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Intact spontaneous emotional expressivity to non-facial but not facial stimuli in schizophrenia: An electromyographic study☆

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ABSTRACT

Emotional stimuli, such as facial expressions, reliably evoke rapid, spontaneous and covert facial reactions in the perceiver that reflect the affective valence of the observed stimulus. These physiological reactions have been linked to a variety of social cognitive processes known to be disrupted in schizophrenia, such as emotion recognition and affective empathy. Moreover, individuals with schizophrenia exhibit atypical rapid facial reactions when observing emotional expressions. The current study aimed to determine if the disruption in schizophrenia is specific to facial expressions, or instead reflects more generalised emotional or motor impairments in the elicitation of this rapid facial response. Here we quantified activity in the *corrugator supercilii* and *zygomaticus major* muscle regions using electromyography while individuals with schizophrenia ($n = 24$) and controls ($n = 21$) viewed images of facial and non-facial emotional stimuli. The results indicate that schizophrenia is marked by a disruption in rapid facial responding to facial expressions, but intact responding to non-facial emotional stimuli. This dissociation between the processing of facial and non-facial emotional stimuli points to the need for a greater understanding of the degree to which facial emotion processing impairments contribute to disruptions in mimetic responding in this population.

1. Introduction

The tendency for individuals to spontaneously and rapidly configure their facial musculature to mimic observed emotional expressions is a pervasive and robust phenomenon (Dimberg et al., 2002; McIntosh et al., 2006). In neurotypical individuals, facial mimetic reactions in response to emotional expressions occur reliably, repeatedly, and involuntarily within 1 s of observing an emotional expression (Dimberg and Thunberg, 1998; Dimberg et al., 2000; Moody et al., 2007). These spontaneous reactions are positively associated with social processes such as emotion recognition (Niedenthal et al., 2001; Oberman et al., 2007; Ponari et al., 2012) and empathy (Bavelas et al., 1987). Moreover, it has been argued that mimicry is integral to the development of typical social functioning (Decety and Chaminade, 2003; Iacoboni, 2005; Niedenthal et al., 2010). Indeed, schizophrenia and autism spectrum disorders (ASD) are both characterized by profound social function impairment (Green et al., 2015; Henry et al., 2016), and rapid, spontaneous facial mimetic reactions are disrupted in both of these clinical groups (Beall et al., 2008; McIntosh et al., 2006; Oberman et al., 2009; Varcin et al., 2010).

Individuals with schizophrenia and ASD have been shown to exhibit slower (i.e., over several seconds) and more voluntary forms of mimicry (i.e., following an instruction to mimic) in reaction to facial emotional expressions (Chechko et al., 2016; Kring et al., 1999; McIntosh et al., 2006). However, *rapid* facial mimicry reactions (i.e., those occurring spontaneously within 1000 ms) are absent (Beall et al., 2008; McIntosh et al., 2006; Oberman et al., 2009; Varcin et al., 2010[1]). This is a striking dissociation given that in non-clinical volunteers, *rapid* facial mimicry responses are highly robust (Dimberg et al., 2002; Moody and McIntosh, 2006). For instance, spontaneous facial reactions occurring within 1 s have been shown to persist in neurotypical individuals even after explicit instructions *not* to react (Dimberg et al., 2002) and when emotional expressions are presented subliminally (Bailey and Henry, 2009; Dimberg et al., 2000).

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[1] Sestito et al. (2013) showed that some components of the rapid facial mimicry response may be preserved in schizophrenia. However, interpretation of these data are confounded due to the use of multi modal stimuli (audio and visual cues were presented simultaneously making it unclear whether rapid facial mimicry would have been seen if visual cues had been presented in isolation).

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Facial EMG is a reliable, objective psychophysiological technique that quantifies changes in facial muscle activity, which may be imperceptible to the human eye (Tassinary and Cacioppo, 2000). Using passive viewing paradigms, EMG studies have reliably demonstrated that observing negatively-valenced stimuli evokes increased *corrugator supercilii* (i.e., brow furrowing) activity relative to positive stimuli, and observing positive stimuli evokes increased *zygomaticus major* (i.e., smiling) activity relative to negative stimuli (Dimberg, 1982; Dimberg and Petterson, 2000; Dimberg and Thunberg, 1998; Dimberg et al., 2000; Dimberg et al., 2002).

