Advancing Research on Emotional Contagion

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CONTENTS

List of Figures

List of Tables

List of Abbreviations

ACME	Affective and Cognitive Measure of Empathy
AMES	Adolescent Measure of Empathy and Sympathy
BES-A	Basic Empathy Scale – Adults
BES-Y	Basic Empathy Scale – Youth
BFI-2	Big Five Inventory 2
CFA	Confirmatory factor analysis
CFI	Comparative Fit Index
CHIPS	Cohen Hoberman Inventory of Physical Symptoms
CI	Confidence interval
EC	Emotional contagion
ECQ	Empathy Components Questionnaire
ECS	Emotional Contagion Scale
EDS	Edinburgh Depression Scale
EEDS	Emotional Empathic Drive Short Scale
EES	Empathic Experience Scale
EFA	Exploratory factor analysis
EI	Empathy Index
EmQue	Empathy Questionnaire
EQ	Empathy Quotient
ESEQ	Emotion-Specific Empathy Questionnaire
ESS	Emotional Sensitivity Scale
FFH	Facial Feedback Hypothesis
FTS	Feeling and Thinking Scale
GAD-7	General Anxiety Disorder 7
GEM	Griffith Empathy Measure
IECA	Index of Empathy for Children and Adolescents
IRI	Interpersonal Reactivity Index
JSPE	Jefferson Scale of Physician Empathy
M	Mean
MBI	Maslach Burnout Inventory
MDEES	Multidimensional Emotional Empathy Scale

MEQC	Multidimensional Empathy Questionnaire for Children
MES	Multidimensional Empathy Scale
PANAS	Positive and Negative Affect Schedule
PES	Positive Empathy Scale
PSS	Perceived Stress Scale
QCAE	Questionnaire of Cognitive and Affective Empathy
QMEE	Questionnaire Measure of Emotional Empathy
RI	Revised Barrett-Lennard Relationship Inventory
RMSEA	Root Mean Square Error of Approximation
SD	Standard deviation
SEC	Susceptibility to emotional contagion
SES	State Empathy Scale
SRMR	Standardized Root Mean Square Residual
SWLS	Satisfaction with Life Scale
TEQ	Toronto Empathy Questionnaire
TLI	Tucker Lewis Index
VDQ	Vicarious Distress Questionnaire

Abstract

The present dissertation investigates the interpersonal process of emotional contagion (EC) and an individual's disposition to be susceptible to emotional contagion. Within this broad context, this work (1) reviews previous definitions and conceptualizations of EC and susceptibility to emotional contagion (SEC) and critically addresses shortcomings and limitations in previous research in this field; (2) systematically reviews existing self-report measures of individuals' SEC; (3) introduces and validates a newly developed self-report scale to assess the SEC of positive and of negative emotions; and (4) describes and evaluates a new methodological approach to examine individuals' facial expressions of emotions in unscripted and authentic group interaction, which are an essential part of the proposed underlying mechanisms of EC, using multiple synchronized video cameras and automatic facial expression recognition software. The reported findings suggest that there has not only been a lack of clarity and consistency in previous research but also a lack of suitable self-report measures to assess the SEC of both positive and negative emotions. Further, the newly developed self-report scale appears to be an internally valid, reliable, and economic measure. In terms of external validity, being susceptible to either catching others' negative or positive emotions seems to be related to different external criterion variables, such as negative emotional experiences and mental health problems as opposed to variables of interpersonal functioning. Additionally, the new multi-camera-approach in combination with automated analyses software appears to be a promising and highly innovative method to investigate individuals' facial expressions in authentic interactional situations outside of the lab. Finally, the reported results are (1) interpreted in the light of previous research, (2) the strengths and limitations of the present work are critically discussed, and (3) possible implications for

future research on EC as an interpersonal process and SEC as an individual's disposition are highlighted.

1. Introduction

In a medical context, contagion is defined as the transmission of diseases from one person to another; a process that can happen directly between individuals (e.g. via skin-to-skin contact) or indirectly via contact with contaminated objects, living organisms, or the surrounding air (Barreto, Teixeira, & Carmo, 2006). In a psychological context, the term contagion is often used to describe the transmission of different phenomena within human behaviors (Provine, 2014; Wheeler, 1966; Wheeler, Smith, & Murphy, 1964) and emotional experiences (Dezecache, Jacob, & Grèzes, 2015; Elfenbein, 2014; Hatfield, Bensman, Thornton, & Rapson, 2014). More specifically, the term *emotional contagion* (EC) describes the automatic and largely unconscious transmission of emotional experiences from one individual to another (Hatfield, Cacioppo, & Rapson, 1994). In psychological research and related disciplines, previous studies have investigated such a contagious propagation of emotional experiences between individuals within the context of interpersonal social interaction. These studies investigated social interaction between teachers and their students (Frenzel, Goetz, Lüdtke, Pekrun, & Sutton, 2009; Frenzel, Becker-Kurz, Pekrun, Goetz, & Lüdtke, 2018; King & Datu, 2017; Oberle & Schonert-Reichl, 2016), of couples (Bolger, DeLongis, Kessler, & Wethington, 1989; Kurtz & Algoe, 2015; Sels, Ceulemans, Bulteel, & Kuppens, 2016), and mother-infant dyads (Reck et al., 2004; Tronick & Reck, 2009; Waters, West, & Mendes, 2014; Waters, West, Karnilowicz, & Mendes, 2017), in group psychotherapy sessions (Rosner, Beutler, & Daldrup, 2000), and of patients with borderline personality disorder (Niedtfeld, 2017), between professional leaders and their staff (Barsade, 2002; Barsade, Coutifaris, & Pillemer, 2018; Barsade & Gibson, 2012; Bono & Ilies, 2006; Erez, Misangyi, Johnson, LePine, & Halverson, 2008; Johnson, 2008, 2009; Sy & Choi, 2013; Visser, van Knippenberg, van Kleef, & Wisse, 2013), service employees and their

customers (Barger & Grandey, 2006; Pugh, 2001), or between professional athletes within a sports team (Moll, Jordet, & Pepping, 2010; Totterdell, 2000), and individuals using communication and entertainment media (Cohen, Bowman, & Lancaster, 2016; Mui, Goudbeek, Roex, Spierts, & Swerts, 2018; Weber & Quiring, 2019), or interacting on social media platforms (Coviello et al., 2014; Ferrara & Yang, 2015; Kramer, Guillory, & Hancock, 2014; Rosenbusch, Evans, & Zeelenberg, 2019). In these studies, empirical evidence has been found for the contagion of both positive emotions (e.g. Frenzel et al., 2009, 2018; Moll et al., 2010) and negative emotions (e.g. Bolger et al., 1989; Oberle & Schonert-Reichl, 2016). More specifically, in an educational context, Frenzel and colleagues (Frenzel et al., 2009, 2018) examined the transmission of experienced enjoyment between teachers and their students. Based on findings that positive teacher and student emotions play an important role for both the wellbeing and the performance of students and teachers (Frenzel, 2014; Frenzel et al., 2016; Pekrun, Goetz, Titz, & Perry, 2002), they conducted longitudinal studies in an educational context using self-report measures of discrete teacher and student enjoyment. Their results show that teachers' and students' enjoyment in class are positively related over the course of a school year and that emotions can be transmitted between teachers and students during classroom interaction (Frenzel et al., 2009, 2018).

However, despite a growing scientific interest in the idea of EC in recent years some important questions still remain unanswered. First, what role does an individual's susceptibility to catching either positive or negative emotions play as a trait-like disposition or tendency? Second, what are the underlying mechanisms of these contagious processes and how do these processes work on a micro-level with a special focus on facial expressions as an essential part of the proposed underlying mechanisms of EC and an important channel to nonverbally communicate how we feel to others, especially in socially interactive situations? Unfortunately, current research on EC seems to be ill-prepared to answer these questions. On

a theoretical level, previous studies have been largely unclear and inconsistent in their conceptualizations of EC and there seems to be an inconsistent use of terminologies and a lack of clarity in the definitions of EC. On a methodological level, there not only seems to be a lack of suitable self-report scales to measure sec of individuals, but there is also no established and evaluated methodological approach to examine individuals' facial expressions of emotions in authentic socially interactive situations.

In order to foster ground for future research, the present work aims at contributing to the theoretical fundament and methodological repertoire of research on EC in several ways: First, I aim to promote clarity and consistency in terms of definitions and conceptualizations of EC by conceptually reviewing previous theoretical frameworks and precisely delineating EC from related concepts, such as empathy. Second, I aim at systematically reviewing existing self-report measures of individuals' *susceptibility to emotional contagion* (SEC) as the tendency or proneness to catch others' emotions. Third, I aim at developing and validating a new self-report measure to assess individuals' SEC of both positive and negative emotions. Fourth, I aim at developing and evaluating a new video-based method to assess facial expressions in authentic and unscripted group interactions using multiple synchronized cameras and automated facial action coding software. To this end, I initially provide a theoretical overview focusing on different definitions and conceptualizations of SEC and SEC over time resulting in a precise and parsimonious definition of EC as the basis for future research. Next, I systematically review published self-report measures of SEC to identify existing scales and items addressing either SEC of positive emotions, of negative emotions, or a general form of SEC. I then report on two empirical studies that represent the main contribution of this dissertation to psychological research on EC. The first study (chapter 4) reports on the development and validation of a new self-report scale to assess individuals' SEC of positive and negative emotions. The second study (chapter 5) focuses on

individuals' facial expressions as an essential part of the proposed underlying mechanisms of EC and shows how multiple synchronized cameras and automated facial action coding software can be used to examine individuals' facial expressions of emotions in authentic and unscripted group interaction. More specifically, I focus on one highly interactive and relevant context: Teachers and students in their every-day classrooms. Last, I conclude with a general discussion of my findings on theoretical, methodological, and substantial levels and I discuss possible limitations and practical implications for future research.

All data were collected by myself, together with a number of student study administrators, in the context of a larger research project that was funded by the DFG and conducted at the Department of Psychology at LMU Munich between September 2016 and August 2019 (see Appendix A for further information on the project). All data processing and statistical analyses have been performed in R (version 3.6.0; R Core Team, 2019) and reproducible scripts have been generated for all reported results and all figures.

2. A Conceptual Review of Emotional Contagion

While scientific interest in the idea of EC has grown rapidly in recent years, previous studies have been largely unclear and inconsistent in their conceptualizations and definitions of EC (Hall & Schwartz, 2019). More specifically, there are two major problems on a theoretical level that have to be addressed in the context of research on EC: First, besides "emotional contagion", many different terms have been used to describe similar phenomena, including "mood contagion" (Neumann & Strack, 2000), "empathic contagion" (Murphy, Costello, & Lilienfeld, 2018), "empathic emotional responsiveness" (Mehrabian & Epstein, 1972), "emotional synchrony" (Kühn et al., 2011), "emotional crossover" (Bolger et al., 1989), "emotional interdependence" (Sels et al., 2016), "emotion transmission" (Frenzel et al., 2009, 2018), or "emotion transfer" (Parkinson, 2011; Weilenmann et al., 2018), "shared emotions" (Thonhauser & Wetzels, 2019), "affective resonance" (Eisenberg & Eggum, 2009), and "affective linkages" (Elfenbein, 2014; Ilies, Wagner, & Morgeson, 2007). Second, there appears to be disagreement in the way EC is conceptualized. On the one hand, EC is often not sufficiently delineated from empathy and other related or subordinate concepts, such as empathic concern or personal distress (Batson, 2009; Hall & Schwartz, 2019). And on the other hand, previous studies differ substantially in their conceptualization of underlying mechanisms of contagion (Elfenbein, 2014). This lack of not only terminological clarity, but also conceptual coherence hinders precise communication between researchers and leads to misunderstandings and confusion regarding the interpretation and discussion of findings, and, therefore, challenges scientific advancement.

The goal of the present work is not to review the countless findings on EC, but to describe and contrast previous definitions and conceptualizations of EC to overcome terminological inconsistencies and conceptual misunderstandings and, thus, foster ground for

future research on EC. To this end, I will first review the theoretical perspectives on EC and its different conceptualizations over time, second, delineate EC from other related concepts of interpersonal emotional interaction, third, provide a brief overview of proposed mechanisms underlying the process of EC, and last, define EC in a clear and precise manner as a basis for future research.

2.1 Theoretical perspectives and conceptualizations

The idea of EC has been around at least since 1739 when Scottish philosopher David Hume wrote the following in his most influential work "A Treatise of Human Nature" (Hume, 1739/1896): "The passions are so contagious, that they pass with the greatest facility from one person to another, and produce correspondent movements in all human breasts" (Hume, 1739/1896, p. 605). Twenty years later, in 1759, Scottish philosopher Adam Smith described a similar phenomenon in his work "The Theory of Moral Sentiments" (Smith, 1759/1869): "The passions, upon some occasions, may seem to be transfused from one man to another, instantaneously, and antecedent to any knowledge of what excited them in the person principally concerned" (Smith, 1759/1869, p.11). A century later, in 1841, Scottish poet and author Charles Mackay portrayed the contagion of fear and enthusiasm in large groups of individuals in his book "Extraordinary Popular Delusions and the Madness of Crowds" (Mackay, 1841). And French psychologist and sociologist (among other professions), Gustave Le Bon, picked up on the idea of EC in his famous work "The Crowd: A Study of the Popular Kind" (1896) and wrote: "The exaggeration of the sentiments of a crowd is heightened by the fact that any feeling when once it is exhibited communicating itself very quickly by a process of suggestion and contagion" (Le Bon, 1896, p. 62). In the beginning of the 20th century, a few years after Le Bon, German philosopher and psychologist Theodor Lipps elaborated on the ideas of Hume and Smith in his essay "Das Wesen von fremden Ichen" and introduced the term "Einfühlung" in the context of

interpersonal interaction which was later, in 1909, translated into the English term "empathy" by US-American psychologist Edward Titchener (Cuff, Brown, Taylor, & Howat, 2016; Pinotti & Salgaro, 2019). In 1907, along with the first scientific theory of the emotional understanding of other individuals, Lipps proposed a natural tendency to automatically imitate other individuals' nonverbal expressions of emotions, a so called "drive for imitation" (Lipps, 1907, p. 716), when observed directly, which activates the same emotional experience in the observer (Preston & de Waal, 2002; Zahavi, 2010). Shortly afterwards, in 1913, German phenomenologist Max Scheler proposed four different phenomena of "fellow-feelings" or interpersonally shared emotional experiences (Scheler, 1913, 1923). According to Scheler, a so-called "emotional infection" (in German "Gefühlsansteckung") is the simplest form of "fellow-feelings" and can be defined as the transference of emotional states from one individual to another in a way similar to viruses spreading between individuals (Salice, 2016); for example an individual being infected with positive emotions when entering the joyful atmosphere in a bar or a group of individuals being infected by the mournful tone of a group member (Scheler, 1923). Most probably the idea of such EC was influenced by the ground-breaking and Nobel prize-winning work on the contagious nature of diseases at that time; like Malaria, Tuberculosis, or Diphtheria of Ronald Ross (Nobel Prize 1902), Robert Koch (1905), Alphonse Laveran (1907), or Ilja Metschnikow and Paul Ehrlich (1908).

Over the course of the 20th century, this relatively clear conceptualization of EC became more and more diluted and the idea of an automatic and unconscious transmission of emotions between individuals has been integrated or absorbed in several different, yet related concepts. These concepts included transference and countertransference (Freud, 1910; Heimann, 1950; Reik, 1948), containment/containing (Bion, 1962), collective emotions and mass hysteria (Cuff et al., 2016; Pinotti & Salgaro, 2019), mentalization

(Bateman & Fonagy, 2010; Fonagy, 2006), mutual regulation in mother-infant-interaction (Tronick, 1989; Tronick, 2017), and, most prominently, the concept of empathy or empathic understanding (Buchheimer, 1963; Mehrabian & Epstein, 1972; Murray, 1938; Stotland, 1969). It was not until later in the century that EC itself came back into view leading to very similar definitions by different theorists. They defined EC as a partly unconscious interpersonal process of sharing emotional states between individuals (Bischof-Köhler, 1988; Miller, Stiff, & Ellis, 1988), converging emotionally (Hatfield, Cacioppo, & Rapson, 1993), and vicariously experiencing similar emotions in response to another person's emotions (Mehrabian, Young, & Sato, 1988) through the perception of nonverbal expressions of emotions (Schoenewolf, 1990) and subsequent mimicking and synchronizing of these nonverbal expressions (Hatfield et al., 1993, 1994).

Alongside this interactional process of contagion, the SEC has been proposed as a trait-like disposition of how susceptible an individual is to catch others' emotions. In line with previous theorists, I define SEC as an individual's tendency or proneness to receive other individuals' emotions through the process of EC (Wheeler, 1966; Mehrabian & Epstein, 1972; Miller et al., 1988; Hatfield et al., 1993, 1994; see also Hatfield et al., 2014). Thus, SEC refers to the tendency or proneness of an individual to automatically and subconsciously receive the emotional experiences from other individuals in socially interactive situations. Therefore, in research on EC, it is crucial to clearly differentiate between the process of contagion and the disposition or tendency of an individual to catch others' emotions.

2.2 Delineation of emotional contagion from empathy

For many years, there has not been a clear definition and conceptualization of empathy or empathic understanding and the term empathy itself has been used ambiguously in both psychological and interdisciplinary literature (Batson, 2009; Coplan, 2011; Cuff et

al., 2016; Decety & Jackson, 2004; Hall & Schwartz, 2019; Pinotti & Salgaro, 2019; Zahavi & Rochat, 2015). While some theorists conceptualize empathy as an overarching concept comprising different phenomena within social cognition, interpersonal understanding, or affective linkage (Preston & de Waal, 2002), others have proposed to overcome and bypass the term empathy as overarching concept and, instead, try to precisely differentiate the subordinate concepts that possibly fall under the term empathy, such as perspective-taking, sympathetic feelings towards another person, or EC (Batson, 2009; Decety & Jackson, 2004; Hall & Schwartz, 2019). Additionally, recent reviews (Batson, 2009; Cuff et al., 2016; Hall & Schwartz, 2019) have pointed out different dimensions or characteristics that most theorists agree or disagree on in their definitions of empathy that can be used to differentiate between empathy and related concepts.

In the case of EC, these criteria can be used to precisely delineate it from empathy and other related concepts. First, EC is a purely affective response to another person's (one or more) emotional experiences, unlike cognitive role-taking or perspective-taking. Second, EC is an automatic, unintentional, and mostly unconscious process of transmission of emotional states, unlike intentionally imagining being in another person's situation or other related mentalization capacities. Third, EC on its own does not involve any behavioral tendency or reaction oriented towards another person, such as comforting, helping, or being empathically concerned. Fourth, and most critically, EC does not require a distinction of one's own emotions and the other person's emotions. While empathy requires at least some self-other distinction and a minimum level of awareness of another person's situation (Decety & Meyer, 2008; Rogers, 1957; Steinbeis, 2016; Zahavi & Rochat, 2015), EC does not necessarily require any awareness of another person, their situation, or them being the source of the transmitted emotional experience (Agosta, 2014; Bischof-Köhler, 1988; Singer, 2006; Steinbeis, 2016). In short, EC means that the emotions of another individual become

my own emotions, while empathy means to respond to another individual's emotions or situation while still distinguishing between my own emotions and the other individual's emotions.

To integrate different concepts related to empathy, Hoffman (1990) took on a developmental perspective and proposed four different levels or stages of empathy (Hoffman, 1990). Although these levels are assumed to develop sequentially, they are not mutually exclusive, but instead are rather building up on each other (Hoffman, 1990). According to Hoffman (1990), the first and most basic level represents a so-called "Global Empathy" which is similar to the process of EC and manifests itself already in infants within in the first months of their lives. At this stage individuals automatically imitate and synchronize their affective expressions without differentiating between self and other, a competence which is developed later in life (Bischof-Köhler, 1988; Decety & Jackson, 2004; Hoffman, 1990). Further stages of empathy, according to Hoffman (1990) include the attention to others' feelings, prosocial actions, and empathy for another persons' life condition.

2.3 Mechanisms behind the process of emotional contagion

Regarding the underlying mechanism of EC, different hypotheses have been proposed, including socio-cognitive appraisals (Elfenbein, 2014; Parkinson, 2011; Parkinson & Simons, 2009) or even radiating biomagnetic energy fields (McDonnell, 2014; Zahran, 2019). The most prominent hypothesis, however, had already been proposed in the beginning of the 20th century by Theodor Lipps (Lipps, 1907) and was later adapted by Elaine Hatfield and colleagues (Hatfield et al., 1993, 1994, 2014; see also Bischof-Köhler, 1988; Schoenewolf 1990) who called this mechanism "primitive emotional contagion". Based on Lipp's proposal (1907) that EC happens through the perception of other individuals' nonverbal behavior or facial expressions of emotions, they propose that the

process of EC involves three steps: (1) The perception of another person's emotional expression, (2) mimicking elements of this expression, and (3) consequently experiencing the associated emotional state, including characteristic physiological, behavioral, cognitive, and expressive responses associated with this emotional experience (e.g. Hatfield et al., 1993, 1994, 2014).

In its reasoning, this hypothesis strongly relies on the so-called *facial feedback hypothesis* (FFH; Cappella, 1993). While the FFH has been criticized and put in doubt recently when a famous study that provided important evidence for the FFH (Strack, Martin, & Stepper, 1988) could not be replicated in a preregistered multi-laboratory replication study (Wagenmakers et al., 2016), a recent meta-analysis concludes that, given the available empirical evidence, the hypothesis' central claim remains justified and widely acknowledged (Coles, Larsen, & Lench, 2019; see also Noah, Schul, & Mayo, 2018). However, empirical evidence for this motor mimicry hypothesis (Bischof-Köhler, 1988) and its role for the process of EC mainly stems from lab studies with reduced ecological validity instead of field studies in authentic and unscripted social situations (e.g. Olszanowski, Wróbel, & Hess, 2020; Wróbel & Olszanowski, 2019).

2.4 Conclusion

I conclude that, first, the idea of EC has been around for almost 300 years and it has been precisely described and defined as a phenomenon of affect transmission between individuals as early as 1913. Second, during the 20th century, the idea of EC has been constantly present and subject to scientific reasoning and empirical research. And third, the specific terminologies and conceptualizations of this phenomenon have undergone repeated alterations and the idea of EC has been integrated into several broader concepts, such as empathy, sympathy, transference/countertransference, or mentalization.

To promote clarity and consistency in future research on this important process of interpersonal emotion transmission, I argue for a concise and parsimonious definition of EC. In line with early phenomenological perspectives and modern theories of interpersonal understanding, I define EC as a basic interpersonal process which comprises the automatic and unintentional transmission of emotional states from individual A to another individual B (or more individuals). This process (1) evokes a somewhat similar emotional experience in the individual B; (2) it happens without the individual B necessarily being aware of this transmission and of the origin of this emotional experience being located in the individual A's emotions; and (3) it does not necessarily lead to any other-oriented behavioral response towards individual A, such as comforting or helping. Additionally, and in line with previous theorists, I define SEC as an individual's tendency or proneness to receive other individuals' emotions through the process of contagion. In order to fully and sustainably overcome the confusion regarding definitions and operationalizations of EC in future research and to foster a more consistent use of terms and concepts, I suggest that, in future studies, researchers explicitly define and transparently operationalize their view on EC and/or SEC.

3. A Systematic Review of Self-Report Measures of SEC

Besides the previously reported inconsistency in the conceptualization and definition of SEC, there also seems to be disagreement and discrepancies when it comes to measuring individuals' SEC. Therefore, this review strives to (1) give a systematic overview of existing self-report instruments to measure individuals' SEC, (2) to describe the theoretical framework of existing scales to measure SEC, and (3) to review the specific items that are used to assess individuals' SEC in different scales.

More specifically, I aim to answer the following research questions:

(1) What self-report measures of SEC have been published in psychological research or related disciplines?

(2) What theoretical conceptualizations of SEC act as foundation or framework for the development and construction of these measures?

(3) What specific items are used in different published measures to assess individuals' SEC and do they relate to positive or negative emotional experiences?

3.1 Method

In addition to the research goals and questions, the following components of my methodological approach have been preregistered under aspredicted.org (see Appendix B): Literature search methods, inclusion criteria, and data extraction/analysis plan.

3.1.1 Literature search

The methods to identify potentially relevant publications included (1) searching multiple bibliographic databases (PsycINFO, PSYNDEX, PubMed, ERIC), (2) scanning reference lists of existing reviews and eligible studies, (3) contacting scholars in the area of research, and (4) broadly searching the internet and academic online networks (www.researchgate.net, www.academia.edu, www.semanticscholar.org). Because different

names are commonly used for similar phenomena of EC, a variety of search terms were used, including all possible combinations of the terms “emotional”, “emotions”, “contagion”, “contagious”, “transmission”, “transfer”, "crossover", “susceptibility”, “measurement”, “measure”, “scale”, “questionnaire”, “index”, and “self-report”.

3.1.2 Inclusion criteria

Following this extensive literature search, the following inclusion criteria were used to select publications for further analyses: First, at least one of the items used in the measure was related to the phenomenon of SEC. Second, the focus of the publication lies on either scale development or scale validation and/or the reported measure could be and is intended to be used beyond a single study (e.g. included reports on content validity, construct validity, criterion validity, or norms, or instructions on how to use the measure, calculate scores, and/or what specific items are used). There were no constraints regarding the publication date, the country of origin or the language of the publication.

3.1.3 Data extraction and analysis

Subsequently, the selected publications were reviewed and analyzed regarding (1) their year of development or publication, (2) target group(s), (3) theoretical conceptualization and framework, (4) subscales, (5) response scale, and (6) the number of items related to SEC in total, SEC of positive emotions, SEC of negative emotions, and general SEC.

3.2 Results

3.2.1 Overview

In total, I found 102 publications that matched my previously defined and preregistered search criteria. Of these publications, 28 fulfilled the inclusion criteria for further analyses and 74 were excluded (for a complete list of the included measures and an overview of their characteristics, see Table 1). These publications were excluded either

because they reported on measures other than self- or other-report measures (N = 5; e.g. picture-based tests or interviews), the specific items were not available (N = 20), the authors used translated or adapted versions of already included measures (N = 34), or none of the items were related to SEC (N = 15).

The included publications were published between 1972 and 2019 and all of them either aimed at the development and/or validation of a self-/other report measure. Their main target population were adults (N = 21), followed by adolescents (N = 4) and children (N = 3) with one of them targeting both children and adolescents and one of them adults and adolescents, respectively. Of the included measures, 26 were self-report measures and two were parent-report measures.

3.2.2 Self-report measures of SEC

Of the included measures, 24 focused on empathy (including specialized constructs like empathic drive and positive empathy), one on relationship quality, one on emotional sensitivity, one on vicarious distress, and only one focused explicitly on SEC. Overall, seven of the included measures were developed as unidimensional measures and 21 of them entailed two or more subscales. Of these 21 bi-/multidimensional measures, six included a subscale explicitly addressing SEC (labeled either “Susceptibility to Emotional Contagion”, N = 1 or “Emotional Contagion”, N = 5). In conclusion, while all of the included measures contained at least one item related to SEC, there were only seven scales or subscales explicitly addressing SEC.

3.2.3 Theoretical conceptualization and framework

Most of the measures that explicitly address SEC were originally developed to assess empathy (N = 6) and they refer to a theoretical conceptualization of empathy with two distinct components: A cognitive empathy component and an affective empathy component. Within this model, cognitive empathy represents an understanding of other people’s

experiences and affective empathy refers to the ability to vicariously experience the emotional experiences of other individuals (e.g. Decety & Jackson, 2004). In these measures, SEC is conceptualized as part of the affective empathy component representing the tendency to automatically and unconsciously feel what others are feeling. However, while these measures clearly aim to assess an individual's SEC, their scales/subscales are misleadingly labeled "Emotional Contagion" which, instead, refers to the process of emotion transmission between individuals and not the individual tendency to catch others' emotions (Carré, Stefaniak, D'Ambrosio, Bensalah, & Besche-Richard, 2013; Caruso & Mayer, 1998; Reniers, Corcoran, Drake, Shryane, & Völlm, 2011; Richaud, Lemos, Mesurado, & Oros, 2017; Rieffe, Ketelaar, & Wiefferink, 2010). In conclusion, (1) most of the published measures of SEC originally aim to measure empathy and (2) while their scales/subscales are labeled EC, they aim to measure SEC instead.

3.2.4 Items assessing SEC

While only seven measures explicitly addressed SEC either as a unidimensional measure or as a subscale of a measure, all of the included measures contained at least one item related to SEC. The total number of items in all included measures was 720 and ranged from 5 to 64 items per measure (M = 25.7 items, SD = 15.1 items). Of these items, I identified 132 items that were at least tangentially related to the SEC of positive or negative emotions or to a general SEC (summarized in Table 2). Of these identified items, 71 were related to the SEC of negative emotions (53.8 % of SEC related items), 34 to the SEC of positive emotions (25.8 %), and 27 to a general SEC (20.5 %). In the subgroup of measures explicitly focusing on SEC (7 measures), I identified 50 items that were related to SEC of 164 items in total (30.5%). Of these items that were related to SEC, 12 were related to positive SEC (24% of all items related to SEC), 30 were related to negative SEC (60%), and

eight to general SEC (16%). In conclusion, the majority of items related to SEC focus on negative SEC and, in the existing measures of SEC, positive SEC is not equally represented.

