Abstract

A substantial body of research demonstrates the importance of sleep for emotional processing and learning, as well as the association between sleep problems and heightened anxiety. However, there is currently no research exploring the impact of sleepiness on vicariously learned fear responses. Experiment 1 (N = 38) first demonstrated no effect of trait or state sleepiness on children's (aged 7-11 years) subjective ratings of fear. Experiments 2 (N=42) and 3 (N=46) used an established vicarious learning paradigm to demonstrate that trait sleepiness facilitated vicariously acquired avoidance preferences for animals paired with fearful faces (fear-paired animals), while state sleepiness facilitated children's fear cognitions and attentional bias towards fear-paired animals. This study is the first to demonstrate the role of state and trait sleepiness on moderating vicarious fear learning in children.

Keywords: Vicarious Learning, Modelling, Sleepiness, Fear Development

Children's sleepiness facilitates the effect of vicarious learning on the development of fear

Insufficient sleep, or poor quality sleep, in children has a damaging effect on daytime functioning, particularly impacting detrimentally on academic performance, neuro-cognitive processing, socialisation, mental health, and emotional processing (e.g., Beebe, Rose, & Amin, 2010; Harrison & Horne, 2000; Hu, Stylos-Allan, & Walker, 2006; Jones & Harrison, 2001; Kopasz et al., 2010; Meijer, Habekothe, & van den Wittenboer, 2001; Sadeh, Gruber, & Raviv, 2003; Smith, 2001; Tempesta et al., 2010; Vriend et al., 2013; Walker, 2009). This negative impact is particularly troubling given that up to 40% of children report having sleep problems (Owens, 2005), although such rates are likely to be gross underestimations, and total sleep duration is continuing to decline over time (Matricciani, Olds, Blunden, Rigney, & Williams, 2012). The most common direct consequence of low sleep quality, sleep problems, disrupted sleep or reduced sleep duration is that of daytime sleepiness (e.g., Fallone, Owens, & Deane, 2002; Moore & Meltzer, 2008). Sleepiness may be described physiologically (the tendency to fall asleep determined by homeostatic and circadian influences), psychologically (how it feels to be sleepy) and/or behaviourally (what it looks like to be sleepy) (Fallone et al., 2002). It has also been described as a 'state-trait phenomenon', differentiating short-term 'state' sleepiness in the present moment, from general individual variation in 'trait' sleepiness' (Valck & Cluydts, 2003). Daytime sleepiness at least once a week is reported in approximately 45% of adolescents (Pagel, Forister, & Kwiatkowki, 2007) although comparable data in young children has not been established, to the authors' knowledge.

High order and complex cognitive functioning are significantly compromised in children receiving insufficient sleep or experiencing high levels of daytime sleepiness (e.g., Gillberg, Kecklund, & Åkerstedt, 1994; Harrison & Horne, 2000; Jones & Harrison, 2001; Randazzo, Schweitzer, & Walsh, 1998). Experimental research adopting sleep restriction

methods demonstrated that restricted sleep (of 6.5 hours per night across 5 nights) diminishes adolescents' learning, attention and arousal (Beebe et al., 2010), whilst extending children's sleep by just one hour over three consecutive nights significantly improved children's (aged 9-12) memory, attention and vigilance during a range of neurobehavioural functioning tasks (Sadeh et al., 2003). Similarly, an hour less sleep across four consecutive nights resulted in poorer short-term and long-term memory, poorer attention, and impaired emotion regulation functioning and measures of positive affect (Vriend et al., 2013). A large meta-analysis also demonstrated that executive functioning, school performance, and tasks using multiple-domain cognitive functioning, were significantly impaired for children (between 5-12 years of age) with shorter sleep duration (Astill, Van der Heijden, Van Ijzendoorn, Marinus, & Van Someren, 2012). On the contrary, the meta-analysis revealed that sleep duration was not related to attention or memory.

Sleep also plays an important role in regulating emotional information processing and emotional brain reactivity (Walker, 2009) with research demonstrating a relationship between poor sleep and symptoms of emotional dysregulation in children (e.g., Gregory, Rijsdijk, & Eley, 2006; Vriend et al., 2013). Sleep plays an important role in consolidating memories for emotionally arousing stimuli (Hu et al., 2006). Experimental studies using adult samples have shown that one night of sleep deprivation leads to dysfunctionality of the MPFC-amygdala circuitry and an increase in negative evaluation of emotional stimuli (Yoo, Gujar, Hu, Jolesz, & Walker, 2007) as well as pupillary responses indicating increased affective reactivity to negative information (Franzen, Buysse, Dahl, Thompson, & Siegle, 2009). Experimental research has also demonstrated that a night of sleep deprivation can lead to neutral stimuli being rated more negatively (e.g., Tempesta et al., 2010).

Lack of sleep has also been shown to adversely impact facial expression recognition. Experimental research with adults has demonstrated that a night of sleep deprivation results

in poorer recognition by females, particularly for threat-relevant emotions (e.g., anger), with less of an impairment found in males (van der Helm, Gujar, & Walker, 2010). Longer reaction times and poorer accuracy in emotion recognition has also been demonstrated in an experimental study with males who experienced 72-120 hours of sleep-deprivation (Pallesen et al., 2004). Using a correlational design with adolescents, Soffer-Dudek, Sadeh, Dahl and Rosenblat-Stein (2011) demonstrated that participants with more sleep problems (i.e., frequent night awakenings and poor sleep efficiency) showed more errors in information processing of emotional facial expressions, but similar findings were not evident in the processing of gender (rather than emotions).

Not only is there substantial evidence demonstrating the important role that sleep plays in emotional processing, learning and memory consolidation, but there is also a large body of literature demonstrating a strong comorbidity between sleep problems and anxiety difficulties (e.g. Alfano, Ginsburg, & Newman Kingery, 2007; Forbes et al., 2008; Hudson, Gradisar, Gamble, Schniering, & Rebelo, 2009). It has been suggested that 90% of children with a clinical anxiety disorder experience at least one sleep problem (Alfano et al., 2007; Chase & Pincus, 2011), and such sleep problems have been found to persist up to 18 months in 76% of children with anxiety disorders (Hansen, Skirbekk, Oerbeck, Wentzel-Larson, & Kristensen, 2013). While the relationship between sleep problems and anxiety is likely to be bidirectional, research has demonstrated that sleep problems in earlier childhood increase susceptibility to the development of anxiety (Leahy & Gradisar, 2012).

Despite research demonstrating that sleep problems and restricted sleep is associated with anxiety in children (Alfano et al., 2007; 2008; Chase & Pincus, 2011; Forbes et al., 2008; Hudson et al., 2009), emotion regulation in children (e.g., Gregory et al., 2006; Vriend et al., 2013), and emotion processing in adults (Franzen et al., 2009; Hu et al., 2006, Tempesta et al., 2010; Yoo et al., 2007), there is no research, to the authors' knowledge,

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regarding the relationship between sleep problems and fear acquisition, and in particular whether trait or state sleepiness adversely impacts the acquisition of *learned* fear responses. One indirect way in which individuals can learn fears is through vicarious (or 'observational') learning (Rachman, 1977). That is, fears may be acquired via a child observing another individual (i.e., a 'model') acting fearfully towards a particular stimulus (e.g., a model responding fearfully in the presence of a dog) or via observing another individual experiencing an aversive stimulus (e.g., a model being bitten by a dog). It is most likely that normative childhood fears acquired vicariously are learned via the first scenario; observing another individual acting fearfully in the presence of a particular stimulus.

There is a wealth of experimental evidence demonstrating changes in all three of Lang's (1968) independent fear response systems (verbal-cognitive, behavioural avoidance and physiological) following vicarious fear learning in children (e.g., Askew, Dunne, Ozdil, Reynolds, & Field, 2013; Askew & Field, 2007; Askew, Reynolds, Fielding-Smith, & Field, 2016; De Rosnay, Cooper, Tsigaras, & Murray, 2006; Dunne, Reynolds, & Askew, 2017; Gerull & Rapee, 2002; Reynolds, Field, & Askew, 2014, 2015, 2017). One popular theoretical framework for understanding learned fears, regardless of how they were initially acquired, is in terms of stimulus-stimulus associations (e.g., Davey, 2002; Field, 2006; Mineka & Zinbarg, 2006). That is, a conditioned stimulus (CS) is associated with an aversive unconditioned stimulus (US) and subsequently the CS elicits a conditioned response (CR). In the context of vicarious learning, the child associates a CS with a model's negative reaction (US) to that CS and subsequently the CS evokes a CR related to the US (see Reynolds et al., 2015). Alternatively, it may be that stimulus-response associations are formed during vicarious learning in that the (CS; e.g., an animal) is associated with an individual's fear-related CR to the stimulus (see Reynolds et al., 2015).

