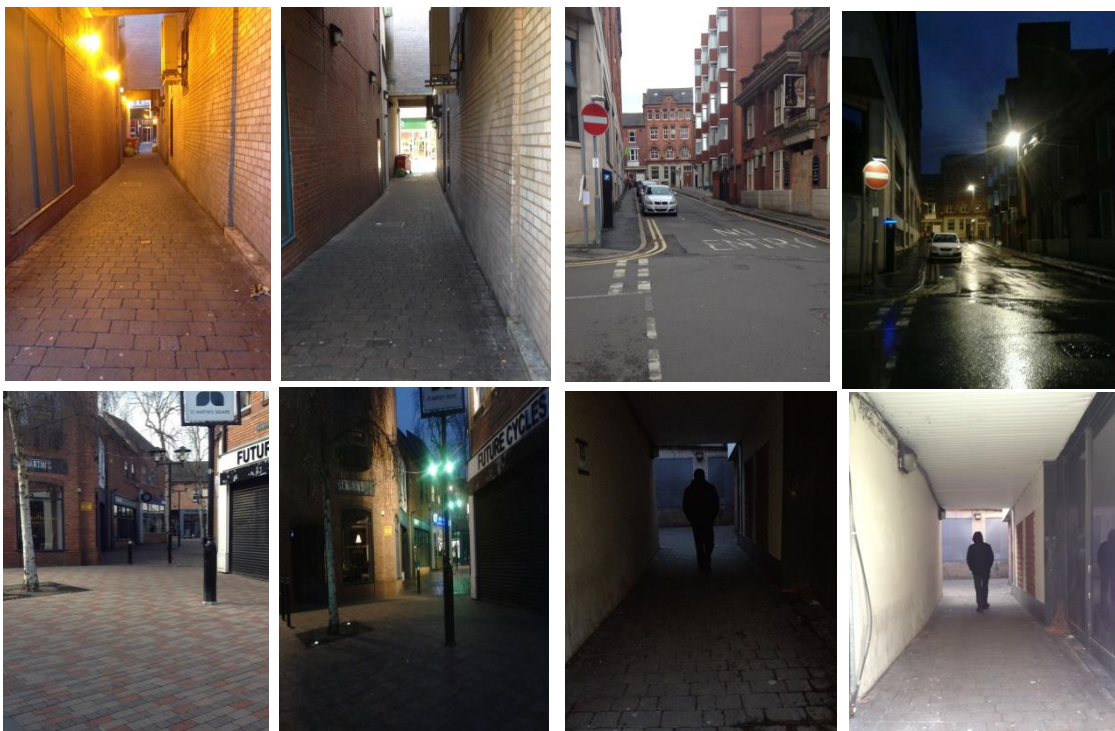
Figure 32. Images of alleyways (top left), back streets (top right), open areas (bottom left), and a shadowy male figure (bottom right) both in the day time and night time.

After completion of the fear rating task, participants completed a self-administered urine based ovulation test to verify fertility status. The tests measured levels of luteinising hormone with a sensitivity of 30 miu/ml (http://www.homehealth-

uk.com/medical/ovulation-tests.htm). A positive ovulation test was indicated by the test line and control line being of equal intensity in colour. To further confirm fertility status, participants were asked to contact the experimenter when their next menses began to allow for cycle day to be determined using the backward count method, which is a more accurate estimation of menstrual cycle phase (Wideman, Montgomery, Levine, Beynnon & Shultz, 2013).

5.2.1.4. Measures and Data Analysis

Average fear ratings for fertile and nonfertile participants were assessed. There were no data manipulations.

5.2.2. Results

Figure 33 displays mean fear for personal safety as a function of risk situation and fertility. As can be seen, fear was higher in response to images depicting crime hotspots and a shadowy male figure, compared to images depicting safe spots. Fear ratings were higher for images taken during the night time compared to day time. Descriptively speaking, fertile women tended to report lower fear on average than nonfertile women in response to the images, at daytime and night time, which is contrary to prediction. Additionally, as can be seen, fertile women did not appear to show greater fear on average than nonfertile women particularly when a shadowy male figure was present, contrary to prediction.
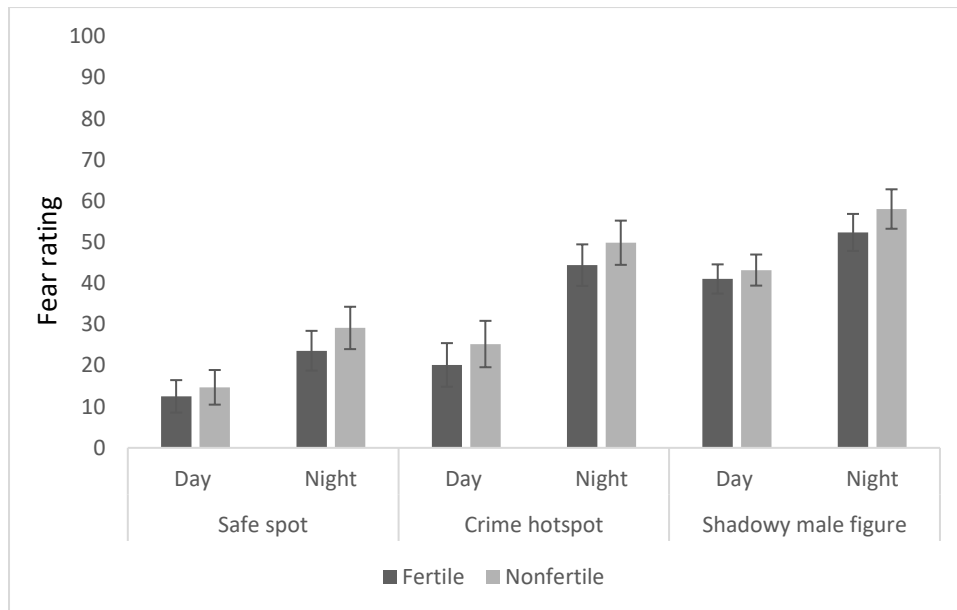
Figure 33. Mean (±1 SEM) fear ratings according to risk situation and fertility

Fear ratings were submitted to a 2 fertility (fertile, nonfertile) x 3 risk situation (crime hotspot, safe spot, shadowy male figure) x 2 time of day (night time, daytime) mixed ANOVA, with fertility as the between-subjects factor and risk situation and time of day as the within-subjects' factors. Greenhouse-Geisser corrections were applied to the degrees of freedom where appropriate. For descriptive statistics, see Table 26. Fear ratings for fertile and nonfertile women did not differ, $F(1, 30) = .56$, $p = .46$. Images taken during the night time elicited higher fear ratings than images taken in the day time, a significant main effect for time of day, $F(1, 30) = 109.48$, $p < .001$, $\eta p^2 = .785$. The main effect of risk situation was significant, $F(1.35, 40.42) = 90.99$, $p < .001$, $\eta p^2 = .782$. Pairwise comparisons adjusted with the Bonferroni correction showed that the mean fear rating for images depicting a shadowy male figure was higher than the fear rating for crime hotspots, and both had higher fear ratings than for the safe spots (all pairwise comparisons significant at $p < .001$). Time of day and stimuli type also interacted, $F(2, 60) = 15.72$, $p < .001$ (see Figure 33). All pairwise comparisons adjusted with the Bonferroni correction were significant (p's $< .001$). This interaction appeared to arise due to the time of day difference for the male presence condition being smaller than for crime hotspots and safe spots. Thus, fear ratings were higher at night time compared to daytime, partially supporting Hypothesis 2.

Fertility did not interact with risk situation, $F(2, 60) = .93$, $p = .86$, indicating that Hypothesis 1 was not supported. Additionally, fertility and time of day did not interact, $F(1, 30) = .57$, $p = .46$, indicating that Hypothesis 2 was not supported. Further, there was no three-way interaction between fertility, time of day and risk situation, $F(2, 60) = .28$, $p = .76$.

Table 26. Mean (±1 SEM) fear rating by time of day, fertility and risk situation

Time of day	Fertility	Safe spot		Crime hotspot		Shadowy male figure	
		M	SEM	M	SEM	M	SEM
Day	Fertile	12.51	3.55	20.16	3.95	41.05	5.30
	Nonfertile	14.71	3.78	25.23	4.21	43.21	5.64
Night	Fertile	23.60	4.51	44.41	4.84	52.35	5.05
	Nonfertile	29.14	4.80	49.86	5.15	58.04	5.38

5.2.3. Discussion

Previous research suggests there is a reduction in risk taking behaviour during ovulation. This is argued to be an evolved mechanism to prevent rape when conception is possible (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003). Avoidance behaviour is associated with fear of crime (Gabriel & Greve, 2003; Killias & Clerici, 2000; Rader, 2004; Rader, May & Goodrum, 2007). Accordingly, it was hypothesised that women would report greater fear in response to images portraying a shadowy male figure and crime hotspots compared to safe spots, particularly if they were fertile as opposed to nonfertile (Hypothesis 1). It was also hypothesised that women would report greater fear in response to the night compared to day images, particularly if they were fertile compared to nonfertile (Hypothesis 2).

Hypothesis 1 was not supported. Women, regardless of fertility, feared the shadowy male figure and crime hotspots more than safe spots. This could be taken as supporting the shadow of sexual assault hypothesis (Ferraro, 1995, 1996), that women fear crime because of the potential for any given male-perpetrated crime to escalate into a sexual crime. Further, Hypothesis 2 was also not supported. Regardless of fertility, women reported greater fear in response to images that were taken in the night time than in the daytime. Moreover, the influence of time of day on fear ratings

for both fertile and nonfertile women was, descriptively speaking, larger for crime hotspots and safe spots compared to male presence, suggesting male presence inflicted feelings of fear with regards to women's personal safety regardless of time of day, whereas women felt relatively less fear in the daytime compared to night time when the image depicted a crime safe spot or a hotspot. Thus, although the images affected women's fear ratings in the manner anticipated, the hypotheses regarding differential fear in relation to fertility were not supported. Therefore, the results of Study 6 indicate that avoidance of situations of increased risk of crime (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003) does not appear to be driven by a fertility-related increase in fear more generally.

Other fluctuating hormones across the menstrual cycle could have influenced women's feelings of fear. It has been shown that oestrogen 'buffers' the fear response, such that fear and anxiety are highest when oestrogen decreases during the luteal phase (e.g., Glover et al. 2013). Oestrogen peaks during ovulation, and is suggested to be positively associated with fear extinction (Lebron-Milad & Milad, 2012). Therefore, high levels of oestrogen during the fertile phase may have prevented women from experiencing conscious feelings of fear. Similarly, testosterone levels peak during ovulation. Administering testosterone appears to inhibit unconscious, but not conscious, responses to fear stimuli (Van Honk et al. 2005). Therefore, women who participated in the fertile phase would have had relatively higher testosterone levels than women in the nonfertile phase, which may explain why they did not feel higher fear in response to cues of crime.

It has been suggested that affective appraisals do not necessarily elicit changes in emotion or affect (Russell & Snodgrass, 1987), and this may also account for why no fertility-linked differences in fear were found. Emotional reactions, such as fear, depend on the relevance of the situation to the perceiver and the strength of the stimulus. The images may not have been perceived as realistic or relevant enough to elicit fertility-related differences in fear. Study 2 showed that perceived risk of a criminal scenario differed by fertility, with fertile women feeling at higher risk. This could particularly affect feelings of vulnerability, which is a different construct to fear (e.g., Fattah & Sacco, 1989). To be vulnerable, is ''to be exposed to the possibility of

being attacked or harmed, either physically or emotionally.'' (The Oxford English Dictionary, as cited in Schroeder & Gefenas, 2009). Therefore, perceived risk of victimisation, which may be heightened during the fertile phase, may drive the risk avoidance, rather than feelings of fear. This was assessed in Study 7.

Alternatively, it is possible the images did not portray enough information to allow participants to gauge their risk with respect to a specific type of crime. Fear of crime varies according to type of crime (Rountree & Land, 1996; Jackson, 2005), with women being most fearful of rape (Pawson & Banks, 1993). Risk of robbery and physical assault is higher in Leicester city centre than risk of sexual assault (Office for National Statistics[15]). Therefore, as these are the most common crimes, participants may have been thinking of their risk of robbery and assault rather than sexual assault. Robbery and physical assault have high victimisation costs regardless of a victim's fertility, and theoretically should not differ by fertility. As such, this could explain the lack of influence of fertility on women's feelings of fear with regards to their personal safety. Therefore, Study 7 asked about risk perceptions according to type of crime, again according to fertility.

Finally, although the manipulation was successful in affecting feelings of fear of crime, it is possible that the manipulation was not strong or realistic enough to tap into fertility-related differences in fear of crime. Participants were asked to imagine being in the situation depicted in the image, which may be too hypothetical to elicit feelings of vulnerability. Indeed, previous research has shown that images of crime cues did not prime fear of crime (Snyder, Fessler, Tiokhun, Frederick, Lee & Navarrette, 2011). An improvement would be to ask about fear of crime in the real world, when women are experiencing crime hotspots and safe spots directly. Therefore, Study 7 used the natural environment as a prompt (see de Leon and Cohen,

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[15] Crime statistics for Leicester were accessed from the Office for National Statistics website (http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition = tcm%3A77-328153). Data shows that theft (total recorded crime: 33,497) was more prevalent than violence against a person (10,822), and sexual offences (1,137)

2005; Jones, Drury & McBeath, 2011), having women walk through parts of the city centre that varied with respect to crime cues.

5.3. Study 7: Risk perceptions

5.3.1. Introduction

Study 7 extended on previous research by examining the multiple dimensions of fear of crime (e.g., Callanan, & Teasdale, 2009; Jackson, 2005), and examined how these might vary in relation to fertility. Based on previous research, Study 7 measured women's perceptions of risk, vulnerability, safety, and perceived victimisation consequences, all which could potentially motivate avoidance and may differ according to fertility. However, perceived risk of victimistion appears to best define fear of crime (e.g., Rountree & Land, 1996; Gabriel & Greve, 2003; Jackson, 2005; Warr, 1987), is strongly associated with fear of crime (e.g., Radar et al. 2007), differs by crime type (Reid & Konrad, 2004), almost entirely mediates the association between crime cues and fear of crime (LaGrange, Ferraro & Supancic, 1992), and contributes, along with perceived offense seriousness, to overall fear of victimisation (Warr & Stafford, 1983). Moreover, Study 2 in this thesis found perceived risk to differ according to fertility, with higher risk perceptions during ovulation compared to the nonfertile menstrual cycle phase. Therefore, differences in risk perception may underlie women's rape avoidance. Indeed, women's fear of sexual assault seems to be based largely on their perceived risk (Fisher & Sloan, 2003; Wilcox, May & Roberts, 2006), which also contributes to behaviours to avoid victimisation (Ferraro, 1995). Therefore, perceived risk may act as the most valid primary dependent variable to assess variations in women's vulnerability to criminal victimisation over the menstrual cycle.

A limitation of Study 6 was that the type of crime for which women were rating their fear was not specified. Fear of crime varies according to the type of crime (Rountree & Land, 1996; Jackson, 2005). Theoretically, although the costs of criminal victimisation are always high, fertility-related differences in fear of crime should only be apparent for sexual crimes, due to the higher risk of conception during ovulation. Along these lines, a second aim of this thesis is to assess domain specificity in the fertility-related rape avoidance hypothesis by assessing responses to the physical versus sexual costs of criminal victimisation. Towards this end, Study 7 assessed perceived risk of victimisation in relation to different types of crimes. Risk perceptions

relating to rape, robbery and physical assault were assessed, with rape posing the highest evolutionary costs and robbery the least. Moreover, as previously mentioned, the shadow of sexual assault hypothesis (Ferraro, 1995; 1996) suggests that women's fear of crime is especially high due to the assumption that any crime can escalate into a sexual crime. For this reason, and to assess domain specificity, perceived risk of victimisation of male versus female-perpetrated crimes was assessed. Arguably, the risk and costs of a crime escalating into sexual assault are eliminated if the perpetrator is female.

Study 7 also extends previous research by considering the ways in which women might mitigate their risk of criminal victimisation, such as through their mate choice. Whilst avoidance of violence is the most effective strategy, oftentimes an attack is unavoidable, meaning alternative protection strategies are needed (Duntley & Shackelford, 2012). Duntley & Shackelford (2012) hypothesise that people have evolved adaptations to reduce their risk of victimisation. For example, women's mate selection criteria includes a preference for mates and male friends who can offer protection for themselves and their offspring (e.g. Buss, 1994; Snyder et al. 2011; Bleske-Rechek & Buss, 2001; Buss & Schmitt, 1993; Greiling & Buss, 2000) through being physically formidable and dominant, according to the bodyguard hypothesis (Wilson & Mesnick, 1997). Moreover, research suggests that women with higher fear of crime have higher preferences for mates who can offer protection (e.g., Snyder et al. 2011).

However, traits that enable protection, such as aggression, dominance and physical formidability, can also be costly to partners (Snyder et al. 2011). Aggressive traits (e.g., anti-sociability, anger), for example, predict partner abuse (Lorber & O'Leary, 2004), and have been associated with coercion (e.g. Hawley, 2003). Men who are physically stronger than average have been shown to be more physically aggressive and angry (Archer & Thanzami, 2009; Sell, Tooby & Cosmides, 2009). Despite these costs, some women still desire men with traits associated with aggressive-formidability.