Table 1. *Overview of All Measures Included in the Systematic Review.*

Measure	References	Report form	Target group	Language	*N* items	Underlying construct	Subscales
Questionnaire Measure of Emotional Empathy (QMEE)	(Mehrabian & Epstein, 1972)	Self-report	Adults	English	33	Empathy	Susceptibility to emotional contagion; Appreciation of the feelings of unfamiliar and distant others; Extreme emotional responsiveness; Tendency to be moved by others positive emotional experiences; Tendency to be moved by others negative emotional experiences; Sympathetic tendency; Willingness to be in contact with others who have problems
Index of Empathy for Children and Adolescents (IECA)	(Bryant, 1982)	Self-report	Children, adolescents	English	22	Empathy	none
Interpersonal Reactivity Index (IRI)	(Davis, 1983)	Self-Report	Adults	English	28	Empathy	Perspective-taking; Fantasy; Personal distress; Empathic concern

(continued)

Table 1 (continued)

Measure	References	Report form	Target group	Language	*N* items	Underlying construct	Subscales
Revised Barrett-Lennard Relationship Inventory (RI)	(Cramer, 1986)	Self-Report	Adults	English	64	Relationship quality	Level of regard; Advice-giving; Empathy; Unconditionality of regard; Congruence
Emotional Contagion Scale (ECS)	(Doherty, 1997)	Self-Report	Adults	English	15	Susceptibility to Emotional Contagion	none
Multidimensional Emotional Empathy Scale (MDEES)	(Caruso & Mayer, 1998)	Self-Report	Adolescents, adults	English	30	Empathy	Empathic suffering; Positive sharing; Responsive crying; Emotional attention; Feeling for others; Emotional contagion
Jefferson Scale of Physician Empathy (JSPE)	(Hojat et al., 2002)	Self-Report	Adults (physicians)	English	20	Empathy	none
Emotional Sensitivity Scale (ESS)	(Guarino, 2003)	Self-Report	Adults	English	41	Emotional sensitivity	none
Empathy Quotient (EQ)	(Baron-Cohen & Wheelwright, 2004)	Self-Report	Adults (asperger syndrome)	English	60	Empathy	none (20 filler items)
Feeling and Thinking Scale (FTS)	(Garton & Gringart, 2005)	Self-Report	Children	English	12	Empathy	Affective empathy; Cognitive empathy

(continued)

Table 1 (continued)

Measure	References	Report form	Target group	Language	*N* items	Underlying construct	Subscales
Griffith Empathy Measure (GEM)	(Dadds et al., 2008)	Parent-Report	Parents	English	23	Empathy	Affective empathy; Cognitive empathy
Multidimensional Empathy Scale (MES)	(Suzuki & Kino, 2008)	Self-Report	Adults	Japanese	24	Empathy	Other-oriented emotional reactivity; Self-oriented emotional reactivity; Emotional susceptibility; Perspective taking; Fantasy
Toronto Empathy Questionnaire (TEQ)	(Spreng, McKinnon, Mar, & Levine, 2009)	Self-Report	Adults	English	16	Empathy	none
Empathy Questionnaire (EmQue)	(Rieffe et al., 2010)	Parent-Report	Parents	English	20	Empathy	Emotional contagion; Attention to others' feelings; Prosocial actions
State Empathy Scale (SES)	(Shen, 2010)	Self-Report	Adults	English	16	Empathy	Affective empathy; Cognitive empathy; Associative empathy
Questionnaire of Cognitive and Affective Empathy (QCAE)	(Reniers et al., 2011)	Self-Report	Adults	English	31	Empathy	Cognitive empathy (perspective taking, online simulation); Affective empathy (emotion contagion, proximal responsivity, peripheral responsivity)

(continued)

Table 1 (continued)

Measure	References	Report form	Target group	Language	*N* items	Underlying construct	Subscales
Vicarious Distress Questionnaire (VDQ)	(Grynberg, Heeren, & Luminet, 2012)	Self-Report	Adults	English	18	Vicarious distress	Distress; Avoidance; Support
Basic Empathy Scale – Adults (BES-A)	(Carré et al., 2013)	Self-Report	Adults	English	20	Empathy	Emotional disconnection; Emotional contagion; Cognitive empathy
Emotion-Specific Empathy Questionnaire (ESEQ)	(Olderbak, Sassenrath, Keller, & Wilhelm, 2014)	Self-Report	Adults	English	60	Empathy	Anger affective empathy; Anger cognitive empathy; Disgust affective empathy; Disgust cognitive empathy; Fear affective empathy; Fear cognitive empathy; Happy affective empathy; Happy cognitive empathy; Sad affective empathy; Sad cognitive empathy; Surprise affective empathy; Surprise cognitive empathy
Adolescent Measure of Empathy and Sympathy (AMES)	(Vossen, Piotrowski, & Valkenburg, 2015)	Self-Report	Adolescents	English	12	Empathy, sympathy	Affective empathy; Cognitive empathy; Sympathy

(continued)

Table 1 (continued)

Measure	References	Report form	Target group	Language	*N* items	Underlying construct	Subscales
Affective and Cognitive Measure of Empathy (ACME)	(Vachon & Lynam, 2016)	Self-Report	Adults	English	36	Empathy	Cognitive empathy; Affective resonance; Affective dissonance
Empathy Index (EI)	(Jordan, Amir, & Bloom, 2016)	Self-Report	Adults	English	14	Empathy	Empathy; Behavioral contagion
Basic Empathy Scale – Youth (BES-Y)	(Heynen, Helm, Stams, & Korebrits, 2016)	Self-Report	Adolescents	German, English	12	Empathy	Affective empathy; Cognitive empathy
Empathy Components Questionnaire (ECQ)	(Batchelder, Brosnan, & Ashwin, 2017)	Self-Report	Adults	English	28	Empathy	Affective reactivity; Cognitive drive; Affective ability; Affective drive; Cognitive ability; Social perspective-taking
Emotional Empathic Drive Short Scale (EEDS)	(Karlstetter, 2017)	Self-Report	Adults	English, German	5	Empathic drive	none
Multidimensional Empathy Questionnaire for Children (MEQC)	(Richaud et al., 2017)	Self-Report	Children	English, Spanish	15	Empathy	Emotional contagion; Self-awareness; Perspective-taking; Emotional regulation; Empathic action

(continued)

Table 1 (continued)

Measure	References	Report form	Target group	Language	*N* items	Underlying construct	Subscales
Empathic Experience Scale (EES)	(Innamorati, Ebisch, Gallese, & Saggino, 2019)	Self-Report	Adults	English, Italian	30	Empathy	Intuitive understanding; Vicarious experience
Positive Empathy Scale (PES)	(Light, Moran, Zahn-Waxler, & Davidson, 2019)	Self-Report	Adults	English	15	Positive empathy	Empathic happiness; Empathic cheerfulness

3.3 Discussion

In this work, I aimed to (1) systematically overview existing self-report measures of SEC, (2) to describe their theoretical framework, and (3) to review published self-report items related to SEC. I found that (1) only few measures exist that explicitly address SEC and (2) most of these measures aim to assess empathy. Further, (3) most of the items in these existing measures of SEC focus on the SEC of negative emotions and the SEC of positive emotions has been strongly disregarded.

3.3.1 Limitations and possible bias

Two important limitations have to be taken into account when interpreting our findings. First, not all publications provided the specific items of the measures. Second, the items were rated by only one rater.

3.3.2 Conclusion and implications

First, there seem to be only very few existing scales that address the measurement of individuals' SEC. Second, most of these measures originally aim to assess different components of empathy and SEC is conceptualized as part of the affective empathy component. Third, these existing self-report measures of SEC focus almost exclusively on the transmission of negative emotions while the transmission of positive emotions has not been equally represented. Therefore, to overcome this lack of suitable self-report measures for the assessment of SEC of positive and negative emotions, new self-report scales have to be developed and validated to adequately assess individuals' SEC of both positive and negative emotions.

Table 2. *Overview of the Published Items Addressing SEC of Positive and Negative Emotions or a General SEC.*

Measure	Items addressing positive SEC	Items addressing negative SEC	Items addressing general SEC
QMEE (Mehrabian & Epstein, 1972)	Another's laughter is not catching for me.	I become nervous if others around me seem to be nervous. I don't get upset just because a friend is acting upset. I am able to remain calm even though those around me worry. I cannot continue to feel OK if people around me are depressed. I often find that I can remain cool in spite of the excitement around me.	The people around me have a great influence on my mood.
IRI (Davis, 1983)		Being in a tense emotional situation scares me. When I see someone get hurt, I tend to remain calm.	
IECA (Bryant, 1982)	Even when I don't know why someone is laughing, I laugh too.	Seeing a boy/girl who is crying makes me feel like crying. I get upset when I see a boy/girl being hurt.	
RI (Cramer, 1986)		When I am hurt or upset he/she can recognize my feelings exactly, without becoming upset her/himself. If I show that I am angry with her/him, he/she becomes hurt or angry with me, too.	Sometimes he/she thinks that I feel a certain way, because that's the way he/she feels.

(continued)

Table 2 (continued)

Measure	Items addressing positive SEC	Items addressing negative SEC	Items addressing general SEC
ECS (Doherty, 1997)	Being with a happy person picks me up when I'm feeling down. When someone smiles warmly at me, I smile back and feel warm inside. Being around happy people fills my mind with happy thoughts.	If someone I'm talking with begins to cry, I get teary-eyed. I clench my jaws and my shoulders get tight when I see the angry faces on the news. I tense when overhearing an angry quarrel. I notice myself getting tense when I'm around people who are stressed out.	
MEES (Caruso & Mayer, 1998)	When I'm with other people who are laughing I join in. I feel happy when I see people laughing and enjoying themselves. If a crowd gets excited about something so do I. Seeing other people smile makes me smile. Being around happy people makes me feel happy, too. I feel other people's joy.	The suffering of others deeply disturbs me. If someone is upset I get upset, too. I feel other people's pain. Being around people who are depressed brings my mood down. It hurts to see another person in pain.	It's easy for me to get carried away by other people's emotions. My feelings are my own and don't reflect how others feel.
JSPE (Hojat et al., 2002)			I do not allow myself to be touched by intense emotional relationships between my patients and their family members.
ESS (Guarino, 2003)	I find it easy to share in other happiness.	I get upset when other people are having a hard time.	I'm easily affected by others' emotional problems.

(continued)

Table 2 (continued)

Measure	Items addressing positive SEC	Items addressing negative SEC	Items addressing general SEC
ESS (Guarino, 2003)	I find it easy to share in others' happiness.	I get upset when other people are having a hard time.	I'm easily affected by others' emotional problems.
EQ (Baron-Cohen & Wheelwright, 2004)		Seeing people cry doesn't really upset me. I get upset if I see people suffering on news programs.	I can tune into how someone else feels rapidly and intuitively. I tend to get emotionally involved with a friend's problems.
FTS (Garton & Gringart, 2005)		When people around me are nervous or worried, I get a bit scared and worried too. Sometimes I feel helpless when people around me are upset.	
GEM (Dadds et al., 2008)	My child acts happy when another person is acting happy. My child laughs when seeing another child laugh.	My child becomes sad when other children are sad. My child gets upset when another person is acting upset. My child cries or gets upset when seeing another child cry. My child becomes nervous when other children around them are nervous. My child can continue to feel okay even if people around are upset.	My child seems to react to the moods of people around them.
MES (Suzuki & Kino, 2008)		Even if my friend is troubled, I cannot share his troubles.	My feelings are prone to be influenced by others. I am not prone to being influenced by others' emotions.

(continued)

Table 2 (continued)

Measure	Items addressing positive SEC	Items addressing negative SEC	Items addressing general SEC
TEQ (Spreng et al., 2009)	When someone else is feeling excited, I tend to get excited too. I remain unaffected when someone close to me is happy.		I find that I am "in tune" with other people's moods.
EmQue (Rieffe et al., 2010)	When my child sees other children laughing, he/she starts laughing too.	When another child cries, my child gets upset too. My child also needs to be comforted when another child is in pain. When another child is upset, my child needs to be comforted too. When another child gets frightened, my child freezes or starts to cry. When other children argue, my child gets upset.	
SES (Shen, 2010)			I can feel the character's emotions.
QCAE (Reniers et al., 2011)	I am happy when I am with a cheerful group and sad when the others are glum.	It affects me very much when one of my friends seems upset. I get very upset when I see someone cry. I am happy when I am with a cheerful group and sad when the others are glum. It worries me when others are worrying and panicky. I am inclined to get nervous when others around me seem to be nervous.	I often get emotionally involved with my friends' problems. People I am with have a strong influence on my mood.

(continued)

Table 2 (continued)

Measure	Items addressing positive SEC	Items addressing negative SEC	Items addressing general SEC
VDQ (Grynberg et al., 2012)		I strongly feel the distress of the other; I am unsettled by the other's tears.	
BES-A (Carré et al., 2013)		I don't become sad when I see other people crying. Seeing a person who has been angered has no effect on my feelings. I tend to feel scared when I am with friends who are afraid. My friend's unhappiness doesn't make me feel anything.	My friends' emotions don't affect me much. I get caught up in other people's feelings easily. I often get swept up in my friends' feelings.
ESE (Olderbak, Sassenrath, et al., 2014)	I easily feel happy when the people around me feel happy. When I see that my friend is happy about something, I automatically feel happy as well. I am not easily infected by the happiness of other people. (-). I am not easily infected by the surprise of other people. (-). I easily feel surprise when the people around me feel surprise. When I see that my friend is surprised about something, I easily feel surprise as well.	I am not easily infected by the anger of other people. When I see that my friend is angry about something, I easily feel angry as well. I easily feel angry when the people around me feel angry. When I see that my friend is disgusted about something, I easily feel disgust as well. I am not easily infected by the disgust of other people. I easily feel disgust when the people around me feel disgust. I am not easily infected by the fear of other people.	

(continued)

Table 2 (continued)

Measure	Items addressing positive SEC	Items addressing negative SEC	Items addressing general SEC
AMES (Vossen et al., 2015)		I easily feel scared when the people around me feel scared. When I see that my friend is scared about something, I easily feel scared as well. I easily feel sad when the people around me feel sad. I am not easily infected by the sadness of other people. When I see that my friend is sad about something, I easily feel sad as well. When a friend is angry, I feel angry too. When my friend is sad, I become sad too. When a friend is scared, I feel afraid. When people around me are nervous, I become nervous too.	
EI (Jordan et al., 2016)	If I see someone who is excited, I will feel excited myself. If I see a video of a Baby smiling, I find myself smiling.		I sometimes find myself feeling the emotions of the people around me, even if I don't try to feel what they're feeling.
ECQ (Batchelder et al., 2017)	I am happy when I am with a cheerful group and sad when others are glum.	It affects me very much when one of my friends is upset. I get very upset when I see someone cry.	The people I am with have a strong influence on my mood. I tend to get emotionally involved with a friend's problems.

(continued)

Table 2 (continued)

Measure	Items addressing positive SEC	Items addressing negative SEC	Items addressing general SEC
		I am happy when I am with a cheerful group and sad when others are glum. It worries me when others are worrying and panicky.	I can tune into how someone feels rapidly and intuitively. I'm sensitive to the feelings of others.
EEDS (Karlstetter, 2017)	I remain unaffected when someone close to me is happy.		
MEQC (Richaud et al., 2017)		When I see someone crying who I do not know, I feel like crying. When I am with someone who is sad, it makes me feel sad too.	
EES (Innamorati et al., 2019)	When I see another person excited because of something that happened to him/her, I feel excited myself.	While I see a friend crying, I feel myself getting teary-eyed.	Those who know me tell me that I am very affected by the emotions of others.
PES (Light et al., 2019)	I easily get excited when those around me are lively and happy. I also feel good when someone I know feels good. It often makes me feel good to see the people around me smiling. I can't help but smile when my friends smile at me. I can't stop myself from laughing when others are doing so.		

(continued)

Table 2 (continued)

Measure	Items addressing positive SEC	Items addressing negative SEC	Items addressing general SEC
BES-Y (Heynen et al., 2016)	I find that other people's happiness easily rubs off on me.	My friend's unhappiness doesn't make me feel anything.	I get caught up in other people's feelings easily. I often get swept up in my friend's feelings.

4. Development and Validation of a Balanced Self-Report Measure of SEC

4.2 Introduction

4.2.1 Emotional contagion

While, in a medical context, contagion is defined as the transmission of a disease from one individual to another (Barreto et al., 2006), the term emotional contagion (EC), in a psychological context, is often used to describe the transmission of emotions between two or more individuals (Bischof-Köhler, 1988; Dezecache et al., 2015; Elfenbein, 2014; Hatfield et al., 1993, 1994, 2014; Mehrabian & Epstein, 1972; Miller et al., 1988; Schoenewolf, 1990). The idea of such a contagious transmission of emotional experiences between individuals has been around since the 18th century (Hume, 1739/1896; Smith, 1759/1869) and it has been introduced to scientific fields related to psychology at least 100 years ago (Lipps, 1907; Scheler, 1913, 1923). Since then it has been conceptualized in different ways (Elfenbein, 2014) and different terms have been used to describe similar processes, including contagion, transmission, transfer, crossover, resonance, mirroring, or linkages (Bolger et al., 1989; Dezecache et al., 2015; Eisenberg & Eggum, 2009; Frenzel et al., 2009, 2018; Ilies et al., 2007; Mehrabian & Epstein, 1972; Murphy et al., 2018; Parkinson, 2011). In line with several theorists, we define EC as a basic interpersonal process which comprises the automatic and unintentional transmission of emotional states from an individual to one or more other individuals (Mehrabian & Epstein, 1972; Bischof-Köhler, 1988; Miller et al., 1988; Schoenewolf, 1990; Hatfield et al., 1994).

In previous research EC has been investigated within the context of social interaction in different fields; for example, educational psychology (Frenzel et al., 2009, 2018; King &

Datu, 2017; Oberle & Schonert-Reichl, 2016), clinical psychology and health psychology (Goodman & Shippy, 2002; Kurtz & Algoe, 2015; Niedtfeld, 2017; Reck et al., 2004, 2011; Rosner et al., 2000; Sels et al., 2016; Tronick & Reck, 2009; Waters et al., 2014, 2017), social psychology and industrial-organizational psychology (Barger & Grandey, 2006; Barsade, 2002; Barsade et al., 2018; Barsade & Gibson, 2012; Bono & Ilies, 2006; Erez et al., 2008; Johnson, 2008; Pugh, 2001; Sy & Choi, 2013; Visser et al., 2013), sports psychology (Moll et al., 2010; Totterdell, 2000), and research on social media and mass media communication (Cohen et al., 2016; Coviello et al., 2014; Ferrara & Yang, 2015; Kramer et al., 2014; Weber & Quiring, 2019).

More specifically, in an educational context, Frenzel and colleagues (Frenzel et al., 2009, 2018) examined the transmission of experienced enjoyment between teachers and their students. Based on findings that positive teacher and student emotions play an important role for both the wellbeing and the performance of students and teachers (Frenzel, 2014; Frenzel et al., 2016; Pekrun et al., 2002), they conducted longitudinal studies in an educational context using self-report measures of discrete teacher and student enjoyment. Their results showed that teachers' and students' enjoyment in class are positively related over the course of a school year and that positive emotions can be transmitted between teachers and students during classroom interaction (Frenzel et al., 2009, 2018). In a similar context, regarding the contagion of negative emotional experiences, Oberle and Schonert-Reichel (2016) explored students' physiological stress response and its relation to their teachers' burnout levels. Their findings suggest that the teachers' self-reported burnout was linked to the salivary cortisol levels in their students (Oberle & Schonert-Reichel, 2016). All in all, previous research on EC has found empirical evidence for the contagion of positive emotional experiences (e.g. Frenzel et al., 2009, 2018; Moll et al., 2010) as well as negative emotional experiences (e.g. Bolger et al., 1989; Oberle & Schonert-Reichel, 2016).

4.2.2 Susceptibility to emotional contagion

Based on the impression that some individuals seem to catch others' emotions quite easily, while other individuals seem to be rather immune against such contagion, it has been speculated that people differ in how prone or susceptible they are to catch others' emotions. Therefore, in contrast to the interactional process of EC, a trait-like disposition has been proposed of how susceptible an individual is to catch others' emotions in the context of socially interactive situations: The so-called susceptibility to emotional contagion (SEC). In line with previous theorists, I define SEC as an individual's tendency or proneness to receive other individuals' emotions through the process of EC (Hatfield et al., 1993, 1994, 2014; Mehrabian & Epstein, 1972; Miller et al., 1988; Wheeler, 1966). While research on the process of EC has investigated the transmission of both positive and negative emotions, previous studies on SEC have predominantly focused on its relation to negative emotions, burnout, and other mental health problems, for example among health care practitioners (Bakker, Schaufeli, Sixma, & Bosveld, 2001; Le Blanc, Bakker, Peeters, van Heesch, & Schaufeli, 2001; Omdahl & O'Donnell, 1999), social workers (Miller, Birkholt, Scott, & Stage, 1995; Siebert, Siebert, & Taylor-McLaughlin, 2007), or salespersons (Verbeke, 1997). More specifically, Omdahl and O'Donnell (1999) examined the relation of different variables of emotional interaction, including SEC, and burnout using self-report surveys in a sample of hospital nurses. In their results SEC was found to be linked to self-reported emotional exhaustion (Omdahl & O'Donnell, 1999). Similarly, Siebert and colleagues (Siebert et al., 2007) examined individuals' SEC in a sample of social workers and found that SEC was positively related to the experience of depression, burnout, and professional impairment (Siebert et al., 2007). However, despite the broad and growing scientific interest in the ideas of both EC and SEC, the specific role of an individual's SEC in the process of

contagion remains largely unclear and the SEC of positive emotions has been largely ignored in previous studies.

4.2.3 Theoretical framework and empirical support for positive and negative SEC

While SEC has been originally conceptualized as a unidimensional and global construct, I argue for a more complex perspective on SEC and propose two distinct subfacets, the SEC of positive emotions and the SEC of negative emotions. On a theoretical level, my reasoning is rooted in Watson and Tellegen's (1985) consensual model of positive and negative affect (Watson & Tellegen, 1985). While many emotion theorists have argued for a specific set of discrete emotions (Ekman, 1999; Ekman & Cordaro, 2011; Izard, 1977; Tomkins & McCarter, 1964), they proposed a more parsimonious explanation of affect related phenomena with positive and negative affect as the two general and relatively independent dimensions of emotional experiences (Watson, Clark, & Tellegen, 1988; Watson, Wiese, Vaidya, & Tellegen, 1999; Watson & Clark, 1992; Watson & Tellegen, 1985). These two dimensions can be subdivided into specific discrete emotions, such as happiness or anxiety, and reflect the valence of these emotional experiences. They have been repeatedly found to produce strong correlations among different types of positive emotions, including happiness and excitement, and negative emotions, such as depression and anxiety, respectively. In line with this model, I propose two distinct subfacets of SEC: The SEC of positive emotions (positive SEC) and the SEC of negative emotions (negative SEC). These subfacets of SEC are thought to reflect the valence of the emotional experiences that are being transmitted through the process of contagion and to be relatively independent of each other. Therefore, I do not expect an antagonistic relation between positive and negative SEC with higher positive SEC automatically leading to lower negative SEC.

However, I do expect positive and negative SEC to be linked to different variables in several important domains of human functioning, namely emotional experiences, social

interaction, and individuals' mental and physical health. First, regarding emotional experiences, I argue that being susceptible to catching others' negative emotions increases one's own frequency of negative emotional experiences when interacting with others, whereas being susceptible to catching positive emotions should increase the frequency of one's own positive emotional experiences, respectively. Accordingly, individuals with higher levels of negative SEC should be prone to experience negative emotions, such as anxiety, depression, anger, or stress more regularly, possibly leading to constantly increased levels of negative emotionality, emotional distress, and psychophysiological stress (Clark, Watson, & Mineka, 1994; Watson, Clark, & Harkness, 1994). Individuals with higher levels of positive SEC, on the other hand, should be more likely to experience positive emotions, such as enjoyment, excitement, or pride when interacting with others, possibly leading to perpetually increased levels of positive emotions and less negative emotions. Second, regarding social interaction, I argue being susceptible to catching others' positive emotions makes interacting with other individuals more pleasant, whereas being susceptible to catching negative emotions presumably makes interacting with others more aversive. Thus, individuals with higher levels of positive SEC could be motivated to approach situations of social interaction and interpersonal contact more strongly and to maintain positive social relationships and connections with others. Therefore, individuals with greater positive SEC should be likely to show higher levels of interpersonal functioning and prosocial behaviors. Individuals with higher levels of negative SEC, on the other hand, could rather be motivated to avoid such situations, leading to less social interaction and, thus, reduced levels of interpersonal functioning. Third, regarding individuals' health status, I argue that positive and negative SEC are related to physical and mental health as well as psychological well-being in different ways. Based on my reasoning that increased negative SEC is associated with greater levels of negative emotions and stress, and in line with several theories of

psychological stress (Folkman, 2013; Hobfoll, 1989; Lazarus, 1966), I argue that individuals reporting greater levels of negative SEC should be prone to experience increased issues regarding their physical health (Cohen, Janicki-Deverts, & Miller, 2007; Glaser & Kiecolt-Glaser, 2005) and mental health (Marin et al., 2011) which is, in turn, related to deficits in social functioning (Lehmann, Maliske, Böckler, & Kanske, 2019). Individuals reporting greater levels of positive SEC, on the other hand, should be less prone to suffer from such health issues. Additionally, together with my assumptions that positive SEC should be linked to increased positive emotional experiences as well as positive social relationships and interpersonal functioning, I argue that greater positive SEC should be related to increased psychological well-being (Keyes, 2002, 2006; Keyes et al., 2008).

Empirical support for the distinction of positive and negative SEC mainly comes from very few studies on positive forms of empathy. Light and colleagues (Light et al., 2019) investigated such positive empathy using a newly developed self-report measure. They found that “empathic happiness”, an emotion-specific form of positive empathy, was negatively related to the experience of anhedonia and depression (Light et al., 2019). Murphy and colleagues (Murphy et al., 2018) investigated the validity of the Empathy Index (Jordan et al., 2016), a self-report measure comprising the subscales behavioral contagion and empathy, of which Jordan and colleagues (2016) explicitly claim to represent a general form of SEC. After conducting factor analyses that revealed three different distinguishable factors, namely SEC of pleasant emotions, SEC of aversive emotions, and physical mimicry, they examined their external validity using correlational analyses. The newly construed subscale SEC of pleasant emotions was related to sympathetic caring, interpersonal attachment, and psychological well-being, as well as substantially negatively correlated with meanness. The subscale SEC of aversive emotions was not associated with sympathetic caring, but positively associated with anxiety, emotional distress, and certain personality

disorder features. The subscale physical mimicry was associated with anxiety and negative affectivity (Murphy et al., 2018). However, certain limitations have to be taken into account when interpreting these findings. First, when looking at the specific items used to assess SEC of pleasant emotions, it has to be noted that only two items explicitly address positive emotions ("If I see a video of a Baby smiling, I find myself smiling"; "If I see someone who is excited, I will feel excited myself"). Second, the three subscales used in the analyses of Murphy and colleagues are construed solely based on factor analyses of the already existing items in the EI measure by Jordan and colleagues. The items have not been developed based on the explicit theoretical framework of SEC of pleasant vs. aversive emotions. Given these limitations, their findings still add to the impression that SEC should not be treated as a unidimensional construct and positive and negative SEC substantially differ in their relations to relevant outcome variables related to emotional experiences and interpersonal interaction. While negative SEC seems to be related to greater experiences of negative emotions, distress, and depression (Light et al., 2019; Murphy et al., 2018; see also Siebert et al., 2007; Omdahl & O'Donnell, 1999), positive SEC seems to be related to increased interpersonal functioning, such as caring for others as well as general psychological well-being (Murphy et al., 2018). To conclude, there seems to be both theoretical and empirical support for a distinct conceptualization of positive and negative SEC.

4.2.4 Existing self-report measures of individuals' SEC

On a methodological level, previous studies most often used self-report scales to measure individuals' SEC. Following an extensive literature search, I identified seven published measures that explicitly addressed SEC either as a unidimensional measure or as a subscale of an empathy measure (see Table 3 for a full list of these measures). These seven measures entailed 164 items in total. Of these 164 items, I identified 51 items that address SEC in the same way we conceptualize SEC in the present work (31%). Of these 51 items,

only 13 were related to positive SEC (25.5% of all 164 items addressing SEC; sample item: “Being around happy people makes me feel happy, too”), 30 were related to negative SEC (58.8%; sample item: “I become nervous if others around me seem to be nervous”), and eight to a general form of SEC (15.7%; sample item: “I get caught up in other people’s feelings easily”). In conclusion, only very few self-report measures have been published to explicitly assess SEC and the majority of items related to SEC focused on negative SEC while items focusing on positive SEC were not equally represented in these measures.

Regarding internal validity of self-reported SEC, several studies have examined the factor structure of the *Emotional Contagion Scale* (ECS; Doherty, 1997) in different non-English speaking contexts. While the ECS has been initially developed as a unidimensional self-report measure of individuals’ SEC (Doherty, 1997), these studies have found several bi-/multidimensional models that fit their data better than the original single-factor model (Gouveia, Gouveia, Guerra, Santos, & Medeiros, 2007; Lo Coco, Ingoglia, & Lundqvist, 2014; Lundqvist, 2006; Lundqvist & Kevrekidis, 2008; Rueff-Lopes & Caetano, 2012; Wróbel & Lundqvist, 2014). More specifically, Lundqvist and colleagues (Lundqvist, 2006; Lundqvist & Kevrekidis, 2008; Wrobel & Lundqvist, 2014; LoCoco et al., 2014) found empirical support for several different models using confirmatory factor analyses (CFA) in Swedish, Greek, Polish, and Italian samples, including hierarchical models with positive and negative affect as second-order factors and four (sadness, anger/fear, happiness, love) to five discrete emotions (anger, fear, sadness, happiness, love) as first-order factors.

These findings imply that SEC as a construct may not be as unidimensional and global as initially thought and that it might be more appropriate to differentiate separate subfacets, such as positive and negative emotional valence. In conclusion, suitable scales to assess the SEC of positive and negative emotions seem to be lacking and, thus, further

research on the specific role of positive SEC as opposed to negative SEC is hindered on a methodological level.

4.2.5 Summary and research gap

First, previous research on individuals' SEC predominantly focused on negative emotions and only very few studies have specifically investigated the SEC of positive emotions. Second, my theoretical reasoning is grounded in Watson and Tellegen's (1985, 1999) consensual model of positive and negative affect, which proposes positive and negative affect as two relatively independent general dimensions of emotional experiences that are related to individuals' mental and physical health (e.g. Clark et al., 1994) as well as their psychological well-being (e.g. Keyes, 2008). Third, while my theoretical assumptions of two distinct subfacets of individuals' SEC are supported by the empirical findings on the external validity of measures of positive forms of empathy, these studies did not explicitly operationalize and deliberately investigate both positive and negative SEC as distinct subfacets of SEC. Instead, they either used preexisting items from a different empathy measure after conducting factor analyses (Murphy et al., 2018) or they only focused on individuals' SEC of positive emotions and fully disregarded the SEC of negative emotions (Light et al., 2019). Last, only very few self-report measures have been published to explicitly assess SEC and the majority of items were focused on negative emotions while items addressing positive emotions were not equally represented in these measures. Findings regarding the internal validity of existing measures of SEC further suggest that the SEC of individuals should not be seen as a strictly unidimensional phenomenon and positive and negative SEC should be measured and investigated separately. In conclusion, (1) the specific role of SEC of positive and negative emotions in the process of EC remains unclear and (2) suitable self-report scales to assess both positive and negative SEC separately are lacking, as of yet.