Interestingly, EMG studies in neurotypical individuals have demonstrated that the production of rapid and spontaneous emotion-congruent facial reactions is not limited to emotional facial stimuli, but is also observed in response to positive and negative affective stimuli more generally. For example, Dimberg et al. (2002) presented neurotypical individuals with images of negatively valenced non-facial stimuli (i.e., snakes) and positively valenced non-facial stimuli (i.e., flowers) and found a pattern of spontaneous EMG facial responding consistent with that observed in response to negatively valenced (i.e., angry) and positively valenced (i.e., happy) facial expressions, within one-second post-stimulus onset. This suggests that spontaneous facial muscle activity reflects the output of a general affective reaction (Dimberg et al., 2002), rather than being an outcome of solely motor-mimetic processes (Dimberg et al., 2002; Moody and McIntosh, 2011). The occurrence of emotion-congruent facial reactions to non-facial stimuli in neurotypical individuals, allows us to examine whether disruptions to rapid facial mimicry in schizophrenia also extend to non-facial stimuli. If so, this may suggest broad disruptions to facial muscle activity in functioning as an emotional readout system in this group versus more specific disruptions responding to emotional facial expressions.

Examining the nature and specificity of spontaneous facial mimetic disruptions within the context of schizophrenia is of interest for a number of reasons. In particular, as previously mentioned, rapid facial reactions have been linked to a variety of social processes known to be disrupted in schizophrenia, such as emotion recognition (Ponari et al., 2012) and empathy (Sonnby-Borgstrom et al., 2003). A greater understanding of the nature and extent of disruptions to spontaneous, facial 'mimetic' reactions could therefore be helpful in more clearly delineating the processes contributing to social disruption in this population.

Varcin et al. (2010) presented the only study to examine *rapid* spontaneous facial mimetic reactions (i.e., those occurring within 1000 ms of observing an emotional expression) in schizophrenia. The results showed that, in contrast to non-clinical controls, there was a lack of differentiated facial EMG responding to angry and happy emotional facial stimuli in people with schizophrenia. However, Varcin et al. (2010) examined spontaneous, rapid facial mimicry reactions solely in the context of responding to emotional facial expressions. Consequently, it remains unclear whether rapid mimetic disruptions in this population are specific to facial stimuli, or extend to emotional stimuli more broadly. The primary goal of the current study was therefore to determine whether individuals with schizophrenia demonstrate broad disruptions in rapid (i.e., within 1000 ms) spontaneous facial responding to emotional stimuli, or if such disruptions are instead specific to facial stimuli.

2. Methods

2.1. Participants

Twenty-four clinical participants (17 with schizophrenia, 7 with schizoaffective disorder; 12 females) and 21 controls (13 females) completed this study. Clinical participants were recruited from an outpatient service at the Prince of Wales Hospital in Sydney and through a participant register maintained by the Australian Schizophrenia Research Bank. Diagnoses were made by two, independent, treating psychiatrists using the Structured Clinical Interview for DSM-IV Axis I Disorders (First et al., 1997), or via clinical assessment with the Diagnostic Interview for Psychoses (DIP; Castle et al., 2006). No differences were observed between schizoaffective or schizophrenia participants on any demographic or clinical variables (all $ps > 0.05$). The average duration of illness was 22.1 years ($SD = 7.29$).

Negative and positive symptoms were assessed by the Scale for the Assessment of Negative Symptoms (SANS; Andreasen, 1984b) and the Scale for the Assessment of Positive Symptoms (SAPS; Andreasen, 1984a), respectively, by a masters level clinician. The mean negative symptom score was 7.3 ($SD = 3.91$), and the mean positive symptom score was 5.0 (3.88). All participants were in a stable phase of illness and aged over 18 at the time of their participation, and all but two were receiving antipsychotic medication (21 atypical, 1 typical).

The control participants were recruited through the general community via advertisements and through a participant register. All participants received AUD$10 per hour for participation. Exclusion criteria included a history of neurological insult, psychiatric disorders or the presence of sensory, communicative, perceptual or motor difficulties that would interfere with testing.

