

Differentiating Facial Incongruity and Flatness in Schizophrenia using Structured Light Camera Data

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Abstract—Incongruity between emotional experience and its outwardly expression is one of the prominent symptoms in schizophrenia. Though widely reported and used in clinical evaluation, this symptom is inadequately defined in the literature and may be confused with mere affect flattening. In this study we used structured-light depth camera and dedicated software to automatically measure facial activity of schizophrenia patients and healthy individuals during an emotionally evocative task. We defined novel measures for the congruence of emotional experience and emotional expression and for Flat Affect, compared them between patients and controls, and examined their consistency with clinical evaluation. We found incongruity in schizophrenia to be manifested in a less specific range of facial expressions in response to similar emotional stimuli, while the emotional experience remains intact. Our study also suggests that when taking into consideration affect flatness, no contextually inappropriate facial expressions are evident.

I. INTRODUCTION

The term schizophrenia was coined by Bleuler in the beginning of the previous century to describe (among other findings) the observed mismatch between patients mood and its outwardly display (*affect*) [3]. In psychiatric clinical evaluation, detecting and monitoring affect incongruity is critically important. First, since this is one of the more typical finding in schizophrenia, it may bias the diagnosis towards it. Second, tracking affect incongruity is a potential candidate for treatment outcome monitoring, since incongruity usually disappears or reduces as the patient positively responds to medications [10].

Currently, the evaluation of affect incongruity is based on the subjective experience of the diagnosing psychiatrist, which leads to low inter-rater reliability and may introduce biases and errors into the diagnosis [13], [6]. Consequently there is a need to define objective measures for mood-congruence assessment, providing psychiatrists with a quantitative indicator for this important symptom.

Although early literature on schizophrenia suggested that the disorder is characterized by the inability to experience

pleasure [12], a growing body of work supports the *Inhibition Theory* [3], stating that the *emotional experience* is not compromised, rather that there is an impairment in *emotional expression* [4], [11], [1]. Many studies, together with a substantial amount of clinical observations, report a severe reduction in emotional expressiveness in schizophrenia patients, also known as *Flat* or *Blunted Affect* [2], [6], [9]. Affect flattening may be expressed not only as a reduction in the intensity of emotional expression, but also as a reduction in its variability and dynamics, as demonstrated in our previous study [14].

Flat Affect is typically thought to be independent of affect incongruity and is therefore measured separately using different clinical and empirical scales [15]. Nonetheless, we may wonder whether the clinical and experimental reports of emotional incongruence are not merely a result of misinterpretation of affect flattening. For example, one of Bleuler's descriptions of incongruent expression is '*We do not feel his anger even when he speaks of it, because his features and his movements are not in agreement with his words. He may strike us with the most friendly smile on his face*'. Maybe the explanation is that this patient has a smile which doesn't change over time (aka 'frozen smile'), or simply flat affect? A confusion in clinical subjective assessment may arise due to the non-specific definition of affect incongruity.

In the past two decades a great effort has been made to empirically evaluate facial expressions in an objective manner. Most of the studies use the Facial Action Coding System (FACS) which gives scores to the activity of 46 individual facial muscles called Action Units (AUs) based on their intensity level and temporal segments [5]. The advantage of the coding system is that it does not interpret the emotional value of specific features, and allows for a detailed and quantitative facial activity analysis.

In this study we used a structured light camera in order to record schizophrenia patients and healthy individuals while observing emotionally evocative photographs. One benefit of using a depth camera is the resulting ability to accurately track facial motion. This allowed us to obtain fairly reliable measures of AU activity. We further computed discriminative features of the AU activity in order to devise data-driven measures for three phenomenological quantities used in the diagnosis of schizophrenia: *Flat Affect*, *Incongruent Affect*, and *Inappropriate Affect*. We show evidence in our data for the *Flat* and *Incongruent Affects* in schizophrenia patients, but hardly any *Inappropriate Affect*. We then directly approach the question - can affect incongruity still be observed in schizophrenia patients when taking into account affect

*This work was supported in part by the Intel Collaborative Research Institute for Computational Intelligence (ICRI-CI), and Gatsby Charitable Foundations.

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flatness? our answer in Section III-C is in the affirmative.

II. MATERIALS AND METHODS

A. Study Design

Participants included 34 patients diagnosed with schizophrenia according to the DSM-5 and 33 healthy control subjects matched for age and education level. The course of illness in patients varied from 1.5 years up to 37 years, with mean of 16.9 years. All patients but one were under stable drug treatment (mood stabilizer, antidepressant, anti-psychotic and/or sedatives). Informed consent was obtained from all individual participants included in the study.