Table 3. *Published Measures that Explicitly Address Individuals' SEC*

Measure	References	Report form	Target group	Language	*N* items	Subscales
Questionnaire Measure of Emotional Empathy (QMEE)	(Mehrabian & Epstein, 1972)	Self-report	Adults	English	33	Susceptibility to emotional contagion; Appreciation of the feelings of unfamiliar and distant others; Extreme emotional responsiveness; Tendency to be moved by others positive emotional experiences; Tendency to be moved by others negative emotional experiences; Sympathetic tendency; Willingness to be in contact with others who have problems
Emotional Contagion Scale (ECS)	(Doherty, 1997)	Self-Report	Adults	English	15	none
Multidimensional Emotional Empathy Scale (MDEES)	(Caruso & Mayer, 1998)	Self-Report	Adolescents, adults	English	30	Empathic suffering; Positive sharing; Responsive crying; Emotional attention; Feeling for others; Emotional contagion
Empathy Questionnaire (EmQue)	(Rieffe et al., 2010)	Parent-Report	Parents	English	20	Emotional contagion; Attention to others' feelings; Prosocial actions

(continued)

Table 3 (continued)

Measure	References	Report form	Target group	Language	*N* items	Subscales
Questionnaire of Cognitive and Affective Empathy (QCAE)	(Reniers et al., 2011)	Self-Report	Adults	English	31	Cognitive empathy (perspective taking, online simulation); Affective empathy (emotion contagion, proximal responsivity, peripheral responsivity)
Basic Empathy Scale – Adults (BES-A)	(Carré et al., 2013)	Self-Report	Adults	English	20	Emotional disconnection; Emotional contagion; Cognitive empathy
Multidimensional Empathy Questionnaire for Children (MEQC)	(Richaud et al., 2017)	Self-Report	Children	English, Spanish	15	Emotional contagion; Self-awareness; Perspective-taking; Emotional regulation; Empathic action

4.2.6 Rationales for test construction

When constructing my new self-report scale, I considered several key issues regarding the measurement of emotional experiences and related phenomena: (1) Conceptualization of emotional experiences, (2) state or trait emotional experiences, (3) specificity of emotional experiences, and (4) discrete emotions and/or dimensional approach.

First, in line with a well-established component process definition of emotions, I conceptualize emotional experiences as episodes of synchronized changes in interrelated organismic subsystems in reaction to individually significant stimuli (Mauss & Robinson, 2009; Scherer, 2005, 2009; Shuman & Scherer, 2014). Accordingly, an emotional episode comprises cognitive, physiological, motivational, and expressive components and can be characterized not only by its affective feelings, but also by specific thoughts, physiological changes, motivational action tendencies, such as approach versus avoidance tendencies, and expressive behavior, including facial expressions.

Second, in line with my conceptualization of SEC, I chose a trait approach to measuring individuals' SEC. More specifically, I conceptualize SEC as a relatively stable disposition of individuals and previous research has shown relations of individuals' SEC to other dispositional variables, such as their emotional exhaustion (Siebert et al., 2007).

Third, regarding the specificity of emotional experiences, I aimed at developing a measure of SEC on a general level instead of a specific social or professional context. Previous research on individuals' emotions has brought forward many different context specific instruments to assess individuals' emotions and related phenomena in very specific contexts, such as their professional background as teachers (Frenzel et al., 2016), students' emotions in achievement situations (Lichtenfeld, Pekrun, Stupnisky, Reiss, & Murayama, 2012; Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011), or the empathic abilities of physicians (Hojat et al., 2002). However, in line with my conceptualization of EC as a basic

and rudimentary interpersonal process between individuals, I assume that the individual tendency to experience this process is not necessarily context specific in its nature and decided to measure individuals' SEC on a general level.

Fourth, in line with Watson and Tellegen's (1985, 1999) consensual model of positive and negative affect, I chose a dimensional approach to characterize individuals' emotions based on the valence of these emotional experiences. In my measure, these dimensions are represented in the two subscales positive SEC and negative SEC. However, within these two subscales, I chose to formulate items with regard to specific discrete emotional experiences, such as being happy or stressed out. This approach is in line with previous studies on the factor structure of existing measures of SEC which often found a hierarchical factor structure with positive and negative affect as second-order factors and several discrete emotions as first-order factors.

In sum, my newly developed self-report scale has been established to represent a trait-level measure of what individuals are able to explicitly infer and report about their own SEC as their general tendency to automatically and vicariously experience positive or negative emotions similar to other individuals' emotions in socially interactive situations. Thus, it is not supposed to serve as an objective measure of how susceptible a person is to catch others' emotions in terms of measuring the frequency of emotions being caught versus not being caught in a specific situation (see Doherty, 1997).

4.2.7 Scale development and item selection

In the development of my new scale, I aimed to create a short and economic measure of positive and negative SEC with items assessing the SEC of positive emotional experiences and of negative emotional experiences being equally represented. I was inspired by existing measures of SEC or affective empathy, including the ECS (Doherty, 1997) and the Emotional Empathic Tendency Scale (Mehrabian & Epstein, 1972), and specific items

within these measures served as the basis for my new items. These items were all related to positive SEC or negative SEC in their content and wording and have been taken either from published German translations of these existing scales or translated to German by the author of this study. To eliminate existing deficits in published self-report measures of SEC, some of the existing items have been reworded and new items have been generated according to my definition and conceptualization of SEC. These deficits included items describing behavioral expressions (e.g. “When someone smiles warmly at me, I smile back and feel warm inside”; Doherty, 1997), competence-oriented items (e.g. “I am able to remain calm even though those around me worry”; Mehrabian & Epstein, 1972), items focusing on a specific interactive context (e.g. “When a friend is angry, I feel angry, too”; Vossen et al., 2015), items that are not precise and unambiguous regarding their content (e.g. “I am happy when I am with a cheerful group and sad when the others are gloom”; Reniers et al., 2011; Batchelder et al., 2017), inverted items (e.g. “Another’s laughter is not catching for me”; Mehrabian & Epstein, 1972), or unnecessary redundancies within the scales (e.g. “I easily feel happy when the people around me feel happy” and “When I see that my friend is happy about something, I automatically feel happy as well“; Olderbak, Sassenrath, et al., 2014). Subsequently, 5 items per subscale have been selected for further analyses in this study based on expert judgement (face and content validity) and criteria like semantic redundancy or comprehensibility.

4.2.8 Strategy for scale analysis

Regarding the internal validity of my new scale, I expected a two-factor structure to emerge, reflecting the two proposed dimensions of SEC (positive vs. negative SEC). In Study 1, I conducted an exploratory factor analysis (EFA) to explore the internal structure of my scale, to investigate whether my expected two subscales measure separable, yet related, latent variables, and to identify items that could be excluded for the purpose of creating a

parsimonious and economic scale. In Study 2, I aimed to replicate and confirm the findings regarding the internal structure of my scale using CFA. Additionally, I aimed to investigate whether a two-factor model (differentiating positive vs. negative SEC) better fits the data than a single-factor model (i.e., denoting a one-dimensional SEC factor). In both studies, I aimed to examine the subscales' reliability by calculating their internal consistencies using the Cronbach's alpha and McDonald's Omega coefficients (Dunn, Baguley, & Brunsden, 2014; McNeish, 2018; Viladrich, Angulo-Brunet, & Doval, 2017) and other psychometric properties.

Regarding its external validity, I calculated correlations to examine the relations of positive vs. negative SEC with other emotion and personality related variables, including emotional exhaustion (in Study 1), and depression, anxiety, stress, and personality variables (in Study 2) while considering potential response biases to the newly developed scale due to social desirability (Study 2).

4.2.9 General research questions and hypotheses

Within the present contribution, I aimed to develop and validate a new balanced self-report measure to quickly and economically assess individuals' SEC of positive and negative emotions as distinct subfacets of an individual's SEC. More specifically, I aimed at answering the following general research questions:

(1) Are positive SEC and negative SEC separable, yet related, constructs as measured with the newly developed scale?

(2) Does my scale prove internally valid, as documented by EFA and CFA showing that a two-factor model fits the data better than a single factor model?

(3) Is the scale a reliable measure of self-reported positive and negative SEC as documented by their internal consistencies?

(4) Does the scale prove externally valid, as documented by theoretically meaningful relations with other self-reported variables?

Two studies were conducted to answer these questions. In Study 1, I preliminarily examined the internal and external validity of the scale in a sample of German teachers from different types of schools. Study 2 aimed to replicate the findings on the internal and external validity of my scale in an online sample in Germany.

In terms of hypotheses regarding the external validity of our scale, I expected diverging patterns in its relations to external criterion variables: First, I expected negative SEC to be related to affective empathy and neither negative nor positive SEC to be related to cognitive empathy and perspective taking. Second, I expected greater positive SEC to be linked with greater experienced positive affect and greater negative SEC to be linked with greater experienced negative affect. Third, I expected greater levels of negative SEC to be related to greater mental health problems and emotion-related psychopathology, and greater levels of positive SEC to be linked to greater subjective well-being. Fourth, I expect that individuals with greater levels of positive SEC report higher levels of interpersonal and social functioning, such as being trustful and sociable, showing sympathy and compassion for other individuals, or higher levels of prosocial tendencies and behaviors, like solving conflicts, offering help and caring for other individuals. In contrast, individuals with higher levels of negative SEC should be more likely to avoid social interactions and interpersonal contact and show less trust, compassion, sympathy, and sociability in their interpersonal interactions and relationships.

4.3 Preliminary analysis of internal and external validity (Study 1)

Study 1 was designed to provide preliminary data on the internal and external validity of my newly developed scale. To this end, I assessed individuals' self-reported SEC (positive SEC and negative SEC) and emotional exhaustion as the core aspect of burnout, a variable that has often been found to relate to SEC in previous studies (e.g. Siebert et al., 2007), in a sample of German teachers.

4.3.1 Research questions and hypotheses

Specifically, I aimed at answering the following research questions:

(1) Are the two subfacets of SEC, positive and negative SEC, separable constructs as determined by EFA?

(2) Are the two subscales reliable in terms of their internal consistencies?

(3) How do the two subscales, positive and negative SEC, relate to self-reported emotional exhaustion as a theoretically meaningful criterion for their external validity?

I predicted that (a) the factor structure of the items would distinguish self-reported SEC of positive emotions from SEC of negative emotions, (b) both subscales would be reliable in terms of their internal consistency, and (c) negative SEC would be substantially related to self-reported emotional exhaustion, whereas positive SEC would not be related to individuals' emotional exhaustion.

4.3.2 Method

Sample and Procedure

The sample of this study consisted of $N = 257$ teachers (71.5% female) from different German states (Bavaria, 82.0%; Baden-Wurttemberg, 11.4%; Saxony, 2.4%; Thuringia, 3.1% 3.9 %; other, 1.1%). Their age ranged from 26 to 64 years ($M = 41.8$; $SD = 10.9$) and they had an average teaching experience of 13.3 years ($SD = 10.3$). The teachers worked at different types of secondary schools (13.8% lowest, 19.4% middle, 53.8% highest academic

track), in primary schools (2.9 %), in vocational schools (4.0%), or in more than one of these school types at the same time (5.1%). They taught a wide range of subjects (e.g. Math, German, English), their average teaching hours per week ranged from 6 to 28 hours (M = 20.7; SD = 5.2) and they taught up to 16 classes regularly during that particular school year (Min = 1; M = 5.4; SD = 2.8). Regarding graduation levels, 98.0% had obtained German A levels and, regarding relationship status, 57.1% were married. All participants were recruited on a voluntary basis through convenience sampling and direct contact to the schools or the teachers (via email, telephone, or written informational letters) and no incentives were given for participation. Paper-pencil-questionnaires were sent out to all participants and completed anonymously (return rate = 50.5 %). All questionnaires were scanned and processed by multiple trained study administrators using an optical mark recognition software (GrafStat, version 4.950; Diener, 2018).

Measures

The newly developed scale was administered to assess individuals' positive SEC and negative SEC with 5 items per subscale (example items: "It fills me with joy to be around happy people" and "I get nervous when others around me are nervous."). All items were answered on a five-point Likert Scale (ranging from 1 = "strongly disagree" to 5 = "strongly agree") and were presented in random order within the questionnaire.

Further, to assess burnout I used the emotional exhaustion scale of the Maslach Burnout Inventory (Maslach, Jackson, & Leiter, 1997), which has been used frequently as a standalone measure of burnout in previous research (Schaufeli & Buunk, 2003). The scale consists of 6 items (example item: "I feel emotionally drained from my work") and all items are answered on a seven-point Likert Scale (ranging from 0 = "never" to 6 = "daily").

In addition to these two measures, several other constructs were assessed, including teacher emotions, teacher self-efficacy, emotion regulation, or emotional labor (see Appendix C for a full list of the assessed variables).

Statistical Analyses

First, I conducted EFA using the package "psych" (Revelle, 2018, version 1.8.12) in R (version 3.6.0; R Core Team, 2019) to explore the scale's factor structure. Subsequently, I excluded items based on empirical and theoretical considerations to create a short and economic self-report measure. Second, I explored the psychometric properties of all scales, including Cronbach's alpha and McDonald's omega coefficients to assess their internal consistency (package "userfriendlyscience"; Peters, 2018, version 0.7.2). Third, I calculated bivariate Pearson correlations (package "stats", R Core Team, 2019) to explore the relations between positive and negative SEC and between emotional exhaustion and both subfacets of SEC separately. All data processing and statistical analyses in this study were done in R, mainly using the packages "base" (R Core Team, 2019), "tidyverse" (version 1.2.1; Wickham, 2017), "dplyr" (version 0.8.4; Wickham et al., 2020), and "ggplot2" (Wickham, 2016), and reproducible scripts for all reported results and figures were generated.

4.3.3 Results and discussion

Preliminary Analyses

All items proved to show deviations from univariate normality using the Shapiro-Wilk test and the Anderson-Darling test and no significant multivariate outliers were detected using the Henze-Zirker test and the Mardia test (package "MVN"; Korkmaz, Goksuluk, & Zararsiz, 2014). When looking at Figure 1 depicting the density distributions for all items, the items regarding negative SEC seem to be relatively normally distributed while the items regarding positive SEC seem to be negatively skewed. Missing values for all

variables did not exceed 2% and all cases were listwise deleted prior to subsequent factor analyses, resulting in $N = 252$ cases for EFA.

Exploratory Factor Analysis

EFA was used to test my theoretical assumptions of two separate latent variables. To investigate the adequacy of the collected data for factor analyses, I inspected the inter item correlations and used the Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) test. Inter-item-correlations ranged between .06 and .65 with the majority of the correlations being in the range between .20 and .80, the KMO measure of sampling adequacy was .84 and Bartlett's test of sphericity was significant [$\chi2(45) = 892.41$, $p < .001$], collectively indicating good factorability of the data for further analyses (Field, Miles, & Field, 2012). To determine the number of factors to retain, I first inspected the factors' eigenvalues revealing two factors with eigenvalues greater than one. Second, when looking at the Scree Plot (see Figure 2), I clearly identified a break after two factors, and, third, when conducting parallel analysis, two factors were suggested. Consistently with these results and our theoretical reasoning, I decided to retain two factors. As I expected minor to moderate correlations between the two variables, I used an oblique factor rotation of the factors ("oblimin" method). Because the data violated the normality assumption, I used an ordinary least squares (OLS) method to find the minimum residuals solution ("minres" method).

After conducting EFA, five items had significant factor loadings on Factor 1 and five items on Factor 2, respectively (ranging between .49 and .85). Consequently, Factor 1 was labeled "positive SEC" and Factor 2 was labeled "negative SEC". In order to create a parsimonious and economic, yet still balanced, measure of SEC, items were excluded from the final version based on their factor loadings and cross loadings. I excluded two items with the weakest factor loadings and with cross loadings > .1 (items "PosSEC3" and "NegSEC1") which resulted in a final scale consisting of eight items in total with four items in each

subscale (see Table 4 for the factor matrix of the final 8-item scale; see Appendix C for the factor matrix of the initially tested 10-item version of the scale). These two factors, positive SEC and negative SEC, showed an interfactor correlation of $r = .37$ and cumulatively accounted for 48 % of the total variance (Factor 1 = 26%, Factor 2 = 22%). In conclusion, EFA clearly revealed two separable, yet related latent variables and the items representing these two factors corresponded to our previously assumed subfacets of SEC of positive emotions and SEC of negative emotions.

Descriptive Statistics

Descriptive statistics for all scales, including emotional exhaustion, are reported in Table 5 and psychometric properties for the final items of the positive SEC and negative SEC subscales are reported in Table 6. Participants reported relatively high mean levels of positive SEC ($M = 4.16$) as compared to negative SEC ($M = 2.76$). However, standard deviations were sufficiently large to preclude ceiling or floor effects. Internal consistencies of the two subscales were examined by calculating Cronbach's alpha and McDonald's omega indices showing acceptable to good reliabilities for positive SEC ($\alpha = .83$; CI 95% [.80, .87] and $\omega = .83$; CI 95% [.80, .87]) as well as negative SEC ($\alpha = .76$; CI 95% [.72, .81] and $\omega = .77$; CI 95% [.72, .82]), according to conventions (Field et al., 2012).

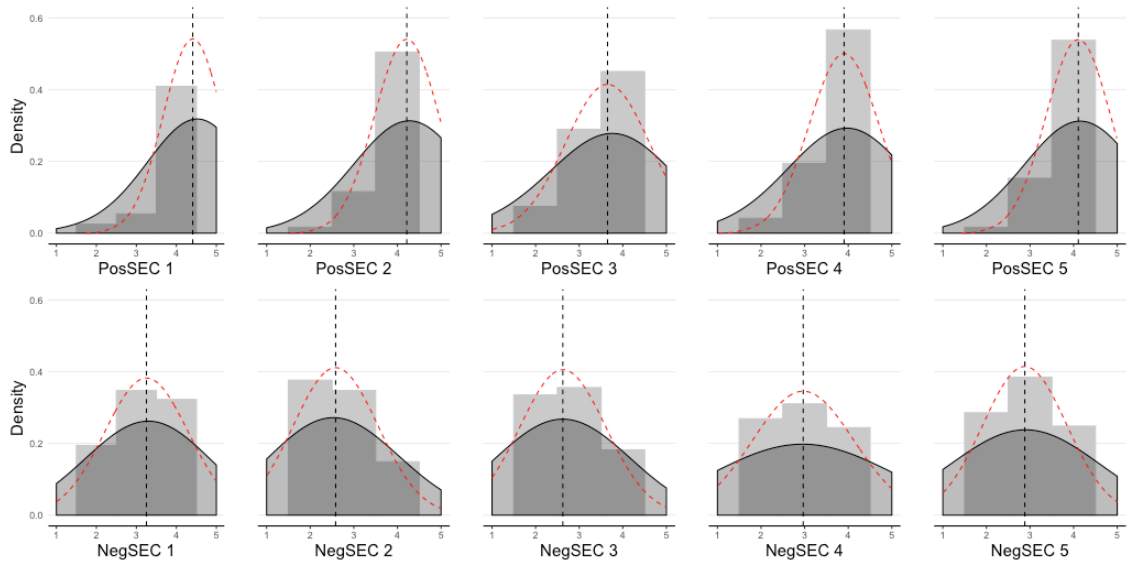

Figure 1. Density distributions for all items of the SEC scale in Study 1.

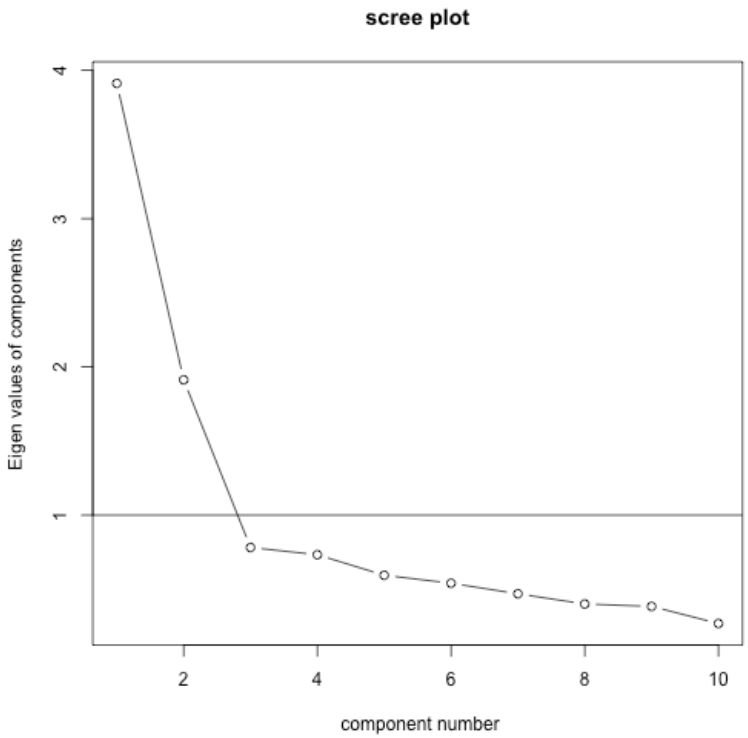

Figure 2. Scree plot showing the eigenvalues on the y-axis and the number of factors on the x-axis.

Correlational Analysis

I calculated bivariate Pearson Correlations which revealed a significant positive relation between positive and negative SEC (r = .28; p < .001; CI 95% [.17, .39]). Further, negative SEC was significantly positively related to self-reported emotional exhaustion (r = .25; p < .001; CI 95% [.13, .37]), while positive SEC was uncorrelated with emotional exhaustion (r = -.02; p = .775; CI 95% [-.14, .11]). A post-hoc power analysis using G*Power (version 3.1.9.2; Faul, Erdfelder, Lang & Buchner, 2007; Faul, Erdfelder, Buchner, & Lang, 2009) revealed that the conducted analyses had sufficient power to detect medium and large effects (power for large and medium effect = 1.00 for medium). However, I was not able to rule out small effects due to insufficient statistical power (power = .49).

Conclusion

To sum up, the findings regarding internal and external validity of my newly developed scale (1) provide initial evidence for my theoretical assumption regarding two separable subfacets of SEC (positive SEC vs. negative SEC); (2) they preliminarily suggest that the newly developed subscales are reliable measures in terms of their internal consistencies, and (3) that positive and negative SEC differ in their relation to a theoretically meaningful external criterion, namely individuals' emotional exhaustion.

Table 4. *Factor Matrix of the 8-Item Version of the Newly Developed SEC Scale*

Items		Factor 1 (Positive SEC)	Factor 2 (Negative SEC)
PosSEC1	It cheers me up to be around a jolly person.	.688	
PosSEC2	It fills me with joy to be around happy people.	.832	
PosSEC4	I let myself be infected by someone's enthusiasm.	.763	
PosSEC5	I get cheerful when I am surrounded by cheerful people.	.705	.170
NegSEC2	I get nervous when others around me are nervous.		.652
NegSEC3	I get angry when I am surrounded by enraged people.		.514
NegSEC4	I tense up when I hear people fighting.		.682
NegSEC5	I get stressed when I am around stressed people.		.847

Note. Only factor loading >.1 are displayed.

Table 5. *Descriptive Statistics of All Scales in Study 1*

Scales	Possible Range	Min/Max	*M*	*SD*	Cronbach's alpha	McDonald's omega total	Average inter item correlation
Positive SEC	1-5	2/5	4.16	0.59	.83	.83	.55
Negative SEC	1-5	1/4.5	2.76	0.75	.76	.77	.45
Emotional Exhaustion	0-6	0.11/4.56	1.83	0.96	.86	.88	.42

Table 6. *Psychometric Properties of the Final Items of Our SEC Scale in Study 1*

	N	% missing	Possible range	Min/ Max	*M*	*SD*	Skewness	Kurtosis	Normality (Shapiro-Wilk)	Item total correlation	Item total correlation if item deleted	α if item deleted
Positive SEC												
PosSEC1	253	1.55	1-5	2/5	4.4	0.71	-1.13	1.22	NO	.77	.59	.82
PosSEC2	254	1.17	1-5	2/5	4.2	0.72	-0.57	-0.05	NO	.85	.73	.76
PosSEC4	254	1.17	1-5	1/5	3.9	0.77	-0.55	0.49	NO	.81	.63	.80
PosSEC5	254	1.17	1-5	2/5	4.1	0.71	-0.40	-0.16	NO	.83	.69	.77
Negative SEC												
NegSEC2	254	1.17	1-5	1/5	2.59	0.93	0.23	-0.36	NO	.76	.56	.70
NegSEC3	254	1.17	1-5	1/5	2.62	0.94	0.00	-0.73	NO	.69	.46	.76
NegSEC4	254	1.17	1-5	1/5	2.99	1.12	0.05	-0.81	NO	.79	.56	.71
NegSEC5	254	1.17	1-5	1/5	2.87	0.92	-0.05	-0.52	NO	.83	.68	.64

4.4 Preregistered analysis of internal and external validity (Study 2)

In Study 2, I had two major goals (preregistered under aspredicted.org; see Appendix D for the preregistration documents). First, I aimed to investigate the internal validity and reliability of my new scale in terms of its psychometric properties, internal consistencies, and factor structure replicating the findings of Study 1. Second, regarding external validity, I aimed to investigate relations of self-reported SEC (of positive and of negative emotions) with relevant emotion related criterion variables and to explore diverging patterns in the relations of positive and negative SEC with these variables. Additionally, to overcome one of the biggest limitations in Study 1, I aimed at testing the scale in a more generalized and independent sample comprised of participants outside of a limited professional or academic context, such as teaching.

4.4.1 Research questions and hypotheses

As preregistered, I aimed at answering the following research questions:

(1) Are positive SEC and negative SEC clearly separable, yet positively correlated constructs as measured by my newly developed scales?

(2) Is the newly developed scale a reliable instrument to assess self-reported positive SEC and negative SEC (internal consistency)?

(3) Is the newly developed scale an internally valid measure to assess self-reported positive SEC and negative SEC, as documented by confirmatory factor analysis (CFA) showing that a two-factor model fits the data better than a single-factor model?

(4) Is the newly developed scale a valid measure to assess self-reported positive SEC and negative SEC in terms of external validity (convergent, divergent, and criterion-oriented validity)?

In line with the preregistration, I tested the following hypotheses regarding internal and external validity of our scale (convergent, divergent, and criterion-related validity):

(1) I expect to replicate the proposed two-factor structure in an independent sample using CFA, clearly identifying positive and negative SEC as two distinct, yet related, factors, with the two-factor model's fit being superior to the single-factor model (internal validity).

(2) Regarding negative SEC, I expect substantial correlations with affective empathy, but not with measures of cognitive empathy (convergent and divergent empathy).

(3) Regarding positive SEC, I do not expect substantial correlations with measures of affective and cognitive empathy (divergent validity).

(4) Regarding negative SEC, I expect positive correlations with negative emotional experiences on a trait-level, emotional instability and distress as well as current depression, anxiety, stress, and physical health symptoms, but negative correlations with positive emotional experiences and life satisfaction (criterion-related validity).

(5) Regarding positive SEC, I expect positive correlations with positive emotional experiences on a trait-level and life satisfaction, but negative correlations with negative emotional experiences on a trait-level, emotional instability and distress as well as current depression, anxiety, stress, and physical health symptoms (criterion-related validity).

In addition to the preregistration, I aimed at testing the following hypotheses which specify the initially preregistered hypotheses even further, following my theoretical reasoning on positive SEC and interpersonal functioning (see Appendix D for a "Transparent-Changes" document detailing the changes I made to the preregistered hypotheses):

(1) Positive SEC is positively related to measures of interpersonal functioning and prosocial tendencies (criterion-related validity).

(2) Negative SEC is not related to measures of interpersonal functioning and prosocial tendencies (criterion-related validity).

4.4.2 Method

Sample and Procedure

The sample of this study consisted of $N = 247$ participants (48.6 % female) that were recruited via Clickworker (www.clickworker.com), a German online recruiting service similar to Amazon MTurk (www.mturk.com). Their age ranged from 18 to 75 years (M = 39.9 years; SD = 12.8 years). Regarding graduation levels, 55.9 % had obtained German A levels and regarding relationship status, 35.5 % were married, 7.7 % divorced, 23.9 % were in a relationship, but living alone, and 30.0 % were single. Due to data privacy reasons, no information on the participants' place of residence or professional occupation was assessed. Thus, all data was completed anonymously and processed confidentially. The online survey was conducted using SosciSurvey, a German open-access online-survey-provider (www.soscisurvey.de) and consisted of 211 items. The participants received a small monetary incentive (3 €) for completing the survey and, on average, they required M = 21.2 minutes to complete the questionnaire (SD = 7.82, Min = 6.2, Max = 59.7). As preregistered, three participants were excluded, prior to any further data processing, because they filled out the questionnaire under five minutes. The acquired sample size (N = 250) was determined based on statistical power estimations using G*Power (version 3.1.9.2; Faul et al., 2007, 2009) with statistical power = .95 for small, medium, and large effects (see Appendix D).

Measures

In addition to my new SEC scale, all participants completed the following self-report measures to examine our scale's external validity (construct and criterion-oriented validity).

