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Citation for final published version:

Hubble, Kelly, Daughters, Katie, Manstead, Antony, Rees, Dafydd, Thapar, Anita and Van Goozen, Stephanie 2017. Oxytocin increases attention to the eyes and selectively enhances self-reported affective empathy for fear. *Neuropsychologia* 106 , pp. 350-357.
10.1016/j.neuropsychologia.2017.10.019 file

Publishers page: <http://dx.doi.org/10.1016/j.neuropsychologia.2017....>
<<http://dx.doi.org/10.1016/j.neuropsychologia.2017.10.019>>

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3 **Oxytocin Increases Attention to the Eyes and Selectively Enhances Self-Reported**
4 **Affective Empathy for Fear**

5
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24 This work is part of a doctoral dissertation and was funded by an Economic and Social
25 Research Council grant (ES/J500197/1) awarded to the first and second authors and by a
26 Wellcome Trust seedcorn grant awarded to SvG and AT.

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Abstract

Oxytocin (OXT) has previously been implicated in a range of prosocial behaviors such as trust and emotion recognition. Nevertheless, recent studies have questioned the evidence for this link. In addition, there has been relatively little conclusive research on the effect of OXT on empathic ability and such studies as there are have not examined the mechanisms through which OXT might affect empathy, or whether OXT selectively facilitates empathy for specific emotions. In the current study, we used eye-tracking to assess attention to socially relevant information while participants viewed dynamic, empathy-inducing video clips, in which protagonists expressed sadness, happiness, pain or fear. In a double-blind, within-subjects, randomized control trial, 40 healthy male participants received 24 IU intranasal OXT or placebo in two identical experimental sessions, separated by a 2-week interval. OXT led to an increase in time spent fixating upon the eye-region of the protagonist's face across emotions. OXT also selectively enhanced self-reported affective empathy for fear, but did not affect cognitive or affective empathy for other emotions. Nevertheless, there was no positive relationship between eye-gaze patterns and affective empathy, suggesting that although OXT influences eye-gaze and may enhance affective empathy for fear, these two systems are independent. Future studies need to further examine the effect of OXT on eye-gaze to fully ascertain whether this can explain the improvements in emotional behavior.

Keywords: Oxytocin, empathy, fear, eye-gaze

1 Oxytocin Increases Attention to the Eyes and Selectively Enhances Self-Reported Affective
2 Empathy for Fear

3 The ability to understand and share another person's emotional state or context,
4 referred to as empathy (Eisenberg & Strayer, 1987), is essential in developing and sustaining
5 successful reciprocal social relationships (Dziobek et al., 2008). Empathy is a broad
6 construct, consisting of both cognitive and affective reactions to others' experiences, and can
7 be split into two components: cognitive empathy and affective empathy. Cognitive empathy
8 is the ability to understand what another person is thinking or feeling, whereas affective
9 empathy involves the vicarious experience of emotions consistent with those of another
10 (Shamay-Tsoory, 2009). In general, empathy is thought to trigger a number of prosocial
11 behaviors intended to benefit others. If the other is perceived to be in a negative state,
12 empathic concern can motivate action and lead to prosocial behavior (de Waal, 2008).
13 Consequently, these abilities facilitate cooperation and helping behaviors and are considered
14 important for appropriate moral development (Hoffman, 2000). Conversely, deficient
15 emotion processing is an important risk factor associated with antisocial behavior and a range
16 of psychiatric and neurodevelopmental conditions including Autism Spectrum Disorders,
17 Conduct Disorder and schizophrenia.

18 Over the last decade, a plethora of studies have implicated the neuropeptide oxytocin
19 (OXT) in a host of prosocial behaviors, including increased trust (Kosfeld, Heinrichs, Zak,
20 Fischbacher & Fehr, 2005), generosity (Zak, Stanton & Ahmadi, 2007) and facial emotion
21 recognition (Domes, Heinrichs, Michel, Berger, & Herpertz, 2007b). Of particular interest to
22 the current study is the commonly referenced finding concerning the benefits of OXT on
23 mind-reading (Domes et al., 2007a). These findings have spurred interest in the potential of
24 OXT to reduce social deficits associated with disorders.

25 However, some recent studies (e.g., Nave, Camerer & McCullough, 2015; Lane et al.,
26 2015; Radke & de Bruijn, 2015; Hofmann, Fang & Brager, 2016) have failed to replicate
27 some of the positive effects associated with OXT, raising concerns that previous studies were
28 underpowered and/or that publication bias has resulted in the selective publication of positive
29 findings (Lane, Luminet, Nave, & Mikolajczak, 2016). This, combined with some evidence
30 that OXT can increase negative responses, such as schadenfreude (Shamay-Tsoory, Fischer,
31 Dvash, Harari, Perach-Bloom & Levkovitz, 2009), has cast doubt on the role of OXT in
32 promoting prosocial behaviors. As a result, there is a need for further research on the effects
33 of OXT on prosocial behavior and for closer consideration of the possible mechanisms
34 through which such effects may occur.

1 Given the important role played by empathy in prosocial behavior, it seems logical to
2 examine whether OXT has an impact on empathy. However, relatively few studies in the
3 OXT literature have examined the role of OXT in empathy, and those that have done so have
4 yielded inconsistent results. Using a between-subjects design with 48 healthy male
5 participants, Hurlemann et al. (2010) examined cognitive and affective empathy using static
6 pictures depicting people in emotionally charged situations. They found that intranasal OXT
7 increased affective, but not cognitive empathy in response to both positively and negatively
8 valenced stimuli. However, Theodoridou, Rowe, and Mohr (2013) found that the self-
9 reported components of affective empathy were unaffected by the administration of OXT, but
10 that performance on a more implicit measure of cognitive empathy was enhanced following
11 OXT. It is worth noting that the findings of Hurlemann and colleagues are also inconsistent
12 with Domes et al.'s (2007) finding that OXT improves cognitive empathy as measured by the
13 Reading the Mind in the Eye task.

14 Attempts to replicate these findings have proven unsuccessful, raising doubts about
15 the effect of OXT on cognitive empathy (Radke & de Bruijn, 2015). Indeed, a recent meta-
16 analysis of 33 studies found that OXT did not significantly influence emotional theory of
17 mind – a similar construct to cognitive empathy – or the expression of negative emotions in
18 healthy individuals (Leppanen, Ng, Tchanturia & Treasure, 2017). A number of studies have
19 further suggested that OXT only improves cognitive empathy in people who rate themselves
20 as less socially proficient (Bartz et al., 2010), or who display lower baseline trait empathy
21 scores (Feesser et al., 2015). Given the large variations in stimuli and methodology in these
22 studies, it is perhaps not surprising that previous results concerning the effect of OXT on
23 empathy are inconsistent.