Background information for the two groups is reported in Table 1. In addition to being matched for gender (50% versus 61.9% female for the schizophrenia and control groups, respectively, $\chi2(1, N = 45) = 0.64$, $p = .423$; $\varphi = 0.12$), the two groups did not differ in age or years of education. However, estimates of premorbid and current intelligence were higher for the control relative to the schizophrenia group (as indexed by the Wechsler Test of Adult Reading, and Wechsler Abbreviated Scale of Intelligence, respectively), and the schizophrenia group reported greater negative affect.

2.2. Procedure and measures

2.2.1. Facial stimuli

The facial stimuli were standardized images of eight happy (i.e., positively-valenced) and eight angry (i.e., negatively-valenced) facial expressions (Ekman and Friesen, 1976). Images were presented approximately 60 cm in front of the participant on a monitor.

2.2.2. Non-facial stimuli

The non-facial stimuli were eight negatively-valenced and eight positively-valenced standardized pictures selected from the International Affective Picture System (IAPS; Lang et al., 2008). Images were

Table 1
Characteristics of the schizophrenia ($n = 24$) and control ($n = 21$) participants.

Measure	Schizophrenia		Control		Inferential statistics			
	M	*SD*	*M*	*SD*	*t*	*df*	*p*	*d*
Demographics								
Age	46.2	8.78	44.9	13.54	0.36	43	0.719	0.11
Education	14.0	2.12	14.9	2.92	1.21	43	0.235	0.35
Cognitive function								
WASI IQ	100.8	11.93	115.6	11.57	4.22	43	<0.001	1.26
WTAR IQ	105.3	15.43	114.9	8.47	2.60	42	0.013	0.77
Negative affect								
DASS Total	42.9	29.93	15.81	13.64	3.99	43	<0.001	1.16
Clinical characteristics								
CPZ Equivalents	379.2	281.09	–	–	–	–	–	–
Illness duration	22.1	7.29	–	–	–	–	–	–
SAPS	5.0	3.88	–	–	–	–	–	–
SANS	7.3	3.91	–	–	–	–	–	–
SPQ Positive	–	–	6.38	6.31	–	–	–	–
SPQ Negative	–	–	7.86	6.44	–	–	–	–

Note: Data for the WTAR are missing for one control participant and data for the SAPS/SANS are missing for one clinical participant. WASI refers to Wechsler Abbreviated Scale of Intelligence; WTAR refers to Wechsler Test of Adult Reading; DASS refers to the Depression Anxiety Stress Scales 21-item version; CPZ refers to chlorpromazine; SAPS refers to the Scale for the Assessment of Positive Symptoms; SANS refers to the Scale for the Assessment of Negative Symptoms; SPQ refers to the Schizotypal Personality Questionnaire.

classified as negative or positive in accordance with pleasure ratings from the data in Lang et al. (2008) where negatively-valenced images are rated less than the neutral midpoint of 5 (i.e., from 1 to 4), and positively-valenced images are rated above the neutral midpoint of 5 (i.e., 6–9). The mean pleasure ratings in the current study were 3.65 for negatively-valenced images ($SD = 0.18$, range 3.46–3.95; IAPS numbers: 1050, 1051, 1052, 1090, 1120, 1200, 1201, 1220) and 7.83 for positively-valenced images ($SD = 0.52$, range 7.11–8.34; IAPS numbers: 1440, 1441, 1460, 1463, 1604, 1710, 1750, 5010). Images were selected that contained content similar to that used by Dimberg et al., 2002 (e.g., snakes and spiders for negatively-valenced images, and flowers and baby animals for positively-valenced images, while simultaneously being devoid of any human facial expressions or social content).