Snyder et al. argue that women's long-term mate preferences are the product of evolved psychological mechanisms, wherein women who feel vulnerable to violence select mates with traits indicative of aggressive dominance and physical formidability. That is, preferences for physically formidable and dominant males (PPFDM) varies with the need for protection. Snyder et al. suggest that women base their perceptions of how at risk they are on the prevalence of violence in their environment, and on their capability for defence. Indeed, Snyder and colleagues (2011) demonstrated that women's fear of crime predicted PPFDM. They found that PPFDM was related to subjective perceptions of crime, with some evidence that PPFDM was related to levels of violence in their childhood environment. Preferences were not related to current actual levels of crime. However, priming women with photographs that portrayed danger or safety cues did not affect fear of crime or mate preferences. They suggested therefore that preference for a formidable mate is dependent on a woman's self-assessed vulnerability, rather than on actual prevailing rates of violence. Therefore, women who feel particularly vulnerable to criminal victimization, such as fertile women, may have a higher preference for physically formidable and dominant mates. Preferences for traits in a male partner have been shown to fluctuate over the menstrual cycle (e.g., Gangestad et al. 2004; Gildersleeve et al. 2013), with traits that are more beneficial when fertile being preferred during this cycle phase.

To summarise, in Study 7, women walked through Leicester city centre, following a route that varied with respect to natural crime cues (e.g., alleyways, deserted backstreets, broken windows) to elicit subjective feelings of fear of crime (see Abdullah, Marzbali, Bahuddin & Tilaki, 2015; de Leon & Cohen, 2005; Jones, Drury & McBeath, 2011). Both fertile and nonfertile women's perceived safety, vulnerability, and consequences of victimization (hereby collectively termed 'fear of crime'), and perceived risk of victimization were measured whilst they were in crime hotspots and safe spots in a city centre. Perceived risk was assessed for various crime types to assess domain specificity. Women's preferences for physically formidable and dominant mates was also assessed.

Based on previous research, it was predicted that fertile women would score higher on fear of crime measures than nonfertile women (Hypothesis 1), particularly in

crime hotspots compared to safe spots (Hypothesis 2). Fertile women should rate their perceived risk of victimisation as higher for more costly crimes, such as sexual assault and male-perpetrated physical assault, compared to less costly crimes such as assault or robbery by a female perpetrator (Hypothesis 3). Fertile women should have a higher preference for physically formidable and dominant mates compared to nonfertile women, due to the higher protection from criminal victimisation afforded (Hypothesis 4). Overall, the association between PPFDM and fear of crime should be stronger in crime hotspots compared to safe spots (Hypothesis 5) and for more evolutionarily costly crimes (Hypothesis 6).

5.3.2. Method

5.3.2.1. Participants

An eligible sample of 40 naturally and regularly cycling women, ranging in age from 18 to 35 (M = 19.8 years, SD = 3.37) participated in the study in return for course credit or payment. Participants were recruited from a larger sample of women who responded to a pre-screening questionnaire that checked eligibility. Eligibility requirements included being between 18-35 years, not using any form of hormonal contraceptives, and having a regular menstrual cycle (i.e., menses consistently occurring every 26-32 days). Informed consent was obtained before completing both the pre-screening questionnaire and the research study itself. The study received full ethical approval, as reviewed by the University of Leicester's research ethics committee.

Participants were contacted via email, and a testing date was arranged with eligible participants. Women were randomly assigned to participate on either days 1-3 (nonfertile phase, n = 21) or days 12-16 (fertile phase, n = 19) of their menstrual cycle. This was calculated using the forward cycle method (Grammer, 1993; Wideman et al. 2013) using information provided in the pre-screening questionnaire regarding cycle length and date of onset of most recent menses, and counting forwards to the corresponding cycle day. Participants were asked and reminded to inform the experimenter once their next menses had begun to further verify menstrual cycle phase during participation using the backwards count method (Haselton & Gangestad,

2006). Sixteen participants responded with their next menses, with 12 having participated in the fertile phase. Ovulatory status was confirmed at the end of the study using a self-administered urine-based ovulation test, as in Study 6.

5.3.2.2. Design

To assess the association between fear of crime and PPFDM in the city centre, a 2 location (crime hotspots, safe spots) x 3 crime type (rape, robbery, assault) x 2 fertility (fertile, nonfertile) mixed design was employed, with fertility as the only between subjects' factor. Additionally, for robbery and assault, perpetrator gender was varied. The outcome measures were vulnerability in relation to fear of crime as measured by the British Fear of Crime Survey (The Crime Reduction Centre, 2000, also adapted by, and cited in Snyder et al. 2011), and fear of crime in the city centre (safety, general fear of crime, vulnerability, risk, and victimization consequences). Women's positive and negative affect (PANAS, Watson, Clark & Tellegen, 1988) were also measured.

5.3.2.3. Materials and Procedure

Participants reported to a laboratory at the start of the study. They were told that they were taking part in a project in collaboration with Leicestershire Police to understand feelings of personal safety in Leicester city centre to avoid disclosing to the participant the true aims of the research. After providing their consent (see Appendix O), participants completed a pre-route questionnaire. This included questions about themselves (i.e., age, sexual orientation, relationship status and living arrangements) and their menstrual cycle (i.e., cycle length, use of hormonal contraceptives, date of onset of last menses), along with distractor questions, regarding their health and general lifestyle to disguise the research aims. Included in the questionnaire was a scale measuring their preference for formidable mates (see Snyder et al. 2011), which assessed participants' preferences for long term partners who were: dominant, domineering, commanding, over-bearing, tough-guy, bad-boy, strong, powerful, broad shoulders, tall, could win a fight if necessary. Women rated these traits on a scale of 1 (not at all important) to 9 (extremely important). A version of the British Fear of Local Crime Survey was adapted (The Crime Reduction Centre, 2000, also adapted by, and cited in Snyder et al. 2011), which measured feelings of vulnerability on a scale of 1

(not at all worried) to 4 (very worried) about being a victim of various crimes. This was further modified to vary perpetrator gender. Therefore, vulnerability to mugging by a male, mugging by a female, violent attack by a male, violent attack by a female, sexual assault, burglary, vehicle damage/vandalism, theft from property, motor vehicle theft and general vandalism was assessed. The Positive and Negative Affect Schedule (Watson, Clark & Tellegen, 1988) and the SF-12; a shorter form of the SF-36 (Ware, Kosinski, and Keller, 1996), which is composed of two scales for assessing physical and mental health were included to assesses mood and feelings of anxiety more generally.

A 1.7-mile route was selected to include a range of geographical locations across Leicester city centre, including alleyways, backstreets, open areas and shopping areas. The route featured nine key points, including five crime hotspots (e.g., alleyways and back streets), and four safe spots (e.g., including open areas, and busy shopping areas), see Figure 34 for examples. A female research assistant escorted the research participant from the lab to the start of the route, and then walked with the participant along the route. Female research assistants were used as interviewer gender can impact fear of crime reports (e.g. Killias, & Clerici, 2000). The research assistants were blind to the participants' fertility and scale responses. Research assistants were instructed to avoid unnecessary conversation with the participant along the route to avoid distracting the participant from her surroundings, and to provoke feelings of being alone. The experimenter and participant stopped at each of the nine key points, in which the participant was asked to record their responses to the questions measuring their fear of crime on a sheet of paper. The experimenter was unaware of the responses recorded by the participant.

A questionnaire was designed based on existing fear of crime research (e.g., Gabriel & Greve, 2003; Jackson, 2005; Killias & Clerici, 2000; Rountree & Land, 1996). Participants were asked to respond as if they were alone, at that present time and in that particular location. The questionnaire began by asking participants to state in which type of location they were (e.g., residential street, alleyway, shop) to verify their perception of that location was veridical. The questionnaire proceeded to ask how safe they felt on a scale from 0 (very unsafe) to 10 (very safe). They were then asked about the extent of their fear of crime in that area, from 0 (no fear at all) to 10 (highly

fearful). Afterwards, open-ended questions were asked regarding which crime they felt most afraid of becoming victim to and for what reason (i.e., what they feared most about criminal victimisation). They were then asked to rate the perceived seriousness of that consequence on a scale from 0 (no negative consequences) to 10 (very serious consequences).
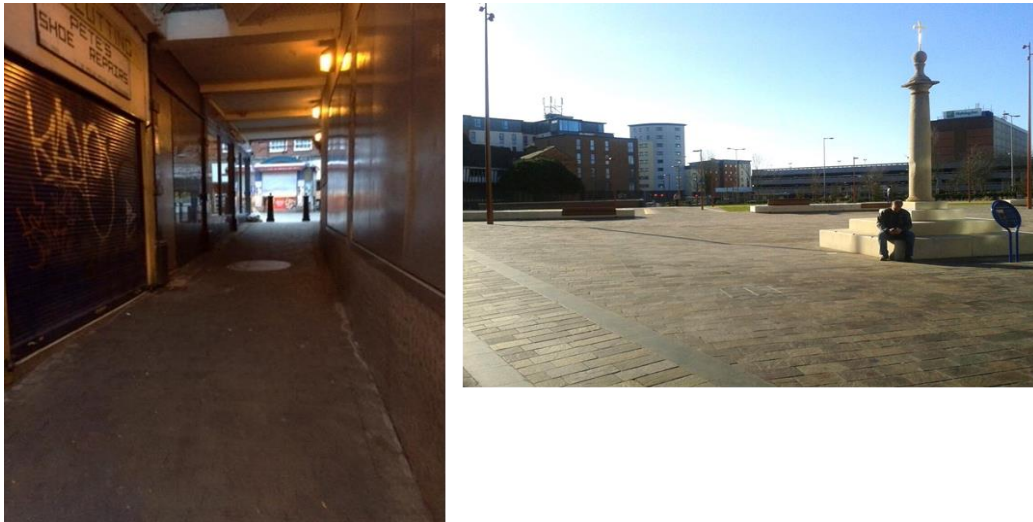
Figure 34. Examples of the crime hotspots (left) and the safe spots (right)

To measure perceived risk, the key dependent variable, participants were asked to report how likely on a scale of 0 (not likely at all) to 10 (extremely likely) they perceived their risk of becoming a victim of each crime. The crimes included: rape by a man, robbery by a man, robbery by a woman, physical assault by a man, and physical assault by a woman. Finally, participants were asked about their feelings of vulnerability with regard to becoming a victim of crime on a scale from 0 (not vulnerable at all) to 10 (extremely vulnerable).

On completion of the route, the participant and experimenter returned to the lab and received a full debrief.

5.3.2.4. Data analysis

Women's risk perception scores were averaged, conditioning the data on location, crime type and perpetrator gender. Women's ratings on the British Fear of Crime Survey were also averaged, conditioning the data on perpetrator gender. To measure PPDFM, ratings given on the scale measuring preferences for formidable mates were summed. Finally, following guidelines for analysing the PANAS, scores for

negative and positive affect were summed separately (see Watson, Clark & Tellegen, 1988).

The data analysis will begin by assessing fertility-linked differences in women's fear of crime from the British Fear of Crime Scale. Next, it is assessed whether the manipulation was successful in affecting fear of crime, perceived safety, vulnerability to criminal victimisation, and assess how serious women perceive the consequences of victimisation to be. Finally, it is assessed whether risk perceptions differed according to crime hotspots and safespots, crime type and fertility. Finally, the findings are assessed in relation to the PPFDM scale.

5.3.4 Results

5.3.4.1. British Fear of Crime Survey

Analysis began with the British Fear of Crime Survey, which was administered to participants before they walked around the city centre. Ratings were submitted to a MANOVA, with fertility as the between-subjects factor. Descriptive statistics can be seen in Table 27. Fertility did not have an overall effect on ratings of how worried women were to becoming a victim of various crimes, $F(10, 29) = .36$, $p = .95$; Wilk's $\Lambda = .89$.

Table 27. Mean (SEM) rating on the British Fear of Crime Scale by crime type and fertility

	Fertile		Nonfertile	
	M	SEM	M	SEM
Mugging by a male	2.68	0.20	2.86	0.19
Mugging by a female	1.84	0.25	2.10	0.24
Violent attack by a male	2.74	0.24	3.05	0.23
Violent attack by a female	2.11	0.27	2.29	0.26
Sexual assault	2.79	0.26	2.95	0.25
Burglary	2.53	0.24	2.67	0.23
Vehicle damage vandalism	1.95	0.20	1.67	0.19
Theft from your property	2.37	0.20	2.24	0.19
Motor vehicle theft	1.89	0.23	1.62	0.21
General vandalism	1.68	0.18	1.57	0.17

5.3.4.2. Preliminary Analyses

To assess whether women had interpreted the visual cues along the route in the anticipated manner, repeated measures t-tests were conducted on women's ratings of safety, fear of crime, vulnerability, and victimisation consequences, with location as the repeated measures factor. The results are presented in Table 28. Women felt significantly less safe, reported higher levels of fear, felt more vulnerable, and perceived that the consequences of crime would be more serious for them in the crime hotspots compared to safe spots. Thus, women had perceived the visual cues of crime in the expected manner.

Table 28. Mean (SEM) Ratings of Personal Safety, Fear of Crime, Consequences, and Vulnerability Ratings in Crime Hotspots versus Safe Spots.

	Hotspots	Safe spots	t (39)	P
Safety	4.16 (1.83)	7.53 (1.57)	-9.88	< .001
Fear of Crime	5.88 (2.04)	3.96 (1.77)	6.06	< .001
Consequences	7.26 (1.74)	4.97 (1.93)	8.57	< .001
Vulnerability	6.08 (1.82)	3.71 (1.55)	8.46	< .001

5.3.4.3. Fertility

To assess whether fear of crime measures differed according to fertility, correlations between fertility and the dependent variables were assessed, including fear of crime measures and risk perceptions, and preferences for physically formidable and dominant mates (see Table 29). Measures 2-10 represent the average ratings across all participants. Measures 6 and 11 are the sum of average perceived risk across all crime types in hotspots and safe spots, respectively.

The correlations between fertility status and the other variables were assessed using Spearman's rho, whereas all other associations were examined with Pearson's r. The results are provided in Table 28. As shown, fertility status was correlated with PPFDM, r_s (40) = .33, p = .04. Fertile women attributed a higher importance to traits indicative of aggressive-formidability in long term mates, thus supporting Hypothesis 4. PPFDM was also significantly positively correlated with risk perceptions, vulnerability, and seriousness of consequences of victimisation in crime hot spots. For

the safe spots, PPFDM was significantly and positively correlated only with perception of seriousness. However, fertility status did not correlate with any of the fear of crime measures. This was confirmed with a MANOVA, comparing fertility on each dependent measure for both crime hotspots and safe spots. There were no fertility-related differences in feelings of safety, fear of crime, vulnerability or perceived seriousness of victimisation consequences in either crime hotspots or safe spots (all p's > .094).

Table 29. Zero-order Correlation Coefficients Across the Variables

	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Fertility Status	0.10	-0.05	0.11	-0.17	0.00	0.09	-0.11	0.26	-0.21	0.02	0.30	.33*	-0.06
2. Crime Hotspot Safety Perception		-.37*	-0.21	-.5**	-.47**	0.20	-0.04	0.00	-0.12	-0.24	0.13	-0.02	-0.12
3. Crime Hotspot Fear of Crime			.56**	.58**	.60**	0.08	.46**	.33*	0.18	0.26	-0.10	0.20	0.03
4. Crime Hotspot Consequence Seriousness				.65**	.71**	0.07	0.24	.59**	.41**	0.25	0.11	.40*	-0.09
5.Crime Hotspot Vulnerability					.73**	-0.18	0.22	0.21	.46**	0.20	-0.18	.34*	0.11
6. Crime Hotspot Risk Sum						-0.09	0.27	.32*	0.19	.38*	0.04	.35*	0.16
7. Safe Spot Safety Perception							0.07	-0.12	-0.13	-0.20	-0.05	-0.14	0.02
8. Safe Spot Fear of Crime								0.20	.34*	0.31	0.01	-0.11	-0.11
9. Safe Spot Consequence Seriousness									.46**	.55**	0.23	.35*	-0.20
10. Safe Spot Vulnerability										.62**	-0.05	0.17	-0.09
11. Safe spot Risk Sum											0.21	0.23	-0.09
12. BMI												0.21	-0.18
13. PPFDM													.36*
14. Negative Affect													

*p<.05, two-tailed; **p<.01, two-tailed

5.3.4.4. Risk perceptions

This section assesses women's risk perceptions as they walk through crime hotspots and safe spots in the city centre according to fertility and crime type.

Table 30. Mean ($\pm$1 SEM) risk ratings by crime type, perpetrator gender, location and fertility status

Crime Type	Perpetrator Gender	Hotspot				Safespot			
		Fertile		Nonfertile		Fertile		Nonfertile	
		M	SEM	M	SEM	M	SEM	M	SEM
Robbery	Male	6.74	0.30	6.52	0.45	4.67	0.47	4.67	0.36
	Female	5.71	0.41	4.99	0.49	4.02	0.47	3.85	0.33
Physical Assault	Male	6.30	0.38	6.45	0.48	3.53	0.41	3.49	0.33
	Female	4.84	0.40	4.67	0.45	2.64	0.37	2.43	0.31
Rape	Male	6.54	0.27	6.38	0.56	2.22	0.30	2.80	0.39

As can be seen in Table 30, risk perceptions were higher for crime hotspots compared to safe spots, and higher for male-perpetrated crimes compared to female-

perpetrated crimes. Moreover, risk perceptions were higher for robbery compared to physical assault. However, risk perceptions appeared to be similar for fertile and nonfertile women.