24 Studies investigating the effects of intranasal OXT on affective empathy are scarce.
25 This may be due in part to the difficulty in defining this construct, given that it encompasses
26 both subjective and physiological responses towards other people's internal states. Apart
27 from the aforementioned study by Hurlemann et al. (2010), few studies have directly assessed
28 affective empathy, and those that have done so have tended to focus solely on empathy for
29 pain. For example, two studies using subjective ratings of responses to painful stimuli found
30 that OXT did not have a main effect on pain ratings, but did increase ratings as a function of
31 the perspective (self vs. other) participants were asked to take, or the nationality of the person
32 with whom to empathize (Abu-Akel, Palgi, Klein, Decety & Shamay-Tsoory 2015; Shamay-
33 Tsoory et al., 2013). Similarly, in a within-subjects neuroimaging study examining empathy
34 for a partner's experience of physical pain, Singer and colleagues (2008) found that OXT

1 neither enhanced subjective empathy nor increased activation in empathy-relevant brain areas
2 such as the anterior insula (AI) and anterior cingulate cortex (ACC). Interestingly, a recent
3 study found that empathy-related activation in the neural circuitry of pain was strongly
4 *reduced* after intranasal OXT, suggesting that OXT might decrease empathy for pain (Bos,
5 Montoya, Hermans, Keysers, & van Honk, 2015). However, because no behavioural data
6 were included in this study, further research incorporating behavioural measures is needed in
7 order to be able to draw firmer conclusions.

8 One technique that has the potential to explain any beneficial effects of OXT on
9 empathy is to use eye-tracking to provide a measure of visual attention allocation. OXT has
10 been shown to increase gaze toward the eye-region of neutral faces (Guastella, Mitchell, &
11 Dadds, 2008), and also to increase attention to objects that are the gaze targets of static faces
12 (Tollenaar, Chatzimanoli, van der Wee, & Putman, 2013). Such findings have led to the
13 suggestion that OXT might improve prosocial behavior by increasing attention to socially
14 relevant cues (Guastella et al., 2008). If the administration of OXT alters eye-gaze to
15 meaningful social information, it is possible that any improvement in prosocial behavior is
16 via this route. Indeed, within the ASD literature there is evidence that improved facial
17 emotion recognition is due, in part, to participants spending more time looking at the eye area
18 of faces (e.g., Andari et al., 2010). Nevertheless, evidence from healthy participants to
19 support this line of argument is mixed, with one study suggesting that OXT selectively
20 enhances gaze to the eyes (Auyeung et al. 2015), another showing that OXT results in
21 increased gaze to the eye areas for positive faces but decreased gaze to the eyes for negative
22 faces (Domes, Steiner, Porges & Heinrichs, 2013), and others suggesting that improvements
23 in facial emotion recognition are unaffected by eye-gaze (Hubble et al., 2016; Lischke et al.,
24 2012;), but instead are related to pupil dilation (Prehn et al., 2013).

25 To our knowledge, no study to date has examined the effect of OXT on eye-gaze in
26 relation to empathy. Furthermore, although the use of dynamic stimuli showing characters
27 experiencing emotions and responding to emotional events is generally considered to provide
28 a more realistic context in which to measure emotional reactions (Karrow & Connors, 2003),
29 none of the previous studies examining OXT and empathy used dynamic real-world stimuli.
30 Similarly, to date the effect of OXT on empathy has only been considered for positively or
31 negatively valenced emotion (Hurlmann et al., 2010), with the exception of pain (e.g. Singer
32 et al., 2008). Given that OXT appears to have differential effects in different contexts (e.g.,
33 De Dreu et al., 2010), coupled with evidence suggesting that OXT may have a selective effect
34 on the processing of fearful facial expressions (Fischer-Shofty, Shamay-Tsoory, Harari &

1 Levkovitz, 2010; Leppanen, 2017), it is important to consider the effect of OXT on empathy
2 for different discrete emotions. These issues are taken into account in the present research. A
3 further point is that most OXT studies to date have used between-subjects designs. In
4 response to recent reviews that are critical of the quality and rigor of OXT research
5 (Churchland & Winkielman, 2012; Leng & Ludwig, 2016; Walum, Waldman, & Young,
6 2016) and in view of evidence of large variations in individual responsivity to OXT across
7 participants (Daughters et al., 2015), we decided to study the effects of OXT using a within-
8 subjects design and to take measures of salivary OXT levels to ensure that the nasal sprays
9 had the intended effect on OXT levels. We also measured eye-gaze during the empathy task,
10 with a view to explaining any observed effects in terms of attention allocation.

11 To summarize, there is conflicting evidence for beneficial effects of OXT on both
12 cognitive and affective empathy. To address these issues, we aimed to measure cognitive and
13 affective empathy for discrete emotions using a double-blind, within-subjects randomized
14 control trial of intra-nasally administered OXT. We also explored the mechanism by which
15 OXT may affect empathy by measuring eye-gaze. To achieve these aims, participants
16 completed a dynamic empathy task that aimed to evoke empathy experimentally using four
17 short video clips inducing the emotions of pain, sadness, happiness and fear, during which
18 participants' eye-gaze was tracked (van Rijn, Barendse, van Goozen, & Swaab, 2014). After
19 each clip participants were asked to identify (a) the main character's emotions and their
20 intensities, (b) their own emotions and their intensities, and (c) the reasons for the main
21 character's and their own emotions.

22 Consistent with the previously hypothesized prosocial effects of OXT, we predicted
23 that OXT would enhance both cognitive and affective empathy for all emotions. We also
24 expected OXT to increase attention to the eye-region of faces and that this increased attention
25 would be related to greater empathy.

26 Method

27 Participants

28 Forty healthy male students ($M_{\text{age}} = 20.98$; $SD = 4.55$) at Cardiff University
29 participated in this experiment in return for course credit or £40. Participants took part in two
30 3-hour study sessions, with a 2-week interval between each session (for practical reasons
31 seven participants had to be tested at later dates; the longest interval between the two sessions
32 was 35 days). The order in which they received OXT or placebo nasal spray was randomized
33 and counterbalanced, with researchers and participants remaining blind to this order. The
34 decision to examine OXT in male participants was taken for two reasons: (1) the effects of

1 OXT have been found to differ in males and females, such that collapsing across gender
2 would not be appropriate (Domes et al., 2010; Kirsch et al., 2005); and (2) administering
3 OXT to females entails additional ethical and logistical considerations (e.g., controlling for
4 menstrual cycle phase and/or pregnancy).