To measure individuals' empathy, I used two different self-report scales. The German version of the *Interpersonal Reactivity Index* (IRI; Davis, 1983; Paulus, 2009) was used to assess different components of empathy and social interaction (16 items in total; 4 subscales; response scale 1-5). The IRI has been used extensively in previous research on empathy and

related constructs and has been translated into several languages other than English (De Corte et al., 2007; Himichi et al., 2017). The IRI perspective taking subscale measures an individual's tendency to adopt another's perspective to find out what another person might be thinking, thus, representing the cognitive empathy component (4 items; example item: "Before criticizing somebody, I try to imagine how I would feel if I were in their place"). The IRI fantasy subscale measures an individual's tendency to imaginatively transpose oneself into the feelings and actions of fantasy characters (4 items; example item: "After seeing a play or movie, I have felt as though I were one of the characters"). The IRI empathic concern subscale aims to measure an individual's tendency to feel concern and sympathy towards others (4 items; example item: "When I see someone being taken advantage of, I feel kind of protective towards them") and has been used as a measure of sympathy in previous research (Eisenberg, Cumberland, Guthrie, Murphy, & Shepard, 2005). The IRI personal distress subscale measures an individual's self-oriented tendency to experience distress and anxiety in highly emotional interpersonal situations, such as emergencies (4 items; example item: "Being in a tense emotional situation scares me"). Additionally, I used the *Adolescent Measure of Empathy and Sympathy* (AMES; Vossen et al., 2015; translated by the author) which specifically distinguishes in its subscales between cognitive and affective empathy as well as sympathy (12 items in total; 3 subscales; response scale 1-5). The AMES scale has been originally developed for adolescents, but has been used and validated in adult samples, too (Zengin, Çaka, & Çinar, 2017). The AMES cognitive empathy subscale (4 items; example item: "I can often understand how people are feeling even before they tell me") aims to measure an individual's capacity to cognitively understand another person's emotions. The AMES affective empathy subscale (4 items; example items: "When people around me become nervous, I become nervous, too") aims to measure the tendency to vicariously experience another person's emotions which is similar

to the concept of EC. The AMES sympathy subscale (4 items; example item: “I feel concerned for other people who are sick”) aims to measure an individual’s tendency to feel concern or sorrow for another person (similar to the IRI scale empathic concern).

I used the German Version of the *Big-Five-Inventory 2* (BFI; Danner et al., 2019; Soto & John, 2017) to assess basic personality traits (60 items; 5 subscales; response scale 1-5). Specifically, I assessed different subfacets of the personality traits extraversion and agreeableness that have been found to be related to interpersonal and social functioning, such as having positive relationships, being likable, generous, and socially connected, or seeking power and being manipulative (Soto & John, 2017): Sociability (e.g. “I am someone who is outgoing, sociable”), assertiveness (e.g. “I am someone who is dominant, acts as a leader”), compassion (e.g. “I am someone who is helpful and unselfish with others”), trust (e.g. “I am someone who assumes the best about people), and respectfulness (e.g. “I am someone who is polite, courteous to others”). Further, I assessed specific subfacets of the Big Five personality traits negative emotionality (formerly known as neuroticism) and extraversion that have been found to be related to mental health and trait like emotional experiences, such as stress resistance, positive/negative affect, or purpose in life (Soto & John, 2017): Emotional volatility (e.g. “I am someone who is temperamental, gets emotional easily”), trait-level depression (e.g. “I am someone who often feels sad”), trait-level anxiety (e.g. “I am someone who can be tense”), and activity/energy level (e.g. “I am someone who is full of energy”).

I used the German version of the *Positive and Negative Affect Schedule* (PANAS; Krohne, Egloff, Kohlmann, & Tausch, 1996; Watson et al., 1988) to assess positive and negative affect/activation (20 items; 2 subscales; response scale 1-5). The PANAS uses adjectives that describe states of affective experiences or activation that are either positive or negative in their valence (e.g. “enthusiastic” or “nervous”).

Current depressive symptoms were assessed using the *Edinburgh Depression Scale* (EDS; Cox, Holden, & Sagovsky, 1987; Matijasevich et al., 2014; Matthey, Barnett, Kavanagh, & Howie, 2001). The EDS (10 items; response scale 0-3; example item: “In the past 7 days, I have been so unhappy that I have been crying”).

Current symptoms of general anxiety were assessed using the *General Anxiety Disorder 7* questionnaire (GAD-7; Löwe et al., 2007; Spitzer, Kroenke, Williams, & Löwe, 2006) consisting of seven items (response scale 0-3; example item: “Over the last two weeks, how often have you been feeling afraid as if something awful might happen?”).

I used the *Perceived Stress Scale* (PSS; Cohen, Kamarck, & Mermelstein, 1983) to assess individuals’ current levels of stress (10 items; response scale 1-5; example item: “In the last month, have you felt that you were unable to control the important things in your life?”).

I used a short version of the *Cohen-Hoberman-Inventory of Physical Symptoms* (CHIPS; Cohen & Hoberman, 1983; Hall, Chipperfield, Perry, Ruthig, & Goetz, 2006) to assess individuals’ current physical symptoms (8 items, response scale 1-5; example item: “During the past three months, how much were you bothered by sleep problems?”).

I used the *Satisfaction with Life Scale* (SWLS; Glaesmer, Grande, Braehler, & Roth, 2011; Reis, Lehr, Heber, & Ebert, 2019) to assess individuals’ satisfaction with their lives and current living conditions (5 items; response scale 1-7; example item: “The conditions of my life are excellent”).

Social Desirability response tendencies were assessed using a short German measure of the tendency to either exaggerate one’s own positive qualities or to conceal negative qualities (KSE-G; Kemper, Beierlein, Bensch, Kovaleva, & Rammstedt, 2012) consisting of 6 items (2 subscales; response scale 0-4; example items: “No matter who I’m talking to, I’m

always a good listener" or "There have been occasions when I have taken ad- vantage of someone").

Statistical Analyses

Regarding internal validity, I conducted CFA using the package "lavaan" (Rosseel, 2012, version 0.6.4) in R (version 3.6.0; R Core Team, 2019). I aimed to replicate and confirm the scale's two-factor structure in an independent sample and to compare this model to a single-factor model. To evaluate model fit, I inspected a range of fit indices, including the *comparative fit index* (CFI), the *Tucker Lewis Index* (TLI; also called the non-normed fit index), the *root-mean-square error of approximation* (RMSEA), and the *standardized root mean-square residual* (SRMR). In line with Hu & Bentler (1999), model fit was recognized as acceptable with a CFI and TLI of close to .95 or higher, an RMSEA of close to .06 or lower and an SRMR of close to .08 or lower (Hu & Bentler, 1999; see also Kline, 2005). Because the data violated the normality assumption, I used robust estimators of model fit (MLR) with robust (Huber-White) standard errors and a scaled test statistic that is (asymptotically) equal to the Yuan-Bentler test statistic (Rosseel, 2020). I conducted model comparisons using the "anova" function (χ^2 Difference Test with "satorra.bentler.2001" method) in the R package "lavaan".

Regarding external validity, I aimed to explore relations of the new SEC scale with relevant measures of personality and emotion related phenomena, according to my hypotheses. To this end, I calculated partial correlations of the two subscales (Positive and Negative SEC) with these measures while controlling for social desirability response tendencies (package "ppcor", Kim, 2015; package "psychometric", Fletcher, 2010), because several variables were substantially related to self-reported social desirability (see Appendix D for a table reporting all bivariate correlations with social desirability). To account for multiple testing and the risk of alpha cumulation, I aimed at a cautious and conservative

interpretation of correlation coefficients. To achieve this, I adjusted alpha significance levels using the Bonferroni correction for 23 correlational tests resulting in a new alpha significance level of $p < .002$ and calculated confidence intervals for all correlation coefficients (Cumming, Fidler, Kalinowski, & Lai, 2012). All data processing and statistical analyses in this study were done in R, mainly using the packages "base" and "stats" (R Core Team, 2019), "tidyverse" (version 1.2.1; Wickham, 2017), "dplyr" (version 0.8.4; Wickham et al., 2020), and "ggplot2" (Wickham, 2016), and reproducible scripts for all reported results and figures were generated (see supplementary files).

4.4.3 Results and discussion

Descriptive Statistics and Reliability

Table 7 shows descriptive statistics for all items of the positive and negative SEC subscales. Relatively high mean levels were reported for positive SEC (> 3 on the five-point scale for all items) as compared to negative SEC (< 3 on the five-point scale for all items) with standard deviations being sufficiently large to preclude ceiling or floor effects in both scales. Item total correlations (part-whole-corrected) ranged between $r = .59$ and .73 for positive SEC and .57 and .75 for negative SEC, indicating good item discrimination capacities, yet reasonable item homogeneity in both subscales (Field et al., 2012). All items of the SEC scale deviated from univariate normality as tested using the Shapiro-Wilk test and the Anderson-Darling test, but no significant multivariate outliers were detected using the Henze-Zirker test and the Mardia test (package "MVN"; Korkmaz et al., 2014). Figure 3 shows the density distributions for all items. While the items regarding negative SEC seem to be relatively normally distributed, the items regarding positive SEC seem to be negatively skewed. No missing values were found in the responses to the items of the SEC scale.

Table 8 shows descriptive statistics of all scales reported on in this study, including positive and negative SEC. Internal consistencies of our SEC subscales were examined by

calculating Cronbach's alpha and McDonald's omega indices showing good reliability for positive SEC (α = .83; CI 95% [.79, .86] and ω = .83; CI 95% [.79, .86]) as well as negative SEC (α = .82; CI 95% [.79, .86] and ω = .83; CI 95% [.79, .86]), according to conventions (Field et al., 2012). Overall, all reported scales showed acceptable reliability with internal consistency indices being at least > .70 for all scales. The mean scores in both SEC subscales violated the normality assumption, as tested by the Shapiro-Wilk test and the Anderson-Darling test. Positive SEC and negative SEC showed a small positive bivariate correlation between each other (r = .17; p < .001; CI 95% [.04, .29]) and a small to medium sized positive correlation (r = .27; p < .001; CI 95% [.15, .39]), when controlling for social desirability, respectively; indicating that individuals reporting higher levels of positive SEC also reported higher levels of negative SEC.

Internal Validity of the SEC Scale

The model fit for the two-factor model (positive SEC and negative SEC) was evaluated as very good ($\chi2$ = 30.378 [p = 0.047]; CFI = .982; TLI = .973; SRMR = .045; RMSEA = .054 [.006, .088]) while the model fit of the single-factor model was unacceptable ($\chi2$ = 329.152 [p = 0.000]; CFI = .520; TLI = .327; SRMR = .189; RMSEA = .267 [.242, .293]). The model comparison was highly significant ($\Delta\chi^2(1) = 1238.8$, $p < .001$) highlighting the superiority of the two-factor model over the single-factor model. As expected, the factor loadings of the two-factor model showed medium to high significant positive standardized coefficients ranging from .63 to .88. See Figures 4 and 5 for a visual depiction of the two different models and Table 8 for the factor matrix of all items of the SEC scale (for comparison purposes and transparency reasons, see Appendix D for the model fit and factor loadings for the 10-item version of our SEC scale that was additionally tested using EFA in Study 1).

Table 7. *Descriptive Statistics of All Items of the SEC Scale in Study 2*

	N	% missing	Possible range	Min/Max	*M*	*SD*	Skew	Kurtosis	Normality (Shapiro-Wilk)	Item total correlation (if item deleted)	α if item deleted
Positive SEC											
Item psec1	247	0	1-5	1/5	4.02	.75	-.66	.81	NO	.59	.81
Item psec2	247	0	1-5	2/5	3.77	.76	-.27	-.21	NO	.73	.74
Item psec3	247	0	1-5	2/5	3.52	.77	-.23	-.37	NO	.59	.81
Item psec4	247	0	1-5	1/5	3.62	.80	-.39	-.07	NO	.70	.76
Negative SEC											
Item nsec1	247	0	1-5	1/5	2.78	1.02	.06	-.51	NO	.63	.79
Item nsec2	247	0	1-5	1/5	2.75	.96	.32	-.37	NO	.57	.81
Item nsec3	247	0	1-5	1/5	2.99	1.04	.07	-.51	NO	.64	.78
Item nsec4	247	0	1-5	1/5	2.91	.93	.05	-.17	NO	.75	.73

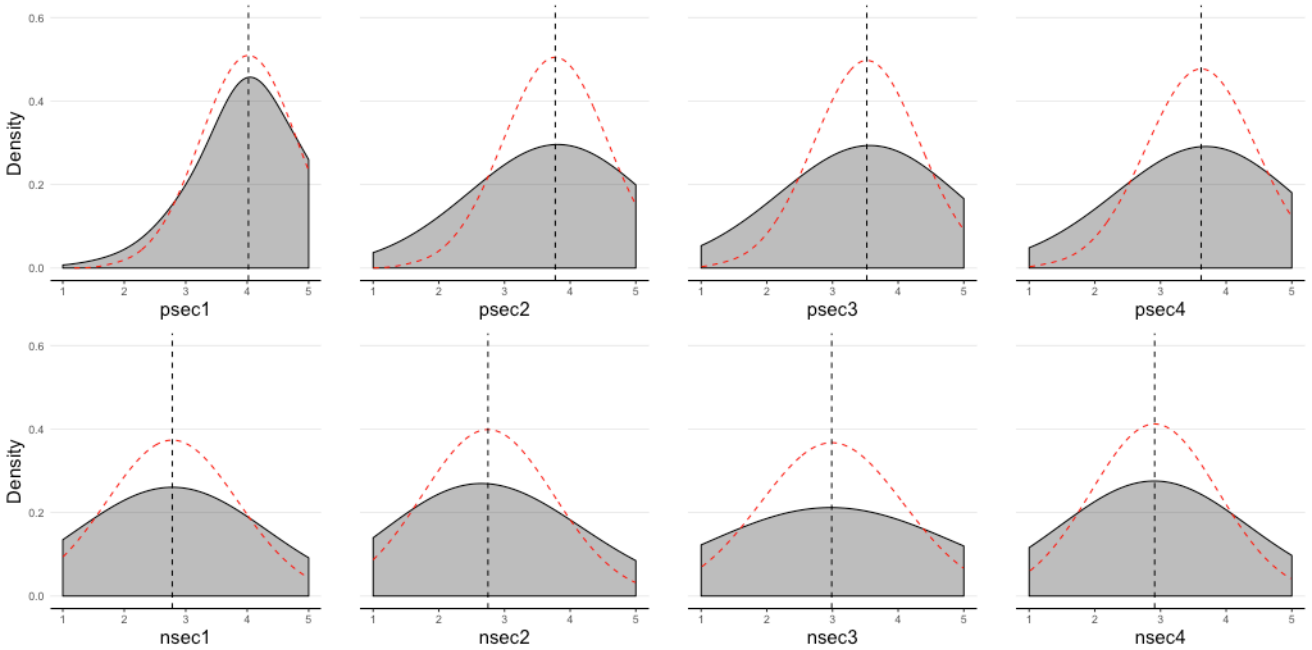

Figure 3. Density distributions for all items of the SEC scale in Study 2.

Table 8. *Descriptive Statistics for All Scales in Study 2*

	Possible Range	Min/Max	*M*	*SD*	Cronbach's alpha	McDonald's omega total	Average inter item correlation	Skew	Kurtosis	Normality (Shapiro-Wilk)
Positive SEC	1-5	2/5	3.73	.62	.83	.83	.55	-.31	-.19	NO
Negative SEC	1-5	1/5	2.86	.80	.82	.83	.54	.19	.16	NO
Positive Affect	1-5	1.60/5	3.38	.62	.88	.91	.41	-.26	.15	YES
Negative Affect	1-5	1/4.10	1.77	.65	.89	.92	.46	.73	-.20	NO
Soc. Des. Positive	0-4	1.67/5	3.51	.60	.62	.64	.35	-.19	.03	NO
Soc. Des. Negative	0-4	1/5	2.22	.88	.70	.72	.44	.72	-.05	NO
Current Depression	0-3	1/3.60	1.91	.60	.87	.90	.40	.34	-.74	NO
Current Anxiety	0-3	1/3.86	1.87	.62	.88	.91	.50	.87	.50	NO
Perceived Stress	1-5	1/4.50	2.69	.69	.87	.90	.39	.21	-.39	NO
Physical Health	1-5	1/4.50	2.47	.80	.80	.86	.33	.32	-.50	NO
Life Satisfaction	1-7	1/7	4.24	1.34	.92	.94	.72	-.37	-.64	NO
Emotional Volatility	1-5	1/4.75	2.70	.73	.75	.80	.43	-.01	-.19	NO
Trait Depression	1-5	1/5	2.66	.85	.83	.87	.54	.31	-.56	NO
Trait Anxiety	1-5	1/5	2.99	.72	.69	.77	.36	.02	-.13	NO
Sociability	1-5	1/5	2.93	.83	.80	.82	.49	-.10	-.54	NO
Assertiveness	1-5	1/5	3.14	.74	.78	.80	.47	-.15	-.08	NO
Activity/Energy	1-5	1/5	3.17	.78	.73	.79	.41	-.23	-.13	NO
Compassion	1-5	2.5/5	3.83	.60	.64	.71	.32	-.17	-.79	NO
Trust	1-5	1.5/4.75	3.06	.67	.61	.73	.28	-.00	-.34	NO
Respectfulness	1-5	2/5	3.97	.61	.73	.80	.42	-.37	-.17	NO
Openness	1-5	1.58/5	3.62	.68	.87	.91	.36	-.13	-.31	YES
Conscientiousness	1-5	1.67/5	3.50	.62	.87	.89	.35	.08	-.17	YES

(continued)

Table 8 (continued)

	Possible Range	Min/Max	*M*	*SD*	Cronbach's alpha	McDonald's omega total	Average inter item correlation	Skew	Kurtosis	Normality (Shapiro-Wilk)
Affective Empathy	1-5	1/5	2.81	.71	.81	.84	.52	.07	.16	NO
Cognitive Empathy	1-5	1.75/5	3.61	.61	.82	.86	.53	-.04	.02	NO
Sympathy	1-5	2.50/5	3.95	.62	.68	.76	.36	-.09	-.71	NO
Perspective Taking	1-5	1.50/5	3.61	.63	.76	.81	.44	-.19	.12	NO
Personal Distress	1-5	1/4.75	2.68	.71	.76	.80	.44	.14	-.32	NO
Empathic Concern	1-5	1.75/5	3.53	.61	.69	.71	.36	.01	-.26	NO
Fantasy	1-5	1/5	3.37	.73	.75	.81	.44	-.04	.12	NO

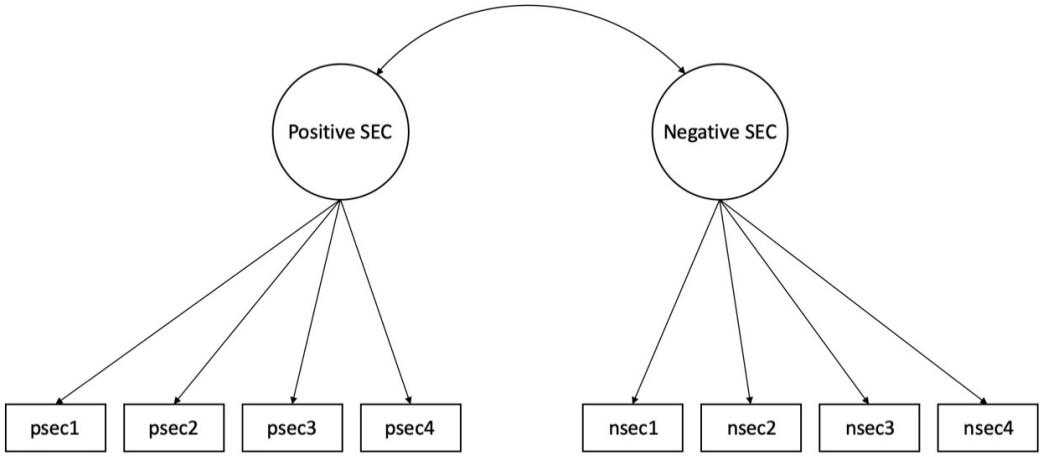

Figure 4. Two-factor model of the SEC scale with the two factors "positive SEC" and "negative SEC".

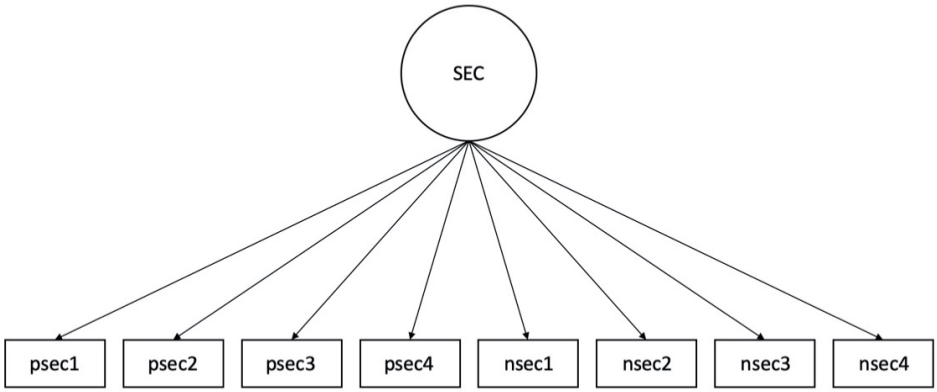

Figure 5. Single-factor model of the SEC scale with a single factor "SEC".

Table 9. *Factor Matrix for All Items of the Newly Developed SEC Scale*

Items		Factor 1 (Positive SEC)	Factor 2 (Negative SEC)
psec1	It cheers me up to be around a jolly person.	.657	
psec2	It fills me with joy to be around happy people.	.829	
psec3	I let myself be infected by someone's enthusiasm.	663	
psec4	I get cheerful when I am surrounded by cheerful people.	.800	
nsec5	I get nervous when others around me are nervous.		.708
nsec6	I get angry when I am surrounded by enraged people.		.629
nsec7	I tense up when I hear people fighting.		.735
nsec8	I get stressed when I am around stressed people.		.876

External Validity of the SEC Scale

To explore the external linkages of the SEC Scale, I calculated correlations with relevant criterion variables included in this study. Table 10 shows partial correlations of positive SEC and negative SEC with all measures while controlling for social desirability.

Correlations with measures of empathy

Negative SEC showed a strong positive correlation with the AMES subscale affective empathy (r = .69) and a small positive correlation with the IRI fantasy subscale (r = .21). These positive relations are not surprising, given the fact that negative SEC and affective empathy as measured by the AMES show substantial conceptual overlap and the two scales even share some of their items. Positive SEC only showed small to medium-sized correlations with all measures of empathy, including affective and cognitive components, which makes sense, because empathy and SEC are related constructs and positive SEC and negative SEC are correlated with each other. Overall, these findings on convergent validity suggest reasonable convergent and divergent validity of our scale with regards to different components of empathy.

Correlations with Measures of trait-like Positive/Negative Emotionality and Distress

Positive SEC was positively correlated with the BFI-2 activity/energy level subscale (r = .36), but uncorrelated with the IRI subscale personal distress (r = .11), the BFI-2 subscales emotional volatility (r = .02), trait-like depression (r = -.03), and trait-like anxiety (r = .09), and the PANAS scales positive affect (r = .16) and negative affect (r = .-.02). Negative SEC showed a strong positive correlation with the IRI personal distress subscale (r = .58) and the BFI-2 trait-like anxiety subscale (r = .52). It showed small to medium-sized correlations with the BFI-2 subscales emotional volatility (r = .44) and trait-like depression (r = .39), as well as with the PANAS subscale negative affect (r = .27), but no significant relations with the PANAS subscale positive affect (r = -.19) and the BFI-2 subscale

activity/energy level (r = -.12). To conclude, these findings seem to demonstrate an asymmetric pattern of relations of positive and negative SEC to measures of trait-like emotionality and distress. This pattern suggests that negative SEC is related to an increased experience of emotional instability, distress, and negative emotions, including depression and anxiety. Positive SEC, on the other hand, does not seem to be related to these measures, with one exception: Individuals' levels of activity/energy level (BFI-2) were positively related to their SEC of positive emotions.

Correlations with Measures of current well-being and mental health/physical symptoms

Negative SEC showed significant medium-sized positive correlations with the EDS depression scale (r = .29), the GAD-7 anxiety scale (r = .43), the PSS stress scale (r = .36), and the CHIPS physical health scale (r = .36). Additionally, negative SEC showed a small negative correlation with the SWLS life satisfaction scale (r = -.26), while positive SEC was uncorrelated with all of these measures. Again, these findings suggest a diverging pattern of relations. Negative SEC seems to be positively related to individuals' current experiences of depression, anxiety, stress, and physical health, as well as negatively related to their subjective well-being. Positive SEC, on the other hand, does not seem to be related to these variables, at all.

Correlations with Measures of interpersonal functioning and prosocial tendencies

Positive SEC showed medium-sized positive correlations with the AMES sympathy subscale (r = .35), the IRI empathic concern subscale (r = .42), the BFI-2 sociability subscale (r = .34), and the BFI-2 compassion subscale (r = .32). Negative SEC was mostly uncorrelated or only weakly correlated with these measures with only few exceptions: A medium-sized negative correlation with the BFI-2 assertiveness subscale (r = -.32) and small to medium sized positive correlations with the IRI empathic concern subscale (r = .29) and the AMES sympathy subscale (r = .25). These findings, again, demonstrate an asymmetric

pattern. But this time, positive SEC seems to be related to greater interpersonal functioning and prosocial tendencies, whereas negative SEC does not seem to be related to these variables.

Conclusion

In sum, the findings in study 2 suggest that the new SEC scale is an internally and externally valid as well as a reliable self-report measure of individuals' SEC of positive emotions and of negative emotions as distinct subfacets of SEC. Additionally, these two facets of SEC seem to be related to different criterion variables with negative SEC being linked with greater experiences of negative emotions, emotional instability, stress, and distress. Whereas positive SEC seems to be linked with greater levels of interpersonal functioning and prosocial tendencies.

Table 10. *Partial Correlations of Positive and Negative SEC With Measures of Empathy, Trait-like Positive/Negative Emotionality and Distress as Well as Measures of Current Mental Health Problems and Physical Symptoms While Controlling for Social Desirability Response Tendencies*

	Positive SEC		Negative SEC	
	r	95% CIs	*r*	95% CI
Measures of empathy				
Affective Empathy (AMES)	.28 ($p < .0001$)	[.16, .39]	.69 ($p < .0001$)	[.62, .75]
Cognitive Empathy (AMES)	.30 ($p < .0001$)	[.19, .41]	.14 ($p = .0346$)	[.01, .26]
Fantasy (IRI)	.30 ($p < .0001$)	[.18, .41]	.21 ($p < .001$)	[.09, .33]
Perspective Taking (IRI)	.20 ($p = .0021$)	[.07, .31]	.04 ($p = .5065$)	[-.08, .17]
Measures of trait-like positive/negative emotionality and distress				
Positive Affect (PANAS)	.16 ($p = .0125$)	[.04, .28]	-.19 ($p = .0027$)	[-.31, -.07]
Negative Affect (PANAS)	-.02 ($p = .8104$)	[-.14, .11]	.27 ($p < .0001$)	[.15, .38]
Personal Distress (IRI)	.11 ($p = .0678$)	[-.01, .24]	.58 ($p < .0001$)	[.49, .66]
Emotional Volatility (BFI2)	.02 ($p = .7149$)	[-.10, .15]	.44 ($p < .0001$)	[.33, .53]
Depression (BFI2)	-.03 ($p = .6127$)	[-.16, .09]	.39 ($p < .0001$)	[.28, .49]
Anxiety (BFI2)	.09 ($p = .1636$)	[-.04, .21]	.52 ($p < .0001$)	[.42, .60]
Activity/Energy Level (BFI2)	.36 ($p < .0001$)	[.25, .46]	-.12 ($p = .0725$)	[-.24, .01]
Measures of current mental health problems and physical symptoms				
Depression (EDS)	.00 ($p = .9614$)	[-.12, .13]	.29 ($p < .0001$)	[.17, .40]
Anxiety (GAD7)	.15 ($p = .0227$)	[.02, .27]	.43 ($p < .0001$)	[.33, .53]
Stress (PSS)	.04 ($p = .5348$)	[-.09, .16]	.36 ($p < .0001$)	[.24, .46]
Physical Symptoms (CHIPS)	.10 ($p = .1247$)	[-.03, .22]	.36 ($p < .0001$)	[.24, .46]
Life Satisfaction (SWLS)	.12 ($p = .0623$)	[-.01, .24]	-.26 ($p < .001$)	[-.37, -.13]

(continued)

Table 10 (continued)

	Positive SEC		Negative SEC	
Measures of interpersonal functioning and prosocial tendencies	*r*	95% CIs	*r*	95% CI
Sympathy (AMES)	.35 ($p < .0001$)	[.23, .45]	.25 ($p < .001$)	[.13, .35]
Empathic Concern (IRI)	.42 ($p < .0001$)	[.31, .52]	.29 ($p < .0001$)	[.18, .41]
Sociability (BFI2)	.34 ($p < .0001$)	[.23, .45]	-.14 ($p = .0288$)	[-.26, -.02]
Assertiveness (BFI2)	.15 ($p = .0180$)	[.03, .27]	-.32 ($p < .0001$)	[-.42, -.20]
Compassion (BFI2)	.32 ($p < .0001$)	[.21, .43]	.04 ($p = .4977$)	[-.08, .17]
Trust (BFI2)	.23 ($p < .001$)	[.11, .35]	-.10 ($p = .1375$)	[-.22, .03]
Respectfulness (BFI2)	.17 ($p = .0077$)	[.05, .29]	-.17 ($p = .0067$)	[-.29, -.05]

4.5 General discussion

In the present work, I had two major goals. First, I aimed to investigate the internal validity and reliability of our new scale in terms of its psychometric properties, internal consistencies and factor structure replicating the findings of Study 1. Second, regarding external validity, I aimed to investigate relations of self-reported SEC (of positive and of negative emotions) with relevant emotion related criterion variables and to explore diverging patterns in the relations of positive and negative SEC with these variables. To this end, I conducted two studies to explore our scale's internal validity by means of EFA (Study 1) and CFA (Study 2) and its external validity by means of correlations with measures of empathy and correlations with relevant external criterion variables, such as emotional experiences, mental health problems, or indicators of social functioning.

4.5.1 Reliability and internal validity

Regarding internal validity, I conducted EFA in Study 1 revealing a two-factor structure with positive SEC and negative SEC as clearly distinct, yet correlated, factors. The factor structure was confirmed in Study 2 using CFA with the two-factor model showing very good model fit; superior to a single-factor model as demonstrated by a chi-square difference test. In both studies, the two subscales of our SEC Scale demonstrated acceptable to good reliability in terms of Cronbach's alphas and McDonald's omegas; ranging between .76 and .83. Hence, the newly developed SEC scale appears to be an internally valid and reliable self-report measure.