Women rated their risk of robbery and physical assault committed by a female perpetrator as well as by a male perpetrator, but evaluated their risk of rape committed by a male perpetrator only. Therefore, risk perceptions could be analysed as a function of perpetrator gender for robbery and physical assault only. Risk perceptions by fertility and location for rape were analysed separately.

A 2 fertility (fertile, nonfertile) x 2 location (crime hotspot, crime safe spot) x 2 crime type (robbery, physical assault) x 2 perpetrator gender (male, female) mixed ANOVA was employed to assess risk perceptions, with fertility as the between-subjects factor and location, crime type and perpetrator gender as the within-subjects' factors. Risk ratings were higher for hotspots compared to safe spots, $F(1, 38) = 63.18$, $p < .001$, $\eta p^2 = .62$, a significant main effect for location. There was a higher perceived risk of male-perpetrated crime than female-perpetrated crime, $F(1, 38) = 34.14$, $p < .001$, $\eta p^2 = .47$, a significant main effect for perpetrator gender. A significant main effect was also obtained for crime type, with women perceiving a higher risk of robbery compared to physical assault, $F(1, 38) = 39.72$, $p < .001$, $\eta p^2 = .51$. Moreover, location interacted with crime type, $F(1, 38) = 11.68$, $p = .002$, $\eta p^2 = .24$; while all pairwise comparisons were significant, differences across crime type in risk perceptions were smaller for crime hotspots (mean difference = .431, SEM = .126) compared to safespots (all p's < .001), see Table 30 for descriptive statistics.

The main effect for fertility was not significant, $F(1, 38) = .18$, $p = .67$, and therefore, Hypothesis 1 was not supported. Fertility did not interact with location, $F(1, 38) = .45$, $p = .51$, crime type, $F(1, 38) = .54$, $p = .47$, or perpetrator gender, $F(1, 38) = .55$, $p = .46$, meaning that Hypotheses 2 and 3 were also not supported. There was no three-way interaction between location, crime type and fertility, $F(1, 38) = .94$, $p = .34$, or location, gender and fertility, $F(1, 38) = .07$, $p = .8$, or crime type, gender and fertility, $F(1, 38) = .2$, $p = .66$. There was no four-way interaction between fertility, crime type, location and perpetrator gender, $F(1, 38) = .14$, $p = .71$.

Perpetrator gender significantly interacted with location, $F(1, 38) = 12.55$, $p = .001$, $\eta p^2 = .25$. All pairwise comparisons adjusted with the Bonferroni correction were significant (all p's $< .001$), but the mean location difference was larger for male-perpetrated crimes (mean difference = 2.41, $SEM = .28$) compared to female-perpetrated crimes (mean difference = 1.82, $SEM = .28$). Gender also interacted with crime type, $F(1, 38) = 5.94$, $p = .02$, $\eta p^2 = .14$, but all pairwise comparisons were significant at $p < .001$. There was no three-way interaction for location, crime type and gender, $F(1, 38) = .14$, $p = .71$.

5.3.4.5. Risk perceptions for rape

A 2 fertility (fertile, nonfertile) x 2 location (crime hotspot, crime safe spot) ANOVA was performed on risk perception scores, with fertility as the between-subjects factor and location the within-subjects factor. There was no main effect of fertility, $F(1, 38) = .21$, $p = .65$, thus Hypothesis 1 was not supported. Risk perceptions for risk of rape were higher in crime hotspots compared to safe spots, $F(1, 38) = 119.66$, $p < .001$, $\eta p^2 = .76$. However, fertility and location did not interact, $F(1, 38) = 1.03$, $p = .32$, $\eta p^2 = .03$, and therefore Hypothesis 2 was not supported.

To examine Hypothesis 3, whether more costly crimes would be feared (as measured by higher perceived risk), it was necessary to compare rape to robbery and assault within the same ANOVA. A 2 fertility (fertile, nonfertile) x 2 location (crime hotspots, crime safe spots) x 5 crime type (rape, male-perpetrated robbery, female-perpetrated robbery, male-perpetrated physical assault, female-perpetrated physical assault) mixed ANOVA, with fertility status as the between-subjects factor and location and crime type as the within-subjects' factors, was computed on risk perception scores. The Greenhouse Geisser correction was applied as appropriate.

There was no main effect of fertility, $F(1, 38) = .61$, $p = .81$. Therefore, Hypothesis 1 was not supported. Women perceived their risk of victimisation as greater in hotspots compared to safe spots, $F(1, 38) = 82.98$, $p < .001$. There was also a significant main effect of crime type, $F(4, 152) = 26.27$, $p < .001$. Perceived risk was highest for male-perpetrated robbery and physical assault, compared to female-perpetrated robbery and physical assault, or male-perpetrated rape.

Pairwise comparisons adjusted with the Bonferroni correction showed that there were significant pairwise comparisons between rape and male-perpetrated robbery (mean difference = 1.17, *SEM* = .2, *p* < .001), rape and male-perpetrated physical assault (mean difference = .45, *SEM* = .15, *p* = .05), and rape and female-perpetrated assault, (mean difference = .84, *SEM* = .21, *p* = .002). Male-perpetrated robbery was rated as higher risk than all other crimes, (all p's < .001). Female-perpetrated robbery was rated as higher risk than female-perpetrated assault (mean difference = -1.0, *SEM* = .18, *p* < .001). Female-perpetrated assault was rated as having a lower risk than both female-perpetrated robbery, (mean difference = 1.0, *SEM* = .18, *p* < .001) and male-perpetrated assault (mean difference = -1.29, *SEM* = .21, *p* < .001).

There was a significant interaction between location and crime type, $F(2.37, 31.8) = 25.19$, *p* < .001, $\eta p^2 = .4$. All pairwise comparisons were significant, with the location difference being largest for rape (mean difference = 3.95, *SEM* = .36, *p* < .001). Fertility did not interact with crime type, $F(4, 152) = .76$, *p* = .55 or location, $F(1, 38) = .22$, *p* = .64, and there was no significant three-way interaction between fertility, crime type and location, $F(4, 152) = .96$, *p* = .43. Therefore, Hypotheses 2 and 3 were not supported.

5.3.4.6. Exploratory Analyses: Fertility and Preferences for Physically Formidable and Dominant Mates *(*PPFDM)

In this section, the positive association between women's preferences for physically formidable and dominant mates and fertility is explored (see Table 29). Short term mate preferences tend to vary with fertility. Women prefer mates with traits that signal masculinity and dominance during ovulation (e.g., DeBruine et al. 2010; Little et al. 2007), such as being tall (Lynn & Shurgot, 1984; Pawlowski & Jasienska, 2005) with broad shoulders (Barber, 1995; Lavrakas, 1975; Singh, 1995). It is apparent that some of the items on the PPDFM scale (e.g., tall, broad shoulders) seem to relate to physical features associated with masculinity, whereas other seem to relate more to dominance as a trait (e.g., commanding). As such, it is assessed whether fertile women's higher PPFDM is due to masculinity preferences, or the protection afforded by a formidable mate.

The factors were clustered in a similar manner across several extraction methods (principal components, maximum likelihood, and principal axis factoring); for simplicity, only the principal axis factoring results is reported, in which promax rotation was employed. Two latent factors were identified, accounting for 61% of the total variance (see Table 30 which provides the pattern matrix). The observed correlation was .60 between factors 1 and 2. Sampling adequacy was verified (KMO = .82), and the variables were significantly correlated, $\chi^2(55) = 292.76$, $p < .001$. The items loading onto the first factor, which accounted for 48.7% of the variance, seemed to pertain largely to psychological adjectives that describe power or influence (dominance) over others (e.g., dominant, domineering, commanding, overbearing), whereas the second factor, which accounted for 12.6% of the variance, seemed to pertain largely to physical features and adjectives around another variable which seemed to be traits relating to masculinity (e.g., strong, powerful, broad shoulders, tall, could win a fight if necessary).

As shown in Table 31, fertility was significantly associated with the physical masculinity factor, but not the dominance factor. Interestingly, the dominance factor was significantly positively associated with feelings of vulnerability in the crime hotspots. The physical masculinity factor was significantly associated with perceived seriousness, and risk, specifically in relation to rape, male- and female-perpetrated robbery, and male-perpetrated physical assault.

Table 31. Factor Structure of the Preferences for Physically Formidable and Dominant Mates Scale.

	Factor	
	Dominance	Physical Masculinity
Dominant	.75	.16
Domineering	.95	-.10
Commanding	.99	-.16
Overbearing	.83	-.14
Tough guy	.38	.54
Bad boy	.13	.49
Strong	.18	.79

Powerful	.17	.78
Broad shoulders		.7
Tall	-.32	.60
Fight	-.12	.79

Extraction Method: Principal Axis Factoring.
 Rotation Method: Promax with Kaiser Normalization.

Table 32. Correlation of the dominance and physical masculinity factors with fertility and the fear of crime measures.

	Dominance	Physical Masculinity
Fertility	.22	.41**
Crime Hotspot Fear of Crime	.08	.18
Crime Hotspot Seriousness Perception	.26	.43**
Crime Hotspot Rape Risk Perception	.16	.39*
Crime Hotspot Male Robbery Risk Perception	.25	.4*
Crime Hotspot Female Robbery Risk Perception	.10	.32*
Crime Hotspot Male Assault Risk Perception	.31	.34*
Crime Hotspot Female Assault Risk Perception	.04	.27
Crime Hotspot Vulnerability Perception	.32*	.27

*$p < .05$, two-tailed; **$p < .01$, two-tailed

5.3.5. Discussion

The results of Study 7 showed that women reported heightened fear of crime (i.e., felt more vulnerable, felt less safe, perceived their risk of crime to be greater, and were more concerned about victimisation seriousness) in crime hotspots compared to safe spots. Therefore, women were sensitive to the cues in their environment, which in turn affected their fear of crime. Moreover, women reported higher perceived risk of male- as opposed to female-perpetrated crimes. However, against expectations, fear of crime measures and perceived risk did not differ according to fertility (Hypothesis 1), even for crime hotspots (Hypothesis 2) or crimes that would be more costly at peak fertility (Hypothesis 3). Thus, the first 3 Hypotheses relating to fertility-related differences in fear of crime were not supported. However, fertile women reported a higher preference for physically formidable and dominant mates (PPFDM), thus supporting Hypothesis 4. However, the relationship between PPFDM and risk

perceptions did not differ according to location (i.e., crime cues) or crime type, and thus Hypotheses 5 and 6 were not supported.

Studies 6 and 7 aimed to assess the psychological mechanisms that may drive the increase in avoidance behaviour during the fertile phase that has been documented in previous research (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003). Study 6 assessed differences in fear of crime. However, women did not differ in their reported fear depending on whether they were fertile. Possibly, this failure to find fertility-linked differences may have been due to the fear-inhibiting effects of oestrogen (e.g., Glover et al. 2013). Alternatively, the lack of fertility-related differences in reported fear of crime in Study 6 could have been due to the lack of specification of crime type for which women were reporting their fear, or due to the use of photographs not being realistic enough. Therefore, in Study 7, women rated their perceived risk of various crimes, as well as other measures of fear of crime including perceived seriousness of consequences and feelings of vulnerability, as they walked through crime hotspots and safe spots, during either a fertile or nonfertile phase of their menstrual cycle. Previous research suggests that risk perceptions are associated with avoidance behaviour (Ferraro, 1995) and differ according to fertility (Šuklová & Sarmány-Schuller, 2011, also see Study 2 in this thesis). Therefore, as criminal victimisation arguably imposes more evolutionary costs to a fertile compared to a nonfertile woman due to the risk of conception from sexual crimes, and due to the assumption that all crimes could lead into sexual crimes (Warr, 1987, Ferraro, 1995; 1996), it was hypothesised that fertile women may feel more vulnerable to crime, as measured by higher perceived risk. Moreover, it was hypothesised that fertile women would have a higher preference for physically formidable and dominant mates due to the protection from criminal victimisation (see Snyder et al. 2011).

Fessler and colleagues (2015) suggest that a woman's evolutionary assets, such as reproductive fitness and survival, are more at risk of incurring costs of victimisation at peak fertility due to the higher risk of conception from sexual crimes. What is more, arguably, any male-perpetrated crime has the potential to escalate into a sexual crime (e.g., Ferraro, 1995; 1996; Warr, 1985); therefore, the reproductive costs of all criminal victimisation may be relatively high during ovulation. Research suggests that ovulating

women are avoidant of the type of locations that were used as crime hotspots (Bröder & Hohmann, 2003; Chavanne & Gallup, 1998) due to the increased likelihood and costs of sexual assault. As such, it was predicted that fertile compared to nonfertile women would report a higher fear of crime in the crime hotspots. However, reported fear of crime did not differ by fertility in Study 6 or 7. Fertile and nonfertile women felt equally as fearful, safe, and concerned about the seriousness of victimisation consequences, and perceived their risk of crime to be equal. In support of this finding, Snyder and Fessler (2013b) did not find higher fear of rape amongst married women, who also arguably face higher costs of rape (see Thornhill and Thornhill, 1990a). Therefore, perceived risk, or fear of crime may not be associated with evolutionary costs of crime. Consequently, it is still unclear which cognitive mechanisms drive the avoidance behaviour that has been documented in existing research. Future research should continue to assess the psychological mechanisms which may motivate fertile women to become particularly avoidant of situations of increased rape risk.

The difference in risk perceptions and fear of crime ratings between the safe spots and crime hotspots in Study 7 may have been so large (as indicated by the effect sizes), that the results reflect ceiling and floor effects for hotspots and safe spots, respectively. These floor and ceiling effects may have concealed fertility-related differences. Alternatively, the 'risky' situations which ovulating women appear to avoid mostly involve dark and dimly lit areas, and being alone at night time (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2002). Darkness is known to elicit feelings of fear with regards to criminal victimisation (Box, Hale & Andrews, 1988). Moreover, an experimenter always accompanied the participant along the route in the city centre. There may have been fertility-related differences in fear, or perceived risk of victimisation, if participants had been alone, particularly at night. However, for ethical reasons, the study was not conducted in the evening, so as not to increase women's actual risk of crime by having them walk through the city centre on their own, or at night. An interesting avenue for future research would be to use virtual environment technology to simulate walking alone at night.

However, although fertility was not associated with risk perceptions in Study 7, it was associated with preferences for physically formidable and dominant mates.

Snyder et al. (2011) suggest that women with higher vulnerability to criminal victimisation should have higher preferences for formidable mates. Indeed, fertile compared to nonfertile women reported a higher PPFDM. This may suggest that the higher asset risks associated with ovulation, and thus increased vulnerability to crime, is associated with a higher need for protection from a formidable mate.

Theoretically, preferences for long term mates, which the PPFDM scale measures, should not vary over the menstrual cycle (The cycle shift hypothesis, Gangestad & Thornhill, 1998). Arguably, sexual strategies are variable (Campbell, 2013), and may be largely dependent upon a woman's environmental circumstances. It is suggested that in dangerous environments, women would benefit most from finding a long-term rather than short-term mate (Campbell, 2013). Therefore, for someone who feels particularly vulnerable to crime, such as during peak fertility, protection may be prioritised over traits that signal a good quality partner. However, some traits associated with a formidable mate (e.g., coerciveness and aggression) carry with them costs that a fertile female may seek to avoid. On the other hand, some traits associated with a formidable mate such as tall and broad shoulders are associated with masculinity, which signals quality genetics (Tybur & Gangestad, 2011; Scott et al. 2013). For example, attractive men are taller than average (e.g., Lynn & Shurgot, 1984), with broad shoulders (Barber, 1995; Lavrakas, 1975; Singh, 1995). Preference for such traits do vary over the menstrual cycle, as they are more beneficial during ovulation, when they are likely to be passed onto potential offspring. Indeed, exploratory analysis showed that two latent factors emerged on the formidable mates' scale, and these traits appeared to be related to dominance and masculinity. Preference for the traits associated with dominance were associated with women's perceived vulnerability, which is in keeping with previous literature; to benefit from the protection afforded by a dominant male. Interestingly, these traits, such as domineering and overbearing, which could be considered costly, did not map onto fertility. On the other hand, preference for traits loading on the masculinity factor were associated with fertility, as well as seriousness of consequences of victimisation and perceived risk of all crimes except female-perpetrated assault. Therefore, fertility may not be related to preference for formidable mates due to their increased

vulnerability to victimisation and asset risk, but rather because such traits are associated with masculinity and therefore may signal a good quality mate. Future research should aim to further assess the association between fertility and PPFDM.

This study has further potential limitations. While precautions were made to avoid extraneous variables, including only testing on weekdays between 10am and 4pm, so that the city centre was not too crowded, it is possible that there was variance in how busy the locations were, weather conditions, and situations encountered. Previous research has shown that manipulating environmental indicators of risk using virtual environment technologies influenced affective state and victimisation-related associations (Houtkamp & Toet, 2012). Using virtual environment technology would help to maintain the realism of the real world, while being able to maintain tight control and manipulate essential crime cues. This is an idea for future research.