2.2.3. Passive viewing facial EMG paradigm

Surface EMG was used to record changes in the levels of muscle activity over the left *corrugator* and *zygomaticus* regions. The skin over the *zygomaticus*, *corrugator* and centre of the forehead was cleansed with an alcohol wipe and then gently abraded with NuPrep gel (Weaver and Co., Aurora, CO). Four gold-plated bipolar surface electrodes, with hat-shaped discs and 9-mm housings, were placed in pairs over the *zygomaticus* and *corrugator* muscle regions, roughly parallel to the length of the muscle, with an interelectrode distance of approximately 1.25 cm; an additional electrode was placed approximately in the centre of the forehead, acting as a ground. Muscle activity was continuously recorded with a PowerLab 4/30 Data Acquisition System (AD Instruments, Castle Hill, Australia) at a sampling rate of 2000 Hz and an amplification factor of 20,000. The PowerLab was triggered by DMDX (Version 3.2.3.0), software that precisely synchronized timing of the stimulus presentations with the recording of the data acquisition system. Data were digitally filtered offline with a 10- to 500-Hz bandpass filter and a 50-hz notch filter.

Participants were told that they would be watching a series of stimuli on a monitor and that they should try to remain still throughout the procedure. Each trial commenced with a 50 ms soft orienting tone followed by the presentation of an image 1 s later. Each image was displayed on the monitor for 5 s, followed by a blank screen for 6 s. Each participant viewed a total of four blocks (happy facial expressions, angry facial expressions, non-facial positive images, non-facial negative images). Images were presented in non-mixed randomized blocks of eight trials (e.g., eight happy face images, followed by eight angry face images) where the two facial stimulus blocks were presented together, and the two non-facial stimulus blocks were presented together. Prior research has identified that non-mixed blocked presentations reduce the influence of extraneous orienting responses on mimicry using facial EMG (e.g., Dimberg, 1996). The order in which stimuli manipulations were presented to participants (i.e., facial expressions, non-facial stimuli) was counterbalanced across participants. Videotaped recordings were reviewed, and any trials with extraneous responding unrelated to the stimuli (e.g., yawning, talking), as well as trials in which participants were not attending to the stimuli, were excluded. This amounted to <5% of all trials.

The average EMG signal was calculated using the root-mean-square (RMS) method, which represents the square root of the average power of the EMG signal over a given period of time (Tassinary and Cacioppo, 2000). The baseline for each trial was calculated as the average RMS EMG activity 500 ms prior to each stimulus presentation. The average of each 100 ms period was calculated separately for each stimulus type (e.g., eight happy, eight angry) in order to reduce potential variability of responding across trials. Subsequently, the average RMS EMG percentage change from baseline (normalized EMG), averaged across individual trials within each block, was calculated for the window 0–1000 ms post-stimulus onset, consistent with research suggesting that in non-clinical individuals rapid facial mimicry reactions occur within 1 s of stimulus onset (Dimberg et al., 2002). All testing procedures received ethical approval from the South Eastern Sydney Area Health Service.

3. Results

3.1. EMG responses to facial emotional stimuli versus non-facial stimuli

The first step in our analyses involved establishing whether there were group differences in EMG activity in the 500 ms prior to presentation of the facial and the non-facial stimuli (i.e., the baseline period). There were no group differences in either *corrugator* or *zygomaticus* baseline activity for either type of stimuli (all $ps > 0.05$).

To determine the comparability of EMG responding between stimulus types, a 2 (group: control, schizophrenia) x 2 (stimulus type: facial, non-facial) x 2 (valence: negative, positive) x 10 (time post-stimulus onset: 0–100, 100–200, 200–300, 300–400, 400–500, 500–600, 600–700, 700–800, 800–900, 900–1000 ms) repeated-measures mixed-design analysis of variance (ANOVA) was conducted separately for the *corrugator* and *zygomaticus* muscle regions. The data that contributed to these analyses are shown in Fig. 1.

For the *corrugator* region, there was no four-way interaction between group, stimulus type, valence and time $F(9, 387) = 1.51$; $p = .143$; $\eta_p^2 = 0.03$, nor a three-way interaction between stimulus type, time and group, $F(9, 387) = 0.41$; $p = .912$; $\eta_p^2 = 0.01$, or valence, time and group, $F(9, 387) = 0.64$; $p = .762$; $\eta_p^2 = 0.02$. There was, however, a three-way interaction between stimulus type, valence and time $F(9, 387) = 3.85$; $p < .001$; $\eta_p^2 = 0.08$, and most interestingly, a marginally significant interaction between stimulus type, valence and group, $F(1, 43) = 4.05$; $p = .050$; $\eta_p^2 = 0.09$.