While it is important to establish whether sleepiness or sleep problems potentially impact fear responses acquired vicariously, there is currently no research considering this relationship. Research is required to experimentally test the interactions between state and/or trait sleepiness and vicarious learning in the development of fears. This is the main objective of the current research. The paper first reports a questionnaire study exploring the relationship between self-reported state and trait sleepiness and the child's perception of the intensity of threat conveyed in pictures of human faces. Children between the ages of 7 and 11 years were recruited because the methodology used in the subsequent studies in the current paper (experiments 2 and 3) have been successfully implemented with this age range in previous studies (e.g., Reynolds et al., 2014). Furthermore, normative fears of animals (which are used in experiments 2 and 3) are often related to animals around this age (e.g., Field & Davey, 2001). These two subsequent experiments sought to explore the relationship between sleepiness (state and trait) and fear responses (cognitive, behavioural and attentional) acquired vicariously.

Experiment 1

There is surprisingly little research exploring the effects of sleepiness on subjective responses to emotional stimuli (e.g., Soffer-Dudek et al., 2011; van der Helm et al., 2010). Tempesta and colleagues (2010) measured the impact of one night of sleep deprivation in university students on the emotional valence and arousal subjective ratings of pleasant visual stimuli (e.g., family, nature), neutral visual stimuli (e.g., neutral faces, household objects) and unpleasant visual stimuli (e.g., spiders, mutilations) taken from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005).

They demonstrated that sleep-deprived participants rated the neutral pictures in a more negative way compared to non-sleep-deprived participants, but both groups judged the

unpleasant pictures similarly. The current study therefore sought to explore whether children's self-reported levels of state and trait sleepiness are associated with subjective affective ratings of pictures of people with neutral expressions or fearful expressions.

Method

Participants

38 children (17 males and 21 females) with an age range of 7 to 11 years ($M = 111.98$ months, $SD = 11.51$) took part in the study. Based on Cohen's (1988) recommended power of 0.8, power calculations suggested that the sample size was adequate to detect a medium effect size ($r = .4$) for the correlation analyses. Parents of children were informed about the study via online forums, social media or personal contacts of the researchers, and were invited to include their child in the study. The procedure took place online via Qualtrics. Parents were requested to remain with their child whilst the child completed the survey, and had to provide consent for the child to participate. Ethical approval was obtained from the Psychology Department Research Ethics Committee at Middlesex University.

Materials

Child Sleepiness Scale (CSS-C): Children completed the CSS-C by hand. This questionnaire is based on the Pediatric Daytime Sleepiness Scale (PDSS, Drake et al., 2003); a validated child-rated measure of general symptoms of daytime sleepiness containing 8 items. The PDSS assesses children's 'trait sleepiness'; however the wording of the questions and the response scale were adapted to additionally measure sleepiness at the time of testing ('state sleepiness'). The adapted questionnaire has 16 items (8 items to measure 'trait sleepiness' and 8 to measure 'state sleepiness'). Children respond on a five point likert scale ranging from 'not at all' to 'very' for 10 items, 'yes' or 'no' for 4 items and 'yes, a lot more', 'yes, some more' and 'no' for the final two items. This adapted version has been piloted in

previous studies (e.g., Ewing & Cartwright-Hatton, in preparation; Ewing, Burnand & Cartwright-Hatton, in preparation), with test-retest reliability for the trait subscale found to be good ($r = .71$) and fair for the state sleepiness subscale ($r = .54$), suggesting reliable differentiation between trait and state sleepiness, with greater consistency in reporting of trait sleepiness symptoms across multiple timepoints, and greater variation in reports of state sleepiness (as would be expected for a state measure). Internal consistency was high, Cronbach's alpha = .88.

Face Stimuli: Children were presented with 10 portrait colour photographs of adult faces (five males and five females) expressing fear and 10 portrait colour photographs of adult faces (five males and five females) with neutral expressions, randomly selected from the 43 models in the NimStim Face Stimulus Set (Tottenham et al., 2009).

Fearfulness Visual Analogue Scale (VAS): Children were presented with a visual analogue scale depicting 'not at all fearful' (0) at one end of the line and 'very fearful' (100) at the other end. They were asked to indicate on the line how fearful they perceived the person in the picture to be.

Procedure

Once parental consent had been provided, the children (with the parent still present) first completed the CSS-C. They were then shown 20 faces (10 fearful and 10 neutral) and rated fear intensities for each face using the visual analogue scale. They were asked to respond as quickly and accurately as possible. The faces appeared in a randomised order and children worked through rating the faces at their own pace. Children were then provided with child-appropriate debriefing which was followed by a parental debrief.

Results

A rejection criterion of p < 0.05 was used for all analyses and effect sizes (r) are reported where interpretable and otherwise as partial eta-squared (η^2_p).

Correlational analyses were conducted between state and trait sleepiness and children's perceived fearfulness VAS score for the fearful and neutral faces. For the fearful faces, no significant correlations were present between state sleepiness ($M = 2.27$, $SD = 0.95$) and trait sleepiness ($M = 2.28$, $SD = 0.88$) and children's perceived fearfulness (state: $r = -.04$, $p = .83$; trait: $r = -.02$, $p = .89$). No significant correlations were also found between children's perceived fearfulness of the neutral faces and both state sleepiness ($r = .15$, $p = .37$) and trait sleepiness ($r = .19$, $p = .25$). Therefore, correlational analyses implied no relationship between state or trait sleepiness and perceived fearfulness for either fearful or neutral faces.

A 2 (gender: male vs female) × 2 (expression: fearful vs neutral) mixed measures analysis of covariance (ANCOVA) with trait and state sleepiness as covariates, and repeated measures on the second variable was conducted to explore the moderation of trait and state sleepiness on differences in perceived fearfulness between the two expressions (fearful or neutral) for males and females. Results revealed a significant main effect of expression, $F(1, 34) = 104.07$, $p = < .001$, $\eta^2_p = .75$ (95% CI [.002, .11]), demonstrating greater perceived fearfulness for the fearful faces ($M = 79.74$, $SD = 9.46$, 95% CI [76.63, 82.85]) compared to the neutral faces ($M = 11.32$, $SD = 11.37$, 95% CI [7.59, 15.06]). While the main effect of gender, $F(1, 34) = 0.37$, $p = .55$, $\eta^2_p = .022$ (95% CI [.00, .15]), was not significant, the face × gender interaction was significant; $F(1, 34) = 5.38$, $p = .03$, $\eta^2_p = .14$ (95% CI [.00, .34]). Simple effect analyses conducted on each expression separately indicated that for fearful expressions, males perceived the faces as significantly more fearful compared to females, $F(1, 34) = 9.04$, $p = .01$, $r = .45$ (males: $M = 82.44$, $SD = 5.90$, 95% CI [79.41, 85.47], females: $M = 77.56$, $SD = 11.24$ 95% CI [72.44, 82.67]), whereas for neutral expressions,

females perceived the faces as significantly more fearful compared to males, $F(1, 34) = 4.24$, $p = .047$, $r = .33$ (males: $M = 7.75$, $SD = 7.82$, 95% CI [3.73, 11.77]), females: $M = 14.21$, $SD = 13.07$, 95% CI [8.27, 20.16]). Interactions with sleepiness were nonsignificant (expression × state sleepiness: $F(1, 34) = 0.04$, $p = .85$, $\eta^2_p = .001$ (95% CI [.00, .05]) expression × trait sleepiness: $F(1, 34) = 0.54$, $p = .47$, $\eta^2_p = .02$ (95% CI [.00, .17]), demonstrating that neither state nor trait sleepiness moderated the perceived fearfulness of the fearful or neutral faces.