There were also potential limitations of this study regarding sample size. Data collection in the real world was prioritised to investigate the effects that authentic crime hotspots had on fear of crime. Similar to McDonald et al. (2015), a trade-off was faced between online data collection which could have resulted in a larger sample size, but the validity of the priming manipulation and accuracy of fertility measures may have suffered. Moreover, there was a lack of regularly and naturally cycling women available for participation. This further limited the sample size. Therefore, it is possible that the lack of effect of fertility on risk perceptions in study 7, and indeed on fear of crime in study 6, may have been due to the small sample sizes, leaving the study underpowered. Post-hoc power analyses in GPower suggested power for study 6 was 18%, while power for study 7 was just 8%. There is no similar comparable previous research regarding the influence of fertility on fear of crime, and therefore it is not possible to assess whether the findings were due to being underpowered, or whether fear of crime indeed does not differ according to fertility status. However, it is important to note that the manipulation of fear of crime through risk stimuli was effective in both studies, suggesting the studies were able to find significant findings. Therefore, it is possible that fertility status simply does not influence ratings of fear of crime. Nevertheless, future research should aim to replicate this methodology using

both a larger sample size and a within-subjects' manipulation of fertility status to reduce any between-subjects' variation and increase statistical power.

In sum, Study 6 and Study 7 aimed to assess the psychological mechanisms that may drive fertility-related increases in avoidance of situations associated with increased risk of crime, such as dimly lit and deserted areas (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003). Study 6 assessed whether women differed in feelings of fear with regard to their personal safety in response to photographs that depicted danger or safety cues. While crime cues were found to differentially affect fear, there were no differences in reported fear across fertile and nonfertile women. Study 7 aimed to overcome some limitations of Study 6, including measuring women's perceived risk in response to specific types of crime. In Study 7, to increase realism, fertile and nonfertile women walked through a pre-determined route in a city centre that varied in exposure to crime hotspots and safe spots, and rated their fear of crime and perceived risk of various crimes. Fear of crime measures and risk perceptions varied in response to crime cues but again did not vary according to fertility. Therefore, differences in fear and perceived risk of victimisation do not appear to underlie the avoidance behaviour that has been documented in previous research (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003). It is possible that the mechanism may operate without conscious awareness. Women may not purposely choose to increase their avoidance of such situations during ovulation. Future research should continue to assess fertility-related differences in psychological mechanisms that may be associated with rape avoidance.

6. Chapter 6

6.1. General discussion

Rape bears psychological and physical costs (Perilloux, Duntley & Buss, 2012). As one example, rape may result in a pregnancy, with an unknown and absent male having fathered the offspring. While rape is costly and traumatising at any time, during peak fertility rape can cause pregnancy, and thus it could be argued that rape is particularly costly to women during ovulation. This thesis aimed to assess the hypothesis that women have evolved a rape avoidance psychological adaptation that is particularly active during ovulation when conception risk is highest. Previous research has suggested that fertile compared to nonfertile women show increased avoidance of situations that theoretically might increase their risk of rape (e.g., Chavanne & Gallup, Bröder & Hohman, 2003) and keep further distance from a male that was manipulated to appear "shady looking" (Guéguen, 2012a). Women have also been shown to over-estimate men's sexual coerciveness (Garver-Apgar et al. 2007), show increased racial bias to outgroup members (McDonald et al. 2011, Navarrete et al. 2009) and show increased handgrip strength in response to a scenario depicting rape (Petralia & Gallup, 2002) when fertility is highest, compared to phases of lower conception risk.

However, whilst this finding appears robust, previous research does not demonstrate that reductions in women's risk taking behaviour that coincide with peak fertility are specific to the domain of rape risk. Previous research suggests that women respond differently and report behavioural changes in response to situations associated with increased rape risk, but it cannot be concluded from this previous research that women are responding specifically to increased risk of rape and the associated risk of pregnancy. Rather, it may be possible that women differentially respond to all risks and dangers when fertile. Previous research has shown that fertile compared to nonfertile women show increased risk avoidance and danger perception in other domains, including being less trusting of strangers and making more cautious investments (Ball et al. 2013), are more risk-averse in gambling tasks (Kaighbodi & Stevens, 2011), and show enhanced detection of fear more generally (Pearson & Lewis, 2005). To conclude an adaptive trait has evolved it should show a specific

purpose (Andrews et al. 2002). To date, only one study has attempted to show domain specificity (Garver-Apgar et al. 2007). As such, this thesis aimed to assess the fertility-related rape avoidance hypothesis by considering the specificity of the mechanism. Previous research has also focused largely on self-reports of behaviours. This thesis aimed to assess the fertility-related rape avoidance hypothesis using multiple methodologies, including assessing physiology, behaviour, attention, psychological and cognitive mechanisms, along with self-reports of emotion and risk perceptions.

Study 1 began with a replication of Petralia and Gallup's (2002) methodology of assessing changes in handgrip strength according to fertility and scenario. The 'sexual assault' scenario they used, while suggestive of a situation that could result in a rape, did not specifically depict rape. Rather, the scenario described a dangerous situation, which could possibly result in any number of different types of crime occurring. Study 1 extended previous research by assessing responses (including handgrip strength and subjective perceptions) to scenarios that varied in the risk of a rape occurring. A more explicit rape scenario was included to reduce ambiguity about what was being portrayed, as well as a male-perpetrated physical assault scenario to assess responses to physical- rather than sexual- costs of victimisation, and a physical assault perpetrated by a female assailant to control for the risk of a rape occurring. Fertility and scenario were manipulated between subjects. For subjective responses, the rape compared to the female-perpetrated assault scenario elicited more negative emotions, higher likelihood of running, less perceived ability to successfully fend off the attacker, and less ability to emotionally cope. However, neither fertility nor scenario affected changes in handgrip strength from baseline to post-scenario or post-rumination. Thus, the findings of Petralia and Gallup (2002) that women's handgrip strength increased when fertile in response to the risk of sexual assault were not replicated.

There were a few possible limitations in Study 1 that may explain the null findings for fertility and scenario. For example, due to the influence of scenario and fertility being measured between-subjects, a large sample was necessary, which was not possible to achieve. Alternatively, all of the scenarios in Study 1 depicted danger, which may explain the lack of effect of scenario. If a control scenario has been

included, as Petralia and Gallup did, there may have been differences in response. Alternatively, fertility may not influence handgrip strength altogether. Study 2 aimed to address these issues.

Study 2 assessed physiological and subjective responses to five scenarios that varied in rape risk, including a control scenario. Petralia and Gallup's (2002) two scenarios, as well as the three new scenarios, wherein risk of rape was varied, were included. Fertility and scenario were manipulated within subjects. Heart rate variability was assessed as an additional physiological measure. Results suggested, firstly, that for hormonal contraceptive users, while scenario influenced handgrip strength, there was no influence regarding testing session. However, for naturally cycling participants, when women were fertile compared to nonfertile, women increased their handgrip strength more from baseline in all of the scenarios that involved men, including the rape, male-perpetrated assault, Petralia and Gallup's sexual assault and control scenarios. The only scenario wherein there was no fertility-related differences in handgrip was the female-perpetrated assault scenario, where danger was present but there was no immediate risk of rape. As such, it is possible that the fertility-related increase in handgrip strength arose in scenarios in which there was a possibility of rape occurring. It may be assumed that dangerous situations, such as criminal victimisation, particularly involving males, could escalate into a sexual assault (the shadow of sexual assault hypothesis [SSAH], Ferraro, 1995; 1996). This finding builds on previous research by investigating the assumptions of the SSAH in relation to fertility. Moreover, Studies 1 and 2 assessed domain specificity in women's physiological responses within risk situations over the menstrual cycle, which has not yet been considered in previous research.

Interestingly, and of importance, women felt at higher risk of the situation being depicted in the scenario happening to them when fertile compared to nonfertile. Further analyses suggested this was true for the rape scenario and male-perpetrated assault scenarios only. This suggests some specificity of response in perception of risk, as these scenarios arguably had the highest risk of rape. The results of Study 2 therefore do not seem to suggest that women are more responsive to all danger at peak fertility. There were no fertility-related differences for the female-

perpetrated assault scenario, which involved danger, but risk of rape was controlled. Rather, fertility-related differences in handgrip strength were found for scenarios involving males. While the dependent variables in Study 2 were not associated, differences in perception of risk, particularly for the only two scenarios that elicited an increase in handgrip from baseline (i.e., rape and male-perpetrated assault) may suggest that cognitive processes are associated with physiological differences in response to the depiction of risk. An adaptive response should be present in cognitions, behaviours and physiology. Previous research has not given much emphasis to the cognitive responses associated with the rape-avoidance mechanism. This was the aim of Study 3.

Efficient avoidance is facilitated by fast detection of the threat. Evolutionary threats (e.g., a snake or spider, or an angry face which signals aggression) are generally detected and attended to more quickly than a neutral stimulus (e.g., dog, sheep, flower, neutral face; for a review see Öhman & Mineka, 2001). Therefore, if fertile women have increased avoidance of situations of rape-risk, or danger in general, they may show enhanced detection of threats to their reproductive fitness. Previous research has lacked focus on women's attention to reproductive threats over the menstrual cycle.

Detection speed of evolutionarily-relevant threats was assessed across 2 experiments in Study 3. Detection speed of reproductive threats (angry versus neutral male and female faces) and general threats (animals versus neutral animals) was assessed using a dot-probe paradigm. Against expectations, women were overall faster to detect neutral compared to fear-relevant animals. However, importantly, fertility did not influence attention to threatening or neutral animals, suggesting that fertility may not influence attention to general threats to fitness. However, for the faces, women were faster to respond to angry faces during the nonfertile phase only. Against expectations, fertile women were slightly faster to detect probes following neutral compared to angry faces. Women were faster to respond to neutral faces when fertile compared to nonfertile.

Firstly, these results suggest that fertility-related differences in attention may be specific to reproductively relevant stimuli rather than general threats; a finding which has not been established in previous research. However, against expectations, women were faster to detect neutral faces when fertile, with no fertility-related differences for angry faces. Faster detection of neutral stimuli could represent attentional avoidance (e.g., Krahé, 2005; Frewen et al. 2008), attraction to neutral stimuli, or vigilance. The 200ms exposure duration could have permitted multiple shifts in attention, meaning reaction time may not have been an accurate measure of initial allocation of attention (e.g., Fox et al. 2001; Weierich et al. 2008). For example, fertile women may have initially and rapidly fixated on the threat, and had time to shift their attention to the neutral stimulus, which is where their attention was when the probe appeared. On the other hand, fertile participants may have had difficulty disengaging their attention from the neutral stimulus because it was more attractive. While dot-probe paradigms may give rise to bottom-up attentional processes, they do not enable understanding of top-down attentional processes.

Therefore, in Study 4, eye tracking was employed to assess fixation patterns in response to the face and animal stimuli that were presented in Study 3. The stimulus-pairs appeared for 2000ms to allow detailed fixation data, and to assess both bottom-up and top-down attentional processes in response to threatening versus neutral stimuli over the menstrual cycle. Overall, for the animal experiment, women made a higher proportion of first fixations towards threatening compared to neutral animals, though this only approached significance. Women were faster to make their first fixations, and focused a higher proportion of time fixating on the animals during their fertile compared to their nonfertile phase. Thus, fixation patterns in response to animals suggested that women may have increased attentional processing in general when fertile compared to nonfertile, rather than specifically in relation to threats. However, for the faces, women were slower to make their first fixations on angry compared to neutral faces when fertile, whilst emotion did not influence first fixation speed when nonfertile. Women then spent a higher proportion of time per trial fixating on angry versus neutral faces, but only during their fertile phase. Therefore, the results suggested that during the fertile phase specifically, women appear to

initially attend to neutral faces, possibly reflecting inhibition of the relatively least threatening stimulus (e.g., Cooper & Langton, 2006), but spend a longer proportion of time fixating on angry compared to neutral faces, which may represent difficulty disengaging attention, or more interest in threat. Thus, threat influenced both top-down and bottom-up attentional processes, but only during the fertile phase. The findings of both Study 3 and Study 4 suggested that fertility-related differences in attentional biases to potentially threatening stimuli are specific to reproductively relevant stimuli.

However, while fertility influenced fixation patterns according to emotion, this did not differ for male compared to female faces. It was hypothesised that women would have an attentional bias towards aggressive male faces in particular due to the relatively higher costs of sexual victimisation during peak fertility (e.g., Fessler et al. 2015). Therefore, the attentional biases in response to angry versus neutral faces during ovulation may not be associated with a rape avoidance mechanism specifically, but rather an increased sensitivity to emotion when oestrogen peaks (e.g., Derntl et al. 2008; Pearson & Lewis, 2005).

However, it could be argued that, although threatening, an angry male face does not necessarily signal risk of rape specifically. Had the stimuli been more specific to rape, there may have been evidence of domain specificity in response to risk stimuli. This was the aim of Study 5, as well as to assess cognitive processing biases. Macrae et al. (2002) posited that hormones influence information processing. They found that women were faster to categorise reproductively relevant stimuli during ovulation. Similar to Study 3 and Study 4 in this thesis, Macrae et al. (2002) found fertility-related differences in processing of faces. They found women were faster to categorise male, but not female faces by gender when fertile compared to nonfertile. Similarly, women categorised stereotypical words related to men more quickly during a high conception risk phase, thus showing an ovulation-related enhancement in access to categorical information that is relevant to reproductive success. As such, Study 5 examined categorisation speed for stimuli relevant to reproductive success (i.e., consensual sex) as well categorisation speed for stimuli relating to threats to

reproductive fitness (i.e., rape). Images and words relating to robbery were included to assess biases to danger more generally.

In Study 5, women performed a speeded binary categorisation task in which they indicated whether an image or word was related to one of three categories (comparing 2 categories at a time); rape, robbery or consensual sex. Overall, women were fastest to categorise stimuli related to consensual sex, and slowest to categorise stimuli related to rape. Moreover, conceptual overlap between rape and robbery categories resulted in slower categorisation speed, regardless of fertility. However, women were particularly slow when fertile compared to nonfertile to categorise stimuli associate with rape, suggesting that rape stimuli are relatively more negative, and a source of anxiety during ovulation.

The findings thus far appear to suggest that there may be increases in fear or anxiety when fertile (e.g., increased strength, longer time spent fixating on threats, slower cognitive processing). Fear drives avoidance behaviour (Ferraro, 1995), which may underlie rape avoidance. This possibility was assessed in Study 6. A lab experiment examined participants' fear of crime in response to images that varied in their depiction of victimisation risk. Women viewed images of crime hotspots, safe spots, and crime hotspots with a shadowy male figure present at night time and daytime. They rated their fear with regards to their personal safety. Fear differed according to crime cues, such that fear of crime was higher for crime hotspots and images involving a shadowy male figure compared to safe spots. However, fear of crime did not differ in relation to fertility. It is possible that viewing images of crime cues in a lab was not realistic enough to elicit fertility-related differences in feelings of fear. Secondly, theoretically, fertility-related differences in fear of crime should only be apparent for sexual crimes, or crimes associated with an increased risk of sexual assault (e.g., violent male-perpetrated crimes). Crime type was not assessed in Study 6, and may explain the lack of effect of fertility in fear of crime. Alternatively, the null findings for fertility regarding fear of crime may be due to the fear-inhibiting effects of oestrogen and testosterone, both which peak during ovulation (Lebron-Milad & Milad, 2012; Van Honk et al. 2005). Therefore, instead of fear, perceived risk of victimisation, as a measure of vulnerability was measured in Study 7. Avoidant behaviour is

associated with perceptions of risk and vulnerability (Gabriel & Greve, 2003; Killias & Clerici, 2000; Rader, 2004). Indeed, Study 2 suggested that women have differences in risk perception according to their fertility status. These considerations were assessed in Study 7.

Study 7 assessed risk perceptions in the real world. Women walked through Leicester city centre during a fertile or nonfertile phase of their menstrual cycle, along a route that varied with regards to cues of crime. Participants were asked about their fear of crime, feelings of personal safety and perceived risk of victimisation of various male- and female-perpetrated crimes in crime hotspots and safe spots. While risk perceptions and fear of crime measures again differed according to location and type of crime, fertility did not affect risk perceptions or any of the fear of crime measures. Therefore, risk of victimisation may not drive avoidance behaviour that is documented in previous research (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003).

However, Study 7 also assessed women's preferences for physically formidable and dominant mates (PPFDM). PPFDM was significantly associated with both risk perceptions and fertility. Fertile women had a higher preference for physically formidable and dominant mates. This could represent that women's fertility is an 'asset at risk' (Fessler et al. 2015) which would benefit from protection from criminal victimisation, which a formidable mate can offer. However, examination of the structure of the PPFDM scale suggests that the higher PPFDM in fertile women was due to preferences for physical masculinity, in line with previous research (e.g., Tybur & Gangestad, 2011; Scott et al. 2013), rather than the protection from victimisation they could afford. This is an interesting avenue for further research.