Each participant was evaluated by a trained psychiatrist using the *Positive and Negative Symptoms Scale* (PANSS), a 30 item scale especially designed to assess the severity of both negative and positive symptoms in schizophrenia [7]. In addition, they underwent mental status examination, being evaluated for the congruity of their affect (incongruent or congruent).

Subjects were presented with 20 emotionally evocative photos retrieved from the *International Affective Picture System* (IAPS), and were asked to rate their subjective emotional experience while watching the photos ('negative', 'neutral' or 'positive'). Presenting and rating of the photos followed the IAPS photo rating paradigm [8]. Each subject was individually recorded using a 3D structured light camera (carmin 1.09).

All procedures performed in the study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

B. Facial Activity Features

Facial activity was extracted out of the video using *Faceshift*[®], a commercial software which provides real time 3D face and head tracking (www.faceshift.com). The software automatically analyzes data from 3D cameras and outputs the intensity level over time for 48 facial AUs based on the Facial Action Coding System (FACS) described in Section I. This output was manually evaluated for tracking sensitivity and noise level. Subsequently 23 AUs were selected for further analysis and learning, including brows, mouth, jaw, lips, eyes, chick, and nose activation.

For each AU separately, the raw *Faceshift* signal was quantized over time using k-means clustering ($k = 4$), and subsequently 5 different features were calculated. The features were designed to capture clinically relevant characteristics of facial expressions, including the presence of specific AUs, their intensity, and their dynamics (activation length and change ratio). See [14] for a full description of the facial features.

III. AFFECT ANALYSIS AND RESULTS

As stated above, we aim to devise automatic measures of two characteristic manifestations of facial expressions in

schizophrenic patients – *Flat Affect* and *Incongruent Affect*. Our analysis below will show that these characteristics are very much correlated in such patients, and therefore the challenge is to devise measures which can distinguish the two concepts. In fact, we propose below 3 measures, measuring flatness, incongruity and appropriateness. We show that the 3 measures capture different aspects of the participants' behavior, and specifically they can independently measure *Flat*, *Incongruent* and *Inappropriate* emotional expression.

In Section III-A we analyze a measure of *emotional experience*, which compares the underlying *emotional experience* of participants independently of facial expressions. In Section III-B we propose a measure for the congruence between a person's reported emotional state and facial expressions, which is significantly lower in patients when compared to controls. In Section III-C we directly approach the question whether affect incongruity can still be observed in schizophrenia patients when taking into account affect flatness.

A. Emotional Experience Agreement

Emotional experience is measured independently from emotional expression, by the reported response of participants when asked to describe their subjective emotional state while viewing the photos. Specifically, for each photo separately we calculated the emotional response (negative, neutral or positive) which was most common among all participants in each group (patients and controls). The congruity of emotional experience was measured by the *Agreement Score* - the percentage of participants in the group which reported the most common emotional response. This measure was compared between groups using *Student's t-test*.

Results: The *Agreement Score* was similar in patients and controls (Fig. 1-b), consistent with previous studies which report normal emotional experience in schizophrenia patients (see Section I).

B. Emotional Experience and Facial Expressions

In order to measure the agreement between facial expressions and the emotional experience of participants, we devised the *Predictiveness Score*. For each photo, we extracted the corresponding facial activity segment and computed the corresponding vector of facial activity features (see Section II-B). We excluded photos rated as 'neutral'. For each participant, a linear SVM algorithm was trained to classify photo rating as 'positive' or 'negative' based on the facial features. A Leave One Out (LOO) train-test paradigm was followed, and the *Predictiveness Score* was calculated as the area under the Receiver Operator Curve (AUC), which is a combined measure for classifier specificity and sensitivity. The measure was compared between groups using *Student's t-test* and effect size was evaluated using *Cohen's d'*.

Results: The *Predictiveness Score* was 0.90 for controls, namely, in 90% of the normal population the vector of facial features was useful enough to correctly determine whether the reported emotional experience was positive or negative. This score was significantly lower for patients ($t = 2.829$,

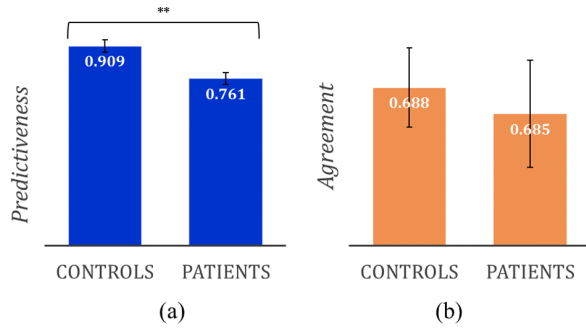


Fig. 1: A difference in emotional expression but not in emotional experience in schizophrenia patients in comparison with controls. a) The *Predictiveness Score* for emotional response classification based on facial expressions was significantly lower in patients ($t = 2.83$, $p < 0.01$). b) No significant group difference was found for the *Agreement Score* between raters.