Experiment 2

Experiment 2 aims to provide initial evidence that state sleepiness or trait sleepiness facilitates vicarious fear learning using an established experimental paradigm whereby children are shown pictures of one novel animal alongside pictures of an adult expressing fear (fear-paired animal) and pictures of a second novel animal alone on the screen (Askew & Field, 2007; see Reynolds et al., 2014). Children's fear responses for the animals are then measured to explore whether observing an adult appearing fearful of a novel animal leads to greater fear responses. Experiment 1 demonstrated that neither trait nor state sleepiness were associated with children's perceived fear ratings for fearful or neutral faces. Despite this finding being based on a small correlational study, it provides some weighting to the assumption that if trait or state sleepiness moderates cognitive and behavioural responses following vicarious fear learning, this is unlikely to be down to mere perception of emotion. In Experiment 2, it was hypothesised that trait and state sleepiness would moderate the effects of vicarious learning on cognitive fear responses and avoidance preferences.

Method

Participants

Forty-two children (23 males and 19 females) with an age range of 8 to 10 years ($M = 110.07$ months, $SD = 8.62$) from two schools in North London, UK, took part in the study.

Of the 42 children, 35 were of a White ethnicity, three were of a Black African or Caribbean ethnicity, three were of a White Asian mix ethnicity and one was Chinese. To ensure inclusion, all children regardless of clinical characteristics were permitted to participate if their parents provided consent. However, parents were advised that children with anxious predispositions may prefer not to participate. Given that the study was based on opt-in consent, it was expected that if parents deemed their child to have a clinical condition that may result in them becoming distressed at all during the study, then parents would not provide consent for them to participate. Furthermore, as previous research (e.g., Reynolds et al., 2014) has found no impact of trait anxiety on fears acquired vicariously, it was deemed unnecessary to measure this.

Power calculations using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) suggested that the sample size was adequate for 80% power to detect a medium effect for the t-tests (dz = .5), repeated measures ANOVA (f = 0.3) and correlational analyses (r = .4). Written signed consent was initially sought from the Headteachers, and permission letters were then sent out to all parents (via the children) at least two weeks prior to the study. Consent was based on an opt-in procedure, so only children who returned parental consent forms were able to take part. All children took part between 9:00am and approximately 11:30am to prevent any time-of-day modulation of effects on cognitive performance (for example, see review by Schmidt, Collette, Cajochen & Peigneux, 2007).

Materials

Child Sleepiness Scale (CSS-C): Children completed the CSS-C by hand (described for Experiment 1).

Animal Stimuli: Ten colour photographs of two Australian marsupials, a quokka and cuscus, were used in the experiment. These animals have been successfully used in previous

research (e.g., Askew & Field, 2007; Reynolds et al., 2014, 2015) and were selected due to their novelty in the UK, reducing the potential that children would have pre-existing fear beliefs.

Face Stimuli: During the vicarious learning paradigm, 10 portrait photographs of faces (five males and five females) expressing fear were randomly selected from the 43 models in the NimStim Face Stimulus Set (Tottenham et al., 2009).

Nature Reserve Task (NRT). The NRT (Field & Storksen-Coulson, 2007) is a rectangular board measuring 620mm × 500mm designed to depict a nature reserve with green felt grass and pipe cleaner trees. The task was implemented before (prelearning) and after (postlearning) a vicarious learning paradigm to measure changes in avoidance preferences for the two animals. Pictures of the quokka and cuscus were simultaneously positioned at one end of the board by the researcher in counterbalanced conditions. Children were asked to imagine a small lego figure of a child was themselves and to place the figure on the NRT in relation to each animal. The researcher measured the distance (min = 0mm, max = 620mm) between the picture of each animal and the figure. The researcher was not aware which animal was the fear-paired animal and which was the unpaired animal.

Fear Beliefs Questionnaire (FBQ): The FBQ (Field & Lawson, 2003) was used prelearning and postlearning to measure changes in fear cognitions for the two animals. The questionnaire contained eight questions (four reverse-scored) for each animal, and included questions such as 'Do you think a QUOKKA/CUSCUS would hurt you?' Children respond on a five point likert scale ranging from 'No, not at all' to 'Yes, definitely'. Internal consistency was high prelearning for the quokka: Cronbach's α = .84 and postlearning: α = .91, as well as for the cuscus subscale prelearning: α = .86 and postlearning: α = .91.

Procedure

Children participated in the study during school hours on an individual basis, in a quiet room free from distractions. The computerised aspects of the experiment were written in E-Prime 2.0 by the first author, and run on a 39.6cm screen Laptop. Visual instructions were provided by 'Safari Sam'; a cartoon character designed to make the program child-friendly. Children first completed the CSS-C by hand to measure state and trait sleepiness, followed by the NRT to measure avoidance preferences for the two animals. They then completed the prelearning FBQ on the laptop to measure fear cognitions for the two animals.

On completion of these tasks, the children read the instructions 'You will now see a photograph slideshow. This will show you some photos of the quokka and cuscus and you will sometimes see a photo of someone's reaction to the animal.' They were then presented with the vicarious learning procedure (see Askew & Field, 2007). In a random order, children were presented with 10 trials consisting of a randomly selected picture of one of the animals (e.g., a quokka) presented beside a face expressing fear (fear-paired), interspersed with 10 trials consisting of a randomly chosen picture of the second animal (e.g., a cuscus) alone on the screen (unpaired). The animal first appeared on the screen for 1s, followed by the picture of the face with both pictures then remaining on the screen for a further 1s. Inter-trial intervals varied randomly between 2s and 4s. Counterbalancing was ensured by giving half the children the quokka as their fear-paired animal and half the children the cuscus as their fear-paired animal.

Children then completed the NRT and FBQ a second time (postlearning) to determine whether changes in avoidance preferences and fear cognitions were different for the fear-paired animal compared to the unpaired animal. Children were then fully debriefed; the nature of the study was explained to them, it was made clear that the people in the photographs had never seen the animals before, and all questions were answered. Children then read an information sheet (with help from the researcher) containing positive

information about the animals to redress any false impressions caused by the study, and completed an age-appropriate worksheet to reinforce this information. They also completed two dot-to-dot pictures (of a puppy and a smiling face) to promote a happy mood.

Results

Initial analyses

Paired-samples t-tests were conducted to confirm that there were no differences in prelearning responses for the quokka and cuscus (that is, responses for the animal itself: quokka or cuscus, as opposed to the animal based on pairing type: fear-paired or unpaired). At prelearning, no significant differences were found in children's behavioural preferences (NRT), $t(41) = 0.49$, $p = .63$, $r = .08$, or in children's cognitions (FBQ), $t(41) = 0.09$, $p = .93$, $r = .01$. Therefore, any changes in fear beliefs or avoidance preferences reported below can be reliably attributed to the association of the animal with the paired picture. Exploratory analyses demonstrated no influence of age or gender on vicariously acquired fear responses and therefore these variables were not included in subsequent analyses.

Avoidance preferences (NRT)

Figure 1 demonstrates the distance on the NRT (avoidance preferences) at prelearning and postlearning for each pairing type (fear-paired or unpaired), demonstrating greater self-reported avoidance of the fear-paired animal from prelearning to postlearning but a reduction in avoidance preferences for the unpaired animal. A 2 (time: prelearning vs postlearning) × 2 (pairing type: fear-paired vs unpaired) repeated measures analysis of variance (ANOVA) carried out on the mean distance on the NRT demonstrated a significant main effect of time, $F(1, 41) = 5.00$, $p = .03$, $\eta^2_p = .11$ (95% CI [.00, .30]), and a significant main effect of pairing type, $F(1, 41) = 23.58$, $p = <.001$, $\eta^2_p = .37$ (95% CI [.14, .54]). Crucially there was also a significant time × pairing type interaction, $F(1, 41) = 101.35$, $p < .001$, $\eta^2_p = .71$ (95% CI

[.54, .80]). Simple effect analyses conducted on each pairing type separately indicated a significant increase in avoidance preferences for the fear-paired animal from prelearning to postlearning, $F(1, 41) = 84.17$, $p < .001$, $r = .82$, and a significant decrease in avoidance preferences for the unpaired animal from prelearning to postlearning, $F(1, 41) = 25.63$, $p < .001$, $r = .62$. Simple effect analyses were also conducted on each time point (prelearning and postlearning), indicating that at prelearning, differences in avoidance preferences between the fear-paired and unpaired animals at prelearning was approaching significance, $F(1, 41) = 3.21$, $p = .08$, $r = .27$. Figure 1 demonstrates slightly higher avoidance preferences at prelearning for the unpaired animal compared to the fear-paired animal. Postlearning, for the fear-paired animal compared to the unpaired animal, avoidance preferences were significantly greater, $F(1, 41) = 154.91$, $p < .001$, $r = .89$. Therefore, children's avoidance preferences were significantly greater for the fear-paired animal compared to the unpaired animal following vicarious learning.