To follow up this latter interaction, separate two-way ANOVAs were conducted for each group. For the control group, there was no main effect of stimulus, $F(1, 20) = 0.35$; $p = .563$; $\eta_p^2 = 0.02$, and no interaction between stimulus and valence, $F(1, 20) = 0.74$; $p = .401$; $\eta_p^2 = 0.04$. There was, however, a main effect of valence, $F(1, 20) = 26.68$; $p < .001$; $\eta_p^2 = 0.57$, indicating that across stimulus types, control individuals demonstrated greater *corrugator* activity to negatively-valenced images compared to positive.

For the schizophrenia group, there was no main effect of stimulus type, $F(1, 23) = 0.34$; $p = .569$; $\eta_p^2 = 0.01$, or valence, $F(1, 23) = 3.24$; $p = .085$; $\eta_p^2 = 0.12$. However, there was a trend toward a significant interaction between stimulus and valence, $F(1, 23) = 4.19$; $p = .052$; $\eta_p^2 = 0.15$. Follow-up paired samples *t*-tests indicated that while individuals with schizophrenia demonstrated comparable *corrugator* responding to positive facial and non-facial stimuli ($p = .308$), *corrugator* activity to negative stimuli (i.e., emotion-congruent responding) was greater in response to non-facial compared to facial stimuli ($p = .047$).

For the *zygomaticus* region, there was no four-way interaction between group, stimulus type, valence and time $F(9, 387) = 0.83$; $p = .590$; $\eta_p^2 = 0.02$, nor a three-way interaction between stimulus type, time and group, $F(9, 387) = 1.08$; $p = .375$; $\eta_p^2 = 0.03$, or valence, time and group, $F(9, 387) = 1.06$; $p = .390$; $\eta_p^2 = 0.02$. There was, however, a three-way interaction between stimulus type, valence and time $F(9, 387) = 4.38$; $p < .001$; $\eta_p^2 = 0.09$, and again, most interestingly, an interaction between stimulus type, valence and group, $F(1, 43) = 5.45$; $p = .02$; $\eta_p^2 = 0.11$.

To follow up this latter interaction, separate two-way ANOVAs were conducted for each group. For the control group, there was no main effect of stimulus, $F(1, 20) = 1.66$; $p = .212$; $\eta_p^2 = 0.08$, and also no interaction between stimulus and valence, $F(1, 20) = 0.18$; $p = .673$; $\eta_p^2 < 0.01$. There was, however, a main effect of valence, $F(1, 20) = 16.40$; $p = .001$; $\eta_p^2 = 0.45$, indicating that across stimulus types, control individuals demonstrated greater *zygomaticus* activity to positively- compared to negatively-valenced images.

For the schizophrenia group, there was no main effect of stimulus type, $F(1, 23) = 1.95$; $p = .176$; $\eta_p^2 = 0.08$. There was a main effect of