4.5.2 External validity

Regarding external validity, I explored relations of our SEC scale to (1) different measures of empathy, (2) to measures of positive/negative emotional experiences and emotionality as well as emotional instability and distress, (3) to measures of current mental health problems (including emotional exhaustion in Study 1), physical symptoms, and well-

being, and (4) to measures of interpersonal functioning and prosocial tendencies. First, in line with my expectations, I found a strong association between negative SEC and affective empathy as measured by the AMES subscale. Within the AMES measure, the definition of affective empathy shows substantial overlap with my definition of SEC and with the items used in the negative SEC subscale (e.g. “When people around me are nervous, I become nervous, too”). Therefore, this strong relation seems to support the convergent validity of the negative SEC subscale. Further, I did not find substantial correlations between negative SEC and other components of empathy, namely cognitive empathy (AMES), perspective taking (IRI), and fantasy (IRI). Regarding positive SEC, I found small to medium correlations with all of these empathy components (ranging between .20 and .30) which I did not expect according to the preregistered hypotheses. However, when looking at the items of these empathy scales more closely, none of their items reflects the tendency to catch others’ positive emotions, but some of them seem to represent being more other-oriented and open in social interactions with other individuals (e.g. “I can often understand how people are feeling even before they tell me” or “Before criticizing somebody, I try to imagine how I would feel if I were in their place”); an interactional tendency or style which could be linked to an individual’s level of positive SEC, according to my theoretical reasoning. Therefore, given the size of these correlations, these findings suggest reasonable divergent validity of both SEC subscales in terms of its relations to self-report measures of empathy.

Second, I found strong positive correlations of negative SEC with negative trait-level anxiety (BFI-2) and personal distress (IRI), medium-sized positive correlations with trait-level depression (BFI-2) and emotional volatility (BFI-2), and a small positive correlation with negative emotional experiences (PANAS), but no substantial correlations with positive emotional experiences (PANAS) and activity/energy level (BFI-2). Regarding positive SEC, I only found a substantial positive correlation with activity/energy level (BFI-2) and, against

my expectations, positive SEC was not related to an increased experience of positive affect (PANAS) or to reduced negative emotional experiences (PANAS), trait-level anxiety and depression (BFI-2), emotional volatility (BFI-2), and personal distress (IRI). While there seems to be a clear relation of negative SEC to the experience of negative emotions and emotional problems, these findings suggest that SEC of positive emotions is not related to an increased experience of positive emotions and a reduced experience of negative emotions or emotional problems, respectively.

Third, I found medium-sized positive correlations of negative SEC with current anxiety symptoms (GAD-7), perceived stress (PSS), and current physical health symptoms (CHIPS), as well as smaller positive correlations with current depressive symptoms (EDS) and emotional exhaustion (MBI), and a small negative correlation with life satisfaction (SWLS). Positive SEC, against my expectations, was found to be uncorrelated with all of these measures. Again, while there seems to be a clear positive relation of negative SEC to the experience of mental and physical health problems, the findings suggest that SEC of positive emotions is neither positively nor negatively related to mental and physical health or life satisfaction, respectively.

Fourth, I found medium-sized positive correlations of positive SEC with sympathy (AMES) empathic concern (IRI), sociability (BFI-2), and compassion, as well as a small positive correlation with trust (BFI-2); but no correlations were found with assertiveness (BFI-2) and respectfulness (BFI2). Regarding negative SEC, we only found small to medium-sized positive correlations with sympathy (AMES) and empathic concern (IRI), as well as a medium-sized negative correlation with assertiveness (BFI-2).

In conclusion, I found diverging patterns of substantial correlations of the two SEC subscales with relevant criterion variables. On the one hand, negative SEC was substantially related to increased trait-like negative emotional experiences, emotionality, and distress, as

well as greater current mental health problems and physical symptoms, whereas positive SEC was not substantially related to these measures. On the other hand, positive SEC was substantially related to increased indicators of interpersonal and social functioning, as well as prosocial tendencies and other-oriented behaviors and cognitions, whereas negative SEC was not substantially related to these measures.

Thus, in terms of external validity, my findings suggest that (1) both subscales seem to show reasonable convergent and divergent validity in terms of their relations with empathy measures, (2) only negative SEC seems to be clearly related to measures of positive/negative emotional experiences, emotional instability and distress, as well as (3) to measures of current mental and physical health problems, (4) whereas only positive SEC seems to be substantially related to measures of interpersonal functioning and prosocial tendencies as opposed to negative SEC.

4.5.3 Limitations

First, in both studies, I used a cross-sectional research design to assess the relations of individuals' SEC to selected criterion variables. Therefore, it is important to be aware that no temporal or causal relationship between the assessed variables can be determined by my analyses and longitudinal studies are needed to investigate the scale's predictive validity.

Second, I only used self-report measures to assess individuals' SEC and other relevant variables. Thus, the reported results could be biased due to common method variance (Avolio et al., 1991). That means, the findings on the relations between individuals' SEC and other variables could possibly be inflated or deflated by overlapping variance which is rather due to the chosen measurement approach instead of the supposed underlying relation between these variables.

Third, while both of the samples were sufficiently large in terms of statistical power and stability of correlations (Schönbrodt & Perugini, 2013), the generalizability of the

findings could still be constrained by several limitations. I used a convenience sample in Study 1 consisting of voluntarily recruited teachers from Germany and, therefore, it is possible that only highly motivated and healthy teachers took part in the study. In Study 2, I used an online sample that was recruited through a crowd-based online platform; also voluntarily, but with a small monetary incentive. While online samples that are recruited via crowd-based services, such as Amazon Mturk or Clickworker, have been found to be reasonably representative of the general population and to provide high-quality data (McCredie & Morey, 2019), participants in these samples have also been found to report increased levels of depression with up to three times higher levels as compared to prevalence estimations in the general population (Ophir, Sisso, Asterhan, Tikochinski, & Reichart, 2020). Both samples were rather homogeneous in terms of cultural background and educational levels with the majority of participants in both samples being highly educated (98% had obtained A-levels in Study 1 and 56% in Study 2, respectively). Additionally, the language of all measures in our studies was German and we used German versions of our items to assess individuals' SEC. Therefore, more generalized and diverse samples are needed to further investigate individuals' SEC outside of the context of the previous samples and an English version of the new SEC scale should be developed and validated in English-speaking samples.

Last, while Study 2 was preregistered following the guidelines of the Center for Open Science (https://cos.io/prereg/), including research questions, hypotheses, measures, and analysis plan, not all of the hypotheses in Study 2 had been explicitly documented in advance. However, all changes were justified and documented transparently in an additional "Transparent Changes" file, following a template provided by the Open Science Framework (https://osf.io/yrvcg/). In light of the insufficient replicability of psychological research findings (Anvari & Lakens, 2018), I suggest that future studies should aim to replicate my

findings in properly preregistered studies including hypotheses, analysis plan, and also expected effect sizes.

4.5.4 Directions for future research

While my work has already provided new valuable insights into the SEC of positive and negative emotions, there are still many important questions to be answered by future research. In addition to replicating the findings, more studies are needed to investigate the temporal stability and predictive validity of individuals' positive and negative SEC. More specifically, possible relations of positive and negative SEC to other highly relevant variables should be investigated, such as emotion regulation capacities, attachment security/insecurity, mentalization capacities, relationship quality, or prosocial behavior.

To go beyond self-report data in future studies, I suggest including other measures of emotional experiences, personality traits, and socially interactive behavior, such as experience sampling approaches (De Vuyst, Dejonckheere, Van der Gucht, & Kuppens, 2019; Goetz, Bieg, & Hall, 2016) or smartphone-based mobile sensing methods (Harari et al., 2016, 2019). Additionally, I propose to include systematic behavioral coding approaches to measure relevant criterion variables. As such, the Facial Action Coding System (FACS; Ekman, Friesen, & Hager, 2002) could be included as a systematic coding scheme to quantify human facial expressions which represent a highly relevant channel to nonverbally communicate emotions to other individuals in socially interactive situations. FACS coding is most commonly done using previously collected video recordings; either manually by trained human coders or automatically using algorithm-based software packages (e.g. Stöckli, Schulte-Mecklenbeck, Borer, & Samson, 2018). To assess and evaluate socially interactive behavior more systematically, the CIB system (Coding Interactive Behavior; Leclère et al., 2016) could be used to code video recordings of interpersonal interaction between individuals, such as couples, parents and their children, teachers and their students,

or psychotherapists and their clients. Further, the Reflective Functioning Scale (RF; Cucchi, Hampton, & Moulton-Perkins, 2018; Fonagy, Target, Steele, & Steele, 1998) could be used to code transcripts of audio recordings to asses an individual's capacities to adequately understand and infer the cognitions and emotions of others and of themselves, a capacity also known as mentalization, including an individual's self-other-awareness/-distinction which represents the core criterion to distinguish between EC and other empathic processes.

My own upcoming and planned analyses will entail (1) replicating the reported findings in a specific and highly interactional context, namely teachers and their students, and thus, expanding the target group of the measure to children and adolescents, (2) testing the scale's retest reliability over the course of several months, and (3) using synchronized video recordings and automated facial action coding software to explore EC processes and their relation to individuals' self-reported SEC in authentic and unscripted social interactions.

4.5.5 Conclusion

Given its limitations, the present work still provides valuable and important insights on a methodological and a substantial level. On a methodological level, the present work provides a first instrument to assess both positive and negative SEC as distinct subfacets of SEC. In short, my findings in both studies suggest that the new SEC scale is an internally and externally valid as well as a reliable and economic self-report measure of individuals' SEC of positive emotions and of negative emotions. On a substantial level, my findings provide further insights into the importance of distinguishing positive SEC and negative SEC as distinct subfacets of SEC. While being susceptible to catching others' negative emotions seems to be a risk factor for mental health problems and increased negative emotional experiences, positive SEC, apparently, does not act as a protective factor. Instead, being susceptible to catching others' positive emotions seems to be more beneficial for

individuals' social relations and interpersonal functioning. Hence, we conclude that, future research should stop treating SEC as a unidimensional construct, and start investigating positive SEC and negative SEC as two clearly distinguishable subfacets of individuals' SEC.

4.6 Supplementary Files

All supplementary files are accessible for the reviewers on a Compact Disc (CD) attached to this dissertation.

4.6.1 Study 1

- Data: The csv file *sec_study1_data.csv* contains all data used in Study 1.
- Analysis script: The R file *sec_study1_script.R* contains reproducible R-code in order to reproduce the reported results using the provided data set.
- Codebook: The pdf file *sec_study1_codebook.pdf* contains variable descriptions of all measures and variables in Study 1.

4.6.2 Study 2

- Data: The csv file *sec_study2_data.csv* contains all data used in study 2.
- Analysis script: The R file *sec_study2_script.R* contains reproducible R-code in order to reproduce the reported results using the provided data set.
- Codebook: The pdf file *sec_study2_codebook.pdf* contains variable descriptions of all measures and variables in Study 2.

5. Automated Facial Expression Analysis in Unscripted Classroom Interaction – A Proof of Concept Study

5.2 Introduction

5.2.1 Measurement of emotions in the context of educational settings

Over the past years, extensive research has been conducted on the emotions of teachers and students (Pekrun, 2016; Pekrun & Linnenbrink-Garcia, 2014). It has been shown that their emotional experiences while teaching and learning play an important role for outcomes like achievement, motivation, and well-being of teachers and students alike (Frenzel, 2014; Goetz & Hall, 2013; Pekrun, Lichtenfeld, Marsh, Murayama, & Goetz, 2017). In line with well-established component process definitions of emotions, I conceptualize emotions as episodes of synchronized changes in interrelated organismic subsystems in reaction to individually significant stimuli (Scherer, 2005, 2009; Shuman & Scherer, 2014). Following such component process definitions, different methods have been developed and used to explore emotional experiences. These measurement approaches try to address at least one of the organismic subsystems emotions are proposedly composed of: subjective feelings, visible motor expression (behavioral, facial, and vocal), cognitive appraisals, neuro- and biophysiological measures, and motivational action tendencies (Pekrun & Bühner, 2014). Even though quite diverse measurement approaches to emotions are thus conceivable, the vast majority of existing studies on students' and teachers' emotions relied solely on self-report measures of subjective feelings (Pekrun & Bühner, 2014; Pekrun, 2016). These measures most typically include trait-based questionnaires or interviews both for students (Goetz et al., 2012; Lichtenfeld et al., 2012; Mainhard, Oudman, Hornstra, Bosker, & Goetz, 2018; Mazer, McKenna-Buchanan, Quinlan, & Titsworth, 2014;

Pekrun, 2006; Pekrun et al., 2002; Putwain, Becker, Symes, & Pekrun, 2018; Reindl, Tulis, & Dresel, 2018; Titsworth, McKenna, Mazer, & Quinlan, 2013; Urhahne, 2015; Westphal, Kretschmann, Gronostaj, & Vock, 2018) and for teachers (Frenzel, 2014; Frenzel et al., 2016; Hagenauer & Volet, 2014; Keller, Frenzel, Goetz, Pekrun, & Hensley, 2014; Slišković, Burić, & Macuka, 2017; Sutton & Wheatley, 2003; Zembylas, 2003). Less commonly, experience sampling methods have been used to assess students' and/or teachers' current emotional state (Becker, Goetz, Morger, & Ranellucci, 2014; Carson, Weiss, & Templin, 2010; Goetz, Lüdtke, Nett, Keller, & Lipnevich, 2013; Goetz et al., 2015; Goetz, Sticca, Pekrun, Murayama, & Elliot, 2016; Keller, Becker, Frenzel, & Taxer, 2018; Nett, Goetz, & Hall, 2011), or diary entries as short-term retrospective self-report (Becker, Keller, Goetz, Frenzel, & Taxer, 2015; Frenzel, Becker-Kurz, Pekrun, Goetz, & Gasbarri, 2015; Lavy & Eshet, 2018; Peterson, Brown, & Jun, 2015).

While self-report measures come with many advantages, such as a quite economical implementation and little depletion of resources (e.g. personnel and time), they also bear a range of disadvantages (Pekrun & Bühner, 2014). First, they are often biased due to social desirability (van de Mortel, 2008), and trait-based self-report measures of emotional experiences, in particular, are prone to retrospective biases (Buehler & McFarland, 2016; Robinson & Clore, 2002). Furthermore, providing self-report judgments of one's emotional experiences is quite cognitively demanding and thus heavily dependent on the individual's mental capacities and meta-emotional competence. They are also fully verbally bound and thus their validity depends on the participants' semantic understanding. Finally, emotional self-reports hardly capture dynamic changes over time or other process-oriented features of emotions (Azevedo, Taub, Mudrick, Farnsworth, & Martin, 2016; D'Mello, Dieterle, & Duckworth, 2017; Sutton & Wheatley, 2003; Wilhelm & Grossman, 2010).

To tackle some of these issues and along with recent advances in technological and computational resources, research into students' emotions has started to measure visible motor expressions to either analyze facial expressions (Bosch, D'Mello, Ocumpaugh, Baker, & Shute, 2016; D'Mello, Kappas, & Gratch, 2018; D'Mello & Graesser, 2010; Monkaresi, Bosch, Calvo, & D'Mello, 2017) or vocal features (Davletcharova, Sugathan, Abraham, & James, 2015; Eyben et al., 2016). And even more recently, measures of physiology, such as EEG signals (Dikker et al., 2017), electrodermal signals and heart rate variability (Zhang et al., 2018), or skin conductance levels (Harley, Jarrell, & Lajoie, 2019), have come into use for exploring students' emotions and other related constructs, but so far only on extremely rare occasions. Notably, research on teacher emotions so far seems to be almost exclusively self-report based. Therefore, alternative approaches to assessing emotions in the classroom are being more and more loudly called for (Azevedo et al., 2016; D'Mello et al., 2017; Reisenzein, Studtmann, & Horstmann, 2013; Scherer, 2005, 2009; Scherer, Mortillaro, & Mehu, 2013), including more objective methods or live assessment in the actual situations of interest to better explore the dynamic and constantly changing nature of emotions. In response to those claims, the present study sought to provide real-time, process-oriented measures of both teachers' and learners' emotions in the classroom, focusing on a channel which has long been proposed to be an important and valid emotion indicator: the human face. I chose a video-based approach to explore emotional expressions in the face while teaching and learning, in combination with lesson-specific retrospective self-report measures of discrete emotions.

5.2.2 Measurement of facial emotion expression

For well over a hundred years, research on emotions has focused on facial expressions and their relation to subjective affective experiences and different emotion-related outcomes (Darwin, 1872; Duchenne de Boulogne, 1862; Ekman, 1964, 1970; Ekman

& Friesen, 1976; Rosenberg, 2005). The Facial Action Coding System (FACS) by Paul Ekman and colleagues represents, as of today, the most elaborate and widely used method to systematically analyze and describe human facial expressions. It comprises an extensive classification and systematic description of all possible facial movements and gives detailed instructions on how to code them in a standardized way. According to the FACS, visible momentary changes in the anatomical appearance of the facial skin, such as wrinkles in the skin texture or movement of the eyebrows, correspond to the activation of underlying facial muscles. Specific combinations of the activation of one or more of these facial muscles are defined as so-called Action Units (Ekman et al., 2002). Within the FACS, there are 44 Action Unit codes (AUs) corresponding with specific facial muscle activation (such as the zygomaticus major which is activated when smiling), and several additional codes to describe head pose, gaze and eye movements. Specific prototypical combinations of such Action Units are thought to correspond to the experience of various discrete emotions, for example AU 6 and AU 12 correspond to the experience of joy (Ekman et al., 2002). FACS coding is originally executed manually by human coders and has been used extensively in previous research.

Matsumoto and colleagues (Matsumoto, Keltner, Shiota, O'Sullivan, & Frank, 2008) reviewed and summarized a large number of studies investigating relations between facial emotion expression and subjective emotional experience. They report medium to high correlations for various emotions and facial expressions, e.g. joy and smiles/AUs 6 and 12 (Ekman, Davidson, & Friesen, 1990; Ekman, Friesen, & Ancoli, 1980; Harris & Alvarado, 2005; Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). They conclude that emotion-specific facial behavior is linked to subjective experience of these discrete emotions when individuals are expressing their emotions freely without any social display rules or other reasons to restrain their emotional expressions.

However, given the current critique and discussion surrounding research using facial expression analysis tools (Barrett, Adolphs, Marsella, Martinez, & Pollak, 2019), I aim to be clear and precise in our terminologies and operationalizations. The present work focuses on facial expressions as an important channel of interpersonal communication, e.g. of subjective emotional experiences. But I do not propose that an individual's subjective internal emotional state can be directly inferred from his or her facial expressions that are visible in his or her face. Instead, in the present work, I am using facial expression analysis to measure changes in the appearance of an individual's face that are visible from the outside which might not fully coincide with an individual's subjective internal emotional experience.

5.2.3 Automated facial expression analysis in educational research

As both training to become a certified FACS coder and coding itself is an extremely time consuming process, different approaches for automated facial expression analysis have been developed to avoid the heavy resource consumption involved in manual facial action coding (Bartlett et al., 2006; Brick, Hunter, & Cohn, 2009; Olderbak, Hildebrandt, Pinkpank, Sommer, & Wilhelm, 2014; Stöckli et al., 2018; Tian, Kanade, & Cohn, 2001, 2011; van Kuilenburg, Wiering, & den Uyl, 2005). Most of these automated coding systems involve three major steps: First, detection of the face and important facial components or landmarks (e.g. nose, chin and eyes) from an input image (pictures or video recordings). Second, extraction of spatial and temporal features, and third, classification of facial expressions using pre-trained pattern classifiers (Ko, 2018; Littlewort et al., 2011; Stöckli et al., 2018; Tian et al., 2001, 2011). Such automated coding of facial expressions has recently found wider application in scientific inquiry within many different fields of research, ranging from clinical psychology research (Ahmed & Goodwin, 2017; Lautenbacher, Bär, Eisold, & Kunz, 2017; Leppanen et al., 2017; Littlewort, Bartlett, & Lee, 2009; Trevisan, Bowering, & Birmingham, 2016), to computational research and human-computer-interaction (Bartlett et

al., 2006; Cohn & Sayette, 2010; Girard, Cohn, Jeni, Sayette, & De la Torre, 2015; Goldberg, 2014), or consumer and marketing research (Danner, Haindl, Joechl, & Duerrschmid, 2014; de Wijk, He, Mensink, Verhoeven, & de Graaf, 2014; He, Boesveldt, de Graaf, & de Wijk, 2016; Kostyra et al., 2016; Leitch, Duncan, O'Keefe, Rudd, & Gallagher, 2015; Lewinski, Fransen, & Tan, 2014; Rocha-Parra, García-Burgos, Munsch, Chirife, & Zamora, 2016; Samant, Chapko, & Seo, 2017; Yu & Ko, 2017).

In the field of educational research, however, only scattered studies have used automated facial expression recognition to investigate student emotions and related constructs, which I will review in more detail below. An early attempt to explore student emotions through automated facial coding was made by Kapoor and colleagues which investigated student interest (Kapoor & Picard, 2005) and frustration (Kapoor, Burleson, & Picard, 2007) in a laboratory setting. Facial features, such as head nods/shakes, or smiles were automatically detected and combined with other measures, such as posture features, from a pressure-sensitive chair and computer mouse, skin conductance levels, and interaction log data. Those combined scores proved to be systematically related with self-reported interest and frustration. Furthermore, Terzis and colleagues (Terzis, Moridis, & Economides, 2013) explored facial expressions of emotions during a computer-based multiple choice test in an introductory informatics course. They filmed 172 students for 45 minutes while taking the test. The video recordings were analyzed both by an automated facial emotion recognition software and rated by two human coders. The authors reported satisfactorily high accordance rates between the manual and automated codes, ranging from 90% for happy expressions to 70% for disgust (overall agreement of 87%).

More recently, Grafsgaard and colleagues (Grafsgaard, Wiggins, Boyer, Wiebe, & Lester, 2013) examined computer-detected facial action codes in a computer learning environment. Sixty-seven students with no prior programming experience interacted with

human tutors through a web-based computer programming learning interface. The authors obtained a measure of learning gain and participants self-reported frustration during learning. Their results showed significant positive correlations between specific Action Units and self-reported frustration (AU4, „Brow Lowerer“, and AU14, „Dimpler“) and negative correlations with another action unit (AU2, „Outer Brow Raiser“) and learning gain, respectively.

Furthermore, Romero-Hall and colleagues (Romero-Hall, Watson, & Papelis, 2014) explored students' interaction with animated pedagogical agents in the context of a multimedia learning environment. During a lesson on African history, 53 students interacted with an either emotionally expressive animated pedagogical agent portraying five emotional states (happy, surprised, sad, angry, and neutral) in relation to the content of the lesson, with an emotionally non-expressive agent, or with no agent at all. They measured, among others, facial expressions using automated emotion recognition software and their results indicated that there were no significant differences in the emotional expressions of participants in response to the three different learning environments.

In a similar setting, Harley and colleagues (Harley, Bouchet, Hussain, Azevedo, & Calvo, 2015) investigated students' emotions during complex learning with a computerized learning system. For approximately 90 minutes, 67 students interacted with an intelligent multi-agent learning environment studying the human circulatory system. Self-reported emotional states were assessed at five time points during the session, and for 10 seconds prior to each of the self-report administrations, learners' facial expressions were analyzed using automatic facial recognition software. The resulting agreement levels between facial expressions and self-reported emotions ranged from 7.1% for surprise to 84% for happiness.

Bosch and colleagues (Bosch, Chen, & D'Mello, 2014) investigated emotional states of 99 novice computer programmers during an introductory programming tutoring session.

They used automated emotion recognition software to analyze facial emotional expressions from student-annotated videos and machine learning techniques to build classification models. Their findings show that confusion and frustration could be detected at levels above chance, but other emotional states (boredom, engagement, and neutral) could not be accurately detected.

Furthermore, automated facial coding has been applied in recent research in game based learning environments in computer enabled classrooms (Bosch et al., 2016; D'Mello et al., 2017, 2018). For example, Bosch and colleagues (Bosch et al., 2016) examined emotional expressions in 137 students engaging in a game based learning environment teaching basic principles of Newtonian physics. Participants' affective states (boredom, confusion, delight, engagement, and frustration) were coded by an automated facial action recognition software as well as by trained observers and according to a standardized annotation scheme during their interactions with the educational software. The authors report well above-chance links between human observer-coded and automated software-generated emotional states and concluded that automated affect detection systems are highly efficient in computer-enabled classrooms.

Finally, Sawyer and colleagues (Sawyer, Smith, Rowe, Azevedo, & Lester, 2017) videotaped 33 students participating in a learning game for a time span of 26 to 105 minutes and obtained automated facial emotion codes for anger, surprise, frustration, joy, confusion, fear, disgust, sadness, and contempt as well as self-reported presence (engagement). They also measured learning gains through a pre-/post-test design. Controlling for a range of learner characteristics, their results showed that higher levels of facially displayed surprise was negatively related to learning gains, and disgust and confusion were negatively related to self-reported presence, respectively. None of the other facially expressed emotions proved

to be systematically related to either learning gain or self-reported engagement during learning.

5.2.4 Summary and research gap

In summary, previous research suggests that, first, it is possible to detect students' emotional states using automated facial emotion recognition from video recordings, but this evidence largely stems from lab-based digital learning environments, and, second, that self-reported emotions and facially expressed emotions covary in various environments, but this evidence mostly stems from contexts other than teaching and learning. So far, no study known to me has examined associations between facial emotion expressions and self-reported discrete emotions of teachers and students in the field.

In sum, previous studies using automated facial emotion recognition in educational psychology typically lack three things. First, most studies have investigated learning situations in laboratories or individualized computer-enhanced learning contexts rather than in real-life classrooms involving one teacher and multiple students possibly reducing ecological/external validity, because the study parameters do not represent real-life scenarios (Wilhelm & Grossman, 2010). Second, mostly video recordings of a short duration are used instead of a whole learning/teaching sequence due to practical reasons and limited resources. Third, existing studies focus solely on students; no study to date has addressed teachers' emotional expressions, or the interpersonal communication and emotional interaction between teachers and students.

5.2.5 The present study

The current study had three main goals: First, I tested and evaluated the feasibility of a new methodological approach to examine emotional expressions of both teachers and students in real learning situations, using multiple synchronized cameras and automated facial action coding software. While doing so, I also aimed to establish a reproducible

workflow to process and analyze similar video data in future studies. Second, I investigated the frequencies and temporal dynamic of teachers' and students' individual emotional expressions over the course of 45 minutes. Third, I explored relations between teachers' and students' automatically coded facial emotion expressions and their self-reported emotions during the session. Following a component process definition of emotions, I assumed that facial expressions are markers of discrete emotions and thus relate to their subjective emotional experience of teachers and students in class (Scherer, 2005, 2009; Matsumoto et al., 2008; Ekman & Friesen, 1976). Specifically, I hypothesized that the relative time share of facial emotional expressions of joy, anger, and anxiety while teaching or learning would be positively related to the retrospectively self-reported experience of those discrete emotions.

5.3 Method

5.3.1 Sample and procedure

I videotaped *N* = 13 lecturers (62% female) and *N* = 69 of their students (90% female) in two of their regular university course sessions of 45 minutes each (mean number of participating students per class = 5.3, ranging from 2 to 7 students). The mean age of the lecturers was 40 years (*SD* = 11.3, Min = 27, Max = 55) and 24 years of the students (*SD* = 4.5, Min = 20, Max = 50), respectively. All videotaped courses used direct-interactive teaching methods and a range of different subjects was covered (including psychology, educational sciences, and English language). The time interval between the two sessions ranged from 1 to 3 weeks (*M* = 1.6 weeks). Participation was voluntary and there were no constraints for the lecturers concerning the content or structure of their sessions. Each of the recorded sessions followed the same procedure: Right before the session, all participants completed a short questionnaire assessing their current affective state. Next, 45 minutes of the session was recorded on video. Right after, participants completed a self-report questionnaire assessing their retrospective ratings concerning the experience of a range of discrete emotions during the past 45 minutes, and sociodemographic variables (see supplementary files for detailed information on the questionnaires used in this study).

5.3.2 Our multi-camera approach

Each participant (teachers and students) was videotaped separately using multiple cameras that were synchronized via a wifi-signal. To meet the needs of a data collection in the field, I used a set of 10 small action cameras (GoPro© Hero 4; see Figure 6) that offer high mobility and robustness, quick and easy setup, simple handling and various mounting options for different surfaces. The student cameras were attached to the students' desks in front of them and the teacher camera was mounted on a height-adjustable camera tripod (see Figure 7 for a visual depiction of the camera setup). Height was adjusted depending on the

instructor's choice to either sit or stand most of the time during their session. Instructors were told they could move freely during the session, and that they would be videotaped once they were within the camera's field of view. All cameras were operated using a remote control (GoPro© Smart Remote; see Figure 6) and their field of view was set up to capture the participants' faces and upper torso (see Figure 8 for exemplary screenshots of video recordings). The videos were recorded in full HD resolution (1920x1080 pixels), at a frame rate of 30 frames per second, and with a focal length of 34.4 mm (see supplementary files for further information on the data collection procedures in this study).

5.3.3 Data processing

To process the video data, I used the iMotions software platform (www.imotions.com) in combination with the automated facial emotion recognition module FACET (Emotient, 2018; www.imotions.com/emotient/) which is a commercialized version of the CERT software (see Littlewort et al., 2011). FACET is based on the Facial Action Coding System (FACS) by Paul Ekman and colleagues (Ekman et al., 2002) and uses machine learning algorithms which have been trained using large face databases with expert human FACS codes as criteria and it has been shown to be highly accurate in detecting basic emotions across multiple datasets (Stöckli et al., 2018). The software provides so-called evidence scores for a range of discrete emotions for each single frame of a video. Evidence scores represent a logarithmic odds ratio of an expert human coder identifying a given video frame as representing a particular emotion versus not representing it. Thus, higher evidence scores represent higher odds that a certain facial expression is present in a particular frame; yet they cannot be validly translated into a measure of the intensity of that facial expression. However, beyond a given threshold value of the evidence, FACET provides valid and meaningful data as to presence of a given emotion (see also Stöckli et al., 2018). For my analyses, I chose to use a threshold of one for each discrete emotion under study. Applying a

threshold of one implies that the observed expression in that particular frame is 10 times more likely to be categorized by an expert human coder as representing the emotion under study than not representing it; e.g. the probability of a given face in a particular frame being judged as joyful is 10 times than this frame not being judged as joyful by an expert human coder (Emotient, 2018). Additionally, odds can be converted into probability values by dividing the odds by one plus the odds (Szumilas, 2010). Consequently, an evidence score of one translates to a probability of .9 which is well above the recommended threshold of 80% for statistical power (Cohen, 1988).