5 **Ethical Considerations**

6 The study was approved by both the School of Psychology Ethics Committee at
7 Cardiff University, and by the Research and Development Office at Cardiff and Vale
8 University Health Board. Participants were cleared to participate in the study by a medical
9 professional (co-author AR) and gave written informed consent at each testing session. They
10 were fully debriefed after the second session. They completed medical pre-screening forms
11 and signed statements of health before leaving each testing session. All participants had
12 normal or corrected-to-normal vision, and none of them reported a history of neurological or
13 mental health disorders, or severe allergic reactions. Participants were asked to refrain from
14 consuming alcohol in the 24 hours prior to each study session and from smoking cigarettes or
15 drinking caffeine in the 2 hours prior to each study session.

16 **Measures and Materials**

17 **Empathy task: emotion-eliciting video clips.** We used eight clips depicting main
18 characters feeling pain/hurt, sad/upset, fearful/scared or happy/cheerful; these will be referred
19 to as the pain, sadness, fear and happiness clips, respectively. The clips were edited from
20 commercially available films or videos and had a duration of approximately 120 seconds.
21 One set of film clips (i.e., those for pain, sadness, fear and happiness) had previously been
22 validated (see van Rijn, Barendse, van Goozen, & Swaab, 2014). The current study used four
23 additional clips, which were selected based on similarity scores from a pilot study to match
24 the previous set of clips with respect to duration, content and emotional intensity. Participants
25 viewed one set of four emotional clips during the first visit and the other four clips on the
26 second visit, and the order of clips was counterbalanced across participants. Clips were
27 shown to participants using Tobii Studio software on a Dell Precision M4700 laptop with a
28 15.6 inch screen.

29 **Empathy scores.** After each clip participants completed two questionnaires,
30 indicating how strongly the main character or they experienced each of 10 emotions (labeled
31 as follows: anger, sad, pain, upset, fearful, happy, scared, cheerful, surprised and hurt).
32 Ratings were made on a 6-point intensity scale, where 0 indicated no emotion and 5 indicated
33 intense emotion. Participants were also asked to explain the reason for the emotion(s) they
34 identified in the main character and in themselves. There were no constraints on the amount

1 information they provided. These responses were coded for cognitive and affective empathy
2 by research assistants who were blind to the participants' drug condition. Scores took into
3 consideration four important elements of empathy: (1) whether the target emotion was
4 correctly identified; (2) whether another, similar emotion was identified; (3) the intensity of
5 the emotion identified; and (4) the explanation for the causes of the emotion (see van Goozen
6 et al., 2016). Scores for cognitive empathy ranged from 0-9; a maximum of 2 points was
7 awarded for identifying the correct target emotion in the main character at the correct
8 intensity; a maximum of 2 points was also awarded for identifying a relevant similar emotion
9 at the correct intensity, and up to 5 points were awarded for the participant's explanation
10 and understanding of the emotion. For example, an explanation stating "she was scared
11 because she was slipping and she thought she might fall and die" would receive a maximum
12 score of 5. Scores for affective empathy ranged from 0-6, where a maximum of 2 points was
13 awarded for indicating personally feeling the target emotion at a high intensity; another
14 maximum of 2 points was awarded for indicating personally feeling a relevant similar
15 emotion at a high intensity, and up to 2 points were awarded for the participant's explanation
16 and understanding of their own emotion. For example, an explanation stating "I felt sad
17 because I thought about that happening to me" would have scored the maximum of 2. Higher
18 scores on both scales reflect greater empathy. The measures exhibited satisfactory internal
19 consistency (Cronbach's alphas: cognitive empathy = 0.70; affective empathy = 0.83). Inter-
20 rater reliability (Cohen k) between two trained coders on a subset of 10% of the data across
21 clips ranged from .74 to .82)

22

23 **Eye-tracking.** Participants were positioned approximately 60-65 cm from a laptop
24 computer and a 9-point calibration was performed. The quality of calibration was checked; if
25 there were no data for one or more points, or if calibration quality was poor, calibration at
26 those points was repeated. This process was completed for a maximum of three calibration
27 attempts, after which it was unlikely that calibration would improve further. Data from seven
28 participants were excluded due to poor calibration quality. Calibration was followed
29 immediately by the empathy stimuli. Eye movements were recorded with a portable Tobii
30 X2-60 compact eye-tracker sampling at 60Hz with a screen resolution of 1920 x 1080. This
31 equipment is robust to changes in head position, removing the need for a chin rest. An I-VT
32 fixation filter with a minimum fixation criterion of 60 milliseconds sampled the average raw
33 data from both eyes to produce information on eye positions and duration. Eye-gaze validity

1 was checked using a sample rate percentage that gives an estimate of the quality of the eye-
2 tracking in a recording by providing a percentage score of successfully-recorded data. One
3 participant whose validity fell below 70%, meaning eye-tracking data were not available for
4 more than 30% of the recording, was excluded from the final analysis. For the remaining
5 participants, validity ranged from 70–97%. The seven excluded participants did not differ
6 from those whose eye-tracking data were retained with respect to performance on the
7 empathy task (overall cognitive empathy: $M_{\text{included}} = 6.2$, $M_{\text{excluded}} = 6.00$, $p > .05$; overall
8 affective empathy: $M_{\text{included}} = 3.8$, $M_{\text{excluded}} = 3.4$, $p > .05$), age ($M_{\text{included}} = 21$, $M_{\text{excluded}} = 23$, p
9 $> .05$), or drug order (four of the seven excluded participants received OXT first, the
10 remaining three received PL first).

11

12 **Saliva Samples**

13 Participants produced four saliva samples during each session: at baseline, and 30, 60,
14 90 min after OXT/placebo administration. These samples were analyzed to measure salivary
15 OXT at each of these time points. These analyses revealed the OXT nasal sprays were
16 successful in increasing OXT levels: mean saliva oxytocin concentration (in pg/mL) for all
17 participants 60 min after administration (during the empathy task) was 952.0 during OXT and
18 46.4 during PL (see Daughters et al., 2015). When participants excluded from the eye-
19 tracking analysis were removed, mean salivary OXT concentration after 60 min was 826.8
20 during OXT and 38.4 during PL. There were no significant differences in OXT
21 concentrations between those included and excluded from the eye-tracking analysis ($p > .05$).