To explore the relationship between state and trait sleepiness and children's avoidance preferences prelearning and postlearning, correlational analyses were conducted. Prelearning, no significant correlations were present between state sleepiness ($M = 1.81$, $SD = 1.24$) and trait sleepiness ($M = 1.98$, $SD = 1.15$) and children's avoidance preferences for the fear-paired animal (state: $r = -.17$, $p = .29$; trait: $r = -.25$, $p = .11$) or the unpaired animal (state: $r = -.19$, $p = .23$; trait: $r = -.19$, $p = .23$). Postlearning, significant positive correlations were found between children's avoidance preferences for the fear-paired animal and both trait sleepiness ($r = .62$, $p < .001$) and state sleepiness ($r = .48$, $p < .001$), with greater distance from the fear-paired animal shown for children with greater sleepiness. No significant associations were found postlearning between children's avoidance preferences for the unpaired animal and trait sleepiness ($r = -.07$, $p = .64$) or state sleepiness ($r = -.04$, $p = .82$).

As state and trait sleepiness were treated as continuous variables (due to statistical issues in creating categories from continuous measures; see MacCallum, Zhang, Preacher, & Rucker, 2002), in order to explore whether state or trait sleepiness moderate the effect of vicarious learning on avoidance preferences, a hierarchical multilevel modelling approach was used. Time (prelearning and postlearning) and pairing type (fear-paired and unpaired) were treated as being nested within the child, and the outcome variable was the distance on the nature reserve task. For the fear-paired animal compared to the unpaired animal, the time × trait sleepiness interaction approached significance, $b = -100.22$, $SE = 57.97$, $t(117) = -1.73$, $p = .086$. However, the time × state sleepiness interaction was not significant, $b = -5.57$, $SE = 53.72$, $t(117) = -0.10$, $p = .92$.

Taken together, while greater state and trait sleepiness was associated with greater avoidance preferences for the fear-paired animal postlearning, but not for the unpaired animal, results demonstrate a trend towards trait sleepiness, but not state sleepiness, moderating the effect of vicarious learning on avoidance preferences.

Fear cognitions (FBQ)

Figure 2 shows the mean fear belief scores prelearning and postlearning for the fear-paired and unpaired animals. The graph demonstrates an increase in fear beliefs for the fear-paired animal following vicarious learning. However, for the unpaired animal, fear beliefs postlearning remained similar to the prelearning baseline. A 2 (time: prelearning vs postlearning) × 2 (pairing type: fear-paired vs unpaired) repeated measures ANOVA carried out on mean fear beliefs revealed a significant main effect of time, $F(1, 41) = 4.70$, $p = .04$, $\eta^2_p = .10$ (95% CI [.00, .29]), and a significant main effect of pairing type, $F(1, 41) = 4.82$, $p = .03$, $\eta^2_p = .11$ (95% CI [.00, .29]). Critically, there was a significant interaction between time and pairing type, $F(1, 41) = 10.29$, $p = .003$, $\eta^2_p = .20$ (95% CI [.03, .39]). Simple effect analyses revealed that children showed an increase in fear cognitions from prelearning to

postlearning for the fear-paired animal, $F(1, 41) = 18.77$, $p < .001$, $r = .56$, and no significant change in fear cognitions for the unpaired animal from prelearning to postlearning, $F(1, 41) = 0.04$, $p = .84$, $r = .03$. Simple effect analyses were also conducted on each time point (prelearning and postlearning), indicating no significant difference in fear beliefs between the fear-paired and unpaired animals at prelearning, $F(1, 41) = 0.008$, $p = .92$, $r = .01$, but fear beliefs were significantly greater for the fear-paired animal compared to the unpaired animal at postlearning, $F(1, 41) = 21.40$, $p < .001$, $r = .59$. Therefore, children demonstrated significantly greater fear cognitions for the fear-paired animal compared to the unpaired animal.

Correlational analyses were conducted between state and trait sleepiness and children's cognitive responses to the fear-paired and unpaired animals prelearning and postlearning. Like avoidance preferences, no significant correlations were found between state and trait sleepiness and children's prelearning cognitive responses to the fear-paired animal (state: $r = -.21$, $p = .18$; trait: $r = -.23$, $p = .15$) or the unpaired animal (state: $r = -.12$, $p = .45$; trait: $r = -.11$, $p = .48$). Postlearning, significant positive correlations were found between children's cognitive responses to the fear-paired animal and both trait sleepiness ($r = .50$, $p < .001$) and state sleepiness ($r = .53$, $p < .001$), with greater fear beliefs reported for children with greater sleepiness. No significant associations were found between children's cognitive responses to the unpaired animal and trait sleepiness ($r = .04$, $p = .83$) or state sleepiness ($r = -.002$, $p = .99$) following vicarious learning. Therefore, the relationship between children's fear cognitions and sleepiness was similar to that of the relationship between avoidance preferences and sleepiness; greater state and trait sleepiness was associated with greater fear cognitions for the fear-paired animal postlearning, but there was no relationship between sleepiness and fear cognitions for the unpaired animal.

As with avoidance preferences, a multilevel model was used to ascertain whether state or trait sleepiness moderate the effect of vicarious learning on fear beliefs. Time (prelearning and postlearning) and pairing type (fear-paired, unpaired) were treated as nested within the child, and the outcome variable was fear belief score. For the fear-paired animal compared to the unpaired animal, the time × state sleepiness interaction approached significance, $b = -0.48$, $SE = 0.25$, $t(117) = -1.90$, $p = .059$. However, the time × trait sleepiness interaction was not significant, $b = -0.06$, $SE = 0.27$, $t(117) = -0.22$, $p = .82$. Therefore, unlike for avoidance preferences, state sleepiness, but not trait sleepiness, moderated the impact of vicarious fear learning on fear beliefs.

Experiment 3

Experiment 2 demonstrated that state sleepiness, but not trait sleepiness, moderated the effect of vicarious learning on fear beliefs, whereas the reverse was true for avoidance preferences, with a trend for avoidance preferences to be moderated by trait sleepiness but not state sleepiness. Such findings suggest that different forms of sleepiness may interact with fear response systems in unique ways. One potential limitation of the fear response measures in experiment 2 is that they are subject to demand characteristics.

An alternative fear response for which children arguably have less conscious control is the acquisition of attentional biases; the tendency for adults and youths with anxiety to show hyper-attention towards, or faster detection of threat-related stimuli (e.g., Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Cisler & Koster, 2010; MacLeod, Mathews, & Tata, 1986; Mathews & MacLeod, 1985; see Field, Hadwin, & Lester, 2011 for a review). From a cognitive perspective, high-level information processing biases, such as attentional bias, may contribute to the maintenance and exacerbation of

anxiety by causing stimulus avoidance, and thus preventing the disconfirmation of fear beliefs and the extinction of fear (e.g., Field, 2006).

It has been argued that attentional biases follow a moderation model (e.g., see Field & Lester, 2010; Kindt & van den Hout, 2001). That is, all young children demonstrate attentional biases but individual cognitive, social, temperamental and emotional developmental factors diminish information processing biases over time. Indeed, research has demonstrated the presence of attentional biases towards threat in infants as young as 8 months old (e.g., Lobue & DeLoache, 2010) as well as pre-school age children (e.g., LoBue & DeLoache, 2008). Given that there is great variation in development, this results in different developmental trajectories for different children, whereby some children show a decrease in cognitive biases whereas such biases are maintained or exacerbated in others. Therefore, child development impacts cognitive biases by moderating the expression of an existing bias. One assumption emerging from a moderation model is that the magnitude of fear-related responses, such as attentional biases, should be mediated by the effect of learning experiences. That is, from this perspective, children who demonstrate greater fear after a learning event should show a greater attentional bias towards threat.

However, the literature on fear and attentional bias is considerably equivocal, and while a full review of this literature is beyond the scope of the current paper, it is important to note that not all research reveals attentional biases towards threat. Some studies (e.g., Fox, 2002) have demonstrated that attentional bias towards fearful faces is only found in individuals with high levels of trait anxiety compared to low-anxious participants, particularly when the faces are presented below the threshold for conscious perception. Furthermore, Morales, Perez-Edgar and Buss (2015) found that children aged six years who were characterised by dysregulated fear at the age of two demonstrated an attentional bias away from threat, whereas children aged six years who were not characterised by

dysregulated fear showed no significant attentional bias. Such attentional bias away from threat was also found by Stirling, Eley and Clark (2006) in children with greater levels of social anxiety, and by Salum and colleagues (2013) in children with a fear disorder. Therefore, the presence of an attentional bias in threat or fear-related situations may vary depending on the population studied and the affective state of participants (see Morales et al., 2015).