5.3.4 Self-report measures

Prior to the video recordings, participants answered the Positive and Negative Affect Schedule (Watson et al., 1988) in its state variant, which provides ten positive and negative adjectives and asks participants to indicate to what degree they currently experienced those emotional states (e.g., “joyful”, “jittery”). Mean values were calculated for positive and negative affect. After the videotaped lessons, I immediately obtained retrospectively self-reported discrete teacher and student emotions. I used single items based on the Teacher Emotions Scales (Frenzel et al., 2016) to measure joy (“In the past 45 minutes, I enjoyed class”), anxiety (“In the past 45 minutes, I was tense and nervous”), and anger (“In the past 45 minutes, I felt angry”) on a 5-point Likert agreement scale. These single items to assess discrete emotions during class retrospectively have been used successfully in prior research with students and teachers (Frenzel et al., 2015; Keller et al., 2018).

5.3.5 Analysis approach

To judge the feasibility and practicability of our synchronized multi-camera approach, I recorded emerging methodological challenges and technical issues during the videotaping process, and I explored the frame detection rate achieved by FACET. Given that the present work was the first study to use multiple synchronized cameras and automated

software in naturalistic classroom settings with only little control over the lighting conditions, furniture arrangement, considerable movements of teachers and fidgeting as well as socially interactive behavior of students (e.g. talking to neighbors, using smartphones etc.) and other audiovisual distractions or real life complications, it was unclear if I would achieve a reasonable frame detection rate. I strived for an average frame detection rate of at least 30% to consider the approach "feasible".

To explore the summative prevalence per session and to visualize the real-time process-oriented face data, I first calculated the aggregated percentage of frames categorized as joy, anxiety, and anger over the whole course session for each participating teacher and student (i.e., summative frequency scores). Second, given that an emotion, or emotional episode, most likely lasts longer than 1/30 of a second (the duration of one frame given our framerate), I sought to aggregate our frame-by-frame data over time intervals to get an idea of the emotional temporal dynamic and of potential "emotional peaks" within the participants over the course of the videotaped session. Such aggregation over certain time intervals also serves the means of data reduction with the goal of achieving a reasonable signal-to-noise ratio (Hamaker & Wichers, 2017; Maclin, Low, Fabiani, & Gratton, 2007). I tested different interval sizes and decided on an interval of 60 frames (= 2 seconds) resulting in approximately 1,000 intervals per person and session (instead of 60,000 single frames). At this interval size, I managed to acquire additional information on the variability and within-person dynamics of the participant's emotional "peak" expressions over time, while still preserving the dynamic moment-to-moment character of the single video frame as our basic unit of analysis. For each 60-frame-interval, I calculated the percentage of frames with an evidence score of one or higher and thus created time series graphs for each participant to visualize dynamic moment-to-moment changes in their emotional expressions (see Figure 9 for exemplary time series graphs of a teacher's facial expressions).

I calculated Spearman correlations to analyze the covariation between facially expressed emotions (operationalized as percentage of frames coded as one given discrete emotion), and the self-reported emotions of teachers and students immediately after the session. To rule out spurious effects due to any strong individual situation-specific emotion stemming from sources other than the teaching and learning situation under study, I controlled for individuals' positive and negative affect as reported immediately before the videotaped session. To account for multiple testing and the risk of alpha cumulation, I adjusted alpha significance levels using the Bonferroni correction for 12 correlational tests resulting in a new alpha significance level of $p < .004$.

All data transformation and statistical analyses were done in R (version 3.60; R Core Team, 2019), using the "ggplot2" (Wickham, 2016), "gridExtra" (Auguie, 2017), "tidyverse" (Wickham, 2017), "ggm" (Marchetti et al., 2015), "psych" (Revelle, 2018), "Hmisc" (Harrell, 2018), "pastecs" (Grosjean & Ibanez, 2018) and the "ppcor" (Kim, 2015) packages. Reproducible scripts for all transformations and analyses were generated (see supplementary files).

Figure 6. Mobile action camera (GoPro© Hero 4; on the left) and wifi remote control (GoPro© Smart Remote; right); both retrieved from https://shop.gopro.com/ Copyright 2014 by GoPro Inc.

Figure 7. Setup of our multi-camera-approach; schematic depiction (on the left) and in a classroom (on the right).

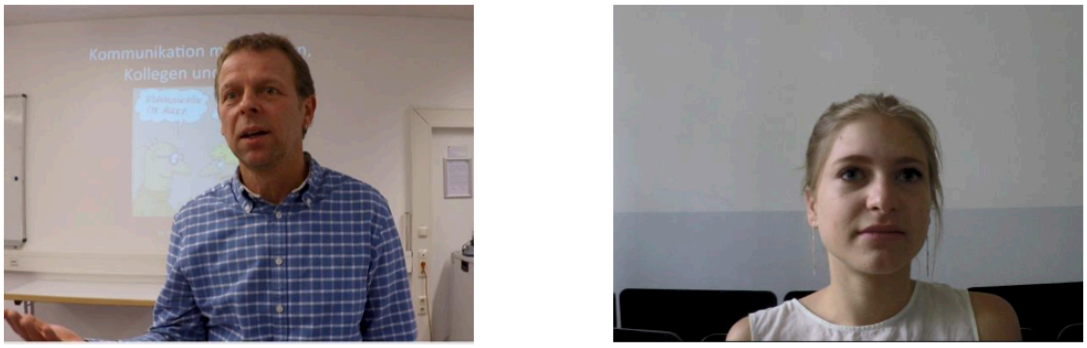

Figure 8. Exemplary video data of a teacher (on the left) and a student (on the right).

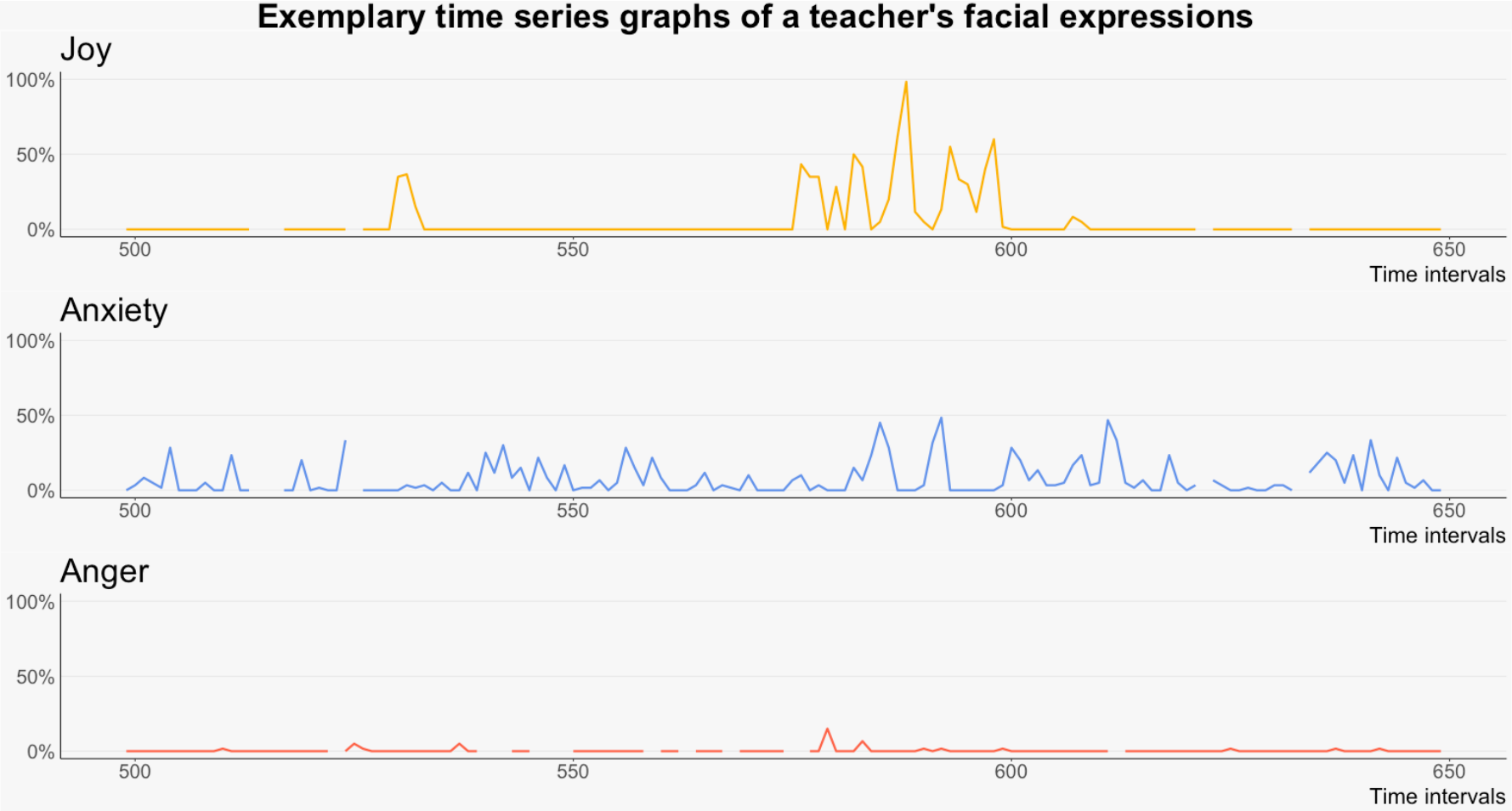

Figure 9. Exemplary time series graph depicting a teacher's facial expressions as recognized by automated coding software during a randomly selected 5-minute period (percentage of recognized frames in time intervals of 60 frames or 2 seconds).

5.4 Results

5.4.1 Feasibility of our multi-camera approach with automated facial action coding

Set up routines of the camera equipment proved to be quick enough to fit into every-day seminar schedules at the university, and no major technical complications occurred in over 120 hours of video recordings with multiple synchronized cameras in the field. The software analyzed a total of *M* = 63,911frames for the teacher data and *M* = 60,575 frames for the student data. On average, *M* = 77.6% of all recorded video frames could be detected and analyzed by the coding software for the teacher data (Frame detection rate; *SD* = 18.9%; Min = 28.7%; Max = 98.2%;) and *M* = 71.5% for the student data (*SD* = 19.7%; Min = 16.2%; Max = 97.9%). Thus, the average frame detection rates were well above my goal of 30% for both teachers and students. In addition, immediately after time point 1, the majority of all participants reported being “not at all” or “only a little” disturbed by this setup (84.6% of the teachers and 82.6% of the students).

5.4.2 Frequencies and temporal dynamic

Frequencies of facially expressed joy, anxiety, and anger of lecturers and students for both sessions are reported in tables 11 and 12 and for self-reported emotions in tables 13 and 14, respectively. On average, teachers facially expressed more joy (about 4-5 minutes of the total 45 minutes) than anxiety (about 1.5-3 minutes) and anger (about 0.5-1.5 minutes) in both sessions. The same pattern applied for students (who facially expressed, on average, about 1.5 minutes of joy, 1 minute of anxiety, and less than 1 minute of anger per session). Clearly, though, teachers obtained higher mean percentage scores for all emotions and in both sessions. A similar pattern was observable for self-reported emotions, with the exception of anger: In both sessions, students on average reported slightly more anger than teachers.

To gain a deeper understanding of the temporal dynamics of teachers' and students' expressions of joy, anger and anxiety in class, I next explored, for each participant in our study, time-series-graphs which depict the percentage of frames with an evidence score of one or higher for 60-frame-intervals over the course of one session. I drew a number of possible conclusions. First of all, as already reflected in the overall frequency analysis, there were clear differences between teachers and students, with teachers not only showing stronger, and more frequent, emotional expressions, particularly of joy, but also showing longer, more extended periods of emotional expressions, than students. Figures 10 to 15 show time series graphs of facial expressions of joy, anxiety, and anger in time point 1 and of all teachers and Figures 16 to 21 for all students nested in their classes, respectively (see Appendix E for additional, more detailed, figures of all students separately within their classes in both time points). Second, within the group of teachers, as well as within the group of students, there were striking interindividual differences. That is, some teachers were clearly highly positively expressive, showing multiple, and extended, periods of joy during teaching, while others literally were almost completely "flat" in their expression of joy. One single teacher also stood out with increased, almost continuous expressions of anger in both sessions, and some teachers showed considerably more signs of anxiety than all other teachers, of whom many did not show any signs of anger or anxiety during the entire teaching period in session 1 and 2. The same applied to students, while on a much lower frequency and intensity level than the teachers: While there were some individuals with repeated (yet short-lived) periods of expressed joy, anger, or anxiety, many individuals barely showed any signs of emotions in their faces for the entire 45-minute session. Third, there were striking differences across the individual classes (i.e. groups of students instructed by one and the same teacher), in that in some groups, quite some of the students showed considerably elevated emotional expressivity, while other groups were collectively

emotionally flat (see Figures 16 to 21). Forth, the nature of temporal dynamic differed across the three discrete emotions under study: For joy and anxiety, emotional episodes tended to be characterized by extended intervals of medium to large frequencies of frames in a row (particularly among teachers). Yet, episodes of anger tended to be characterized by single-interval short peaks, both for teachers and students.

5.4.3 Covariation between facial expressions and self-reported emotions

Spearman partial correlations were calculated (summarized in Tables 15 and 16) between self-reported emotions and facial expressions, controlling for positive affect for the correlation of self-reported and facially expressed joy and for negative affect for the correlations of anxiety and anger, respectively, as reported immediately prior to the session. For students, I found robust null correlations for self-reported and facially expressed anxiety and anger in both sessions. In case of student joy, I found small to medium positive correlations in session 1 ($r = .30$, $p = .014$) and 2 ($r = .23$, $p = .067$) that were not clearly statistically significant. For teachers, I found non-significant correlations that varied considerably in size across session 1 and 2, indicating untrustworthy parameter estimations due to the small sample size.

Table 11. *Descriptive Statistics of Teachers' Facial Expressions of Emotions While Teaching (Percentage of All Frames) in Session 1/Session 2*

	N	Min	Max	*M*	*SD*
Joy	13	1.29/1.03	25.28/29.65	8.80/10.0	8.01/10.12
Anxiety	13	0.02/0.43	21.74/14.33	5.14/2.52	7.0/3.93
Anger	13	0.0/0.0	22.02/6.76	2.23/1.26	5.98/2.15

Table 12. *Descriptive Statistics of Students' Facial Expressions of Emotions While Learning (Percentage of All Frames) in Session 1/Session 2*

	N	Min	Max	*M*	*SD*
Joy	69	0/0	11.43/10.30	2.58/2.86	2.83/2.51
Anxiety	69	0/0	16.45/17.16	0.94/1.85	2.23/3.49
Anger	69	0/0	3.77/8.21	0.20/0.26	0.59/1.02

Table 13. *Descriptive Statistics of Teachers' Self-Reported Affect as Reported Prior to Videotaping and Discrete Emotions Reported Afterwards for Session 1/Session 2*

	N	Min	Max	*M*	*SD*
Positive affect	13	2.1/2.1	4.5/4.2	3.42/3.27	0.62/0.54
Negative affect	13	1.0/1.0	2.7/4.2	1.48/1.45	0.51/0.88
Joy	13	3/3	5/5	4.31/4.31	0.63/0.63
Anxiety	13	1/1	4/4	2.08/1.92	0.86/1.12
Anger	13	1/1	3/2	1.23/1.23	0.60/0.44

Table 14. *Descriptive Statistics of Students' Self-Reported Affect as Reported Prior to Videotaping and Discrete Emotions and Affect as Reported Afterwards in Session 1/Session 2*

	N	Min	Max	*M*	*SD*
Positive affect	69	1.3/1.3	3.9/4.0	2.69/2.48	0.52/0.59
Negative affect	69	1.0/1.0	2.4/2.2	1.30/1.24	0.31/0.29
Joy	69	1/1	5/5	3.68/3.66	0.91/0.96
Anxiety	69	1/1	4/4	1.74/1.72	0.89/1.01
Anger	69	1/1	4/5	1.32/1.33	0.66/0.73

Table 15. *Spearman Correlations Between Teachers' Self-Reported and Facially Expressed Joy, Anxiety, and Anger in Session 1 and Session 2*

	Session 1	Session 2
Joy	.15	-.09
Anxiety	-.24	-.49
Anger	.02	-.18

Note. $N = 13$. Correlation coefficients shown for session1/2 controlling for positive affect (for joy) and negative affect (for anxiety and anger) as measured with the PANAS immediately prior to the videotaped session. None of the correlations were statistically significant and p-values ranged from $p = .103$ to $p = .955$.

Table 16. *Spearman Correlations Between Students' Self-Reported and Facially Expressed Joy, Anxiety, and Anger in Session 1 and Session 2*

	Session 1	Session 2
Joy	.30	.23
Anxiety	.11	-.10
Anger	.06	-.02

Note. $N = 69$. Correlation coefficients shown for session1/2 controlling for positive affect (for joy) and negative affect (for anxiety and anger) as measured with the PANAS immediately prior to the videotaped session. None of the correlations were statistically significant and p-values ranged from $p = .014$ to $p = .891$.

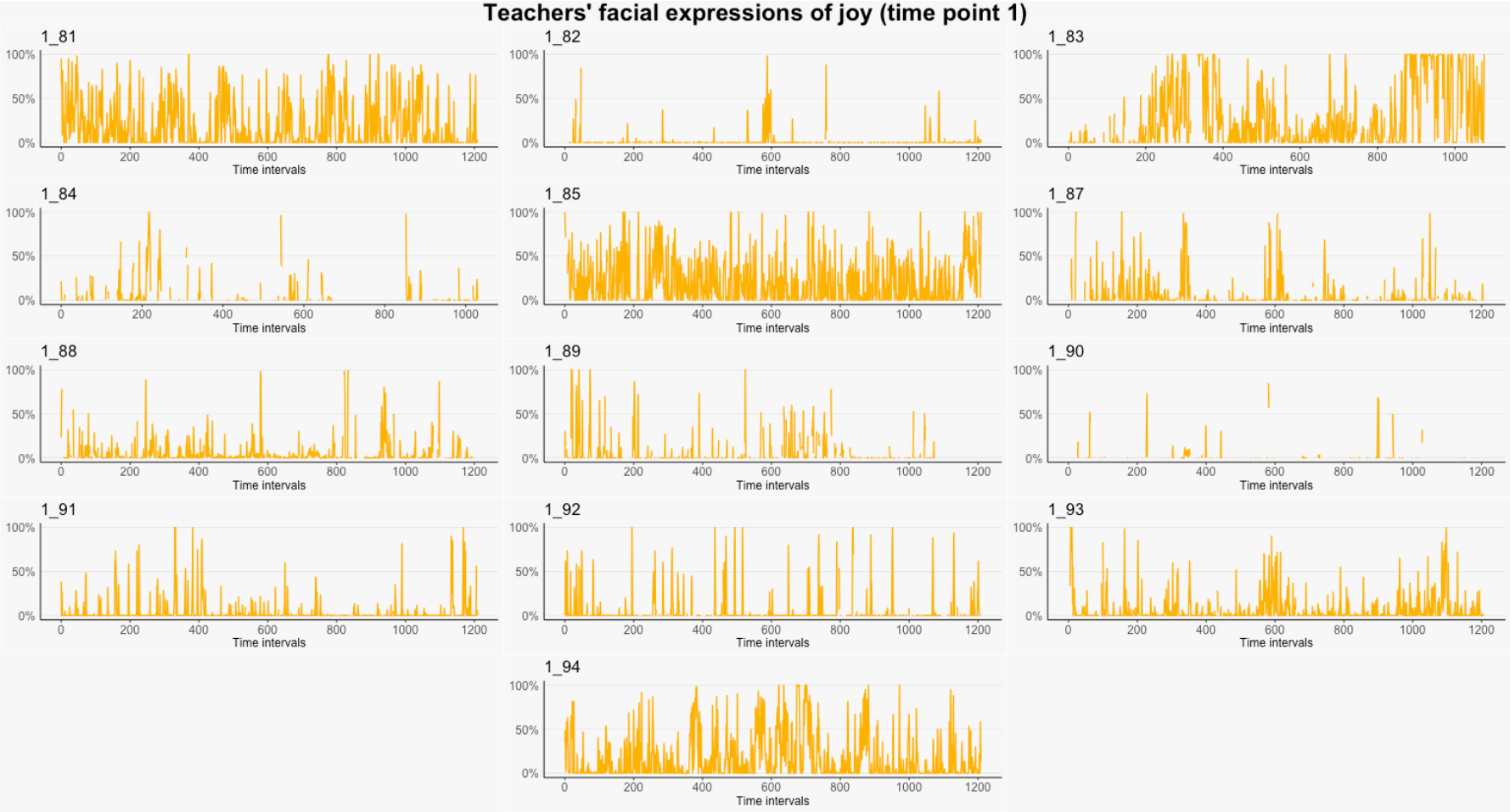

Figure 10. Time series graphs of facial expressions of joy as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds) of all teachers at time point 1.

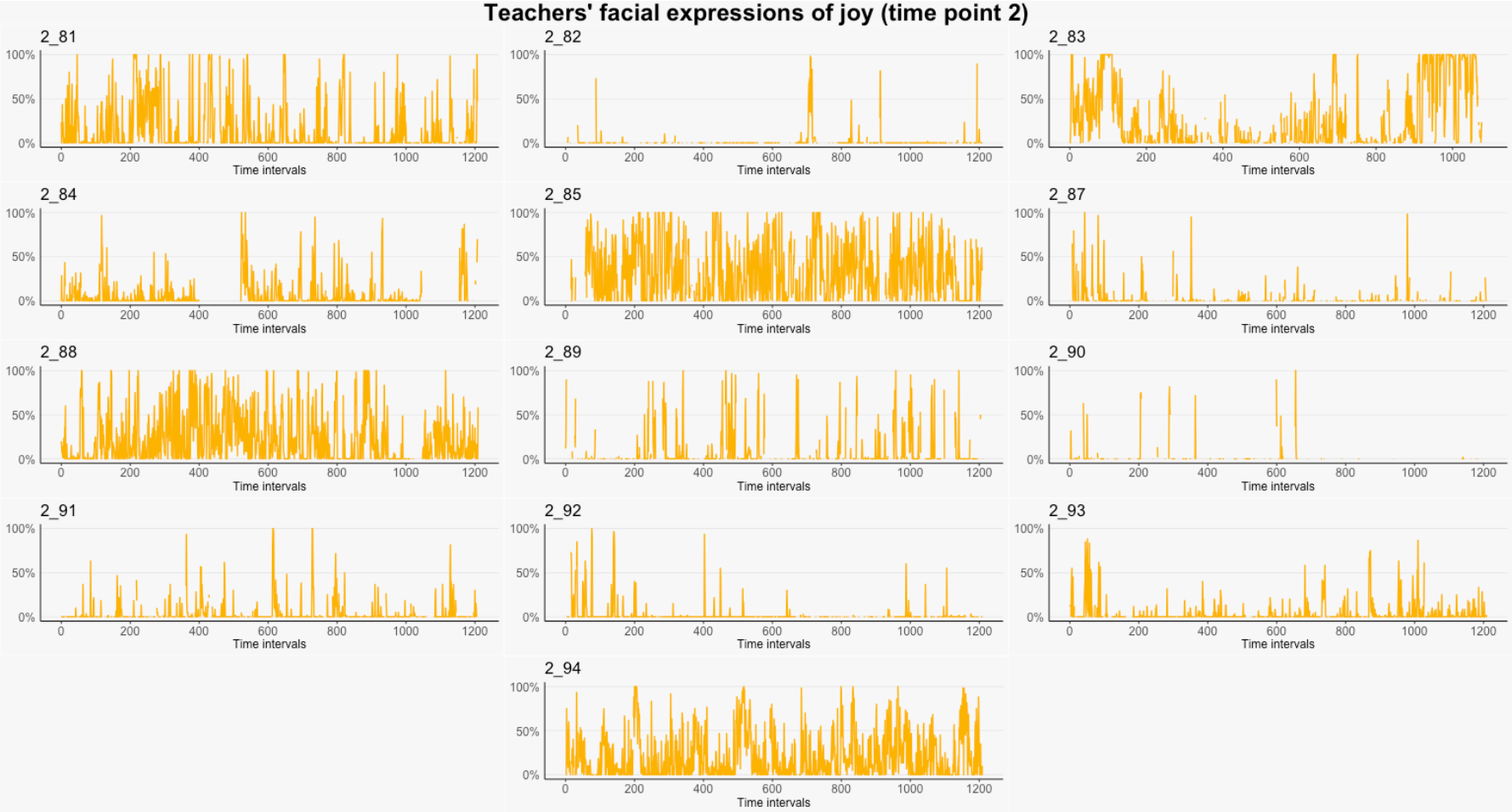

Figure 11. Time series graphs of facial expressions of joy as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds) of all teachers at time point 2.

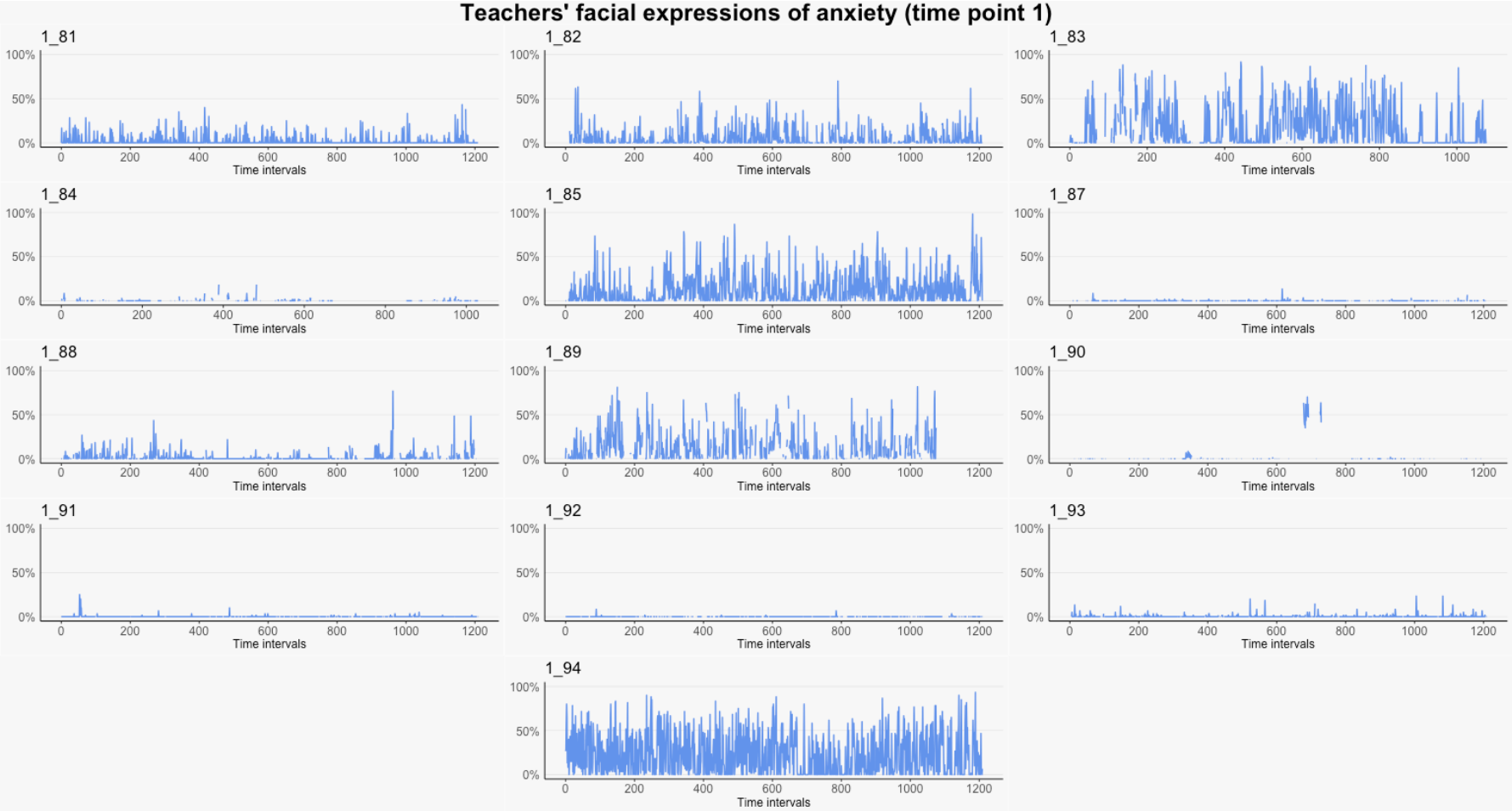

Figure 12. Time series graphs of facial expressions of anxiety as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds) of all teachers at time point 1.