22

23 **Procedure**

24 Participants self-administered 24 IU (three 4IU puffs per nostril) of synthetic OXT or
25 an independently manufactured placebo nasal spray (PL) that chemically matched the OXT
26 spray for all compounds, except OXT. Both sprays were manufactured by St Mary's
27 Pharmaceutical Unit, Cardiff (<http://www.wales.nhs.uk/sites3/home.cfm?orgid=828>). A
28 medical doctor was present during administration, and for the subsequent 15 minutes. A 30-
29 min waiting period was used between drug administration and task start in order to allow the
30 drug to take effect. This interval was based on previous studies suggesting that OXT
31 concentrations in both plasma (Gossen et al., 2012) and saliva (Weisman, Zagoory-Sharon &
32 Feldman, 2012) peak at 30 minutes. This waiting time also ensures that saliva measures
33 obtained after this point do not reflect spiking due to direct transfer from nose to saliva (for
34 details, see Martin, Schipper, Verhoef & Merkus, 1998). During the waiting period,

1 participants completed a set of measures asking for demographics and food and caffeine
2 intake. At the end of the waiting period they completed a 15-minute face processing task (see
3 Hubble et al., 2016), which was followed by the empathy task that started 45 minutes after
4 OXT administration and lasted approximately 30 minutes. Each video clip was followed
5 immediately by the empathy questionnaire. In the second session, participants completed the
6 same empathy task but with different (matched) clip. After completing all tasks, participants
7 were debriefed about the aims of the study and were asked to indicate which spray they
8 thought they had during which session and how confident they were of this. Participants
9 could not accurately report, above chance levels, the session in which they received OXT, (23
10 guessed correctly) $X^2(1) = 0.9, p = .34$. Furthermore, participants who identified the correct
11 spray order indicated that they were less certain of that order than those who reported the
12 incorrect order (Correct $M = 3.8$; Incorrect $M = 5.7$), $t(38) = 2.35, p = .024$.

13

14 **Data Analysis**

15 Tobii analysis software was used to analyze eye movements, which allowed areas of
16 interest (AOI) to be created and a variety of summary reports generated. The eyes were
17 grouped into one area. A second AOI was created around the mouth. A third AOI was around
18 the face as a whole to allow for analysis of when participants were looking at the face. Eye-
19 gaze was analyzed during a 4s segment (equivalent to the time-frame given in static emotion
20 recognition tests) that showed a clear, dynamic development of the emotion. Percentage
21 dwell time (the sum of the duration of all fixations to an AOI divided by the total duration of
22 the segment) for each AOI was calculated. The percentage of time spent looking at the eye
23 and mouth regions was subtracted from that for the whole face to yield a percentage of time
24 spent looking at the other face areas.

25 Analyses were carried out using SPSS 20 (SPSS Inc., Chicago, IL). The principal
26 analyses reported below are analyses of variance. Where the assumption of sphericity was
27 violated, Greenhouse-Geisser corrections were used. Within each analysis, Bonferroni
28 corrections were applied for all post-hoc comparisons. Effect sizes were calculated as partial
29 eta squared (η_p^2); small $\geq .01$, medium $\geq .06$, large $\geq .14$; Cohen, 1988). Confidence intervals
30 have been calculated at the 95% level for the differences of all key findings (CI_{diff}) and at the
31 90% level for effect sizes (CI_{es}).

Results

Within-subjects ANOVAs were computed, with Drug (OXT or Placebo [PL]) and Emotion (pain, sadness, fear and happiness) as the within-subject factors. Separate analyses were carried out on the dependent variables of cognitive empathy and affective empathy.

Cognitive Empathy

Mean cognitive empathy scores are shown in Figure 1. Results revealed a significant main effect of Emotion, $F(3, 117) = 12.93, p < .001, \eta_p^2 = .25$, but no main effect of Drug, $F(1, 39) = 0.04, p = .84, \eta_p^2 = .00$, and no interaction between Drug and Emotion, $F(3, 117) = 2.14, p = .10, \eta_p^2 = .05$. Follow-up analyses revealed that cognitive empathy for pain ($M = 6.4, SD = 0.7$), and fear ($M = 6.5, SD = 0.9$) were similar ($p > .05$) and significantly higher than those for sadness ($M = 5.9, SD = 0.7$) and happiness ($M = 5.9, SD = 0.8$) (all $ps < .05$) which did not differ ($p > .05$).

INSERT FIGURE 1 HERE

Affective Empathy

Mean affective empathy scores are shown in Figure 2. There was a main effect of Emotion, $F(3, 117) = 16.03, p < .001, \eta_p^2 = .29$. Affective empathy was significantly greater for sadness ($M = 4.6, SD = 0.9$) compared to pain, happiness and fear (all $ps < .001$), and there were no significant differences in affective empathy between fear ($M = 3.5, SD = 1.6$), pain ($M = 3.4, SD = 1.3$) and happiness ($M = 3.5, SD = 1.0$) (all $ps > .05$). There was no main effect of Drug, $F(1, 39) = 0.13, p = .73, \eta_p^2 = .00$, but there was a significant interaction between Emotion and Drug, $F(3, 117) = 2.77, p = .045, \eta_p^2 = .06, 90\% \text{ CI}_{\text{es}} [.001, .13]$. Affective empathy for fear was significantly higher ($p = .02, \eta_p^2 = .14, 90\% \text{ CI}_{\text{es}} [.02, .31]$), in the OXT ($M = 3.9, SD = 1.7$) than PL ($M = 3.2, SD = 1.8$) condition ($95\% \text{ CI}_{\text{diff}} [0.1, 1.1]$). The corresponding differences were not significant for pain ($p = 1.00$), happiness ($p = .25$) or sadness ($p = .35$).

INSERT FIGURE 2 HERE

Eye-gaze Patterns

An ANOVA was conducted with three within-subjects factors: Drug (OXT vs PL), Emotional Clip (Pain, Happiness, Sadness, or Fear) and AOI (Eye, Mouth, or Rest of face). There was a main effect of AOI, $F(1.31, 41.95) = 35.58, p < .001, \eta_p^2 = .53$, reflecting the fact that percentage dwell time to the eye-region was greatest ($M = 36\%, SD = 15.1$), followed by that for the rest of the face ($M = 29\%, SD = 7.6$); dwell time to the mouth region was significantly lower than both the eye-region ($p < .001$) and the rest of the face ($p < .001$) ($M =$

1 11%, $SD = 8.2$). Dwell times for the eye-region and the rest of the face did not significantly
 2 differ from each other ($p = .13$).

3 A significant main effect of Emotion, $F(2.49, 79.6) = 25.81, p < .001, \eta_p^2 = .45$,
 4 showed that participants spent significantly more time looking at the face of the main
 5 character during the sadness clip ($M = 30\%$, $SD = 4.3$), compared to the happiness ($M = 26\%$,
 6 $SD = 4.3$) pain ($M = 24\%$, $SD = 5.2$) and fear ($M = 21.2\%$, $SD = 5.5$) clips (all $ps < .05$).
 7 There was no significant difference in dwell time for the face when watching the happiness
 8 and pain clips ($p = .33$) but during the fear clip participants spent significantly less time
 9 looking at the face compared to the other clips (all $ps < .05$). The main effect of Drug was
 10 marginal, $F(1, 32) = 3.76, p = .06, \eta_p^2 = .11$, and reflected the fact that participants in the PL
 11 condition tended to spend more time looking at the face in general ($M = 26\%$, $SD = 3.3$)
 12 compared to the OXT condition ($M = 25\%$, $SD = 4.4$). The Emotion by Drug interaction was
 13 not significant, $F(2.29, 73.2) = .05, p = .99, \eta_p^2 = .00$.