Recent research has revealed that fear-related vicarious learning is one route via which attentional biases towards novel animals can be learned (e.g., Reynolds et al., 2016). Reynolds et al. (2014) used a visual search task to demonstrate that fear-related vicarious learning creates an attentional bias for novel animals which is moderated by increases in fear beliefs during learning. Similarly, Reynolds and Askew (2019) used an alternative measure of attentional bias, the dot probe task, to demonstrate an attentional bias towards fear-related animals following vicarious learning.

Given the impact of sleep quality on cognitive processing and attention (e.g., Gobin, Banks, Fins, & Tartar, 2015), this study sought to determine whether higher levels of state or trait sleepiness would be related to greater attentional bias towards threat created by vicarious learning and whether this would be mediated by changes in fear beliefs.

Method

Participants

Forty-six children (26 males and 20 females) with an age range of 7 to 8 years ($M = 94.74$ months, $SD = 5.95$) from two schools in North London, UK took part in the study. To ensure there was no overlap of samples with Experiment 2, different schools were used in this study. However, recruitment procedures were the same as Experiment 2: the researchers first acquired consent from the headteacher, teachers then distributed information letters and

consent forms to the parents via the children, and parents returned opt-in consent forms to the teacher. These were collated and provided to the researchers prior to the study beginning. The majority of the children were of a White ethnicity (37), while six were of a Black African or Caribbean ethnicity, two were of a White Asian mix ethnicity and one chose not to state their ethnicity. As with the previous studies, power calculations suggested the sample size was adequate for 80% power to detect a medium effect size for the t-tests (dz = .5), correlational analyses (r = .4), repeated measures ANOVA (f = .3), and mediation analyses (f^2 = .2). Consent procedures were identical to Experiment 2 and parents were advised not to provide consent for children with anxious dispositions to take part. Like Experiment 2, all children took part in the morning (between approximately 9:00am and midday) to ensure cognitive performance was not impacted by length of wakefulness.

Materials

Materials and paradigms were identical to Experiment 2 with the exception that children were not required to complete the NRT and instead were asked to complete a dot probe task (measuring attentional bias) postlearning. The main reason children were asked to complete the FBQ but not the NRT was to ensure that the vicarious learning procedure was eliciting increases in fear responses. Fear beliefs as measured by the FBQ have now been consistently shown to increase following fear-related vicarious learning using this paradigm across a number of studies (e.g., Askew et al., 2013, 2016; Dunne et al., 2017; Reynolds et al., 2014, 2015, 2017). However, research using this paradigm to explore the acquisition of attentional bias is still relatively new (Reynolds & Askew, 2019; Reynolds et al., 2014, 2016). Therefore, the FBQ was used in order to ensure construct validity. Additionally, measuring fear responses using the FBQ enabled analyses to explore whether attentional bias towards threat is mediated by the change in fear beliefs.

Dot Probe Task: A pictorial dot probe task programmed in e-prime by the first author was used in order to measure attentional bias towards the animals (see also Reynolds et al., 2016). During this task, a fixation cross first appeared on the laptop screen for 500msec. The cross then disappeared and was immediately followed by a picture of the quokka beside a picture of the cuscus (346 × 444 pixels). The pictures of the animals remained on the screen for 500msec, then disappeared to immediately reveal a dot probe (either : or ..) 'behind' one of the animal pictures. Children were asked to press a Z on the keyboard of the laptop if the probe was ':' and an M on the keyboard if the probe was '..'. Children were told to respond as quickly and accurately as possible and the probe only disappeared from the screen once the child had responded. E-prime automatically recorded the response times and accuracy.

Before the trials with the quokka and cuscus commenced, children were given 16 practice trials with random neutral pictures taken from the British Picture Vocabulary Scale (e.g., a bus and a teapot). The trials with the quokka and cuscus then commenced. For these trials, two different pictures of a cuscus and quokka were each used, therefore making four different pairs of pictures. For each pair of pictures, whether the animal appeared on the left or right of the screen was counterbalanced, so each of the four picture pairs appeared twice over eight trials, with the position of the picture on the screen being reversed. Each of these combinations were repeated with each of the two probes (: and ..) appearing equally on the left or right of the screen over 32 individual trials. Each trial was presented twice, creating a total of 64 trials (see Field, 2006b; Reynolds & Askew, 2019; Reynolds et al., 2016).

Procedure

Children first completed the CSS-C by hand to measure sleepiness, followed by the prelearning FBQ on the laptop to measure fear cognitions for the two animals. They were then presented with the same vicarious learning procedure as Experiment 2, followed by the

postlearning FBQ. Children then completed the dot probe task (starting with the practice trials) and on completion of the task, were fully debriefed.

Results

Initial analyses

Paired-samples t-tests confirmed no differences in prelearning responses for the quokka and cuscus (as opposed to pairing type: fear-paired vs unpaired) in children's cognitive (FBQ) responses to each animal, $t(45) = -0.75$, $p = .46$, $r = .11$. Therefore any changes in fear beliefs are a result of the pairing type as opposed to the animal. As with Experiment 2, exploratory analyses demonstrated no influence of age or gender on vicariously acquired fear responses and therefore these variables were not included in subsequent analyses.

Fear cognitions (FBQ)

Figure 3 demonstrates the mean fear belief scores prelearning and postlearning for the fear-paired and unpaired animals, showing comparable results to experiment 2; fear beliefs for the fear-paired animal increased postlearning, however, fear beliefs for the unpaired animal decreased following vicarious learning. A 2 (time: prelearning vs postlearning) × 2 (pairing type: fear-paired vs unpaired) repeated measures ANOVA carried out on mean fear beliefs showed a main effect of time that approached significance, $F(1, 45) = 3.21$, $p = .08$, $\eta^2_p = .07$ (95% CI [.00, .23]), a significant main effect of pairing type, $F(1, 45) = 6.35$, $p = .02$, $\eta^2_p = .12$ (95% CI [.00, .30]) and crucially a time × pairing type interaction, $F(1, 45) = 13.18$, $p = .001$, $\eta^2_p = .23$ (95% CI [.05, .41]). Simple effect analyses revealed that children showed a significant increase in fear cognitions from prelearning to postlearning for the fear-paired animal, $F(1, 45) = 14.43$, $p < .001$, $r = .49$, but no change in fear cognitions for the unpaired animal from prelearning to postlearning, $F(1, 45) = 1.77$, $p = .19$, $r = .19$. Simple

effect analyses were also conducted on each time point (prelearning and postlearning), indicating no significant difference in fear beliefs between the fear-paired and unpaired animals at prelearning, $F(1, 41) = 0.13$, $p = .72$, $r = .06$, but fear beliefs were significantly greater for the fear-paired animal compared to the unpaired animal at postlearning, $F(1, 41) = 22.51$, $p = 2.54$, $r = .60$.

Although fear beliefs were primarily measured in this experiment to ensure the vicarious learning procedure was eliciting fear cognitions in children (construct validity), given the data was available it was decided to repeat the analysis exploring the effect of sleepiness on fear cognitions (as was already carried out in experiment 2). This was particularly useful because the findings of experiment 2 were approaching significance. Correlational analyses were therefore conducted between state and trait sleepiness and children's fear beliefs for the fear-paired and unpaired animals prelearning and postlearning. At prelearning, there was no significant correlation between trait sleepiness ($M = 1.94$, $SD = 1.22$) and prelearning cognitive responses to the fear-paired animal ($r = -.20$, $p = .90$) but a borderline significant negative correlation between state sleepiness ($M = 1.71$, $SD = 1.16$) and prelearning cognitive responses ($r = -.29$, $p = .05$). For the unpaired animal, no significant correlations were found between trait or state sleepiness and prelearning cognitive responses (state: $r = -.24$, $p = .12$; trait: $r = .20$, $p = .18$). Postlearning, a significant positive correlation was found between children's cognitive responses to the fear-paired animal and state sleepiness ($r = .49$, $p = .001$), but a negative correlation approached significance for children's cognitive responses to the fear-paired animal and trait sleepiness ($r = -.26$, $p = .08$). Therefore greater fear beliefs were reported for children with greater state sleepiness, but there was a trend towards greater fear beliefs being associated with lower trait sleepiness. For the unpaired animal, there was a significant correlation between children's cognitive responses and trait sleepiness ($r = .31$, $p = .04$) but no significant relationship with state

sleepiness ($r = -.22$, $p = .14$) postlearning. Therefore, the results of Experiment 2 were partially replicated in that greater state sleepiness was associated with greater fear cognitions for the fear-paired animal postlearning, however, there was no relationship between trait sleepiness and fear cognitions for the fear-paired animal.