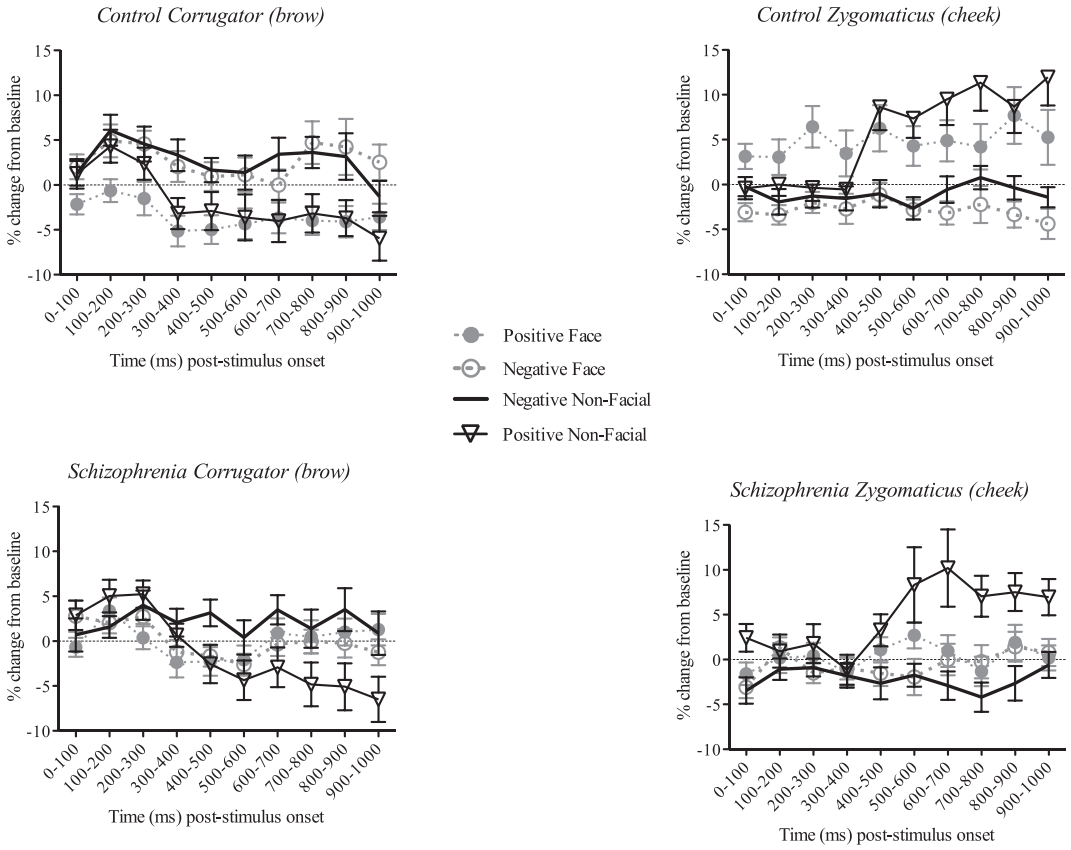

Fig. 1. Mean *corrugator* and *zygomaticus* EMG response as percentage change from baseline (+*SE*) to negative and positively valenced facial, and non-facial, stimuli for schizophrenia ($n = 24$) and control ($n = 21$) participants. The line running through 0 represents the value at baseline (mean EMG activity 500 ms prior to stimulus onset).

valence, $F(1, 23) = 9.84$; $p = .005$; $\eta_p^2 = 0.30$, indicating that across facial and non-facial stimulus types, individuals with schizophrenia demonstrated greater *zygomaticus* activity to positively- compared to negatively-valenced images. However, this main effect was superseded by the finding of an interaction between stimulus and valence, $F(1, 23) = 10.69$; $p = .003$; $\eta_p^2 = 0.32$. Paired samples *t*-tests to follow up this interaction indicated that while individuals with schizophrenia demonstrated comparable *zygomaticus* responding to negative facial and non-facial stimuli ($p = .262$), *zygomaticus* activity to positive stimuli (i.e., emotion-congruent responding) was greater in response to non-facial compared to facial stimuli ($p = .003$). Thus, as for the analyses involving the *corrugator* region, these *zygomaticus* data indicate that it is not the case the schizophrenia group failed to exhibit muscle activity in response to the facial emotional stimuli, but rather that they do not show the typical pattern of facial responding (as noted earlier, the psychophysiological definition of mimicry is greater cheek activity to happy facial expressions compared to angry, and greater brow activity to angry facial expressions compared to happy).

3.2. Correlates of EMG responding to facial and non-facial stimuli

To test the possibility that medication effects, or clinical features of the disorder may contribute to rapid facial responding disturbances, the current study also investigated associations between these variables

Table 2
Pearson correlations between zygomaticus activity to positive stimuli and corrugator muscle activity to negative stimuli and clinical and emotional functioning measures. Correlations are reported separately for people with schizophrenia ($n = 24$) and non-clinical controls ($n = 21$).