$p < 0.01$, $df = 30$, effect size=0.508), meaning that in patients facial expressions were much less indicative of their subjective emotional experience (Fig. 1-a).

One should caution against interpreting these results as necessarily demonstrating the incongruity of facial expressions in patients. The difference may be the result of the *Flat Affect* and its effect on the learning procedure, simply because a weaker (lower) signal has typically lower SNR and is therefore harder to learn. In accordance, we found that the clinically *Flat Affect* score is significantly higher in participants with clinically reported incongruity than in congruent participants ($t = 2.08$, $p = 0.045$, $df = 42$, $effectsized' = 0.32$). In order to further isolate the possible influence of affect flatness, we looked at additional measures in the next section.

C. Distinguishing Flatness from Incongruity

In order to define measurements which differentiate facial flatness from facial incongruity, we looked more closely into the signal. We restrict the term *Incongruity* to refer to the consistency of subject's facial expressions when viewing photos evoking a similar emotional response. The term *Inappropriateness* refers to the agreement between subject's facial expressions and the typical expression in the healthy population for photos that elicit a similar emotional response.

Notations: First, the facial feature matrix of all subjects was normalized to Z scores: $Z = [X - E(X)]/\sigma(X)$. Let $j \in [k]$ denote a possible emotional response to a photo, $k = [1 - negative, 2 - neutral, 3 - positive]$. Let n_j denote the set of photos rated as j . Let $N_j = |n_j|$ denote the number of photos rated as j and $N = \sum_j N_j$ denote the total number of rated photos. Let \mathbf{z}_{ji} denote the feature vector of subject's facial activity while watching photo $i \in n_j$. For each participant, $\bar{\mathbf{z}}_j = \frac{1}{N_j} \sum_i \mathbf{z}_{ji}$ denotes the vector of mean facial activity while watching photos in n_j , and $\bar{\mathbf{z}} = \frac{1}{N} \sum_{ji} \mathbf{z}_{ji}$ denotes the vector of mean facial activity while watching any photo.

Flatness Measures: For each subject separately, we calculated the variance in facial activity for similarly rated photos, $SS_{within} = \sum_j \sum_i (\mathbf{z}_{ij} - \bar{\mathbf{z}}_j)^2$, the variance in the average response to differently rated photos $SS_{between} = \sum_j N_j (\bar{\mathbf{z}}_j - \bar{\mathbf{z}})^2$, and the total variance over all photos $SS_{total} = SS_{within} +$

TABLE I: Results of *Student's t-test* on our different measures in schizophrenia patients vs. control subjects. SS_{within} and SS_{total} were significantly lower in patients, indicating facial flatness, while *Incongruity* tended to be higher in patients. *Inappropriateness* was not significantly different in the two populations.

	Controls	Patients	t	p-val
SS_{within}	7.52	15.91	2.305	0.027
SS_{total}	8.53	18.07	2.376	0.022
<i>Incongruity</i>	0.92	0.88	-2.014	0.051
<i>Inappropriateness</i>	28.62	38.27	1.414	0.168

$SS_{between} = \sum_j \sum_i (\mathbf{z}_{ij} - \bar{\mathbf{z}})^2$. Note that all 3 measures may be considered as indicative of general facial flatness, with lower values indicating higher flatness.

Results: The total facial activity variance SS_{total} was higher in controls in comparison with patients ($t = 2.38$, $p = 0.022$, $effectsized' = 0.43$), and so were the other types of variance ($t = 2.30$, $p = 0.027$, $effectsized' = 0.41$ for SS_{within} and $t = 2.16$, $p = 0.037$, $effectsized' = 0.39$ for $SS_{between}$), see Table I. This reinforces the clinical observation that patients' affect is more flat than that of controls.

Congruity Measures: *Incongruity* is defined as the ratio between the variance within each emotion and the total variance (1). This measure tells us how unique facial expressions are with respect to each emotional state relative to the overall variance in facial expressions. In other words, we measure the inconsistency of emotional response given the total emotional flatness.

$$Incongruity = \frac{SS_{within}}{SS_{total}} \quad (1)$$

Inappropriateness is defined as the difference between the typical expression in response to a specific stimuli (the mean of facial activity over all control subjects), and each subject's individual facial activity (2). This tells us how different subject's expressions are from the expected normal response.