As with experiment 2, a multilevel model was used to ascertain whether state or trait sleepiness moderated the effect of vicarious learning on fear beliefs. Time (prelearning, postlearning) and pairing type (fear-paired, unpaired) were treated as being nested within the child, and the outcome variable was fear belief score. For the fear-paired animal compared to the unpaired animal, the time × state sleepiness interaction was significant, $b = -0.55$, $SE = 0.17$, $t(129) = -3.18$, $p = .002$. However, the time × trait sleepiness interaction was not significant, $b = 0.09$, $SE = 0.16$, $t(129) = 0.55$, $p = .58$. Therefore, results complement Experiment 2 demonstrating that state sleepiness, but not trait sleepiness, moderated the effect of vicarious learning on fear beliefs.

Attentional Bias (Dot Probe Task)

All incorrect responses and reaction times less than 200ms were excluded from data analysis. Log transformed reaction times were used to adjust for possible outliers (see Ratcliff, 1993). Regardless of pairing type, the number of incorrect responses when the probe appeared behind the quokka was 4.79% and the number of incorrect responses when the probe appeared behind the cuscus was 5.23%. A paired samples t-tests demonstrated no significant effect of animal type, $t(45) = -0.60$, $p = .55$, $r = .09$. The number of incorrect responses was 5.64% when the probe was fear-paired and 4.39% when the probe was unpaired. A paired samples t-tests demonstrated the effect of pairing type to be approaching significance, $t(45) = 1.77$, $p = .08$, $r = .26$. Therefore, there was a trend towards children being more likely to incorrectly respond when the probe was fear-paired compared to unpaired.

Figure 4 shows the log transformed reaction times for the fear-paired and unpaired animals, demonstrating that children responded quicker to the probe when it appeared behind the fear-paired animal compared to the unpaired animal. A paired samples t-test revealed this difference to be significant, $t(45) = -4.36$, $p < .001$, $r = .54$. Therefore, children were significantly quicker at detecting the dot probe behind the fear-paired animal compared to the unpaired animal.

Two Hayes-style (2013) mediation analyses were used to explore whether higher trait sleepiness (analysis 1) or state sleepiness (analysis 2) leads to greater attentional bias, and furthermore whether this attentional bias is mediated by changes in fear beliefs. An attentional bias score was first calculated (log reaction times when the probe appeared behind the unpaired animal minus log reaction times when the probe appeared behind the fear-paired animal). This score provides an indication of how much faster children were at detecting fear-paired compared to unpaired animals (see Reynolds et al., 2014).

In the first mediation analysis, trait sleepiness did not significantly predict postlearning changes in fear beliefs for fear-paired animals, $b = -0.16$, $SE = 0.11$, $\beta = .21$, $t(44) = -1.45$, $p = .15$, but was approaching significance for postlearning attentional bias for fear-paired animals, $b = -0.01$, $SE = 0.01$, $\beta = -.26$, $t(43) = -1.81$, $p = .08$. Postlearning changes in fear beliefs also did not significantly predict attentional bias for fear-paired animals, $b = 0.01$, $SE = 0.01$, $\beta = -.19$, $t(43) = 1.33$, $p = .19$. In the second mediation analysis, state sleepiness did significantly predict postlearning changes in fear beliefs for fear-paired animals, $b = 0.54$, $SE = 0.09$, $\beta = -.67$, $t(44) = 6.04$, $p < .001$, as well as postlearning attentional bias for fear-paired animals, $b = 0.03$, $SE = 0.01$, $\beta = .86$, $t(43) = 5.67$, $p < .001$. Postlearning changes in fear beliefs also significantly predicted attentional bias for fear-paired animals, $b = -0.02$, $SE = 0.01$, $\beta = .33$, $t(43) = -2.16$, $p = .04$ (see Figure 5). Therefore, whilst there was no indication of any relationship between trait sleepiness and

attentional bias for fear-paired animals, there was a relationship between state sleepiness and attentional bias for fear-paired animals and this was mediated by changes in fear beliefs.

Discussion

The primary objective of the current research was to investigate how state and trait sleepiness are associated with children's fear responses acquired following vicarious fear learning. To begin with, the findings replicated previous research (e.g., Askew et al., 2013; Askew & Field, 2007; Askew et al., 2016; Dunne et al., 2017; Reynolds et al., 2017) demonstrating increases in fear beliefs and avoidance preferences for an animal paired with fearful faces compared to an unpaired animal. Additionally, following vicarious learning, children showed an attentional bias towards threat, with children being significantly faster in detecting the dot probe when it was displayed behind an animal previously paired with fearful faces (see also Reynolds & Askew, 2019; Reynolds et al., 2014, 2016). The novel contribution of the current findings is the exploration of the interaction between sleepiness (state and trait) and the vicarious learning pathway to fear acquisition. While significant relationships were found between sleepiness (both state and trait) and fear cognitions, avoidance preferences and attentional bias towards threat, the key findings were that: (1) trait sleepiness may facilitate children's avoidance preferences for novel animals paired with fearful faces, (2) state sleepiness facilitates children's fear cognitions about novel animals paired with fearful faces, and (3) state sleepiness facilitates children's attentional biases towards novel animals paired with fearful faces.

In order to identify whether any effects found between state or trait sleepiness and fear responses in experiments 2 and 3 were merely due to the impact of sleepiness on the perception of emotion, as opposed to the associative learning of fear via vicarious learning, the first experiment explored the effect of sleepiness on children's subjective responses to

fear and neutral facial expressions. The findings revealed no significant relationship between state or trait sleepiness and children's affective ratings of fearfulness for either the fearful or neutral faces. These results are inconsistent with adult literature demonstrating that sleep deprivation can impair recognition of moderately intense emotional expressions of sadness, happiness and anger (van der Helm et al., 2009). Additionally, van der Helm found that the effect of sleep deprivation on poor recognition was greater in females compared to males, whereas the current study indicated that males perceived the fearful faces as significantly more fearful than did females, whereas females perceived the neutral faces as significantly more fearful than did males. A likely explanation for these divergent findings is that the interaction of sleep and gender only affects the accuracy of emotion recognition, rather than subjective affective ratings of emotional facial expressions. Additionally, while sleep deprivation may impair recognition of sad, happy and angry emotions, van der Helm and colleagues did not explore recognition of fearful emotions. On the contrary, the current findings based on *sleepiness* data complement research showing that sleep deprivation had no effect on adults' evaluations of positive or negative stimuli (Tempesta et al., 2010). However, Tempesta et al. (2010) also found that sleep deprived adults perceived neutral pictures as more negative than non-sleep deprived adults, which was not found in the current study. It is possible that perceptions of ambiguous neutral stimuli are influenced by sleep deprivation, but not by everyday state or trait sleepiness as measured in the current study. It is also possible that the effect found by Tempesta and colleagues is specific to adult rather than child samples. Furthermore, the previous research using adult samples generally sleep-deprived participants before the assessment, whereas the current studies using child samples had no sleep-deprivation manipulation. In addition, the current studies used clear neutral and fearful facial expressions. It is possible that these unambiguous faces may not be sensitive enough to reveal sleep-related differences in emotion perception as was the case in experiment 1. Using

morphed faces with different intensities of fearfulness to explore interpretation of ambiguous facial expressions as a function of sleepiness may have yielded different results. However, different intensities were not appropriate for experiment 1 as the stimuli were required to match those used in experiments 2 and 3.