This thesis aimed to assess domain specificity in women's responses to risk of rape over the menstrual cycle. There was some evidence that may suggest specificity of response to risk stimuli when fertile. For example, Study 2 found handgrip strength to increase when fertile compared to nonfertile for all scenarios involving a male, while the scenario featuring a female physical assault perpetrator did not differentially affect handgrip in relation to fertility, despite the scenario involving danger. Similarly, women felt at higher risk of rape and male-perpetrated assault occurring when fertile

compared to nonfertile. Arguably, in line with the SSAH, these crimes have the highest risk of rape. Therefore, women's heightened risk perceptions in rape and male-perpetrated physical assault may be indicative of domain specificity with regard to fertility-related differences in risk perceptions. In Study 3 and Study 4, fertility-related differences in attention to potential reproductive threats were apparent in response to faces, but not animals, which may suggest some specificity of response. However, results did not show faster detection of threats when fertile, as was predicted; but, fertile women did fixate for longer on angry faces. However, these findings were not specific to male faces, and therefore while this suggests a fertility-related bias to attention to faces that may signal aggression, this was not specific to aggressive males. Therefore, the fertility-related increase in attention to threat may not be due to risk and costs of rape specifically. However, Study 5 showed delayed cognitive processing when fertile compared to nonfertile in response to rape stimuli only, rather than general threats (i.e., robbery) which may lend some support for domain specificity. In contrast, RTs in Study 3 and fixations in Study 4 in response to animal stimuli may represent overall attentional vigilance more generally during the fertile compared to nonfertile phase (i.e., faster fixations and longer time spent fixating on all animals). However, fertility did not influence explicit ratings of fear of crime, or perceptions of victimization risk overall, or in response to rape stimuli specifically in Studies 6 and 7. Thus, whilst there was some evidence in support of specificity of the mechanism, this was not consistent across studies.

A second aim of this thesis was to assess the hypothesised rape-avoidance mechanism using multiple types of responses, including behaviour, physiology and cognitions over the menstrual cycle. Study 2 assessed whether each of the dependent variables (handgrip, heart rate and subjective perceptions) were associated, in an attempt to understand the psychological mechanisms associated with the rape avoidance adaptation. Overall, the measures were not associated. However, in Study 2, fertile women showed an increase in strength from baseline in response to a sexual assault and male-perpetrated physical assault scenario, and similarly showed increased perception of risk of these two scenarios occurring compared to when nonfertile. This may suggest that the mechanism influenced both handgrip strength

and risk perceptions. However, fertile compared to nonfertile women did not report increased fear or perceived risk of victimization in response to rape or male-perpetrated crimes in Studies 6 and 7. One reason for this could be due to the measurement of fertility status. Fertility was measured within-subjects in Study 2 and between-subjects in Study 7. The influence of hormonal status is not consistent across women (Moos & Leiderman, 1978). For example, there are individual differences in how hormones influence feelings of negative affect and anxiety (Gottschalk et al. 1962). Therefore, this may explain the inability to demonstrate convergence across studies within this thesis.

Overall, the findings suggest that fertility does appear to influence responses to risk. However, hormonal influences appeared to only manifest in unconscious, visceral responses (i.e., physiology, attention, cognitive biases) rather than more conscious reports of feelings and perceptions (i.e., fear of crime, risk perceptions). This finding is similar to previous research. For example, Navarrete et al. (2009) assessed racial bias over the menstrual cycle. While they found fertile women to show increased racial bias, this was only apparent in implicit rather than explicit measures of racism. Similarly, administration of testosterone reduced unconscious measures of fear but did not influence self-reports of feelings of fear (Van Honk et al. 2005). Thus, hormonal influences may be apparent in automatic, system 1 processes, rather than system 2 processes (e.g., Kahneman, 2003). System 1 processes are fast, automatic, subconscious and emotional modes of thought, while System 2 processes are slow, rational, conscious and logical thought processes. Women may be unaware of any influence their hormones have on their explicit, rational judgements and controlled actions in response to risk (Bargh, 1994). This makes sense from an evolutionary perspective. As well as being domain specific, adaptations should involve efficiency (Williams, 1966) and fast processing (Fodor, 1983). Automatic processes are efficient as they use fewer cognitive resources (Pettinelli, 2014).

However, even though women do not appear to feel higher fear of situations of increased risk of victimisation at peak fertility, it is possible that avoidant behaviour can be present without changes in cognition or emotion (Gabriel & Greve, 2003), known as reflex behaviours (Gabriel & Greve, 2003). Some "core" emotional responses

can be unconscious, yet still manifested in overt behaviour or physiological responses (LeDoux, 1996; Damasio, 2000; Zajonc, 2000). Therefore, a rape-avoidance mechanism may manifest in behaviour and physiology, rather than in conscious awareness. The reduction in risk-taking behaviours during ovulation (e.g., Chavanne & Gallup, 1998; Bröder & Hohmann, 2003) may be instinctual, without women being aware of their behavioural change.

Alternatively, fertility-related differences may not be apparent when explicitly asking about feelings towards violent crimes such as rape. Rape imposes high evolutionary costs, including physical and psychological pain, regardless of menstrual cycle phase. Moreover, rape could be misperceived as adultery and risk potential loss of a current partner and their resources. Thus, women are likely to be hard-wired to fear rape regardless of fertility. Consequently, when asking about fear of rape or other violent crimes through explicit measures, women's responses seem to approach ceiling. Rape is always devastating, which would be reflected in rational and controlled, system 2 thought processes. However, markers that differ according to fertility may be shown in unconscious and automatic system 1 processes.

One reason for this could be because it is not always adaptive to constantly feel fearful. For example, feelings of anxiety or fear could be associated with missed mating opportunities. Though always costly and traumatising, it can be argued that rape during peak fertility, inflicts particularly high costs to evolutionary fitness. Behaviours to reduce the risk of rape, such as decreased social behavior, may prevent opportunities of finding a high quality mate. Similarly, there may be health complications associated with a constant state of high physiological arousal and vigilance, which could interfere with chance of conception with a consensual mate. There is some evidence to suggest psychosocial stress is associated with decreased fertility (Sanders & Bruce, 1997). Thus, while controlled and conscious processes appear to always show high fear of victimization, fertility-related differences in mechanisms that motivate rape-avoidance may work on an unconscious, automatic level. This argument lends support for one of the primary aims of this thesis in assessing multiple methodologies, which may result in different conclusions. Future

research on adaptive traits should continue to assess multiple modalities, with a focus on assessing implicit versus explicit measures.

The concept of trade-offs in relation to psychological and physiological adaptive mechanisms may be an area that would benefit from further research. For example, it would be interesting to see whether cognitive, attentional and physiological mechanisms vary in tandem with relative costs of rape. McKibbin et al. (2011) found rape avoidance behaviours differed according to individual differences which may influence the relative evolutionary costs and risks of rape, such as proximity to family members and marital status. In keeping with this argument, implicit measures of cognitive biases or physiological responses to threats may differ with risk and relative costs of rape, such as women's self-perceived attractiveness, presence of a protective partner, and self-perceived ability to thwart off an attacker (Thornhill & Palmer, 2000). This would be an interesting avenue to further understand the adaptiveness of a rape-avoidance mechanism in relation to costs to fitness.

It is also important to note that the literature and evidence reviewed in this thesis focuses on mechanisms that may enable avoidance of stranger rape. The mechanisms which may encourage avoidance of situations of increased risk of rape would likely differ for stranger rape, compared to acquaintance or partner rape. For example, avoidance of dark and deserted areas (e.g., Chavanne & Gallup, 1998) or distance from 'dangerous looking' men (e.g., Guéguen, 2012a), may help avoid rape perpetrated by a stranger, but are unlikely to reduce the likelihood of rape perpetrated by acquaintances or partners. Future research could consider mechanisms associated with rape avoidance according to the type of perpetrator, though the ethical implications around investigating partner or acquaintance rape should be fully considered.

This thesis aimed to examine domain specificity in a rape-avoidance adaptation in women. However, in addition to being domain specific, Fodor (1983) suggested than an adaptation is characterised by informational encapsulation, obligatory firing, automaticity, shallow and simple outputs, limited accessibility, characteristic ontogeny and fixed neural architecture. As such, future research could consider assessing

additional traits associated with the adaptation. For example, neuropsychological approaches could be used to examine obligatory firing of neural architecture in response to rape-related stimuli over the menstrual cycle, which would further assess implicit responses to rape-risk.

In conclusion, this thesis aimed to assess the fertility-related rape avoidance hypothesis. I have built on existing research by testing for domain specificity in women's responses to risk stimuli across the menstrual cycle, using multiple methodologies. Physiological and psychological responses to stimuli that varied in the risk of rape were assessed. Risk of rape was manipulated through dissecting the physical versus sexual aspects of rape, controlling for risk of rape through manipulation of gender, and varying the type of threat. Overall, fertility influenced implicit measures of strength, attention, cognitive processing and some measures of risk perception. More specifically, fertility-related increases in feelings of risk (Study 2), handgrip strength (Study 2) and cognitive processing (Study 5) appeared to be specific to situations in which there is increased risk of rape occurring, while there were no fertility-related differences in response to risk more generally, as opposed to risk of rape (i.e., physical assault perpetrated by a female in Study 2, detection of fear-relevant animals in Studies 3 and 4, cognitive biases to robbery stimuli in Study 5). More generally, during peak fertility women showed increased handgrip strength, fixation speed, higher proportion of time spent fixating on stimuli, slower cognitive processing and higher fear of snakes and spiders, which may suggest increased vigilance, as well as a possible increased activation of a fear module (e.g., Öhman & Mineka, 2001). It is possible that the mechanism initially evolved to protect women from rape, but has generalised to increase vigilance more generally during peak fertility. As suggested by Masataka and Shibasaki (2012) women may avoid all danger to survival to protect their chances of reproducing, or to protect a potential pregnancy. In contrast, fertility did not influence more explicit measures regarding conscious feelings and perceptions, which may reflect differences in system 1 and system 2 processing (Kahneman, 2003). Future research should continue to assess multiple modalities, and should focus on understanding the differences between the

unconscious versus conscious aspects underlying the fertility-related rape avoidance

hypothesis.

Appendices

APPENDIX A. Example of a pre-screening questionnaire

1. Please enter your email address so that the experimenter can contact you to arrange a time for participation

2. Please choose a unique 4-digit identifier code. This needs to be a combination of any 4 numbers. However, they cannot be consecutive (1234) and all need to be unique (i.e. 7643 but not 3333). Also, please don't use your year of birth (e.g. 1996). You will need to remember this code for testing session 1 and 2, so please choose a code that you will remember (you may want to note it down).

3. What is your age?

4. What is your relationship status?

Single (skip to question 6)

Casually dating

Serious Relationship

Married

5. Currently, do you and your partner….

Live together in the same home

Live apart in the same city

Live apart in different cities

6. How many times per month do you exercise?

7. Do you often get headaches?

Never

Rarely

Sometimes

Often

Frequently

8. How many times per month do you go to bars/pubs?

9. How many times per month do you drink alcohol?

10. How many hours, on average, do you sleep per night?

11. Are you currently on hormonal contraceptives (e.g. birth control pill, Depo-Provera injection, Implanon, Ormeloxifene etc.), or have been in the past 6 months?

Yes, currently

Yes, in the past 6 months

No

If you answered 'Yes', please indicate the type of hormonal contraceptive:

12. When was your first date of your last menstrual cycle? (i.e., when did you start your last menstruation)? If you are on hormonal contraceptives and still have periods, please state when this started. If you are on hormonal contraceptives and do not have periods please put N/A.

13. Would you class your menstrual cycle as...

Regular (e.g. occurs consistently every 28 days)

Irregular (inconsistent lengths/vastly deviating 28 days)

14. How long is your monthly menstrual cycle? That is, how many days are there between the onsets of each menstruation? If inconsistent lengths between cycles, please state this.

15. How frequently in the last month have you been unwell with colds, stomach flus and other minor illnesses etc.?

APPENDIX B. Scenarios for Study 1

Rape

Sophie sighs as she takes off her apron and shuts the coffee machine down. She hates being on the late shift and having to lock up, especially when her mum's away and can't pick her up. She fumbles to find the correct key. She hears the door lock shut and dreads her long walk home. It would take just as long for a taxi to get here though, in the middle of nowhere. If only there were more than two barely-working street lights.

She peers through the bar window to double-check all the lights are off, and jumps at the sight of a figure moving behind her in the reflection. She looks over her shoulder, but no-one is there. It's late and I'm tired, I must be imagining things, Sophie thinks to herself. As she finally finds the correct key and hears the door lock shut, a chill sweeps through her body. She pulls her scarf up over her ears and begins the cold, long walk home.

Almost half-way, she thinks to herself. The air is so bitterly cold she can see her breath. She wraps her coat tightly around herself, regretting not wearing more layers. She can hear the quickening of her footsteps echoing in the desolate alleyway. She hates this alleyway; the graffiti always makes her feel uneasy. The sole streetlight flickers, ready to die out, and she makes a mental note to walk around the alleyway tomorrow night.

She thinks she can hear footsteps behind her, but she tells herself she is just imagining things. It seems to be getting darker the further down the alleyway she gets. Feeling anxious, she hurries her pace and regrets letting the battery on her phone die out. As she turns the corner she jumps at the sight of the silhouette of a male in the alleyway. He is stood still, smoking a cigarette.

Sophie can feel the man's eyes on her, and she considers turning around. The man begins to walk towards Sophie, stubbing out his cigarette on the wooden fence. Sophie can tell he has been drinking; the smell of alcohol is overwhelming. The man is very close now, and Sophie is frozen with fear. With one strong, unexpected move he pushes Sophie up against the wall, putting a finger over her mouth so she knows not to make a sound. He grabs her wrists.

Sophie tries to escape, but this only angers the man more. He presses himself tighter against her. The man eases away just enough to force his hand down Sophie's knickers and she can't help but let out a whimper. He asks Sophie to lie on the ground. He begins to unbutton his trousers and eagerly lifts up Sophie's dress.

The man is now facing Sophie. His every move is torture and she wills for it to be over. Tears stream down her face, but she has learnt by now not to make a sound. She feels his body shudder and he lets out a groan.

Male-perpetrated physical assault

Sophie sighs as she takes off her apron and shuts the coffee machine down. She hates being on the late shift and having to lock up, especially when her mum's away and can't pick her up. She fumbles to find the correct key. She hears the door lock shut and dreads her long walk home. It would take just as long for a taxi to get here though, in the middle of nowhere. If only there were more than two barely-working street lights.

She peers through the bar window to double-check all the lights are off, and jumps at the sight of a figure moving behind her in the reflection. She looks over her shoulder, but no-one is there. It's late and I'm tired, I must be imagining things, Sophie thinks to herself. As she finally finds the correct key and hears the door lock shut, a chill sweeps through her body. She pulls her scarf up over her ears and begins the cold, long walk home.

Almost half-way, she thinks to herself. The air is so bitterly cold she can see her breath. She wraps her coat tightly around herself, regretting not wearing more layers. She can hear the quickening of her footsteps echoing in the desolate alleyway. She hates this alleyway; the graffiti always makes her feel uneasy. The sole streetlight flickers, ready to die out, and she makes a mental note to walk around the alleyway tomorrow night.

She thinks she can hear footsteps behind her, but she tells herself she is just imagining things. It seems to be getting darker the further down the alleyway she gets. Feeling anxious, she hurries her pace and regrets letting the battery on her phone die out. As she turns the corner she jumps at the sight of the silhouette of a male in the alleyway. He is stood still, smoking a cigarette.

Sophie can feel the man's eyes on her, and she considers turning around. The man begins to walk towards Sophie, stubbing out his cigarette on the wooden fence. Sophie can tell he has been drinking; the smell of alcohol is overwhelming. The man is very close now, and Sophie is frozen with fear. With one strong, unexpected move he pushes Sophie up against the wall. From the look on his face, Sophie knows not to make a sound. He grabs her wrists.

Sophie tries to escape, but this only angers the man more. He tightens his grip on her wrists. The man eases away enough to force his hand into Sophie's back pockets to check for

belongings. She can't help but let out a whimper. He asks Sophie to hand over her purse, but she had left it at home.

The man is now facing Sophie, his face contorts into a grimace. He spits at Sophie before head-butting her forehead and kicking her in the leg. Sophie is dizzy with pain. As she finally manages to open her eyes, she is relieved to see the man has gone.

Female-perpetrated physical assault

Sophie sighs as she takes off her apron and shuts the coffee machine down. She hates being on the late shift and having to lock up, especially when her mum's away and can't pick her up. She fumbles to find the correct key. She hears the door lock shut and dreads her long walk home. It would take just as long for a taxi to get here though, in the middle of nowhere. If only there were more than two barely-working street lights.

She peers through the bar window to double-check all the lights are off, and jumps at the sight of a figure moving behind her in the reflection. She looks over her shoulder, but no-one is there. It's late and I'm tired, I must be imagining things, Sophie thinks to herself. As she finally finds the correct key and hears the door lock shut, a chill sweeps through her body. She pulls her scarf up over her ears and begins the cold, long walk home.

Almost half-way, she thinks to herself. The air is so bitterly cold she can see her breath. She wraps her coat tightly around herself, regretting not wearing more layers. She can hear the quickening of her footsteps echoing in the desolate alleyway. She hates this alleyway; the graffiti always makes her feel uneasy. The sole streetlight flickers, ready to die out, and she makes a mental note to walk around the alleyway tomorrow night.

She thinks she can hear footsteps behind her, but she tells herself she is just imagining things. It seems to be getting darker the further down the alleyway she gets. Feeling anxious, she hurries her pace and regrets letting the battery on her phone die out. As she turns the corner she jumps at the sight of the silhouette of another female in the alleyway. She is stood still, smoking a cigarette.