Specifically, let $\bar{\mathbf{z}}_{Hj}$ denote the mean facial activity of control subjects while watching photo j . For each subject, $\bar{\mathbf{z}}_{Hj}$ was calculated using all remaining control subjects (following a LOO paradigm). Then:

$$Inappropriateness = \sum_j \sum_i (\mathbf{z}_{ij} - \bar{\mathbf{z}}_{Hj})^2 \quad (2)$$

We also define a normalized version of this same measure, dividing each summand of least square distances by the variance of the subject's response to similar photos: $\sum_j [\sum_i (\mathbf{z}_{ij} - \bar{\mathbf{z}}_{Hj})^2 / \sum_i (\mathbf{z}_{ij} - \bar{\mathbf{z}}_j)^2]$. In each of the measures listed above, we tested the difference between schizophrenia patients and control subjects using *Student's t-test*.

Results: We found that *Incongruity* tend to be higher in patients ($t = -2.014$, $p = 0.051$, $df = 30$, $effectsized' = 0.36$), indicating that the facial response to stimuli evoking similar emotions is less consistent. The *Inappropriateness* measure did not significantly differ between groups nor did the normalized measure. Results are summarized in Table I.

Correlation with Clinical Evaluation: To justify the interpretation of our measures in terms of affect congruity and facial flatness we further tested the way these measures behave in accordance with clinical evaluation. Correlation between the various measures and the clinical score for

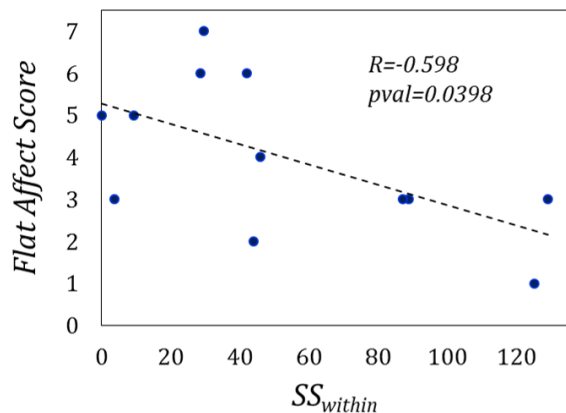


Fig. 2: Pearson correlation between patients' variance in facial expressions while looking at photos which elicit similar emotional response (SS_{within}), and the Flat Affect score given to them by the psychiatrist (based on the PANSS scoring system).

Flat Affect was calculated, in the patients group only, using Pearson correlation test. The difference in these measures between subjects diagnosed as having incongruent affect vs. congruent subjects was evaluated using Student's *t*-test.

Results: (i) SS_{within} was found to be negatively correlated with the Flat Affect score given by the psychiatrist ($R = -0.598$, $p = 0.0398$, Fig. 2), as expected, supporting our interpretation of this measure as indicative of the clinical Flat Affect. No such correlation was found for the Incongruity measure ($r = -0.0066$, $p = 0.980$). (ii) The Incongruity measure was found to be significantly higher in subjects that were clinically diagnosed as having incongruent affect ($t = 2.238$, $p = 0.0373$, $df = 22$, $effectsized' = 0.47$). No significant difference was found for any of the other measures. Additionally, the Incongruity measure was not correlated with the SS_{within} measure ($r = 0.10$, $p = 0.585$). These results reinforce our choice of measures and are in accordance with their clinical interpretation.

IV. SUMMARY AND DISCUSSION

We automatically tracked facial activity of schizophrenia patients and healthy individuals during an experimental paradigm where subjects watched a set of emotionally evocative photos and reported their emotional response. From the recorded facial activity, we obtained automatic measures of two phenomenological characteristics of schizophrenia: Flat Affect, which describes a severe reduction in emotional expressiveness, and Incongruent Affect, which refers to a mismatch between facial expression and the subjective emotional response to the current situation. Our study refined and readjusted the definition of the two symptoms, eliminating the prevalent misinterpretation of facial flatness as incongruity. Our results suggest that Incongruity is manifested independently of affect flatness, by means of a less specific range of responses to similarly evocative emotional stimuli.

Specifically, we showed that affect flatness is measured reliably by the variance in facial expressions, while the relative variance in response to similar emotional stimuli is a separate, reliable measure of affect incongruity. When taking into consideration affect flatness, we did not find evidence

for Inappropriate Affect, when the emotional response does not fit the socially expected response in similar situations. The measures introduced in our study, together with their clinical interpretations, should be further examined in both clinical and empirical settings in light of these results.

Theoretically, our results support the inhibition hypothesis of Kraepelin and Bleuler [3], which suggests that impairment and blunting of facial expression as observed in schizophrenia patients is not a result of compromised emotional experience. We found the emotional experience of schizophrenia patients to be comparable to that of healthy individuals.

The study demonstrates the importance of an objective, quantitative and precise definition of clinical symptoms in schizophrenia. Our hope is that the novel measures and analysis approach we offer will contribute to the reliability of psychiatric diagnosis, will allow better characterization of patients' behavior, and will promote both research and treatment in the field.

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