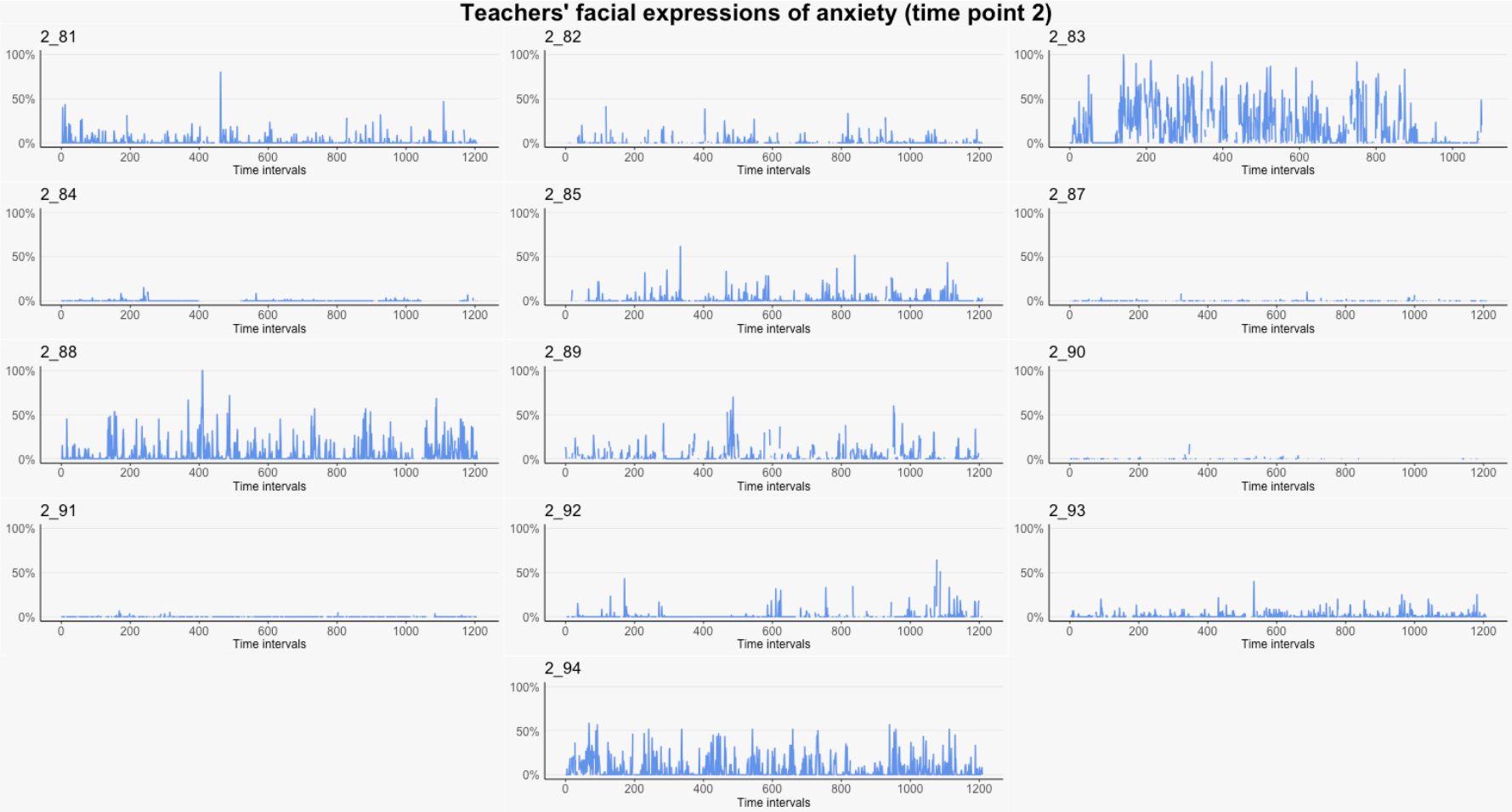

Figure 13. Time series graphs of facial expressions of anxiety as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds) of all teachers at time point 2.

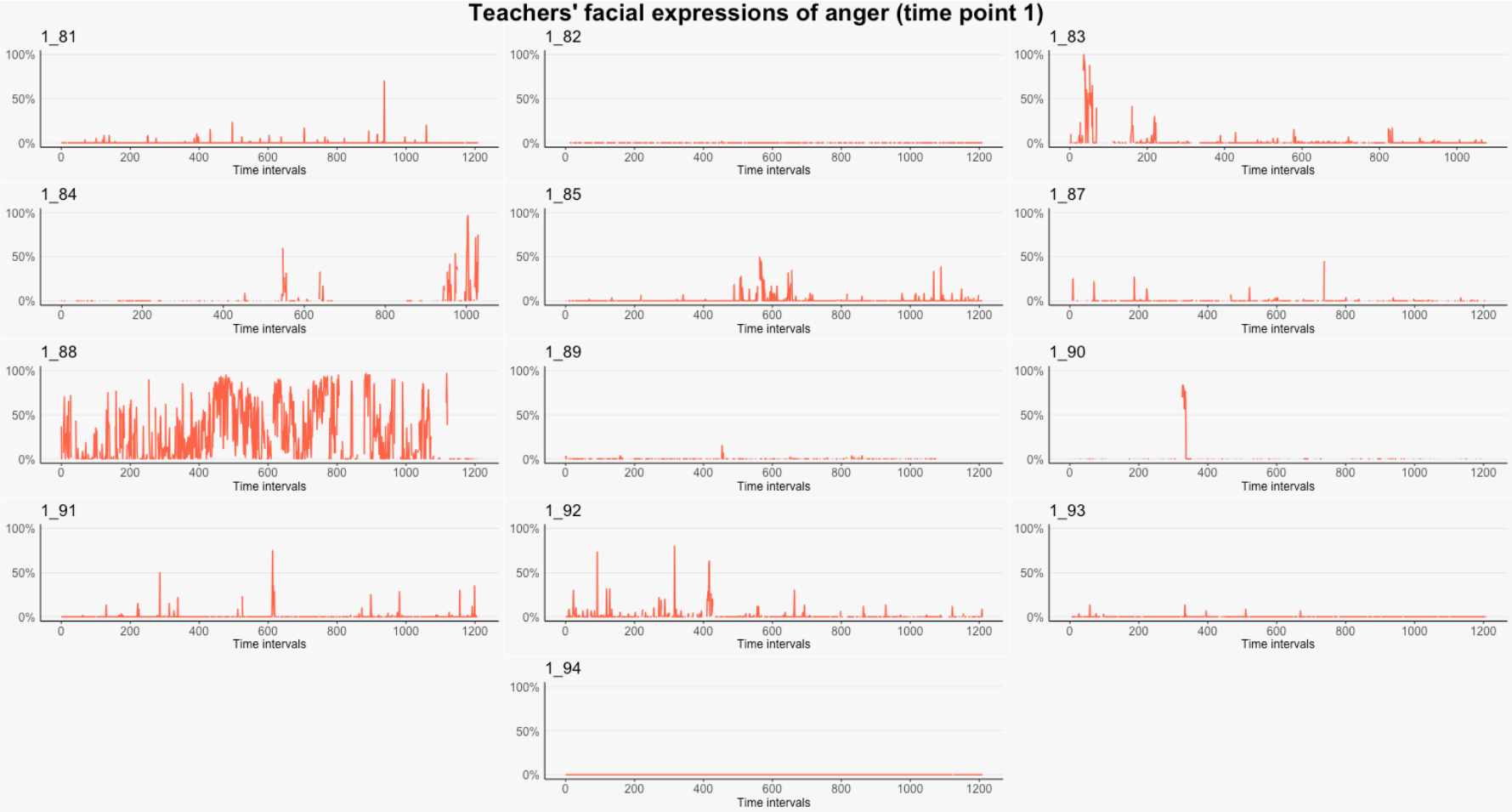

Figure 14. Time series graphs of facial expressions of anger as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds) of all teachers at time point 1.

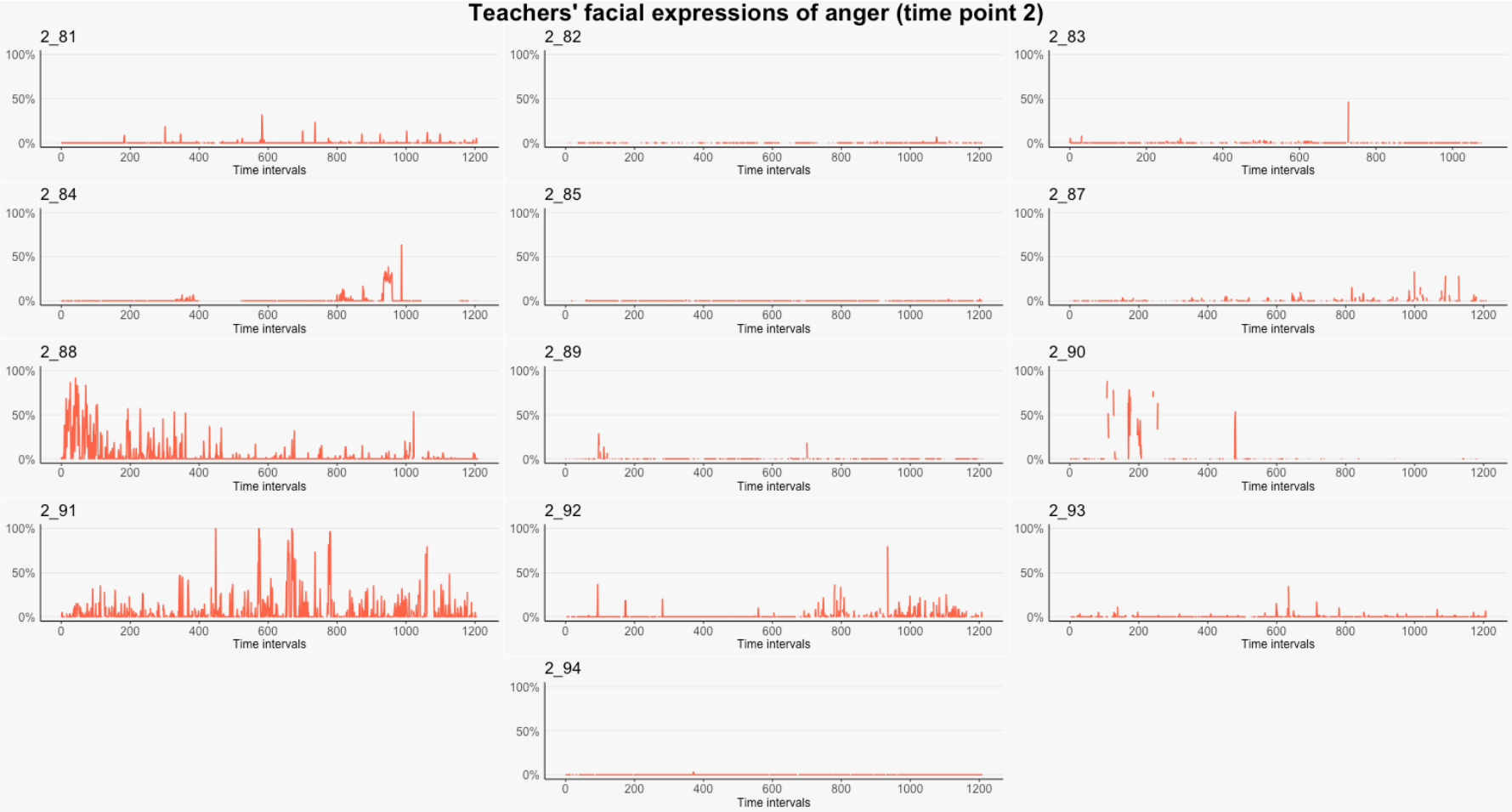

Figure 15. Time series graphs of facial expressions of anger as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds) of all teachers at time point 2.

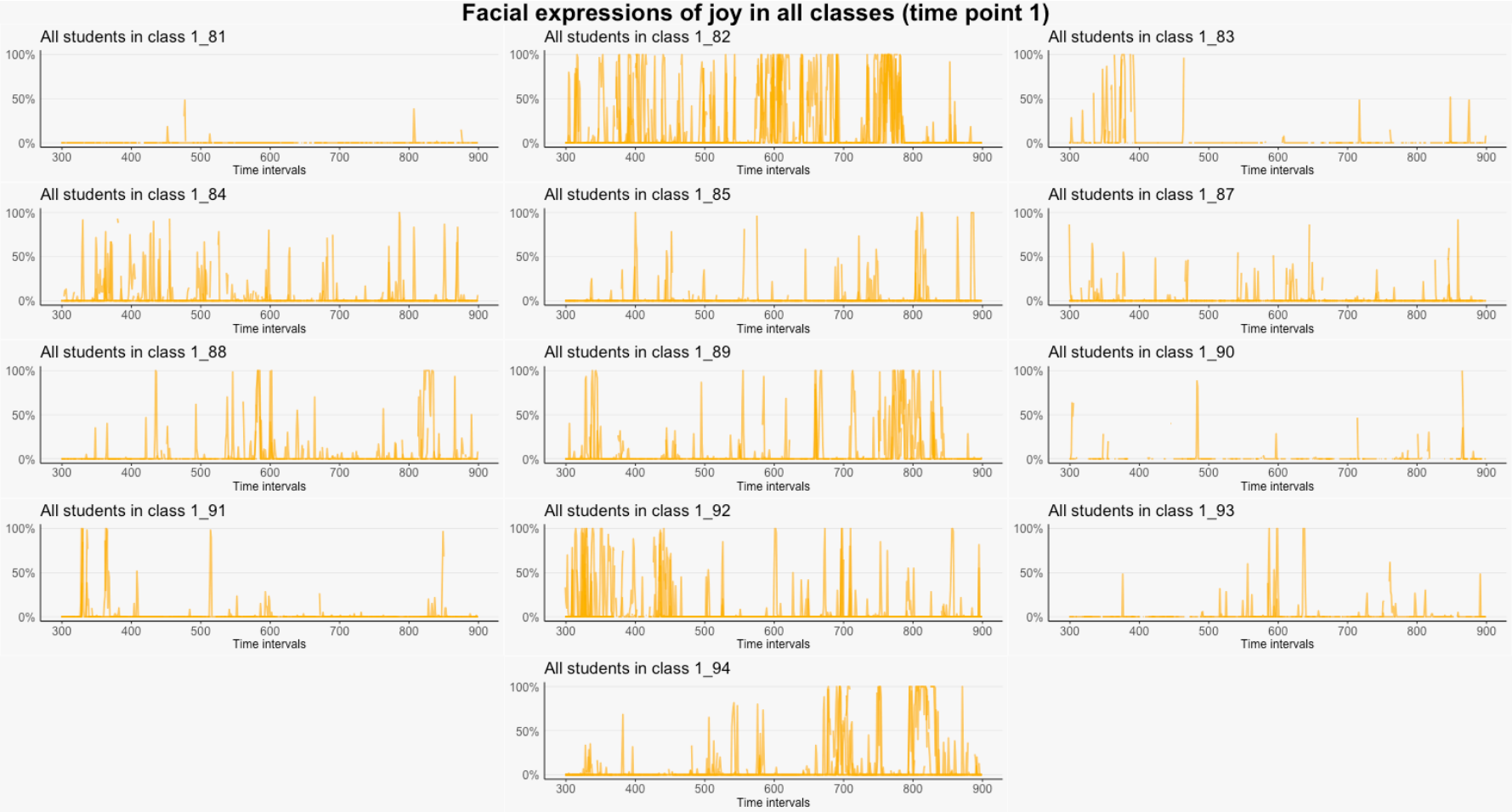

Figure 16. Time series graphs of facial expressions of joy as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds) of all students in their classes at time point 1.

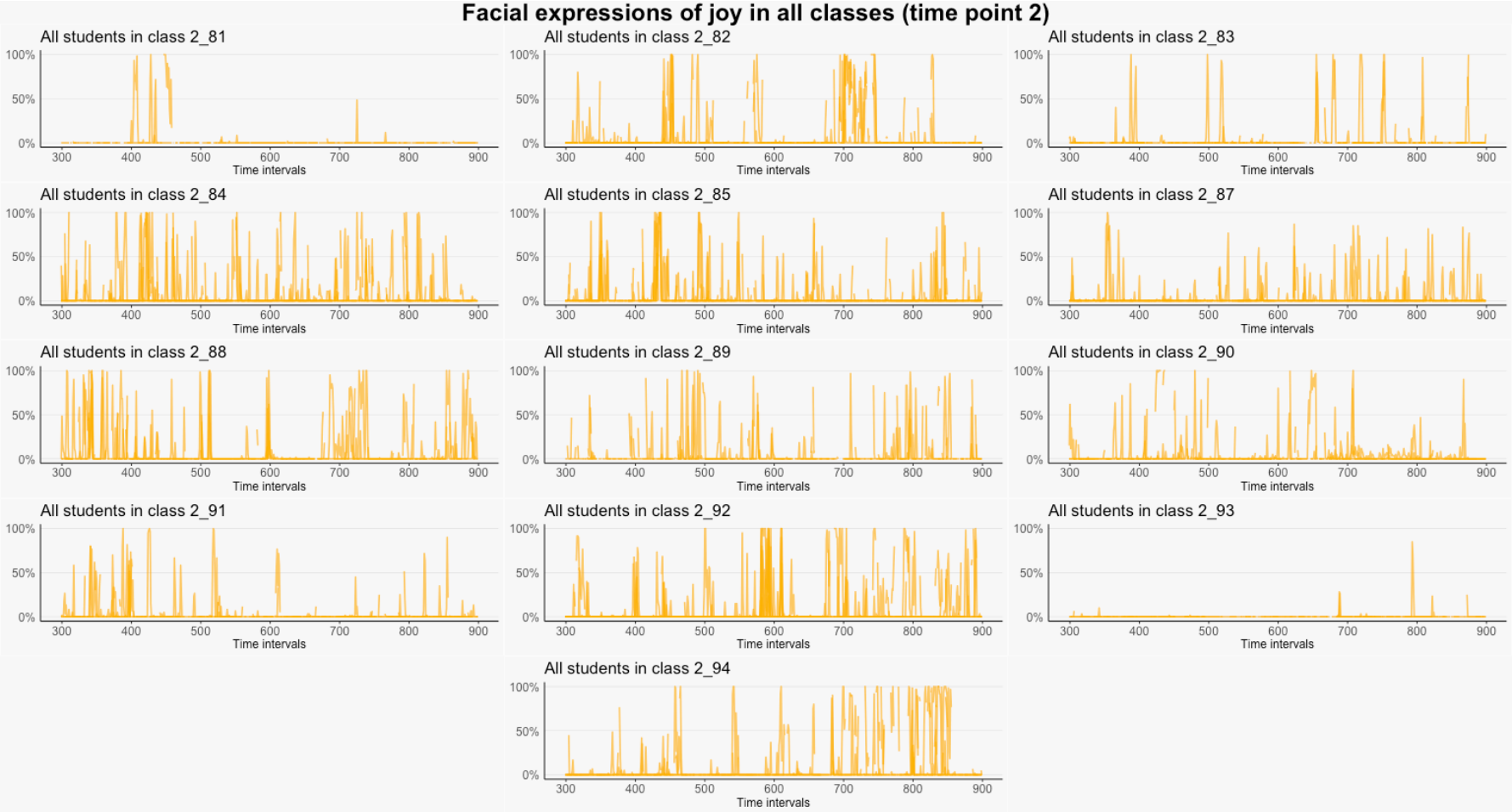

Figure 17. Time series graphs of facial expressions of joy as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds) of all students in their classes at time point 2.

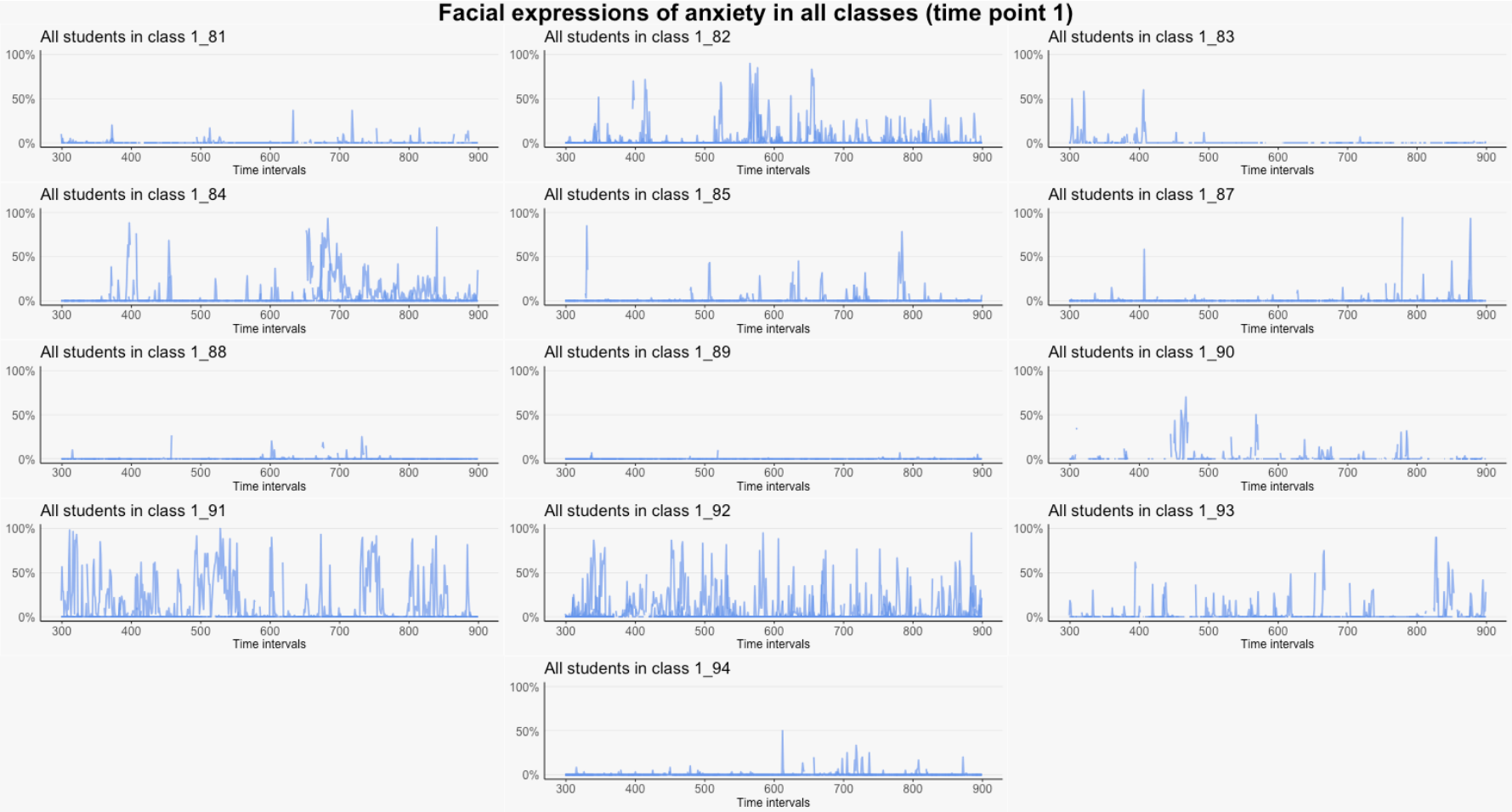

Figure 18. Time series graphs of facial expressions of anxiety as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds) of all students in their classes at time point 1.

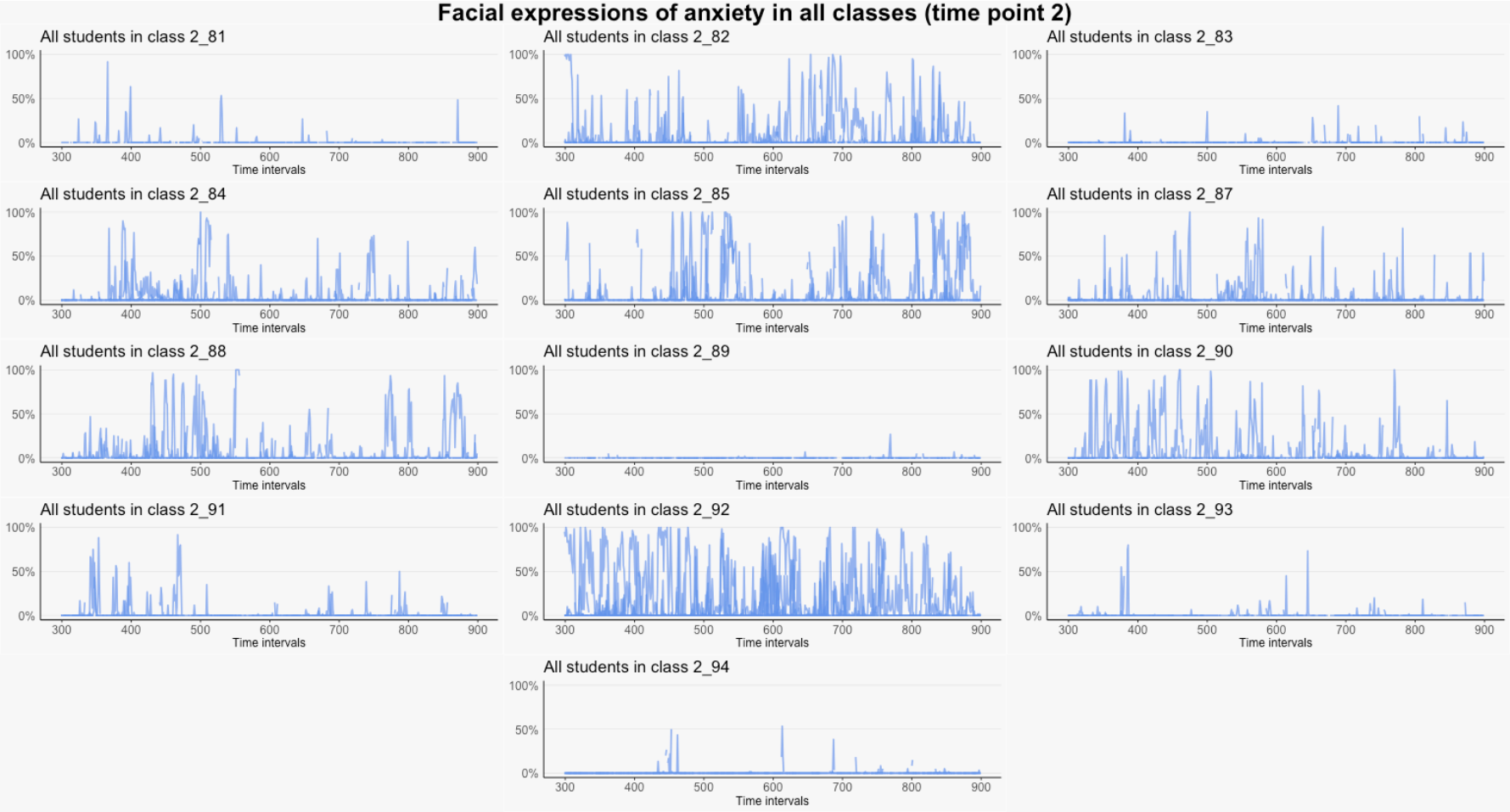

Figure 19. Time series graphs of facial expressions of anxiety as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds) of all students in their classes at time point 2.

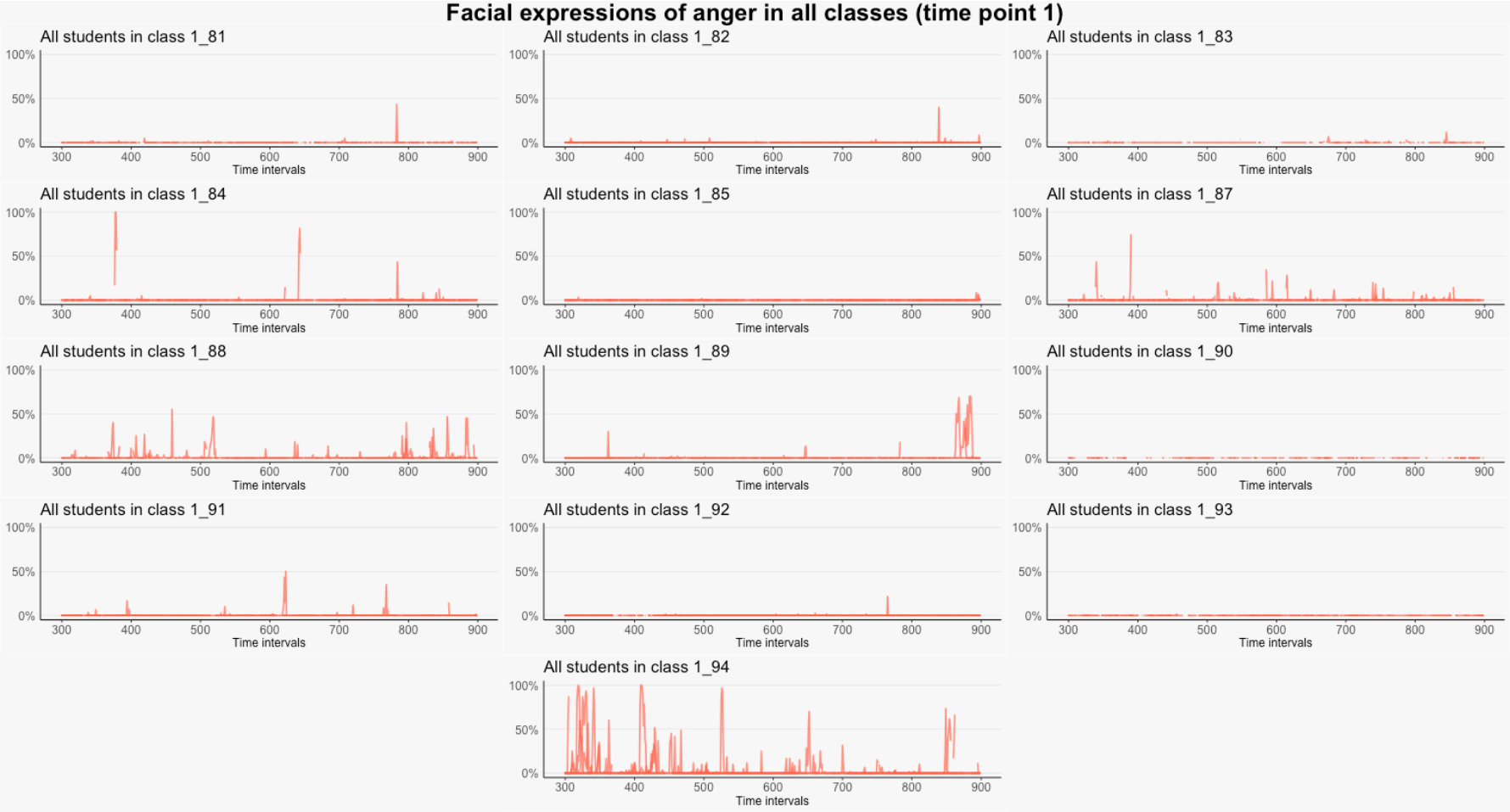

Figure 20. Time series graphs of facial expressions of anger as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds) of all students in their classes at time point 1.