14 The three-way interaction between Drug, Emotion and AOI was not significant,
 15 $F(4.53, 144.79) = 0.68, p = .62, \eta_p^2 = .02$, but there were significant interactions between Drug
 16 and AOI, $F(2, 64) = 10.71, p < .001, \eta_p^2 = .25$, 90% $CI_{es} [.09, .37]$ and between Emotion and
 17 AOI, $F(3.72, 118.96) = 20.2, p < .001, \eta_p^2 = .39$, 90% $CI_{es} [.26, .47]$ Means relevant to the
 18 Drug by AOI interaction are shown in Figure 3. Follow-up tests revealed that OXT resulted
 19 in a greater proportion of time fixating on the eye-region, $F(2, 96) = 11.33, p = .002, \eta_p^2 =$
 20 $.26$, 90% $CI_{es} [.08, .29]$, 95% $CI_{diff} [2.7, 10.9]$; given this, it is not surprising that OXT also
 21 led to less time spent looking at the mouth, $F(2, 96) = 3.73, p = .06, \eta_p^2 = .10$, 90% $CI_{es} [.004,$
 22 $.15]$, 95% $CI_{diff} [-7.2, 0.2]$, and the rest of the face, $F(2, 96) = 12.86, p = .001, \eta_p^2 = .29$, 90%
 23 $CI_{es} [.09, .30]$, 95% $CI_{diff} [-11.8, -3.2]$.

24
 25 INSERT FIGURE 3 HERE
 26

27 Means relevant to the Emotion by AOI interaction are shown in Figure 4. Follow-up
 28 tests revealed that there were significant differences between the clips in the proportion of
 29 time spent fixating upon the eyes, $F(4, 119) = 34.05, p < .001, \eta_p^2 = .77$, and mouth, $F(4, 119)$
 30 $= 21.29, p < .001, \eta_p^2 = .68$. Further analyses revealed that participants spent a significantly
 31 greater proportion of time fixating on the eyes during the sadness clip compared to the
 32 happiness, fear and pain clips (all $ps < .05$), whereas a significantly greater proportion of time
 33 was spent looking at the mouth during the pain clip compared to the happiness, sadness and

1 fear clips (all $ps < .05$). There were no differences between clips with respect to the amount
2 of time spent fixating upon the rest of the face, $F(4, 119) = 0.98$, $p = .41$, $\eta_p^2 = .09$.

3
4 INSERT FIGURE 4 HERE

5 **Comparing Empathy and AOI**

6 To examine the relationship between eye-gaze and empathy, we calculated
7 Spearman's rhos to assess the association between changes in cognitive empathy and
8 affective empathy scores from PL to OXT for each emotional clip and the change in dwell
9 time to the eye-region from PL to OXT for the same clip (difference scores were calculated
10 as OXT – PL for each variable). As can be seen in Table 1, there was a significant inverse
11 correlation between affective empathy for fear and dwell time to the eye-region ($p < .05$).

12 INSERT TABLE 1 HERE

13 14 **Discussion**

15 We set out to establish whether OXT affects self-reported empathy and whether any
16 changes in empathy are associated with altered eye-gaze to socially relevant stimuli. In
17 contrast to our hypothesis, which predicted that OXT would result in enhanced cognitive and
18 affective empathy across all emotions, our results demonstrate that a single dose of OXT
19 administered to healthy male subjects enhanced their ability to empathize affectively with a
20 fearful protagonist, but not with a protagonist displaying pain, sadness or happiness. This is
21 inconsistent with the findings from Domes et al. (2007) who found that OXT improved
22 cognitive empathy. However, our findings are partly consistent with evidence from
23 Hurlemann et al. (2010), who found that OXT increased affective but not cognitive empathy,
24 although these authors found increased affective empathy for both positively and negatively
25 valenced stimuli. A possible reason for this discrepancy in findings is that the empathy-
26 inducing stimuli differed between the two studies. Hurlemann et al. used static photos,
27 whereas we used dynamic clips. Dynamic clips are arguably of greater ecological validity, in
28 that they reflect more closely the kind of everyday interpersonal interaction in which an
29 empathic response could be aroused (Karrow & Connors, 2003). An additional strength of the
30 present study is the use of a within-subjects design, which controls for the sizeable individual
31 differences that arise in response to intranasally administered OXT (Daughters et al., 2015).

32 The selective effect of OXT on fear observed in the present study is consistent with
33 findings from research exploring the effect of OXT on facial emotion recognition. Fischer-
34 Shofty et al. (2010), also employing dynamic video clips of emotional facial expressions,

1 found that OXT selectively enhanced recognition only for fearful faces. In a recent meta-
2 analysis of 9 studies investigating the effects of intranasal OXT on the recognition of fear
3 (two of which included people with schizophrenia and borderline personality disorder),
4 Leppanen et al. (2017) concluded that OXT significantly improved the recognition of basic
5 emotions, albeit with a small effect size, and that the effect is robust, with no evidence of
6 publication bias. However, it was only reliable for healthy individuals. OXT has also been
7 found to increase attention and approach towards fearful facial expressions (Clark-Elford et
8 al., 2015; Tollenaar et al., 2013). In a further meta-analysis, Leppanen, Ng, Kim, Tchanturia,
9 and Treasure, (2018) found that OXT significantly increased the physiological startle
10 response to threat in healthy participants, but did not increase fixations to threatening stimuli.
11 Thus the present findings are consistent with evidence that OXT influences the salience of
12 threatening stimuli.

13 Interestingly, neuroimaging evidence suggests that the administration of OXT inhibits
14 amygdala activation (Domes et al., 2007b; Kirsch et al., 2005; Singer et al., 2008), thereby
15 dampening the fear response, which appears to be inconsistent with the improvement in fear
16 recognition observed by Fischer-Shofty et al. (2010) and with the greater affective empathy
17 for fear responses observed in the present research. Given that there are a number of brain
18 areas associated with the processing of fearful stimuli and affective empathy, and that OXT
19 binding sites have been observed in different areas of the rats brain that are involved in
20 emotion processing (Febo, Numan & Ferris, 2005; Ferris, 2008; Smeltzer, Cutis, Aragona &
21 Wang, 2006), it is possible that OXT modulates different cortical regions that are important
22 for processing threatening stimuli, and thereby improves affective empathy for fear (Fischer-
23 Shofty et al., 2010).