Experiments 2 and 3 implemented an established vicarious learning paradigm (see Askew et al., 2013; Askew & Field, 2007; Askew et al., 2016; Dunne et al., 2017; Reynolds et al., 2014) to explore the effects of state and trait sleepiness on vicariously acquired fear responses, in terms of avoidance preferences, fear cognitions, and attentional bias towards threat. Findings revealed greater levels of both trait and state sleepiness were associated with increases in avoidance preferences and fear cognitions for animals paired with fearful faces, as well as a greater attentional bias towards this fear-paired animal. More importantly, analyses demonstrated that state sleepiness was associated with increases in fear cognitions for the animal paired with fearful faces. While this finding approached significance in experiment 2, the robust finding in experiment 3 contributes to the likelihood that the findings in experiment 2 were due to a lack of power to detect a small effect size. Indeed, small sample sizes are a limitation of the current studies. However, power calculations suggested the sample size was adequate for 80% power to detect a medium effect size. Additionally, state sleepiness facilitated attentional bias towards the fear-paired animal; an effect that was further mediated by changes in fear beliefs. On the other hand, the moderating effect of trait sleepiness on the effect of vicarious learning on avoidance preferences for the animal paired with fear faces approached significance. As with fear beliefs in experiment 2, the marginal significance is likely due to a lack of power to detect a small effect size and this result requires further exploration. Trait sleepiness did not have any moderating effect on other fear responses acquired vicariously.

State and trait sleepiness therefore appear to have differential effects on Lang's (1968) independent fear response systems (verbal-cognitive and behavioural avoidance). One possible explanation is that trait sleepiness, rather than state sleepiness, may have a greater influence on motivation and subsequently on the performance aspects of vicariously acquired responses. For instance, negative associations have been found between trait daytime sleepiness and learning motivation (including refusal to work) amongst adolescents with evening-chronotypes, indicating that greater trait sleepiness may be associated with lower performance motivation (Roeser, Schlarb, & Kübler, 2013). This could explain why trait sleepiness interacted with avoidance preferences towards threat, but not cognitive processes.

The findings of the current experiments are in line with research that explores the impact of sleep restriction on later emotional responses. For instance, sleep restriction has been associated with more negative emotional responses in infants towards neutral and negative picture stimuli (Berger, Miller, Seifer, Cares, & Lebourgeois, 2012). Previous research has identified the important role of sleep in learning, emotional processing, and cognitive functioning (e.g. Beebe et al., 2010; Kopasz et al., 2010; Randazzo et al., 1998; Vriend et al., 2013), however this is the first study to establish that everyday sleepiness can negatively impact avoidance preferences, fear cognitions and attentional bias towards threat following a negative vicarious learning event. An additional strength of the study is that it differentiates state and trait sleepiness, rather than combining them into one phenomenon. While the importance of the sleepiness findings should not be underestimated, it is worth acknowledging that the sleepiness measure used in the current studies is a modified and simple self-report questionnaire. Using a wider variety of measures of sleep, for example, objectively measuring sleep quality and quantity with actigraphs, the use of frequent sleep diaries, and gaining an insight into the child's sleeping environment, would provide a more extensive understanding of the role of sleepiness and/or sleep problems in the vicarious

acquisition of fears. In addition to this, further research is required to infer causality with regards to the role of sleep in subsequent fear learning. The current study is limited by its correlational design. Not only does this mean that causality cannot be determined, but also sleepiness associated with post-learning measures, but not pre-learning measures, may be explained by a simple order effect. Future studies would benefit from using randomised experimental designs. Such studies should also take into account other factors, such as physical activity and medication, that may impact sleepiness. In the current studies, children participated in the morning only, to minimise the impact of daytime sleepiness increasing through the course of the day. Despite children only taking part in the morning, a minority of the children (five in Experiment 1 and six in Experiment 2) took part after breaktime. Given that physical activity may impact sleepiness (e.g., Leproult, van Reeth, Byrne, Sturis, & van Cauter, 1997), future research should consider the influence of physical assertion prior to the study taking place.

Crucially, the findings have important implications for understanding the impact of sleepiness on vicarious learning of fears in children. While the vicarious pathway to fear learning is well established, it is important to understand factors that may augment fear learning. The studies presented here focused on normative daytime sleepiness rather than using a sample of children with clinically significant sleep problems. This may be considered a strength of the experiments given that it provides an understanding of interactions between sleepiness and fear learning in typically developing children, but it also means that inferring clinical implications should be done so with caution. Furthermore, for ethical reasons, only mild levels of fear responses are elicited using this experimental paradigm, as opposed to phobic levels of fear. Still, this knowledge is important in identifying children at greater risk of developing fears, as well as in advancing development of effective preventative or treatment interventions.

In summary, the current study is the first to consider the impact of state and trait sleepiness on vicarious fear learning in the development of fears. Results across the experiments suggest that there is a relationship between sleepiness and vicariously acquired fear responses. Findings revealed significant relationships between sleepiness (both state and trait) and fear cognitions, avoidance preferences and attentional bias towards threat. Additionally, it was demonstrated that state sleepiness facilitates vicariously acquired fear cognitions and attentional bias, while trait sleepiness may facilitate children's vicariously acquired avoidance preferences.

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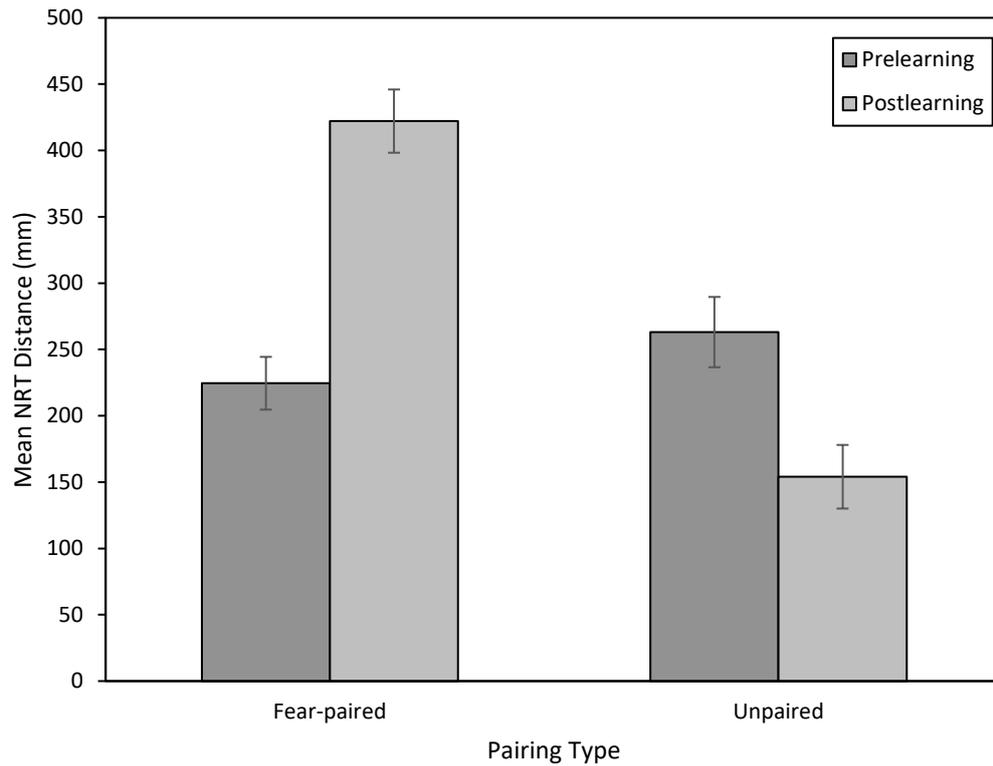
Figure 1: Mean distance on the NRT (avoidance preferences) for each animal (fear-paired and unpaired) prelearning and postlearning in experiment 2 (errors bars = SEM)
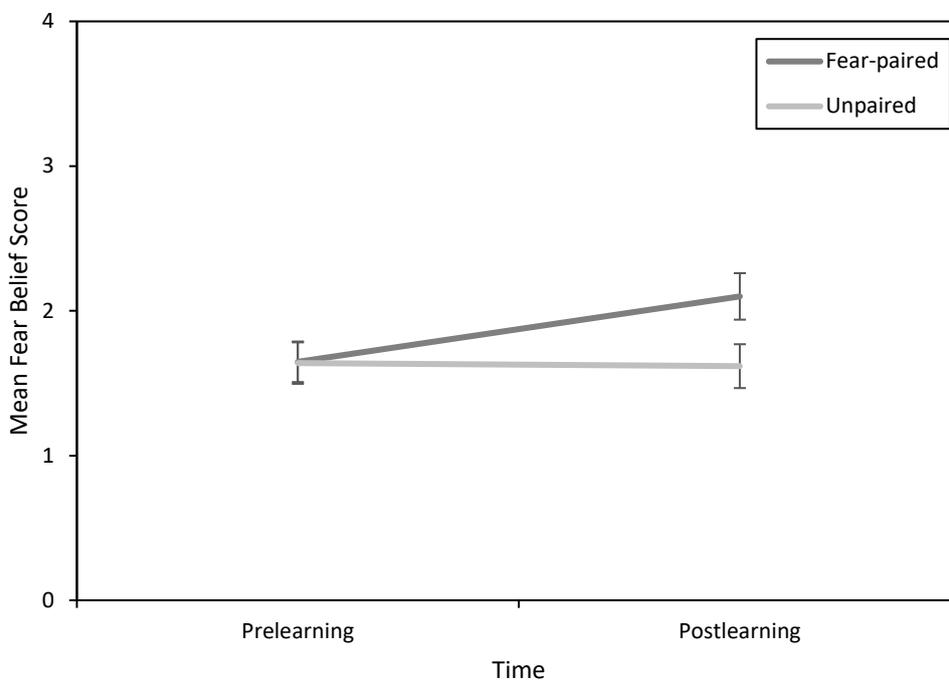