	Facial stimuli				Non-facial stimuli			
Measure	Schizophrenia		Control		Schizophrenia		Control	
	Corrugator	*Zygomaticus*	*Corrugator*	*Zygomaticus*	*Corrugator*	*Zygomaticus*	*Corrugator*	*Zygomaticus*
Emotional state								
DASS total	0.15	−0.30	0.14	−0.13	0.03	−0.20	0.18	−0.33
Clinical variables								
SAPS	0.17	−0.05	–	–	0.19	−0.28	–	–
SANS	−0.19	−0.45*	–	–	−0.29	−0.23	–	–
Blunted Affect	0.03	−0.17	–	–	−0.08	−0.12	–	–
CPZ Equivalents	−0.04	−0.35	–	–	0.15	−0.34	–	–
Illness duration	0.12	0.07	–	–	−0.04	−0.47*	–	–
SPQ-P	–	–	−0.10	−21	–	–	0.13	−0.34
SPQ-N	–	–	0.14	−0.32	–	–	0.17	−0.18
SPQ-D	–	–	0.06	−0.27	–	–	0.26	−0.18

Note: * $p < .05$. WASI refers to Wechsler Abbreviated Scale of Intelligence; DASS refers to the Depression Anxiety Stress Scales; SAPS refers to the Scale for the Assessment of Positive Symptoms; SANS refers to the Scale for the Assessment of Negative Symptoms; CPZ refers to chlorpromazine; SPQ refers to Schizotypal Personality Questionnaire, P refers to positive symptoms, N refers to negative symptoms and D refers to disorganized symptoms.

and facial EMG responding to emotional stimuli. Thus, the final analyses focused on investigating the correlates of *zygomaticus* muscle activity to positively-valenced stimuli, and *corrugator* muscle activity to negatively-valenced stimuli across the 1 s post-stimulus period (i.e., patterns of facial responding consistent with emotion-congruent rapid facial responding). It can be seen in Table 2 that the only significant associations to emerge were in the schizophrenia group, where *zygomaticus* activity to happy facial expressions was inversely correlated with levels of negative symptomatology ($p = .033$), and *zygomaticus* activity to positive *non*-facial stimuli was inversely correlated with illness duration ($p = .021$).

4. Discussion

These data show for the first time, that a disruption to spontaneous, emotional facial 'mimicry' reactions in schizophrenia is unique to facial emotional stimuli and not a result of a broader disturbance to the capacity to produce rapid facial reactions in response to emotional stimuli. Specifically, the results indicate a dissociation in spontaneous psychophysiological reactivity whereby there is intact responding to non-facial, but not facial, stimuli. Importantly, these results align with the broader schizophrenia literature which has shown that the processing of social and non-social information can be differentially affected, with intact ability to detect non-social threats despite impaired processing of social threat (Pinkham et al., 2014), and specific deficits in emotion (but not general) perception tasks (Penn et al., 2000).

Thus, the key finding to emerge was that, replicating prior research in neurotypical individuals (e.g., Dimberg et al., 2002), spontaneous, affect-congruent patterns of EMG activity were identified across both clinical and control groups, in reaction to negative and positively-valenced *non*-facial stimuli within 1000 ms post-stimulus onset (i.e., greater *zygomaticus* activity in response to positive stimuli relative to negative, and greater *corrugator* activity to negative stimuli relative to positive). The occurrence of these involuntary, 'mimicry' type facial reactions to non-facial emotional stimuli is consistent with the notion of facial muscle activity being influenced by affective processes, as opposed to an outcome of purely motor-mimetic processes (Dimberg et al., 2002; Moody and McIntosh, 2011).

The current results indicate that individuals with schizophrenia are psychophysiologically and motorically capable of eliciting rapid emotion-congruent facial reactions (as demonstrated in their typical response to non-facial emotional stimuli). However, there is a breakdown in this early affective response to emotional facial stimuli, where it is likely most required to confer social-cognitive advantages. Previous EMG research examining spontaneous facial responding in schizophrenia has been unable to rule out the possibility that medication or psychomotor disturbances could account for atypical rapid muscle responses to facial emotional expressions, despite attempts to do so (e.g., Kring et al., 1999; Varcin et al., 2010). The current study provides strong evidence against these factors; the schizophrenia group demonstrated spontaneous, rapid emotion-congruent facial EMG reactivity to negatively- and positively-valenced non-facial stimuli. This suggests that the psychophysiological and motor processes responsible for producing such early affective muscle reactions are intact in schizophrenia; however, facial stimuli fail to activate emotion-specific facial muscle reactions in this group. Further to ruling out medication as a factor for disrupted early affective facial responding, EMG reactivity was not related to chlorpromazine equivalents in the current study, consistent with previous studies examining facial EMG in this group (Kring et al., 1999; Varcin et al., 2010).