24 A strength of the present study is the use of eye-tracking technology to investigate
25 whether any improvement in empathy resulting from OXT was matched by increased
26 attention to socially relevant stimuli. We found that OXT led to a general increase in the
27 amount of time participants fixated on the eye-region of the face for four different types of
28 emotion. These results contrast with those reported by Lischke et al. (2012), who found no
29 evidence that OXT altered eye-gaze in healthy participants. Nevertheless, our results are
30 consistent with evidence from ASD literature suggesting that OXT increases attention to
31 socially relevant stimuli, and specifically for the eye-region (e.g., Andari et al., 2010).

32 ASD researchers have argued that improvements in facial emotion recognition
33 associated with OXT administration result from increased attention to the eye-region,
34 although few studies have empirically tested this notion. With respect to empathy research,

1 no prior study has examined eye-gaze as a possible mediator of enhanced empathy. We
2 found no evidence that changes in eye-gaze resulting from OXT were related to greater
3 empathy. Thus the observed increase in affective empathy for fear did not result from
4 increased attention to socially relevant stimuli. Indeed, improved empathy for fear was
5 associated with a *reduced* time looking at the eye region, a pattern that was also evident for
6 other emotions, albeit to a lesser extent. Given the relatively small sample size in this study,
7 further research is needed to establish the reliability of this finding. If replicated, it may
8 reflect an attempt by participants who are empathizing more strongly with the protagonist's
9 fear to regulate their own emotions by looking less at the protagonist's eyes.

10 A possible explanation for absence of a strong link between emotional responding
11 and eye gaze concerns the stimuli used. Evidence for a link between emotion recognition and
12 eye-gaze has typically been found in studies using images where the only basis for judgments
13 is provided by facial features. The emotional stimuli used in the current study depicted
14 protagonists experiencing emotions in arousing situations. Participants therefore had access
15 to non-facial cues, such as tone of voice, gestures and contextual information. This may have
16 rendered information from the face less important. However, we do not regard this as a
17 limitation, because dynamic stimuli showing people responding to emotional situations is
18 more reflective of everyday occurrences; instead, the results suggest that eye-gaze may be
19 less important in everyday interactions than it is in studies simply investigating responses to
20 facial images. It is worth noting that in a separate task, using the same group of participants
21 but static facial expressions, OXT did not result in significant changes in eye-gaze (Hubble et
22 al., 2016), which also suggests that the dynamic nature of the stimulus was important in the
23 current finding.

24 Another possible reason for the absence of a strong relationship between eye-gaze and
25 empathy concerns the timing of the measures. Affective empathy was measured after each
26 clip, requiring participants to integrate their emotional experiences during the 2-min stimulus
27 into a single score, whereas the eye-gaze data were collected during a 4-sec segment of each
28 clip that showed a clear, dynamic development of the emotion. Comparing strictly
29 contemporaneous eye-gaze and empathy data might reveal a stronger relationship between
30 them, although this would be very difficult to implement, given that providing continuous
31 ratings of emotions (one's own or another's) would likely interfere with eye-tracking
32 analysis. Physiological measures therefore offer a better way of comparing eye-gaze and
33 empathy continuously, although but they are affected by other issues (e.g., they reflect
34 arousal but are relatively insensitive to valence; see Lang, Greenwald, Bradley & Hamm,

1 1993). Given the evidence that OXT may be especially involved in the initial allocation of
2 attentional resources (Gamer, Zurowski & Buchel, 2010), future studies could consider
3 whether monitoring early fixations would result in a stronger relation between eye-gaze and
4 empathy.

5 **Limitations**

6 Our conclusions concerning the possible role of OXT on affective empathy for fear
7 and eye-gaze derive from an exogenous administration study, in which participants received
8 intranasal OXT or a matching PL. This method has the advantage of being able to draw
9 conclusions about cause and effect relationships, which would not be possible if one were
10 correlating endogenous oxytocin with empathy or eye-gaze. The disadvantage of this method,
11 however, is that the pathways through which intranasal OXT affects brain activity and
12 behavioral responses are not fully understood (e.g., McCullough, Churchland, & Mendez,
13 2013). Although there is good evidence that intranasal OXT increases the concentration of
14 endogenous OXT found in blood plasma and saliva (Daughters et al., 2015; Gossen et al.,
15 2012; Weisman et al., 2012), doubt has been cast on the extent to which intranasal OXT
16 crosses the blood-brain barrier (Neumann et al., 2013; Paloyelis et al., 2014; Striepens et al.,
17 2013). Walum et al. (2016) also raised concerns about the power of OXT studies, suggesting
18 that a sample size of more than 300 participants is needed to achieve sufficient power,
19 compared to the average of 49 participants (between-subjects) used in previous studies.
20 Although nowhere near the size proposed by Walum et al., our study represents an
21 improvement on many previous studies, especially given that it benefitted from the use of a
22 within-subject design. We were also able to confirm that OXT levels were higher in the OXT
23 condition, thereby mitigating some of the concerns associated with exogenous administration
24 of OXT. Nevertheless, we acknowledge that the results from this study would benefit from
25 replication with larger samples.

26 A further limitation of the present study stems from the fact that our measure of
27 affective empathy depended on self-reports of emotion. Self-reported emotional states can be
28 confounded by conscious awareness of the response or even the willingness to report this
29 response. They are also vulnerable to demand characteristics and social desirability (e.g.,
30 Eisenberg-Berg & Hand, 1979). Consequently, self-reports might not necessarily reflect how
31 the individual actually felt, but rather indicate perceptions of how other people expect one to
32 feel. Physiological measurements, such as skin conductance or facial responsivity can help to
33 overcome some of these pitfalls. For example, Korb et al. (2016), used facial EMG to show
34 that facial mimicry increased during OXT, particularly in response to angry infant faces.

1 Nevertheless, physiological measures also have limitations; for example, they do not
2 distinguish between empathy, sympathy and personal distress (Zhou, Valiente & Eisenberg,
3 2003).

4 The limitations associated with particular measures of affective empathy suggest that
5 no single measurement is perfect. Studies examining the convergence between different
6 measures of affective empathy show that some measurements, such as self-report measures
7 and facial responsiveness, correlate with each other (Anastassiou-Hadjicharalambous &
8 Warden, 2007), suggesting there is a common construct that is tapped by each measure. This
9 points to the importance of measuring affective empathy using a multi-method approach to
10 examine whether OXT enhances different components of affective empathy. Indeed,
11 evidence from studies examining the effect of OXT on facial emotion recognition (Prehn et
12 al., 2015) suggests examining pupil dilation in response to empathy could be a worthwhile
13 next step.