Sophie can feel the woman's eyes on her, and she considers turning around. The woman begins to walk towards Sophie, stubbing out her cigarette on the wooden fence. Sophie can tell she has been drinking, the smell of alcohol is overwhelming. The woman is very close now, and Sophie is frozen with fear. With one strong, unexpected move she pushes Sophie up

against the wall. From the look on her face, Sophie knows not to make a sound. She grabs her wrists.

Sophie tries to escape, but this only angers the woman more. She tightens her grip on her wrists. The woman eases away enough to force her hand into Sophie's back pockets to check for belongings. She can't help but let out a whimper. She asks Sophie to hand over her purse, but she had left it at home.

The woman is now facing Sophie, her face contorts into a grimace. She spits at Sophie before head-butting her forehead and kicking her in the leg. Sophie is dizzy with pain. As she finally manages to open her eyes, she is relieved to see the woman has gone.

APPENDIX C. Consent form for Study 1

Participant Consent Form

BACKGROUND INFORMATION

Title: Reactions to a crime situation
Researchers: Hannah Ryder and Dr. Heather Flowe from the University of Leicester School of Psychology.
Purpose of data collection: PhD research

Details of Participation: You will be asked questions regarding your demographics, physical health and general lifestyle. The study will involve reading and listening to a short crime scenario, which may include physical and/or sexual assault. You will complete questionnaires about the scenarios and your handgrip strength will be measured. Additionally, heart rate and skin temperature readings will be taken throughout the study using non-invasive measures. You may be asked to provide a urine sample, which will be used only to assess the level of luteinising hormone present. You are allowed a break at any time during the study. You will participate for approximately 10 minutes.

CONSENT STATEMENT

1. I understand that my participation is voluntary and that I may withdraw from the research at any time up until 1st March 2014 without giving any reason. To withdraw, you will need to email me at hr98@le.ac.uk with your unique participant code.

2. I am aware of what my participation will involve.

3. My data are to be held confidentially and only Hannah Ryder and Heather Flowe will have access to them.

4. My data will be kept in a locked filing cabinet for a period of five years after the appearance of any associated publications. Any aggregate data (e.g. spreadsheets) will be kept in electronic form for up to four years after which time they will be deleted.

5. In accordance with the requirements of some scientific journals and organisations, my coded data, which will not include my name or any personally identifying information, may be shared with other competent researchers. My coded data may also be used in other related studies. My name and other identifying details will not be shared with anyone.

6. The overall findings may be submitted for publication in a scientific journal, or presented at scientific conferences.

7. This study will take approximately two months to complete.

8. I will be able to obtain general information about the results of this research by contacting the researcher (Hannah Ryder) after March 2014

I am giving my consent for data to be used for the outlined purposes of the present study
All questions that I have about the research have been satisfactorily answered.

I agree to participate.

Participant's signature: _____

Participant's name (please print): _____   Date: _____

Please note that this form will be kept separately from your data

APPENDIX D. Examples of the scenarios for Study 2

Rape

She sighs as she takes off her apron and shuts the coffee machine down. She hates being on the late shift and having to lock up, especially when her mum's away and can't pick her up. She fumbles to find the correct key. She hears the door lock shut and dreads her long walk home. It would take just as long for a taxi to get here though, in the middle of nowhere. If only there were more than two barely-working street lights.

She peers through the bar window to double-check all the lights are off, and jumps at the sight of a figure moving behind her in the reflection. She looks over her shoulder, but no-one is there. It's late and I'm tired, I must be imagining things, she thinks to herself. As she finally finds the correct key and hears the door lock shut, a chill sweeps through her body. She pulls her scarf up over her ears and begins the cold, long walk home.

Almost half-way, she thinks to herself. The air is so bitterly cold she can see her breath. She wraps her coat tightly around herself, regretting not wearing more layers. She can hear the quickening of her footsteps echoing in the desolate alleyway. She hates this alleyway; the graffiti always makes her feel uneasy. The sole streetlight flickers, ready to die out, and she makes a mental note to walk around the alleyway tomorrow night. Feeling anxious, she gets her phone out of her pocket to stop her unease, but the icy air has frozen her hands, causing her to drop the phone in the damp leaves. As she bends down to pick it up she sees a shadow not far behind. She's stopped, but the sound of footsteps hasn't.

The end of the alleyway is near. She begins typing in her friend's number but the battery on her phone dies out. The footsteps become louder.

Suddenly, someone grab her from behind. She tenses as she feels warm breath down her neck, wretching at the stench of stale beer and musty aftershave. With one strong move he pushes her up against the wall of the alleyway. He tells her she is sexy, and if she stays quiet he will make it quick.

He eases away just enough to force his hand down her knickers and she can't help but let out a whimper. He asks her to lie on the ground. He begins to unbutton his trousers and eagerly pulls hers down.

His every move is torture and she wills for it to be over. Tears stream down her face, but she has learnt by now not to make a sound. She feels his body shudder and he lets out a groan.

Male-perpetrated physical assault (MPA)

She hadn't meant to stay so late in the library. But the impatient cough coming from the librarian and the sight of the fading lights descending upon her signalled it was time to leave. Gathering her folders and books, she mumbles an apology and pushes her way through the library doors.

The cold, dark night greets her and sends a shiver through her body. Glancing around, her eyes strain through the darkness, hoping to find other fellow students. She realises with a feeling of dread that she is the only person around campus at this hour. Strange how unfamiliar and unsettling the university buildings seem at this time of night compared to the light of day. But it's only a ten-minute walk home.

As the last of the lights through the windows of the buildings are switched off, she finds herself engulfed by darkness. Quickening her pace, she scurries along knowing that in a few short minutes she will be on the busy main road alongside the university. Taking her mobile phone out of her pocket, she turns it on knowing that the light from the screen would help to guide her way. The phone casts a dim light on the ground.

She can hear footsteps in the distance behind her. Her heart races and she walks faster. All she has to do now is make it through the narrow passage of trees to the iron Gate that leads to the main road, about a hundred metres. It seems the footsteps are becoming more urgent. If she were to walk any faster she would be breaking into a run. The footsteps behind her, however, do break into a run. She sprints through the archway of trees, willing not to fall on the slippery floor below.

A forceful blow between her shoulder blades makes her fall to the ground, dropping her books. She tries to scream, but all she can manage is a whimper. A slight male figure towers over her, his rough hands grabbing her phone. As he leans over her she wretches at the repulsive mixture of beer, smoke and sweat.

He demands she hands over her handbag. A kick to her stomach stops her breath. She turns her head just in time to see his muddy boots crunch down on her face. She hears her nose crack before she feels it.

Female-perpetrated physical assault

She hated being the only sober one on a night out with her friends, but she had agreed to work the early shift the next day. She never could keep up with her friends anyway. With a regretful face, she says her goodbyes to her friends on the dance floor before exiting the club. Her mum had made her promise to take enough money so that she didn't have to walk home alone. But there are no taxis in the taxi rank. In fact, there's no-one around at all. Anyway, the crisp, cold air outside is a welcome change from the crowded sweatiness of the club. She won't tell her mum she walked alone, she will never find out.

It's a lot later than she had hoped. The whistling strong wind blows her blonde hair across her face. She regrets not bringing a coat out with her, and decides to take the short cut home through the park. She always avoided the park, the known hotspot for drugs. But tonight it seemed empty, so she began quickly making her way across. As she turns the corner, nearing the park exit she notices a group of girls sitting on a bench, drinking something from a large bottle. One of them looks up at her and her first instinct is to look away. She gets out her mobile phone and begins to write a text to her mum, telling her she'll be home soon.

She can't help but feel their eyes on her. She whips her head around to see a tall girl, probably in her mid-teens, walking briskly behind her. Her dark hair hangs limply around her pale face. She seems quite strong and athletic. She decides to smile politely at the girl and quickens her pace.

But the girl catches up with her. She detects the smell of spirits and cigarette smoke. She asks for change for the bus home, but she knows better than to get her purse out. Apologising, she tells her she has no change. The girl swears at her and calls her a liar. Before she has a chance to run, she is yanked down to the floor, causing her to drop her phone. As she reaches to pick it up, the young girl slams her foot into her cheekbone. She cries out at the pain and falls to the floor.

She tries to pull herself up to run away, but the big, dark haired girl holds her down. She feels a sharp blow deep into her stomach, and what appears to be a sharp heel in the back of her head.

Petralia and Gallup's sexual assault scenario

As she leaves the science building she realizes that it is much later than she thought and the campus is now deserted. It is a long walk out to her car. On this dark night, the dim glow of the outside lights seems to disappear before it reaches the ground. She remembers that the moon should be almost full but as she looks up to find the large silver globe her eyes are met with a blanket of cloudy darkness. ''No wonder it is so dark tonight,'' she thinks to herself as she begins the trek to her car.

It's late and she's tired so without thinking she takes the short cut through the pine trees. In the shadow of the trees, she must watch where she places her feet otherwise she may trip on the large tangled roots beneath her. She hears a noise, perhaps another footstep, but in the darkness she cannot discern what it is. A chilling gust of wind strikes and causes her to tighten her coat and quicken her step. She hears something else. What was that? Was it a noise or just the wind?

She doesn't like walking alone this late at night and is glad to have the darkness of the pine trees behind her. Now the parking lot is just ahead, all that she has to do is cross the deserted campus green. As the wind picks up she hears another noise and looks back. She sees the silhouette of a tall man emerging from the pine trees and the sight of him startles her. Again, she quickens her pace.

At the edge of the vacant parking lot she pauses and looks for her car. It is parked between two of the few remaining vehicles, a beat-up old pick-up truck and one of those family vans. Happy with the sight of her car she reaches into her coat pocket for her keys and finds that they are not there. They must be in her purse and as she begins to feel around for them in her large bag she notices that strange man again. This time he appears to be headed directly towards her. At her car she places her handbag on the hood and peers into it, but in the darkness nothing is visible. She now feels his eyes upon her and frantically searches for her

keys. Finally, her fingers make contact with her keys and she pulls them out of her purse. As she inserts the key into her car door she feels his cold hand on her shoulder . . .

Petralia and Gallup's control scenario

As she leaves the science building she realizes that it is much earlier than she thought and that at this time of day the campus is full of life. On this dazzling day, the brightness of the sun engulfs her as it beats down on the sidewalk beneath her feet. As she looks up at the cloudless sky the intensity of the sun makes her squint and she remembers that the weather forecasters had predicted a flawless day. ''For once the weatherman was right,'' she thinks to herself as she begins the trek to her car.

It is early and she is happy to be free on such a glorious day so she decides to take the long route through the pine trees. In the shadow of the trees, her eyes take a moment to adjust and she must watch where she places her feet; otherwise she may trip on the large tangled roots beneath her. She hears a noise and looks up to see two squirrels chasing each other. A cool sweet breeze whispers through this small forest and she savours the relief it brings from the intensity of this afternoon's heat.

She enjoys walking alone on this sunny afternoon and as she leaves the shelter of the pine trees the heat of the day surrounds her once again. Now the parking lot is just ahead and all that she has to do is cross the crowded campus green. Today there are many students out playing Frisbee and soaking up the summer sun. She slows her pace and savours being outdoors on a day like today. She sees the silhouette of a tall man emerge in front of her and then watches as its owner dives for a football. Again, she slows her pace to enjoy the moment.

At the edge of the full parking lot she pauses and looks for her car. Usually it would bother her to have to search for her vehicle, but on this splendid day she is happy to wander aimlessly through the sea of automobiles looking for her own. After a while she spots her car and reaches in her pocket for her keys. As she opens her car door she feels a blast of heat coming from the interior. She immediately rolls down the windows and slides back the sunroof. She starts her car, adjusts the stereo, and as she pulls out of the parking lot those nearby can hear her music blasting.

Participant Consent Form

BACKGROUND INFORMATION

Title: Reaction to crime situations
Researchers: Hannah Ryder and Dr. Heather Flowe from the University of Leicester School of Psychology.
Purpose of data collection: Postgraduate student research

Details of Participation: You will be asked questions regarding your physical health and general lifestyle. You will be asked to provide a urine sample, which will be used only to assess the level of luteinising hormone present. The study will involve reading five short crime scenarios, including physical and sexual assault, with breaks in between. You will complete questionnaires about the scenarios and your handgrip strength will be measured. You are allowed a break at any time during the study. You will participate for approximately 60 minutes.

CONSENT STATEMENT

1. I understand that my participation is voluntary and that I may withdraw from the research until September 1st 2013. To withdraw, you will need to email me at hr98@le.ac.uk with your unique participant code.
2. I am aware of what my participation will involve.
3. My data are to be held confidentially and only Hannah Ryder and Heather Flowe will have access to them.
4. My data will be kept in a locked filing cabinet for a period of five years after the appearance of any associated publications. Any aggregate data (e.g. spreadsheets) will be kept in electronic form for up to four years after which time they will be deleted.
5. In accordance with the requirements of some scientific journals and organisations, my coded data, which will not include my name or any personally identifying information, may be shared with other competent researchers. My coded data may also be used in other related studies. My name and other identifying details will not be shared with anyone.
6. The overall findings may be submitted for publication in a scientific journal, or presented at scientific conferences.
7. This study will take approximately 2 months to complete.
8. I will be able to obtain general information about the results of this research by contacting the researcher after June 2013.

I am giving my consent for data to be used for the outlined purposes of the present study
All questions that I have about the research have been satisfactorily answered.

I agree to participate.
Participant's signature: _____
Participant's name (please print): _____
Date: _____

If you would like to receive a summary of the results by e-mail, when this is available, please provide your email address: _____

Please note that this form will be kept separately from your data

APPENDIX F. Animal stimuli for Study 3 and Study 4 (from Flykt, 2006)

Dogs (neutral)

Sheep (neutral)
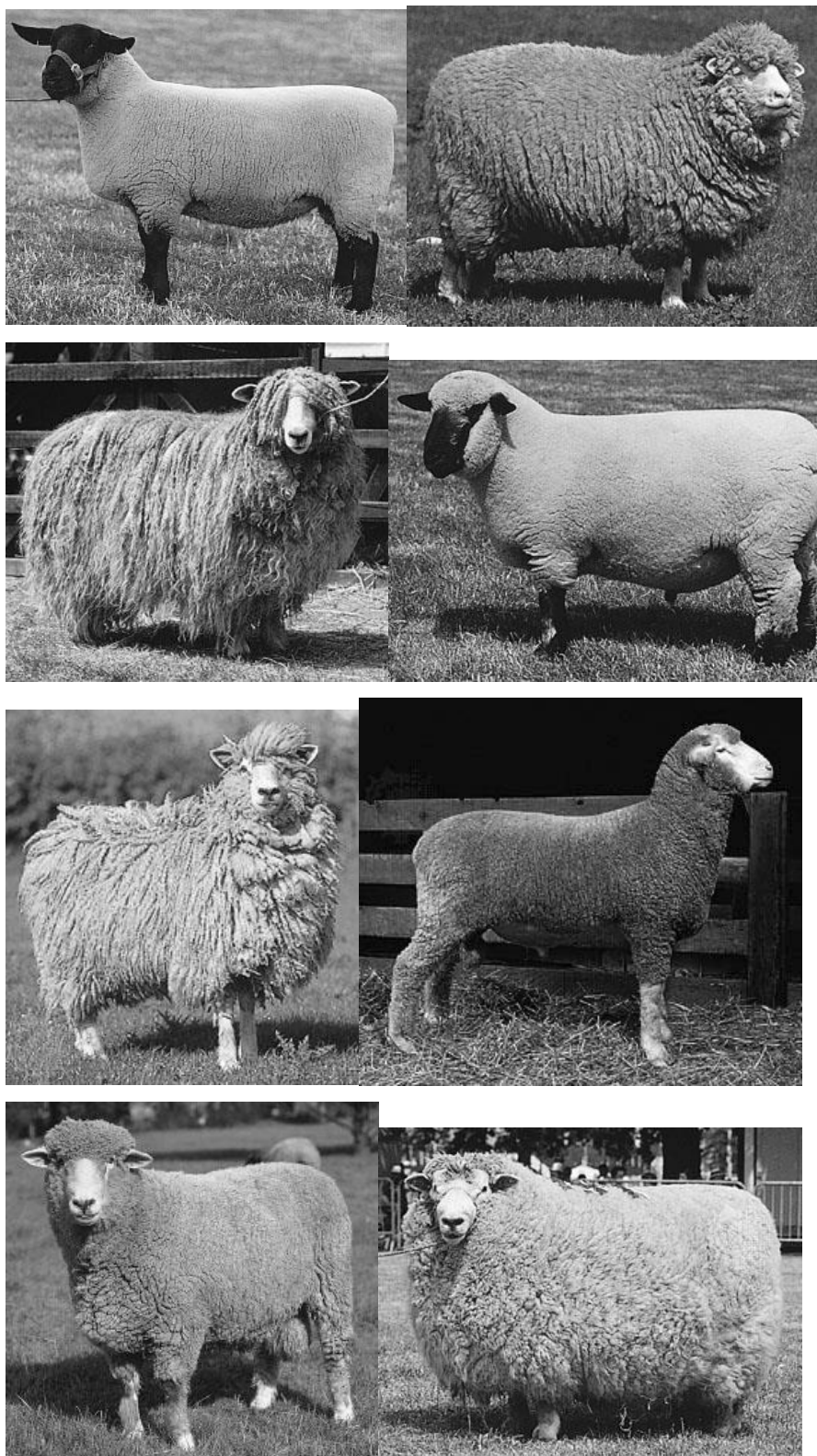
Snakes (fear-relevant)