In addition to identifying that atypical rapid facial responding in schizophrenia is specific to emotional facial stimuli, the current study also found that higher levels of negative symptoms were related to reduced *zygomaticus* reactivity (associated with smiling) to happy facial expressions, and longer duration of illness was related to reduced *zygomaticus* reactivity to positive non-facial stimuli in the schizophrenia group. Consistent with these findings, in non-clinical samples Riehle and Lincoln (2017) reported that smiling behaviour was negatively related to expressive negative symptoms, while the appropriate experience of, and responding to, *positive* emotional stimuli has been linked to adaptive affective and social functioning (Fredrickson, 2001; Fredrickson et al., 2008). In schizophrenia specifically, low rates of contagion for laughing in individuals is related to higher levels of negative symptoms and poorer social functioning (Haker and Rossler, 2009). Together, these findings suggest that understanding the relationship between emotional reactions to positive emotional stimuli and negative symptomatology may be one avenue for enhancing social function outcomes in this group.

Indeed, in neurotypical volunteers, manipulations that disrupt rapid facial mimicry are associated with poorer emotion recognition (Niedenthal et al., 2001; Oberman et al., 2007). Further, rapid facial reactions have been implicated in affective sharing, one of the earliest stages in an affective empathic response (Decety, 2011), and emotional mimicry has also been argued to function as a social regulator (Hess and Fischer, 2013). An important next step for this line of research will therefore be to link disturbances in rapid facial mimicry reactions directly to social cognitive and functional outcomes in schizophrenia in order to understand the functional significance of spontaneous mimetic reactions, and the implications of their disruption.

Despite the strengths of the current study, several limitations need to be acknowledged. In particular, while the size of the schizophrenia sample in the current study is comparable to, or larger than, previous EMG studies that have been conducted both with this clinical group, as well as in individuals with ASD (Kring et al., 1999; Mattes et al., 1995; McIntosh et al., 2006; Oberman et al., 2009; Varcin et al., 2010), power may have been limited to detect more subtle group differences in responding. In addition, it might be argued that stimulus-specific differences on dimensions such as valence and arousal may have influenced facial EMG responding to the two stimuli sets. Indeed, research has demonstrated that IAPS images are typically rated higher on valence than facial expressions, despite facial expressions eliciting stronger brain activation (Britton et al., 2006). Moreover, it has been demonstrated that facial EMG activity is correlated with subjective ratings of valence to IAPS images depicting facial and non-facial content (Lang et al., 1993). However, individuals with schizophrenia tend to subjectively rate the affective valence of emotional stimuli comparably to controls (Anticevic et al., 2012). Moreover, facial EMG activity has been shown to be unrelated to ratings of experienced arousal (Lang et al., 1993), and individuals with schizophrenia subjectively rate the arousal levels of facial and non-facial affective stimuli comparably to controls (Anticevic et al., 2012). Nevertheless, while it seems unlikely that the dissociation in rapid, emotion-congruent responding to facial versus non-facial stimuli observed in the clinical (but not the control) group is attributable to differences in perceived valence or arousal across the two stimuli sets, further empirical studies are needed that directly address this possibility.

In conclusion, this study shows that atypical emotional facial expressivity in schizophrenia is specific to facial stimuli, and not a result of broader emotional or motor disturbances. These data underscore the need to better understand the nuances to social disruption in schizophrenia. Highlighting those affective processes that remain intact in this population has implications for the development of psychosocial remediation targets.

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Conflicts of interest

None.

CRediT authorship contribution statement

Kandice J. Varcin: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing - original draft. **Matthew R. Nangle:** Investigation, Methodology, Software, Validation, Writing - review & editing. **Julie D. Henry:** Conceptualization, Funding acquisition, Methodology, Resources, Supervision, Writing - review & editing. **Phoebe E. Bailey:** Investigation, Methodology, Software, Supervision, Writing - review & editing. **Jenny L. Richmond:** Supervision, Writing - review & editing.

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