14 A final limitation is that we examined the effects of OXT in a male-only sample. This
15 arose from the practical and ethical complications entailed in administering OXT to women.
16 Evidence suggests that there are sex differences in empathic abilities (e.g., Baron-Cohen &
17 Wheelwright, 2004) and that OXT differentially modulates the neural circuitry involved in
18 face processing in men and women. For example, while it has been demonstrated that OXT
19 decreases amygdala activity in response to fear in men (Kirsch et al., 2005), it appears to
20 increase amygdala activity to similar stimuli in women (Domes et al., 2010). Additionally,
21 women typically report higher levels of affective empathy than men (Hurlemann et al., 2010;
22 Theodoridou et al., 2013). Our results may therefore not be generalizable to women. In
23 addition, given that our sample were all undergraduates who tend to perform reasonably well
24 in these types of tasks, it is possible that our results may not be generalizable to populations
25 who might find these tasks more challenging. It is worth noting that OXT has been found to
26 have stronger effects when task difficulty is higher (Domes et al., 2007a; Feeser et al., 2015),
27 suggesting the effect of OXT on empathy may be greater in populations showing empathy
28 deficits (Feeser et al., 2015).

29 **Conclusion**

30 The present results suggest that the administration of OXT selectively enhances affective
31 empathy for fear, whilst leaving cognitive empathy and affective empathy for sadness,
32 happiness and pain unaffected. Furthermore, we show for the first time using an emotion-
33 inducing film clip paradigm that OXT significantly increased gaze towards the eye-region of
34 faces across the four emotions studied here. However, increased dwell time for the eyes was

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- 1 not positively related to affective empathy for fear, suggesting that the widely held, but rarely
- 2 tested, notion that OXT-induced effects on emotional responding result from increased
- 3 attention to socially relevant stimuli is in need of closer scrutiny.

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15

1 **Acknowledgements**

2 Dr. Hubble, Dr. Daughters, Dr. Manstead, Dr. Rees, Dr. Thapar and Dr. van Goozen reported
3 no competing interests.

4

5 The authors confirm that all conditions and data exclusions, including the reasons for these
6 exclusions, have been reported. Sample size was determined based on the number of
7 participants used in previous key studies.

8

9 This work was funded in part by an Economic and Social Research Council grant
10 (ES/J500197/1) awarded to the first and second author and by a Wellcome Trust seedcorn
11 grant awarded to SHMvG and AT.

12

13 We would like to thank Dr. Andrew Lansdown and Dr. Anil Narayanaswamy for their
14 medical supervision during the study. We would also like to thank the management team and
15 staff at the Clinical Research Facility at the University Hospital of Wales where this research
16 was conducted.

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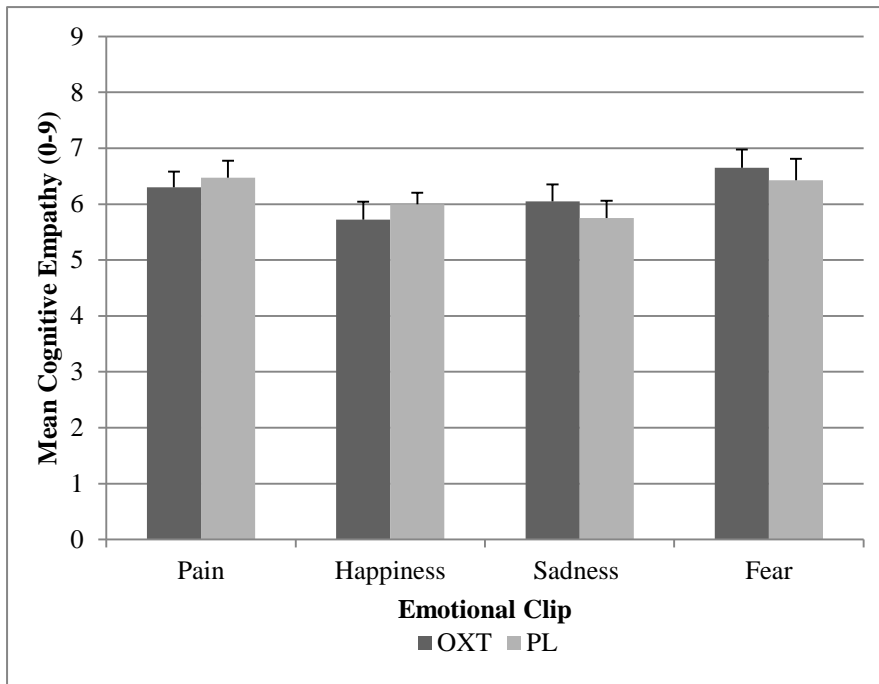
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Table 1

Intercorrelations (Spearman’s rho) between the difference in affective and cognitive empathy scores between OXT and PL conditions for each clip and the difference in eye-region dwell times for OXT and PL conditions for each clip

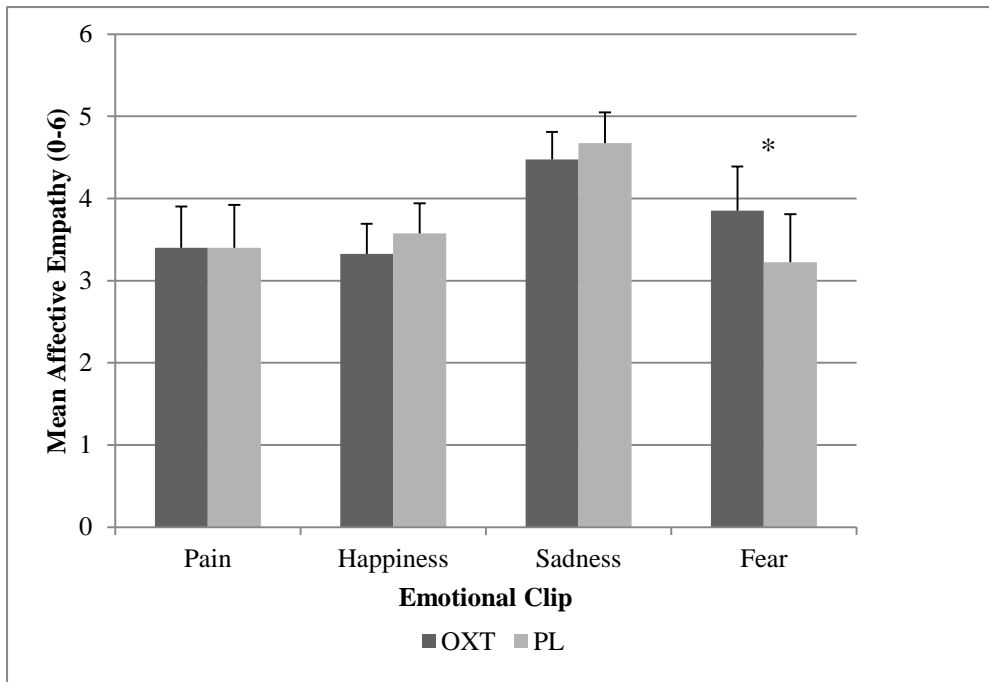
Affective Empathy	Eye-region dwell time N=33	Cognitive Empathy	Eye-region dwell time N=33
Pain	-.06	Pain	-.29
Happiness	.06	Happiness	.002
Sadness	.16	Sadness	.13
Fear	-.43*	Fear	-.33 ⁺

* = p < .05, + = .058



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Figure 1: Cognitive empathy as a function of emotional clip and drug. Error bars show +2 SE



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2 Figure 2. Affective empathy as a function of emotional clip and drug. Error bars show +2 SE.