Spiders (fear-relevant)
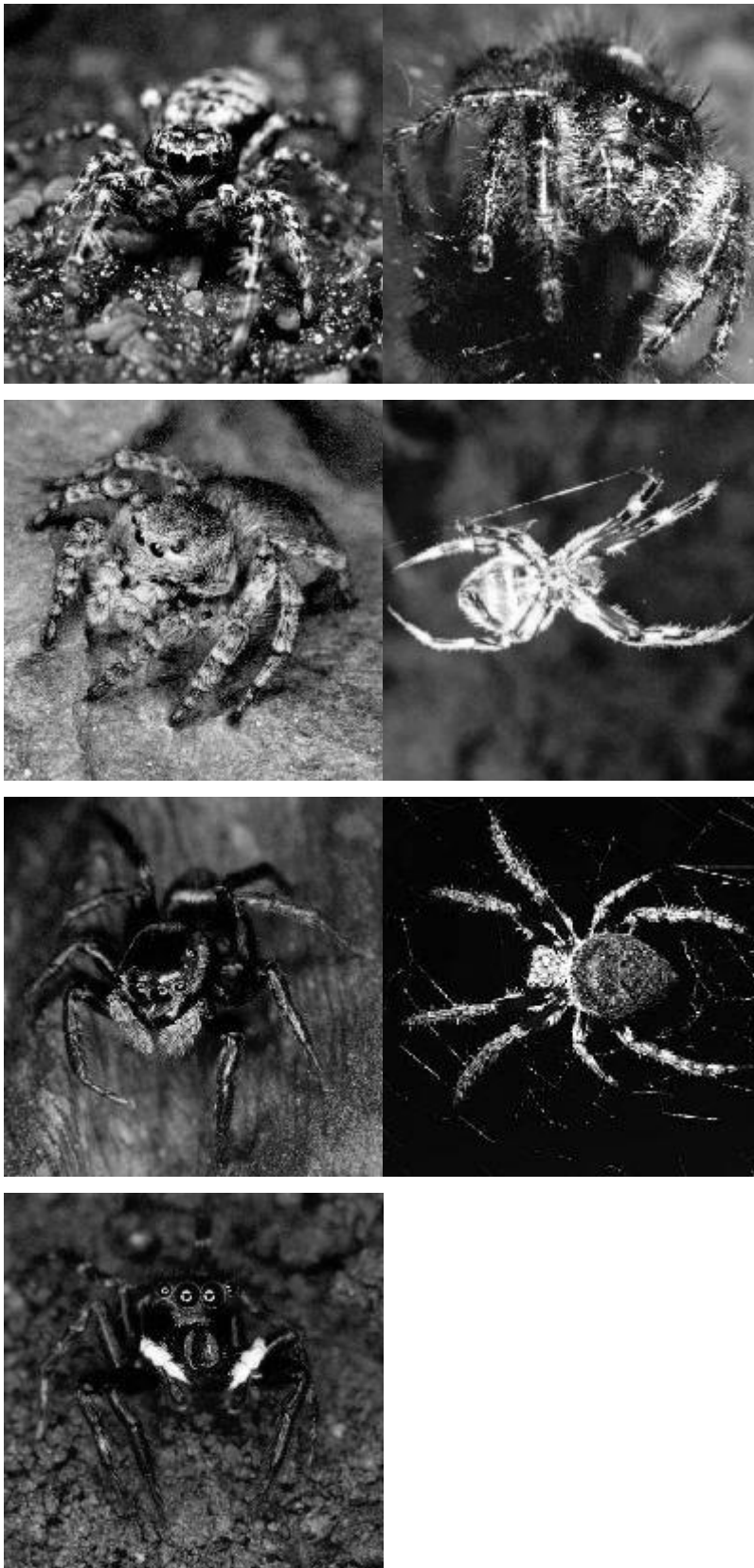
APPENDIX G. Face stimuli for study 3 and 4, from the Radboud database (Langner et al. 2010)

Angry males

Angry females

Neutral males
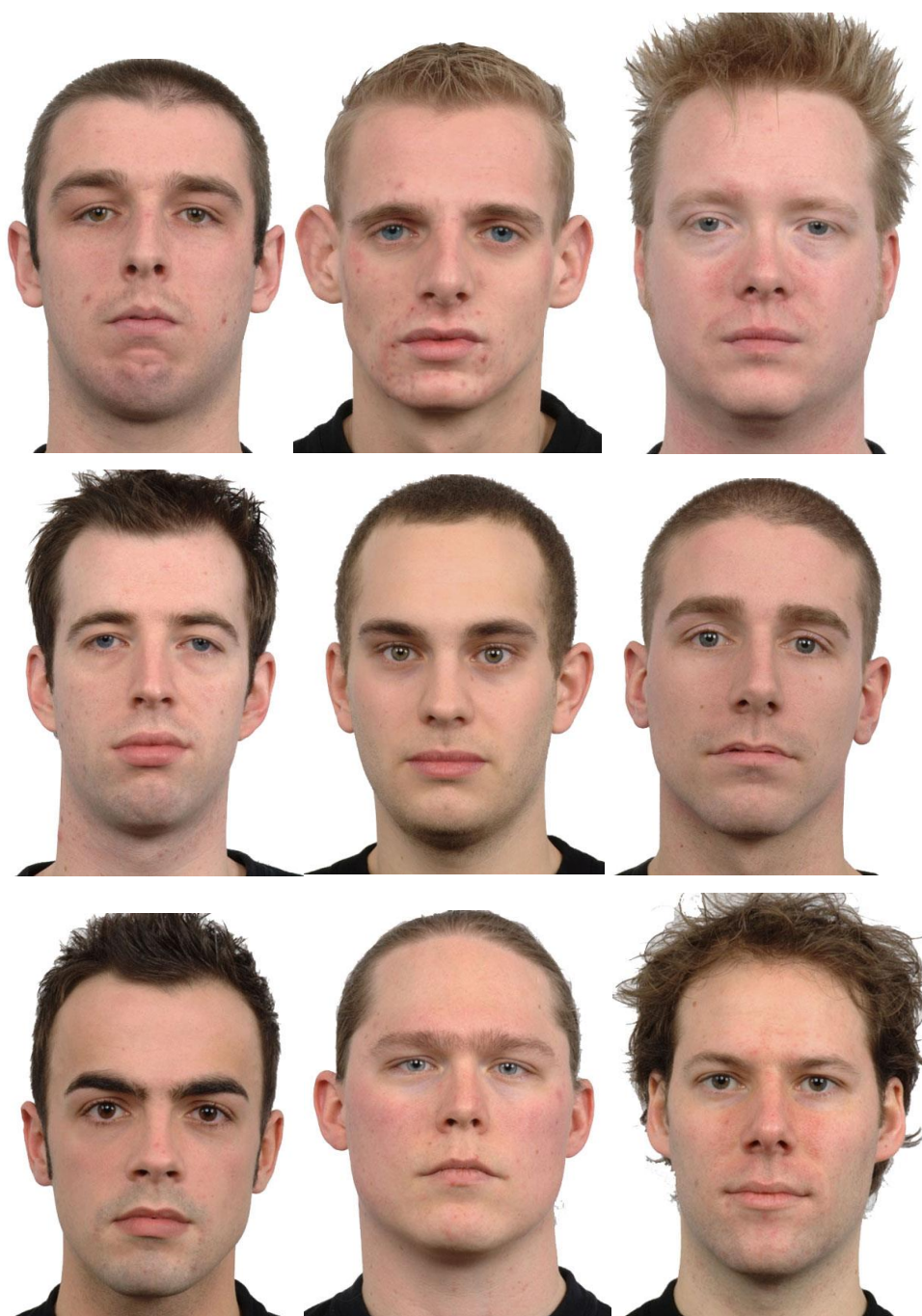
Neutral females

<u>**APPENDIX H. Consent form for Study 3**</u>

Participant Consent Form

BACKGROUND INFORMATION
Title: Behavioural perception/perception across time?
Researchers: Hannah Ryder and Dr. Heather Flowe from the University of Leicester School of Psychology.
Purpose of data collection: Postgraduate student research

Details of Participation: You will be asked questions regarding your physical health, general lifestyle and your fear of snakes and spiders. The study will involve seeing various stimuli including snakes, spiders, sheep and dogs, and faces varying in appearance appear on the screen for a short period of time. You will see a dot appear on the screen and your task is to determine as quickly as possible the position on the screen that the dot appeared. You are allowed a break at any time during the study. You may be asked to provide a urine sample, which will be used only to assess the level of luteinising hormone present. You will participate for approximately 30 minutes.

CONSENT STATEMENT

1.   I understand that my participation is voluntary and that I may withdraw from the research until May 1st 2014. To withdraw, you will need to email hr98@le.ac.uk with your unique participant code.
2.   I am aware of what my participation will involve.
3.   My data are to be held confidentially and only Hannah Ryder and Heather Flowe will have access.
4.   My data will be kept in a locked filing cabinet for a period of five years after the appearance of any associated publications. Any aggregate data (e.g. spreadsheets) will be kept in electronic form for up to four years after which time they will be deleted.
5.   In accordance with the requirements of some scientific journals and organisations, my coded data, which will not include my name or any personally identifying information, may be shared with other competent researchers. My coded data may also be used in other related studies. My name and other identifying details will not be shared with anyone.
6.   The overall findings may be submitted for publication in a scientific journal, or presented at scientific conferences.
7.   This study will take approximately 3 months to complete.
8.   I will be able to obtain general information about the results of this research by contacting the researcher after May 2014.

I am giving my consent for data to be used for the outlined purposes of the present study
All questions that I have about the research have been satisfactorily answered.

I agree to participate.
Participant's name (please print): _____
Participant's signature: _____   Date: _____

If you would like to receive a summary of the results by e-mail, when available, please provide your email address: _____

Please note that this form will be kept separately from your data

APPENDIX I. Consent form for Study 4

Participant Consent Form

BACKGROUND INFORMATION
Title: Assessing visual attention
Researchers: Ryder and Dr. Heather Flowe from the University of Leicester School of Psychology.
Purpose of data collection: Postgraduate student research
Details of Participation: The study will begin by repeating some of the questions you previously answered in the pre-screening questionnaire about your demographics and physical health. You will see two images appear on the screen one of which will be replaced by a dot. You will be asked to indicate which side of the screen the dot appeared on using keys 'A' and 'L' (referring to 'left' and 'right'). The stimuli will involve male and female faces, or various animals including snakes, spiders, sheep and dogs. Your eyes will be tracking during the experiment. There will be dedicated breaks within the study, but if you feel you need a break at any time please let the experimenter know. You may be asked to take a self-administered urine-based ovulation test, which will be used only to assess the level of luteinising hormone present. You will be compensated approximately £8-12 for your participation, or 5.25 credits (depending on conditions and time taken), and will participate for about 30-35 mins per testing session

CONSENT STATEMENT
1. I understand that my participation is voluntary and that I may withdraw from the research until June 1st 2015. To withdraw, you will need to email hr98@le.ac.uk with your unique participant code.

2. I am aware of what my participation will involve.

3. My data are to be held confidentially and only Hannah Ryder and Heather Flowe will have access.

4. My data will be kept in a locked filing cabinet for a period of five years after the appearance of any associated publications. Any aggregate data (e.g. spreadsheets) will be kept in electronic form for up to four years after which time they will be deleted.

5. In accordance with the requirements of some scientific journals and organisations, my coded data, which will not include my name or any personally identifying information, may be shared with other competent researchers. My coded data may also be used in other related studies. My name and other identifying details will not be shared with anyone.

6. The overall findings may be submitted for publication in a scientific journal, or presented at scientific conferences.

7. This study will take approximately 6 months to complete.

8. I will be able to obtain general information about the results of this research by contacting the researcher after June 2015.

I am giving my consent for data to be used for the outlined purposes of the present study
All questions that I have about the research have been satisfactorily answered.

I agree to participate.
Participant's name (please print): _____
Participant's signature: _____   Date: _____

If you would like to receive a summary of the results by e-mail, when available, please provide your email address: _____

Please note that this form will be kept separately from your data

APPENDIX J. Images relating to rape, robbery and consensual sex for Study 5

Rape

Robbery
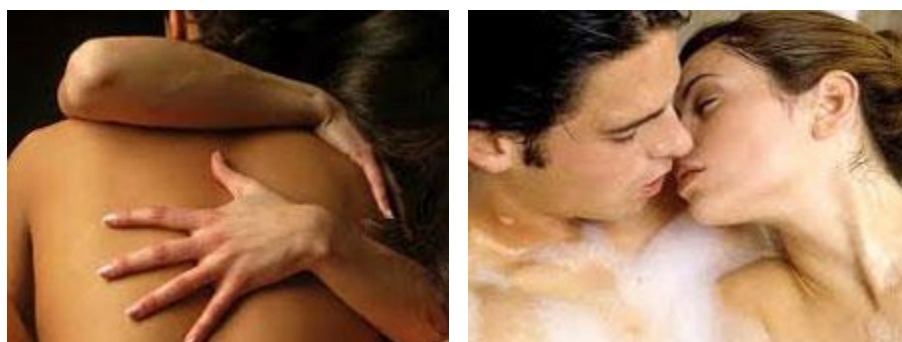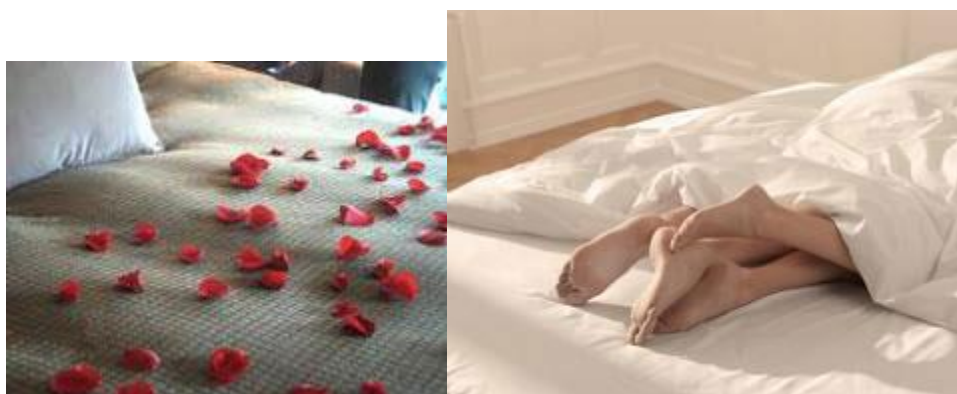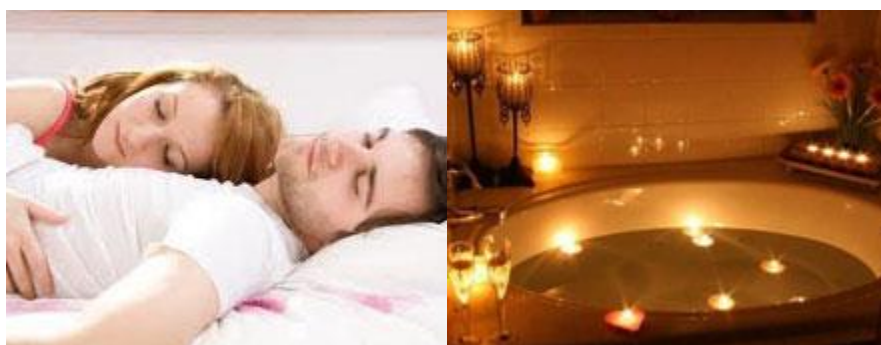
Consensual sex

APPENDIX K. Words relating to rape, robbery and consensual sex for Study 5

Rape	Robbery	Consensual Sex
alcohol	armed	affection
alley	bank	bath
alone	broken	bed
ashamed	cash	candle
assault	disguise	contact
beat	glove	couple
bruise	goods	cuddle
choke	grab	embrace
dark	gun	hold
follow	hood	intimate
force	mask	kiss
grip	money	love
pain	safe	petal
pressure	smash	romance
punch	snatch	rose
spiked	steal	sheets
stalk	thief	smile
strangle	vault	stroke
trap	weapon	touch

<u>**APPENDIX L. Consent form for Study 5**</u>

Participant Consent Form

BACKGROUND INFORMATION
Title: Categorisation of words and images
Researchers: Dr. Heather Flowe and Hannah Ryder from the School of Psychology.
Purpose of data collection: Postgraduate student research

Details of Participation:
You will start by answering some questions about your physical health and general lifestyle. These will include questions about your menstrual cycle (e.g. use of hormonal contraceptives, regularity of cycle, date of most recent onset of menses). The categorisation task involves viewing a series of words and images followed by a choice of two categories on screen. You will be asked to decide which category the word/image you have previously seen best fits into as quickly as you can. The images depict three categories, some of which are sensitive topics. These are consensual sex, non-consensual sex (rape) and robbery. You will be shown an image and word before the experiment starts so that you can gauge the severity of these images and fully understand the nature of the stimuli that you will be seeing. You may also be asked to take a urine-based ovulation test. This will be used only to test the level of luteinising hormone present. The study will take approximately 15 minutes to complete.