Figure 2: Mean fear belief scores for each animal (fear-paired and unpaired) prelearning and postlearning in experiment 2 (errors bars = SEM)
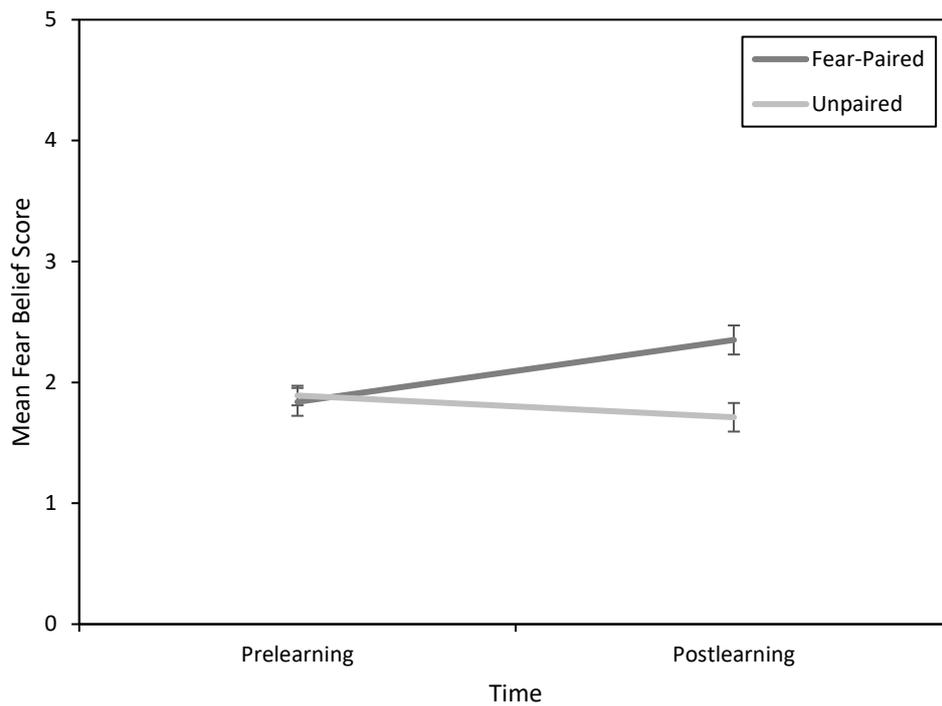
Figure 3: Mean fear belief scores for each animal (fear-paired and unpaired) prelearning and postlearning in experiment 3 (errors bars = SEM)
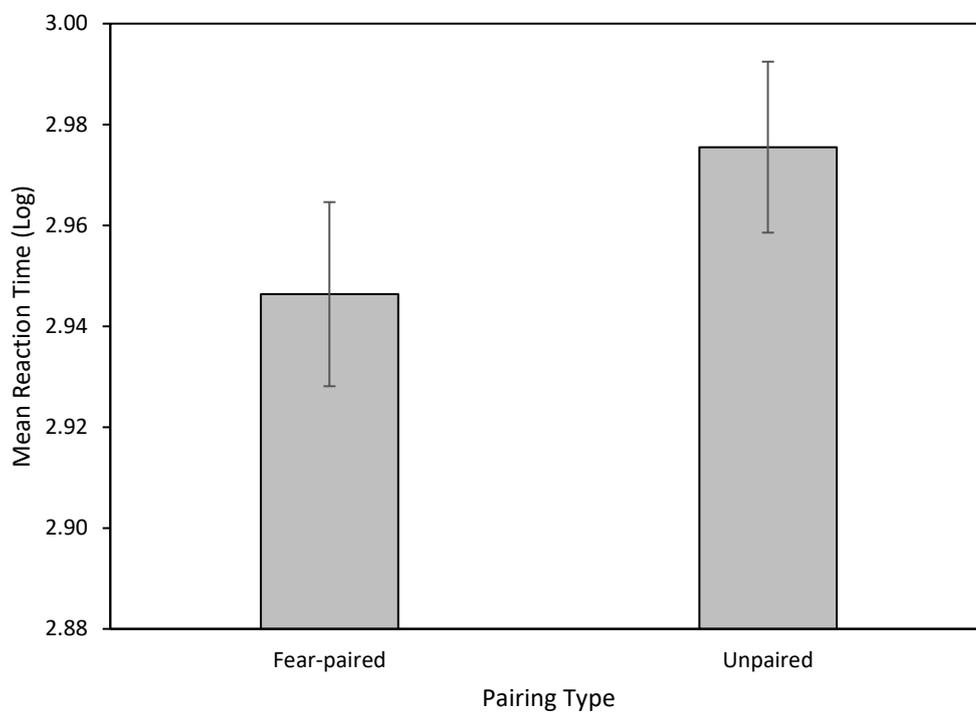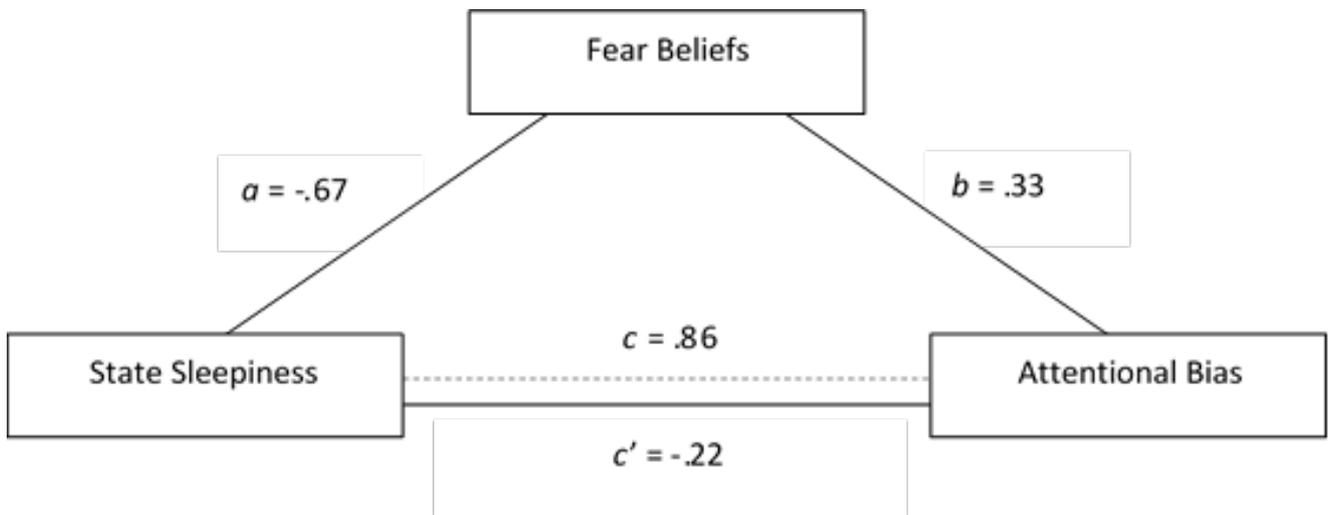

Figure 4: Mean reaction times for detecting the probe behind each animal (fear-paired and unpaired) in the dot probe task in experiment 3 (errors bars = SEM)

Figure 5: Standardised residual coefficients for the relationship between state sleepiness and postlearning attentional bias for fear-paired animals as mediated by changes in fear beliefs (experiment 3)