3 * $p < .05$

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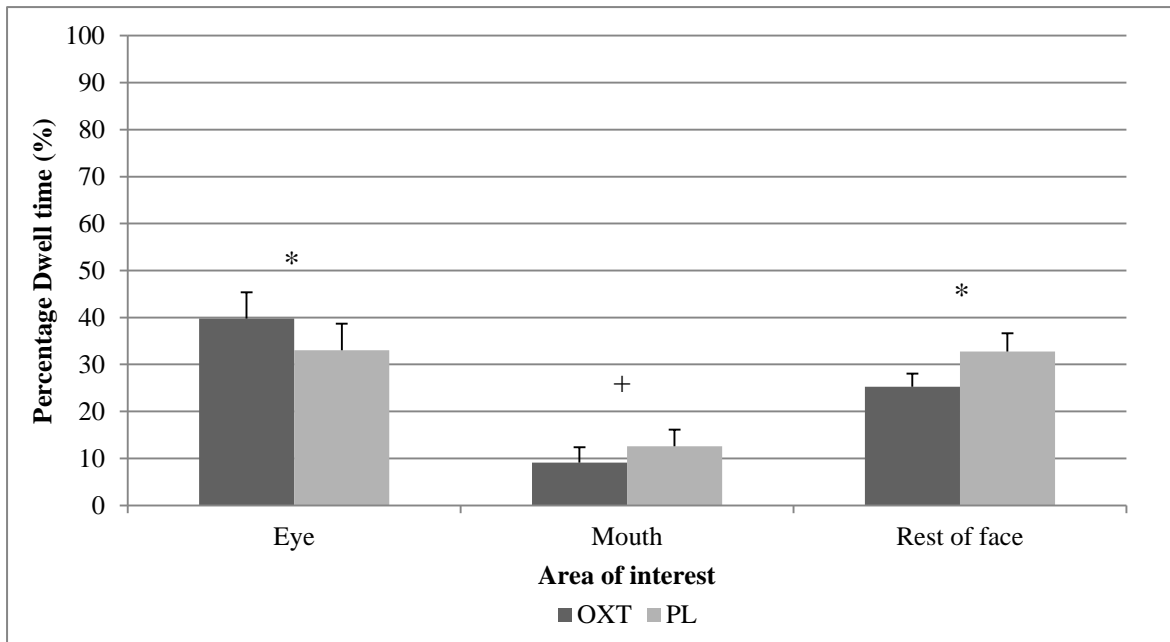
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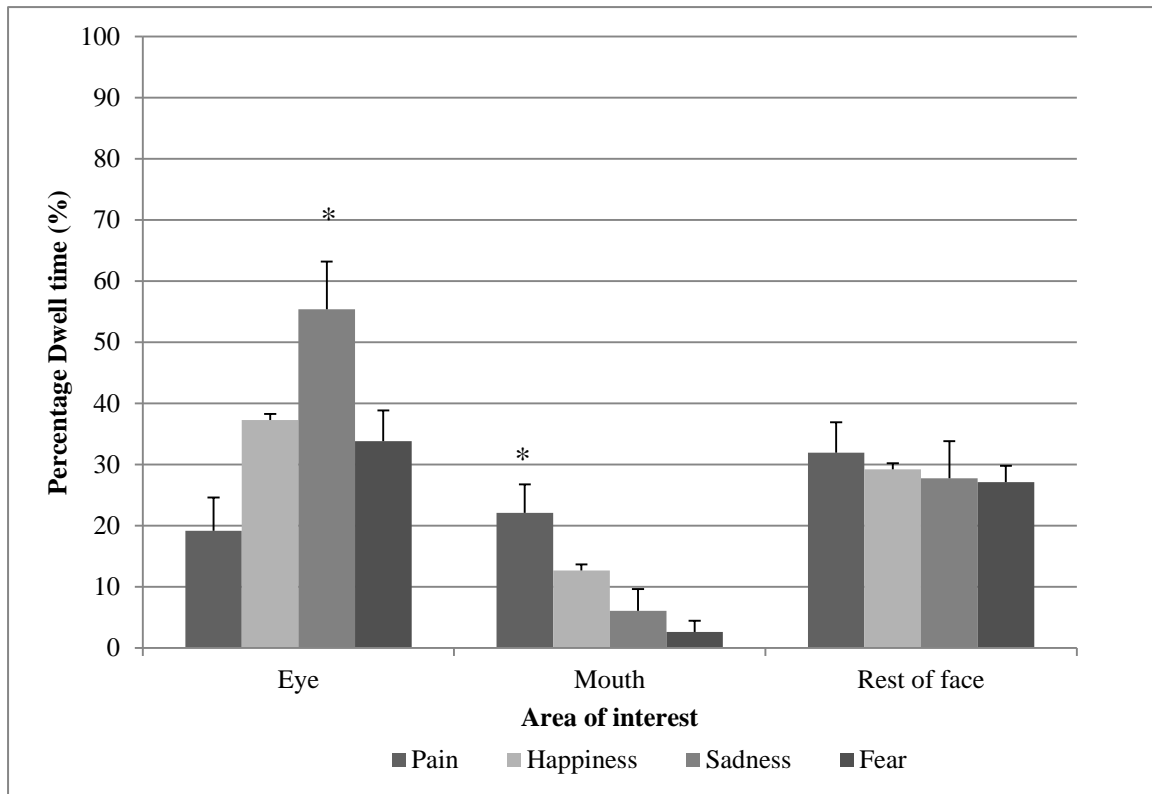
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Figure 3: Percentage dwell time as a function of area of interest and drug. Error bars show +2 SE. + $p < .10$, * $p < .05$



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2 Figure 4: Percentage dwell time as a function of area of interest and emotion. Error bars
 3 show +2 SE. * $p < .05$

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