CONSENT STATEMENT

1. I understand that my participation is voluntary and that I may withdraw from the research at any time without giving any reason.
2. I am aware of what my participation will involve.
3. My data are to be held confidentially and only Hannah Ryder and Heather Flowe will have access to them.
4. My data will be kept in a locked filing cabinet for a period of at least five years after the appearance of any associated publications. Any aggregate data (e.g. spreadsheets) will be kept in electronic form for up to four years after which time they will be deleted.
5. In accordance with the requirements of some scientific journals and organisations, my coded data may be shared with other competent researchers. My coded data may also be used in other related studies. My name and other identifying details will not be shared with anyone.
6. The overall findings may be submitted for publication in a scientific journal, or presented at scientific conferences.
7. This study will take approximately 3 months to complete.
8. I will be able to obtain general information about the results of this research by giving the researcher my email address now.

I am giving my consent for data to be used for the outlined purposes of the present study
All questions that I have about the research have been satisfactorily answered.

I agree to participate.
Participant's signature: _____

Participant's name (please print): _____ Date: _____

If you would like to receive a summary of the results by e-mail when this is available, please provide your email address: _____

Please note that this form will be kept separately from your data

Appendix M. Example images of crime hotspots, safe spots and a shadowy male figure in the day and night time

<u>Crime hotspots in the day</u>
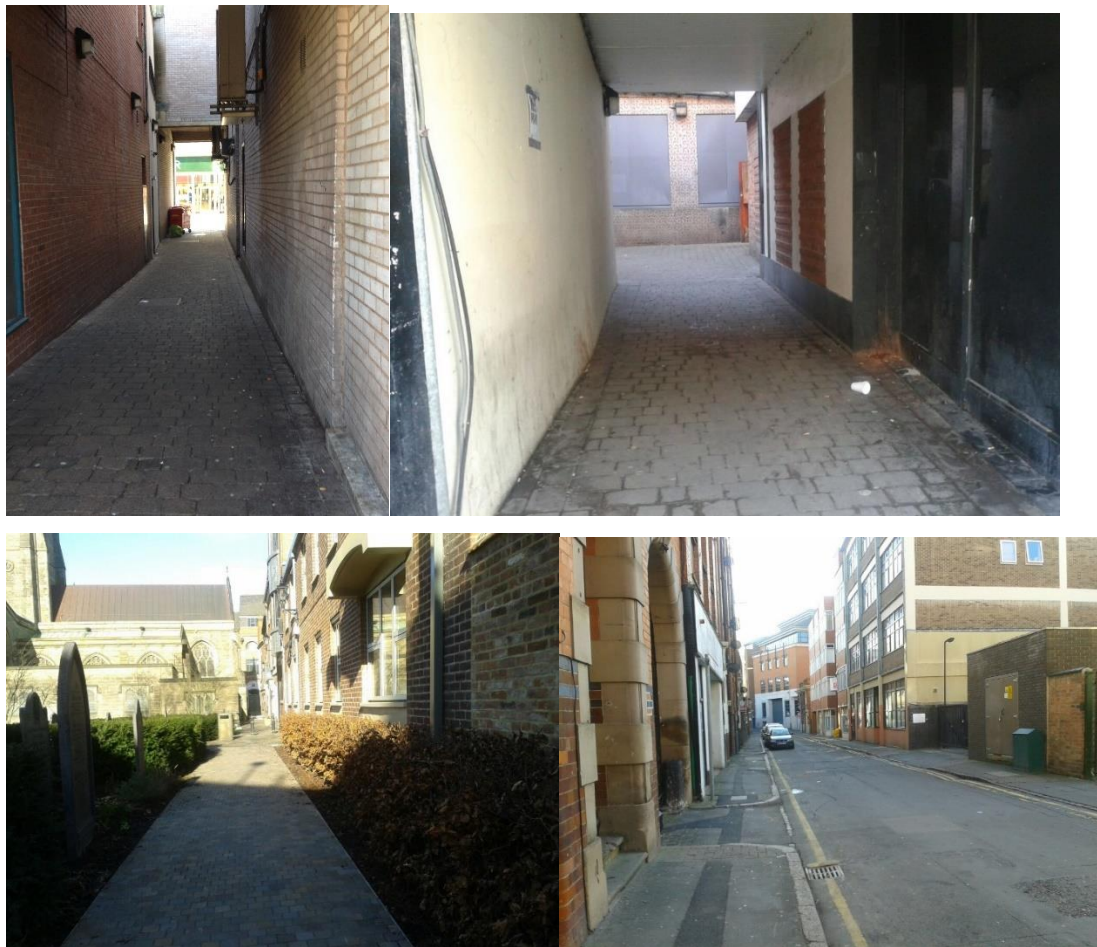
Crime hot spots at night

Safe spots in the day

Safe spots at night
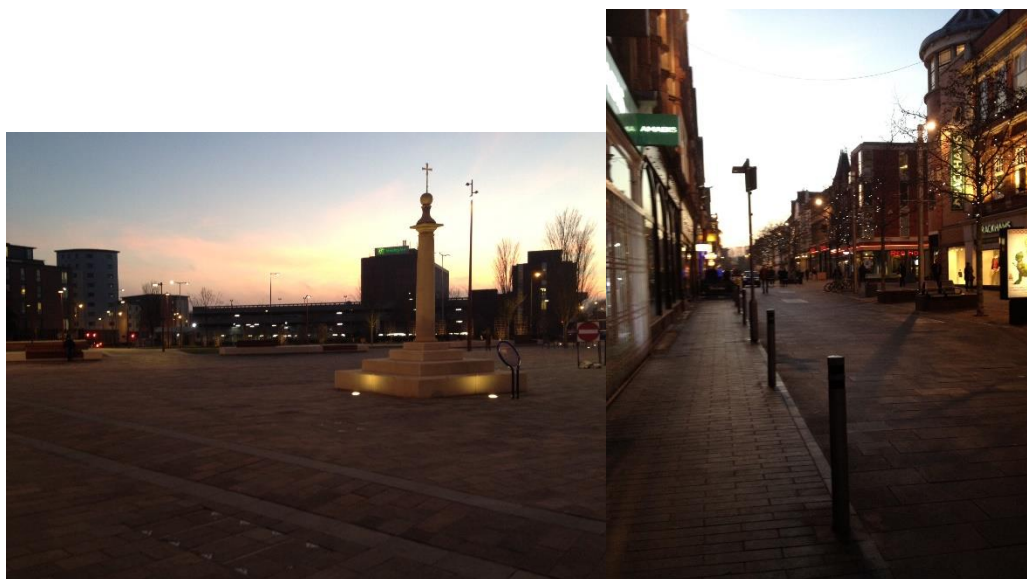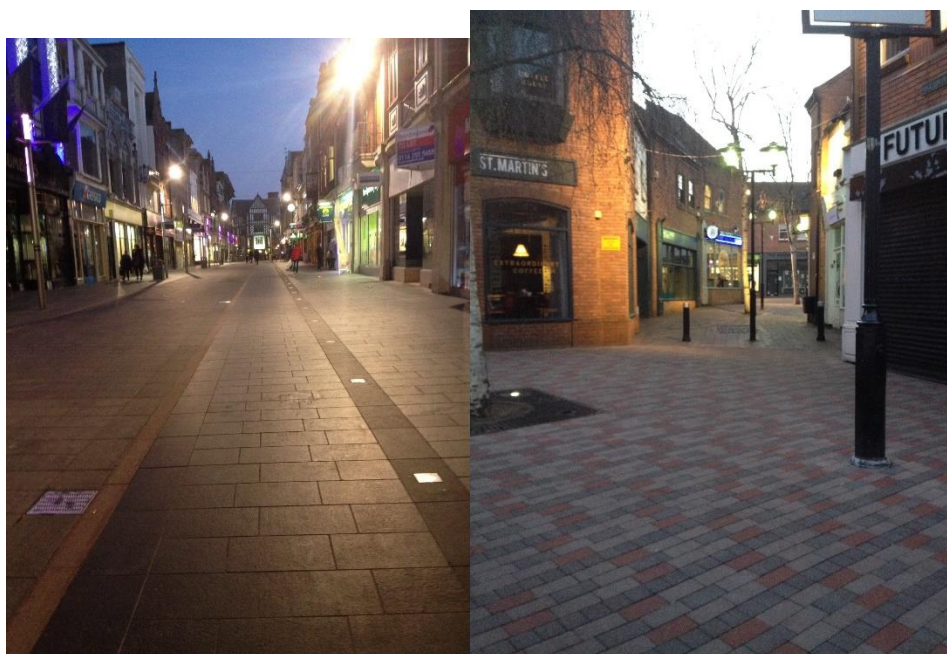
Shadowy male figure in the day
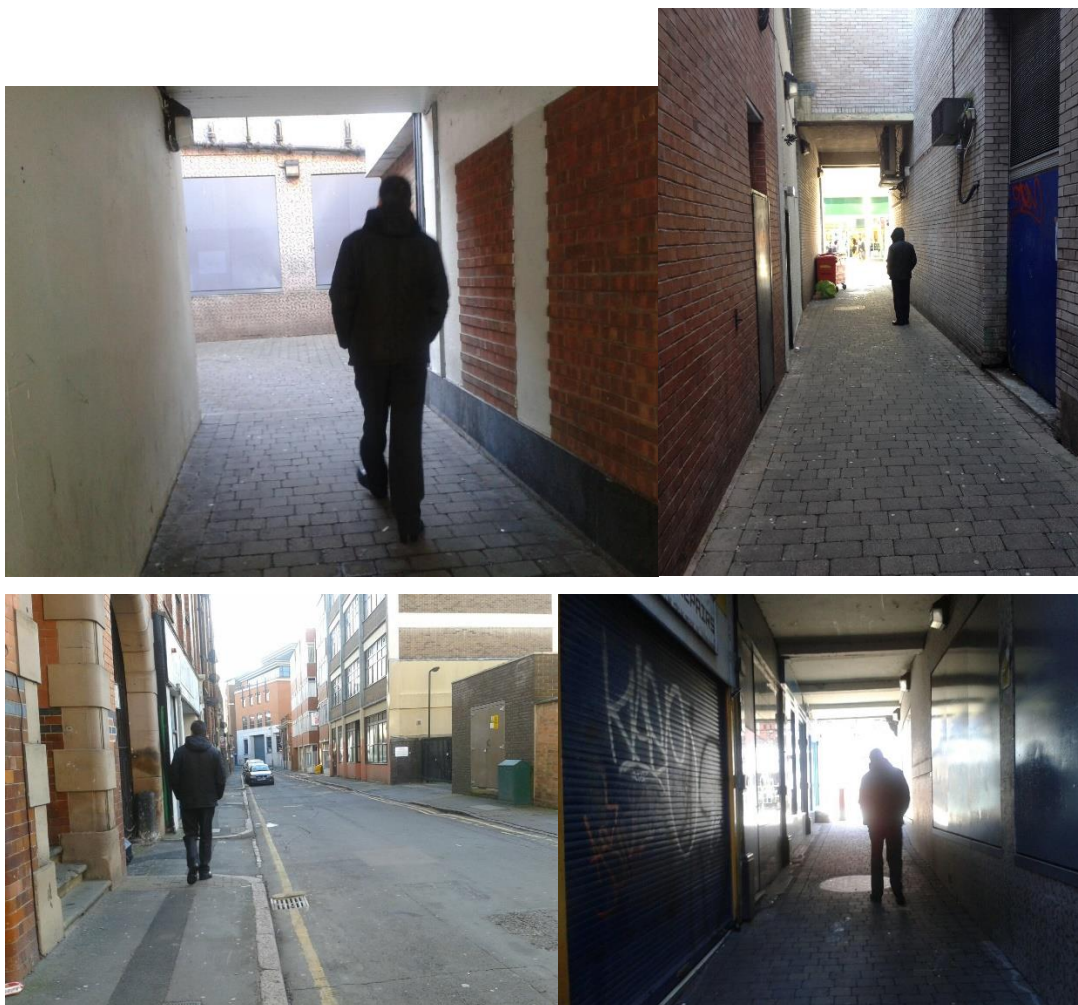
Shadowy male figure at night

Participant Consent Form

BACKGROUND INFORMATION
Title: Examining fear of crime
Researchers: Lovedeep Rai, Dr Heather Flowe and Hannah Ryder from the University of Leicester
Purpose of data collection: Postgraduate research
Details of Participation: Before taking part in this experiment, you will be asked to complete a short novel questionnaire regarding your menstrual cycle, which involves questions about your age, start date for your recent period, whether you have a regular 28-30 day cycle and if you have used hormonal contraceptives in the previous 6 months.

After you have completed this questionnaire you will be viewing an array of images followed by a scale. Please indicate your level of fear with regards to personal safety by moving the arrows LEFT or RIGHT. Further instructions will be on the screen. Once you have finished you will be required to complete TWO questionnaires.

Finally you will be required to complete a urine-based ovulation test- you may do this today after the experimental session in the ladies toilets, which are located onsite or you may take this test away with you. If you do decide to take this test away with you, you will need to take a picture of the test and send this to the experimenter today. If you feel uncomfortable with the material being shown to any of these measures during the study or you do not wish to take part, you may withdraw at any point. If you have any further questions please ask the experimenter now.

CONSENT STATEMENT
1. I understand that my participation is voluntary and that I may withdraw from the research at any time until August 2015 without giving any reason.
2. I am aware of what my participation will involve.
3. My data will be held confidentially and only Dr Heather Flowe, Lovedeep Rai and Hannah Ryder will have access to them.
4. My data will be kept in a locked filing cabinet for a period of at least five years after the appearance of any associated publications. Any aggregate data (e.g. spreadsheets) will be kept in electronic form for up to four years after which time they will be deleted.
5. In accordance with the requirements of some scientific journals and organisations, my coded data may be shared with other competent researchers. My coded data may also be used in other related studies. My name and other identifying details will not be shared with anyone.
6. The overall findings may be submitted for publication in a scientific journal, or presented at scientific conferences.
7. This study will take approximately 7 months to complete.
8. I will be able to obtain general information about the results of this research by giving the researcher my email address now.

I am giving my consent for data to be used for the outlined purposes of the present study
All questions that I have about the research have been satisfactorily answered.

I agree to participate.
Participant's signature: _____

Participant's name (please print): _____   Date: _____

If you would like to receive a summary of the results by e-mail when this is available, please provide your email address: _____

Please note that this form will be kept separately from your data

Participant Consent Form

BACKGROUND INFORMATION
Title: Examining feelings of personal safety through Leicester city centre
Researchers: Dr Heather Flowe, Dr John Maltby, Hannah Ryder, and project students Beth Shelton, Shaquille Stephen, Hannah Robinson, Emma Shillcock, Sam Palmer, Ellen Green and Olga Pacholec from the University of Leicester School of Psychology, and Dr Phil Jones from Birmingham University Geography department.
Purpose of data collection: Project student and postgraduate student research

Details of Participation: This project works with Leicestershire Police to understand people's feelings of personal safety through Leicester city centre. You will be asked questions that were previously answered in the pre-screening questionnaire (e.g. regarding your physical health and general lifestyle) for up-to-date information. Some may be classed as sensitive, such as use or hormonal contraceptives. During the study, you will be asked to walk around Leicester city centre with a researcher whilst carrying a smartphone. This route can take place between the hours of 9am-6pm, and therefore may occur during dusk. The route may include walking through alleyways, open spaces and housing estates. The smartphone will use the app 'MapLocal' to track your location using GPS technology, and also record your responses regarding your feelings of personal safety. During the route, which is approximately 3km long, you will be asked about your happiness with regards to your feelings of personal safety if you were walking alone. This will be indicated using a slider, with the options 'very happy' to 'very unhappy'. You will also be asked questions by the researcher along the route whilst your responses are audio recorded. The questions will be with regards to your perceptions of risk of crime at certain geographical locations in the city centre. Once you arrive back at the laboratory, you may be asked to take a self-administered urine based ovulation test. This is only used to test the level of luteinising hormone present. Afterwards, you will be given a full debrief. You may withdraw from the research at any point along the route without consequences. Your responses will be entirely anonymous and will not include any identifiable information. Thus, once the study is complete it will not be possible to withdraw your data as data.

CONSENT STATEMENT

1. I understand that my participation is voluntary and that I may withdraw from the research at any time until January 2015 without giving any reason.
2. I am aware of what my participation will involve.
3. My data will be held confidentially and only Heather Flowe, John Maltby, Phil Jones and Hannah Ryder will have access to them.
4. My data will be kept in a locked filing cabinet for a period of at least five years after the appearance of any associated publications. Any aggregate data (e.g. spreadsheets) will be kept in electronic form for up to four years after which time they will be deleted.
5. In accordance with the requirements of some scientific journals and organisations, my coded data may be shared with other competent researchers. My coded data may also be used in other related studies. My name and other identifying details will not be shared with anyone.

6. The overall findings may be submitted for publication in a scientific journal, or presented at scientific conferences.
7. This study will take approximately 6 months to complete.
8.   I will be able to obtain general information about the results of this research by giving the researcher my email address now.

I am giving my consent for data to be used for the outlined purposes of the present study
All questions that I have about the research have been satisfactorily answered.
I agree to participate.
Participant's signature: _____
Participant's name (please print): _____
Date: _____

If you would like to receive a summary of the results by e-mail when this is available, please provide your email address: _____

Please note that this form will be kept separately from your data

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