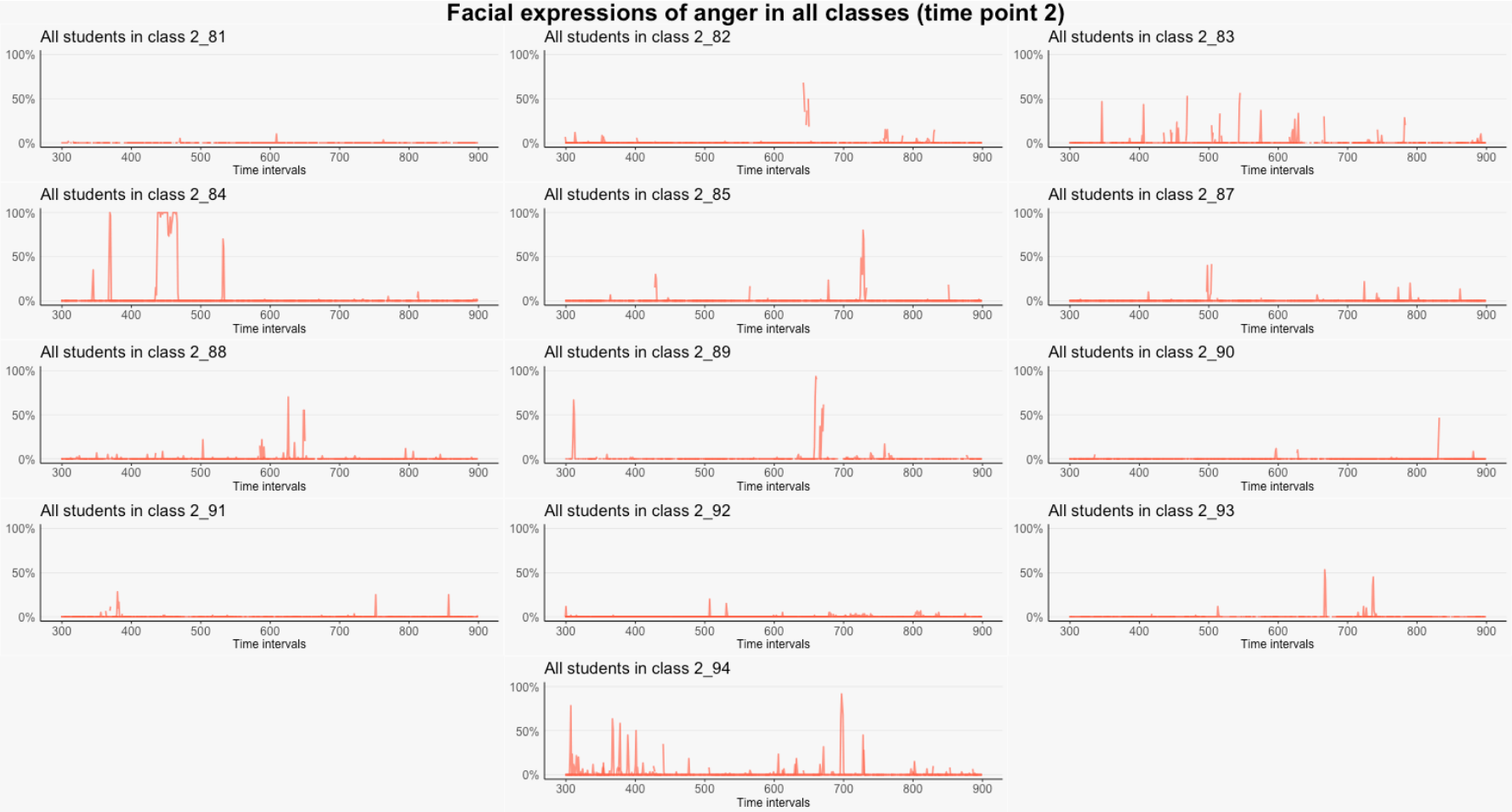

Figure 21. Time series graphs of facial expressions of anger as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds) of all students in their classes at time point 2.

5.5 Discussion

The present study aimed at (1) testing a newly developed methodological approach to examine the emotional expressions of teachers and students in a real-life learning environment and on a frame-by-frame level using multiple synchronized video cameras and automated facial emotion recognition software, (2) investigating the frequencies and temporal dynamic of teachers' and students' emotional expressions in their real learning environments and (3) exploring relations between facially expressed and self-reported emotions. The reported results (1) clearly support the applicability and feasibility of the methodological approach, (2) provide new insights regarding the frequencies and temporal dynamics of teachers' and students' emotional expressions in real teaching and learning situations, and (3) suggest that students' subjective feelings in class as retrospectively self-reported discrete emotions are not systematically reflected in their facial expressions in real learning situations.

5.5.1 Evaluation of our methodological approach

In contrast to the vast majority of previous research which used a face reading approach to investigate emotions during learning which typically were laboratory based or used computer-based digital learning environments, I sought to take the face reading approach into real classrooms, thus exploring teaching and learning situations in authentic learning environments outside of the lab. No study known to me has collected comparable data on the emotional expressions of both teachers and students with individualized high-quality video recordings using multiple synchronized cameras. As this approach involved massive amounts of video data, it was critical to combine it with automated, computer-based facial expression coding. Thanks to ever-growing computational power and speedy developments in computational machine learning, automated facial coding has made considerable progress in recent years, and today, different powerful engines are available

which provide, quite time- and cost-effectively, valid and reliable frame-by-frame emotion recognition based on facial video data (e.g. Stöckli et al., 2018). In the present study, I used the software package iMotions FACET (https://imotions.com/emotient/) which is a commercialized version of the CERT software (see Littlewort et al., 2011). I combined the automated facial expression recognition approach with traditional self-report measures to explore possible relations between emotional expressions and subjective feelings of teachers and students.

The results support the applicability of the methodological approach in real teaching and learning situations with high average frame detection rates for both teachers and students. Despite multiple cameras in the room, their small size made the filming process rather inconspicuous and allowed teachers and students to perform their teaching and learning tasks without interruption. Although being in naturalistic learning environments in the field, instructors and students proved to remain considerably static during the 45 minutes of video recording (either sitting or standing), lighting conditions in authentic classroom setting proved to be sufficient, set up routines of the camera equipment were quick enough to fit into every-day seminar schedules at the university, no major technical complications occurred in over 120 hours of video recordings with multiple synchronized cameras in the field, and the majority of the participants reported not being disturbed by the camera setup. Thus, the newly developed multi-camera-approach in combination with automated facial emotion recognition provides a promising avenue for future investigations in the field of teacher and student emotions.

5.5.2 Frequency of facially expressed and self-reported emotions and temporal dynamic

The reported results show generally pretty low frequencies of facial emotion expressions, with joy being clearly the most predominant emotion visible in the faces of both

teachers and students. Teachers showed higher levels of facial expressions of emotions and of self-reported emotions than students.

Regarding the temporal dynamic, the data shows differences between groups (teachers and students, different classes), interindividual differences within these groups, and emotion-specific patterns in the expression of joy, anxiety, and anger. I observed considerable moment-to-moment changes in all individuals, generally higher frequencies of peak emotion expressions for teachers than for students and, for many teachers, joy seemed to fluctuate on much higher levels, while anger tended to show fewer and short-lived peaks. Thus, the findings add to the picture of emotions as highly individual and dynamically fluctuating phenomena.

5.5.3 Covariation between facial expressions and self-reported emotions

I had hypothesized that teachers' and students' facially expressed emotions would be positively correlated with their corresponding retrospectively self-reported discrete emotions (joy, anxiety, and anger). The data does not provide support for those hypotheses. Regarding the teachers, the results were highly inconsistent over the two times of measurement for all three discrete emotions. Due to the small sample of size ($N = 13$), I interpret those findings as inconclusive. For the students, the results suggest that retrospectively self-reported discrete emotions are not systematically reflected in their facial expressions in real learning situations. More precisely, I found self-reported and facially expressed emotions to show very small, nonsignificant correlations between one another at both time points of measurement, even when controlling for current affective state as measured immediately prior to the videotaped session. There was just one exception: students' self-reported and facially displayed joy in session 1 showed a medium-sized, positive correlation approaching an acceptable significance level. However, given the inconsistency of our findings, I refrain from interpreting this correlation substantially. I conducted a post hoc power analysis using

the software G*Power (version 3.1.9.2; Faul et al., 2007, 2009) which indicated that, given the student sample size, large and medium effect sizes can be ruled out in view of the reported null-findings, whereas small effects cannot be ruled out confidently (power for large effects = 1.00, for medium effects = .83, and for small effects = .21). Given the size of the teacher sample, power was too low to make confident conclusions regarding either small, medium, or large effect sizes. Consequently, larger sample sizes are needed to validate the null findings I obtained for teachers and to further explore the inconsistent findings on student levels.

While studies on the covariation of facially expressed and self-reported emotions have reported positive relations between facially expressed and self-reported emotions outside of a specific learning or teaching context (e.g. Matsumoto et al., 2008), only few studies have investigated facial emotion expression and its relation to individuals' subjective feelings or other emotion related variables in teaching or learning situations. These studies have mainly focused on single students in contexts with low levels of social interaction, such as laboratory settings, computerized learning environments or performance assessment tasks, which do not represent everyday life in a real classroom.

Therefore, possible explanations for the reported results include: (1) Social display rules of emotional expressions in teaching and learning situations in the field with higher social acceptance for positive facial expressions, and a lower social acceptance of negative facial expressions, potentially resulting in restrictions of range and reduced variance in expressed emotions. (2) Within the teaching and learning context, Action Unit 4, consisting of the activation of the facial muscles "Corrugator supercilii" and "Depressor supercilii" (Ekman et al., 2002) may have been particularly frequent. Action Unit 4 is a strong marker for both concentration and anger, possibly leading to a false coding of concentrated facial expressions as displayed anger. Similarly, the fact that most teachers' were very frequently

talking may have resulted in invalid or imprecise markings of Action Units pertaining to the mouth region (e.g. Danner & Duerrschmid, 2018). (3) As participation was voluntary, only highly engaged teachers and students participated, which might have restricted the range of both self-reported and expressed emotions among our participants, thus limiting their possible covariation. (4) The retrospective self-report measures I obtained after the session may have been biased due to recency effects, peak emotional experiences during the sessions, or response tendencies, such as social desirability (Pekrun & Bühner, 2014), while the summative percentage scores of facially expressed emotions during the session possibly represented the individuals' emotions more objectively. The correlations between the self-report and face data could therefore be limited by these methodological challenges and differential fallacies involved in both to the facial and the self-report data.

5.5.4 Limitations and challenges

First, the methodological approach involved several very time consuming and complicated features. Videotaping, automatically coding and post-processing the facial data of one single seminar session required a total of approximately 10 hours. Therefore, the sample sizes both for teacher and student data were naturally limited. Second, in its very nature, video data has to be considered personal and highly sensitive data, especially video recordings of an individual's face. Therefore, data privacy and security issues have to be considered and solved throughout the whole process of data collection, data processing, data analysis, publishing, and archiving, which adds to the complexity of this methodological approach. Third, when analyzing the video data, I chose a threshold value of one for the evidence scores in each analyzed frame which implied that the observed expression in that particular frame is 10 times more likely to be categorized by an expert human coder as representing a particular emotion than not representing this emotion. While this threshold appears to be a reasonable decision, it is, at the same time, somewhat arbitrary. Future

studies should, therefore, systematically compare different approaches to analyze these evidence scores, including other threshold values based on profound theoretical considerations, such as statistical power. Finally, given that collecting and analyzing behavioral data in the field comes with many technological and methodological challenges and classrooms full of students being especially „noisy places“, several technical issues and challenges of this study design have to be taken into account. Given the real-life, field nature of the data, expected and unexpected, yet actually teaching- and learning-unrelated disturbances and class distractions occurred, such as technical issues with laptops, projectors, or microphones, students in the wrong classroom, students suddenly leaving the classroom or even students bringing their little dogs to class, and thus increasing the “noise” in the classroom even further.

Therefore, to tackle some of these challenges of research using automated facial expression analysis on a frame-by-frame basis, I propose a collaboration of researchers and laboratories to increase sample size and statistical power, to replicate the reported findings, and to investigate individuals’ facial expressions and their role in social interaction and interpersonal functioning more deeply. Similar to already existing collaboration projects, such as the “Many Lab” project (https://osf.io/89vqh/) or the “Many Babies” project (https://osf.io/rpw6d/), a so-called “Many Frames” project could serve as a solid foundation for future research on individuals’ facial expressions.

5.5.5 Conclusion

The present work acts as an initial demonstration of how individuals’ facial expressions of emotions can be collected in unscripted classroom interactions in the field using multiple synchronized video cameras and automated facial action recognition and it is an example of how such dynamic and process-oriented data may be utilized for future investigations of teacher and student emotions and interactional processes. My own

upcoming and planned analyses will involve manual coding of the automated facial action codes to cross-validate these results. In addition, I aim at applying time-series analyses to explore the temporal dynamic of teachers' and students' emotional expressions in a more systematic and statistically elaborated way than the mere visual inspection presented herein. Finally, I also strive to explore covariation between teachers' and learners' state emotional experiences and expressions to explore processes of EC in the classroom on a real-time, micro level, thus extending upon earlier research which demonstrated enjoyment transmission between teachers and students using self-report trait data (Frenzel et al., 2018).

To conclude, I believe that – despite its limitations, this study provides unique insights into the frequencies and temporal dynamic of teachers' and learners' emotional expressions in the classroom. The classroom is a highly interactive place, and facial expressions constitute an important non-verbal channel for communication between teachers and learners. Getting insight into the frequencies and temporal dynamics of teachers' and learners' facial expressions of emotions in class will provide the ground for exploring how those emotional expressions may support – or hinder – effective instruction and subjective well-being.

5.6 Supplementary Files

All supplementary files are accessible for the reviewers on a Compact Disc (CD) attached to this dissertation.

5.6.1 Raw data

The following compressed zip files contain all raw data used in this study as exported from the automated facial action coding software.

- Teachers: Time point 1 (*teacher_data_t1.zip*) and 2 (*teacher_data_t2.zip*)
- Students: Time point 1 (*student_data_t1.zip*) and 2 (*student_data_t2.zip*)

5.6.2 Processed datasets

- Facial expression data: The compressed zip file *data_facialexpression.zip* contains all processed facial expression data used in this study (including variable descriptions in a codebook).
- Self-report data: The compressed zip file *data_selfreport.zip* contains all self-report data used in this study (including variable descriptions in a codebook).

5.6.3 Reproducible analysis scripts

The following R files contain executable R-code in order to reproduce the reported results using the provided data set.

- Data processing: R file *fx.01.processing.R*
- Analyses: R file *fx.02.analyses.R*
- Data visualization: R files *fx.03.plots.teachers* and *fx.04.plots.students*

5.6.4 Additional figures of all participants

The following compressed zip files contain separate time series graphs of all participants' facial expressions of joy, anxiety, and anger during the video recorded sessions.

- Teachers: Time point 1 (*add_fig_t1_teachers.zip*) and 2 (*add_fig_t2_teachers.zip*)

- Students: Time point 1 (*add_fig_t1_students.zip*) and 2 (*add_fig_t2_students.zip*)

5.6.5 Procedures and material

The following zip files contain detailed information on the specific data collection procedures of this study, including informed consent forms, questionnaires or protocols.

- Procedures (*fx.procedures.zip*)
- Questionnaires (*fx.questionnaires.zip*)

6. Overall Discussion

6.1 Findings and contributions

In the present work, I aimed to advance psychological research on EC and SEC on both a theoretical and a methodological level. To this end, I, first, conceptually reviewed previous theoretical frameworks of EC and SEC (chapter 2). I pointed out that the ideas of EC and SEC have not only been described as early as 1739, but they have been subject to scientific reasoning for at least 100 years. I highlighted the lack of clarity and consistency in terms of definitions and conceptualizations over time and concluded with a precise definition of EC and SEC in order to foster ground for future research on both EC and SEC. Second, I systematically reviewed existing self-report measures of individuals' SEC (chapter 3). I found that only very few measures have been published to assess individuals SEC and in these existing measures, the items predominantly address the SEC of negative emotions while the SEC of positive emotions has been mostly neglected, as of yet. Thus, my findings suggested that suitable self-report measures to assess individuals' SEC of positive emotions and of negative emotions were lacking. Third, I presented and validated a newly developed self-report measure to assess individuals' SEC of both positive and negative emotions (chapter 4). In two studies, I examined its reliability and its internal and external validity. My findings suggest that the new SEC scale is an internally valid, reliable, and economical measure to examine individuals' SEC of negative and positive emotions. Regarding its external validity, I found diverging patterns of linkages with external criterion variables for the SEC of positive and of negative emotions. While being susceptible to catching others' negative emotions seemed to be related to mental health problems and increased negative emotional experiences, being susceptible to catching others' positive emotions seemed to be related to individuals' social relations and greater interpersonal functioning. Fourth, I

developed and evaluated a new video-based method to assess individuals' facial expressions in unscripted group interactions using multiple synchronized cameras and automated facial action coding software (chapter 5). My results supported the applicability and feasibility of the methodological approach in realistic teaching and learning situations in the field and they provided unique insights into the frequencies and temporal dynamics of teachers' and learners' facial expressions of emotions as an essential part of the proposed underlying mechanisms of EC. For teachers, I generally found greater aggregated levels of facial expressions over time and higher frequencies of peak facial expressions of emotions as compared to the students. Students, on the other hand, seemed to show relatively low levels and frequencies of facial expressions of emotions while being in class. In both teachers and students, I observed considerable moment-to-moment changes in the facial expressions of joy, anger, and anxiety with facial expressions of joy clearly being the most visible expressions overall.

Hence, the present work contributed to the theoretical fundament and methodological repertoire of research on EC and individuals' SEC in several ways. On a methodological level, (1) it provided a systematic overview of existing measures of SEC and pointed out their weaknesses and shortages when assessing individuals' SEC; (2) it introduced and validated a newly developed self-report measure to assess individuals' SEC of both positive and negative emotions; and (3) it developed and evaluated a multi-camera-approach to simultaneously videotape individuals in unscripted group interaction in combination with automated facial action coding software to examine their facial expressions of emotions on a frame-by-frame basis. On a more substantial and theoretical level, (1) it put forward a clear and concise definition of EC and SEC and a precise delineation from empathy and related constructs; (2) it provided evidence for differences of positive and negative SEC in terms of their linkages with relevant external variables; and (3) it provided new valuable insights into

the frequencies and temporal dynamics of teachers' and students' facial expressions of joy, anxiety, and anger in their real-life classroom environment during authentic and unscripted teaching and learning interaction.

6.2 Strengths and limitations

The present work showed several strengths in its goals, study design, and research practices. First, this dissertation aimed to examine two highly relevant and innovative topics in psychological research on human emotions and social interaction, namely an individual's SEC of positive and negative emotions and automated facial expression analysis in unscripted group interaction. Second, the development and evaluation of the new multi-camera-approach in combination with automated facial expression analysis involved not only logistically, but also technically and computationally demanding procedures. Collecting, processing, and analyzing more than 120 hours of video recordings from authentic classrooms in the field required high levels of expertise in the fields of technical implementation, project coordination, data management, computational programming, and statistical analyses. Third, the present work strongly embraced the values of openness and transparency in psychological science (e.g. Crüwell et al., 2019; Renkewitz & Heene, 2019) with (1) preregistered hypotheses and analyses plans, (2) reproducible R scripts for all data processing steps and statistical analyses as well as open data to reproduce all reported results and figures, (3) extensive and detailed descriptions of methods and procedures as well as open materials to facilitate replication studies, and (4) transparent reporting of results including statistical power and confidence intervals.

However, given the strengths of the present work, two major limitations have to be taken into account when interpreting the results. First, in chapter 4, only self-report measures have been used to assess relevant criterion variables and only correlational analyses have been conducted to examine relations of our new scale with these criterion variables in terms

of our scale's external validity. Thus, no causal inferences can be drawn from these analyses. Second, in chapter 5, only relatively small samples have been recruited due to restrictions in available resources, such as time and personnel. Thus, statistical power for some of the reported analyses were relatively low or even insufficient and these analyses have to be replicated in larger samples.

6.3 Directions for future research

In the past years, there has been growing scientific interest in the topics of EC and SEC in psychological and related research disciplines. While this dissertation contributed to these lines of research, there still remain important questions to be examined in future research. Regarding individuals' SEC, more studies are needed to investigate the temporal stability and predictive validity of individuals' positive and negative SEC. More specifically, possible relations of both positive and negative SEC to other highly relevant variables should be investigated, such as emotion regulation capacities, attachment security/insecurity, relationship quality, or prosocial behavior. Additionally, to go beyond self-report data in these studies, I suggest including other measures of personality traits, socially interactive behavior, emotional experiences, and also expressive components of emotions, such as individuals' facial expressions.

Regarding automated facial expression analysis in socially interactive situations, future studies are needed to not only replicate the reported findings in larger samples and more standardized environments, but also to systematically explore the role of facial expressions of discrete emotions for the transmission of emotional states in different socially interactive settings, such as collaborative learning, conflict solving, or psychosocial counseling or psychotherapy. To tackle some of the challenges of research using automated facial expression analysis on a frame-by-frame basis, I propose to form a collaboration of researchers and laboratories to increase sample size and statistical power and to deeper

investigate individuals' facial expressions and their role in social interaction and interpersonal functioning. Similar to already existing collaboration projects, such as the "Many Lab" project (https://osf.io/89vqh/) or the "Many Babies" project (https://osf.io/rpw6d/), a so-called "Many Frames" project could serve as a powerful accelerator of future research on individuals' facial expressions.

6.4 Conclusion

Regarding SEC, the reported findings highlight the importance of distinguishing positive SEC and negative SEC as separate subfacets of SEC and they suggest that the newly developed SEC scale is a suitable and promising self-report measure to assess an individual's SEC of positive emotions and of negative emotions. I conclude that future research should stop treating SEC as a unidimensional construct, and start investigating positive SEC and negative SEC as two clearly distinguishable subfacets of individuals' SEC. Regarding automated facial expression analysis, the present work acts as a proof of concept and an initial demonstration of how individuals' facial expressions of emotions can be collected in unscripted classroom interactions in the field using multiple synchronized video cameras and automated facial expression recognition software. It is an example of how such dynamic and process-oriented data can be analyzed in future studies on emotion expression and interactional processes. To sum up, the present work substantially contributes to both the theoretical fundament and the methodological repertoire of research on EC and individuals' SEC.

7. Zusammenfassung

Der Titel der vorliegenden Dissertation lautet zu Deutsch sinngemäß „Fortschritte in der Erforschung der emotionalen Ansteckung“ und sie beschäftigt sich mit dem Phänomen der emotionalen Ansteckung, der individuellen Neigung sich emotional anstecken zu lassen und den dahinterliegenden auf dem nonverbalen Emotionsausdruck basierenden Mechanismen. In der medizinischen Praxis steht der Begriff „Ansteckung“ für die Übertragung einer Krankheit von einem Organismus auf einen anderen. In der psychologischen Forschung wird der Begriff der „Ansteckung“ ebenso gebraucht in Bezug auf verschiedene Übertragungsphänomene. Der Begriff „Emotionale Ansteckung“ bezeichnet hierbei im Speziellen die größtenteils unbewusste und automatische Übertragung von emotionalen Zuständen von einem Individuum auf ein oder mehrere andere Individuen.

Innerhalb dieses thematischen Rahmens thematisiert die vorliegende Arbeit zunächst auf theoretischer Ebene (Kapitel 2) die historischen Ursprünge und sich wandelnden Definitionen emotionaler Ansteckungsprozesse in der Psychologie und verwandten Disziplinen sowie die inhaltlichen und methodischen Schwächen bisheriger Forschung in diesem Feld. Trotz eines deutlich gestiegenen Interesses in das Phänomen der emotionalen Ansteckung in der psychologischen Forschung, scheinen sich eine Vielzahl der Autoren und Autorinnen uneinig zu sein in den Begrifflichkeiten, der genauen Definition, Operationalisierung und Abgrenzung verschiedener verwandter Prozesse im Bereich der sozio-emotionalen Interaktion und interpersonellen Kommunikation. Diese Uneinheitlichkeit und Inkonsistenz stellt ein großes Hindernis dar für eine konsequente und transparente wissenschaftliche Erforschung emotionaler Ansteckungsprozesse. Zudem scheint in der bisherigen Forschung eine teilweise ungenaue Abgrenzung von verwandten Konstrukten vorzuliegen, v.a. der Empathie, und die Begriffe werden teilweise deckungsgleich verwendet

bzw. nur unscharf abgegrenzt. Um zu einer konsistenten und eindeutigen Abgrenzung und Definition von emotionaler Ansteckung beizutragen, definieren wir emotionale Ansteckung als einen interpersonellen Prozess, bei dem sich ein emotionaler Zustand von einer Person A auf eine andere Person B bzw. auf mehrere andere Personen überträgt. Diese Übertragung geschieht vorwiegend unbewusst und teilweise automatisch. Person B muss diesen Prozess hierbei nicht zwingend als solchen wahrnehmen und muss nicht einmal Bewusstsein darüber haben, dass eine andere Person A existiert oder diesen emotionalen Zustand ursprünglich erlebt hat bzw. die Quelle des emotionalen Erlebenszustandes darstellt. Diese fehlende Selbst-Andere-Abgrenzung stellt dabei das wichtigste Kriterium für eine trennscharfe Abgrenzung von Empathie dar. Empathie sieht immer vor, dass eine Person B Kenntnis über Person A hat und sich bewusst ist, dass der eigene momentan erlebte emotionale Zustand auf die andere Person A zurückzuführen ist. Zudem wird eine sogenannte emotionale Ansteckbarkeit einer Person definiert als die Vulnerabilität einer Person, sich mit den Emotionen anderer Personen anstecken zu lassen.

In einer systematischen Übersichtsarbeit (Kapitel 3) wird nach ausgiebiger Literaturrecherche ein systematischer Überblick über die bisher verfügbaren Instrumente zur Erfassung der emotionalen Ansteckbarkeit, vorwiegend Selbstberichtsinstrumente, und deren Eigenheiten gegeben. Auffallend ist hierbei, dass sich bestehende Instrumente vorwiegend mit der emotionalen Ansteckbarkeit mit negativen Emotionen beschäftigen und die emotionale Ansteckbarkeit mit positiven Emotionen bislang noch nicht angemessen repräsentiert ist. Es scheint demnach kein angemessenes Messinstrument zu existieren zur Erfassung der emotionalen Ansteckbarkeit mit sowohl positiven als auch negativen Emotionen.

Den Kern der vorliegenden Arbeit bilden in der Folge die Kapitel 4 und 5 bzw. die darin enthaltenen empirischen Studien. In Kapitel 4 wird eine neu entwickelte

Selbstberichtsskala zur Erfassung der emotionalen Ansteckbarkeit mit positiven und negativen Emotionen vorgestellt. In zwei Studien mit jeweils ca. 250 Teilnehmerinnen und Teilnehmern wurde deren interne Validität mittels Exploratorischer und Konfirmatorischer Faktorenanalyse, die externe Validität mittels korrelativer Analysen sowie die Reliabilität mittels Analysen der internen Konsistenz getestet. Die Ergebnisse dieser Studien zeigen, dass die neu entwickelte Skala ein intern und extern valides sowie reliables und ökonomisches Instrument ist, wobei die beiden Subskalen, emotionale Ansteckbarkeit mit positiven Emotionen und emotionale Ansteckbarkeit mit negativen Emotionen umfassen jeweils vier Items umfassen und insgesamt gute testtheoretische Kennziffern aufweisen. Bezüglich der externen Validität beider Subskalen, liefern die Ergebnisse Hinweise darauf, dass sich die positive emotionale Ansteckbarkeit und die negative emotionale Ansteckbarkeit in ihren Zusammenhängen mit externen Kriteriumsvariablen unterscheiden. Während ein höhere negative emotionale Ansteckbarkeit mit einem erhöhten Erleben negativer Emotionen, Emotionalität und Leiden sowie mit Depression, Ängstlichkeit, Stress und körperlichen Krankheitssymptomen einhergeht, zeigten sich keine Zusammenhänge zwischen diesen Variablen und der positiven emotionalen Ansteckbarkeit. Eine höhere positive emotionale Ansteckbarkeit dagegen ging einher mit verschiedenen Variablen des zwischenmenschlichen Miteinanders und der sozialen Interaktion, z.B. Offenheit für sozialen Kontakt, Geselligkeit, zwischenmenschliches Vertrauen und Mitgefühl. Negative emotionale Ansteckbarkeit zeigte im Gegensatz dazu keine substanziellen Zusammenhänge mit diesen Variablen. Zusammengenommen liefern diese Ergebnisse Hinweise dafür, dass die emotionale Ansteckbarkeit mit positiven und mit negativen Emotionen zwei klar voneinander abgrenzbare und in ihren Zusammenhängen mit externen Variablen unterschiedliche Subfacetten der emotionalen Ansteckbarkeit ausmachen. Zukünftige Studien sollten die emotionale Ansteckbarkeit also nicht als eindimensionales und

einheitliches Konstrukt verstehen, sondern stattdessen jeweils die beiden separaten Dimensionen positive und negative emotionale Ansteckbarkeit und deren Zusammenspiel genauer untersuchen.

Kapitel 5 beschäftigt sich mit dem nonverbalen Ausdruck von Emotionen im Gesicht von Individuen in einer authentischen Gruppeninteraktion in realen Klassenzimmern im Sinne einer Feldstudie außerhalb des Labors. Dazu wurde in dieser Arbeit ein neuer methodischer Ansatz entwickelt und evaluiert. Dieser Ansatz umfasst mehrere synchronisierte Videokameras und automatisierte Kodiersoftware für die Analyse des emotionalen Ausdrucks im Gesicht der Teilnehmerinnen und Teilnehmer. Dieser Ansatz wurde in einer universitären Stichprobe von 14 Seminaren mit je einer Lehrperson und insgesamt 69 Studierenden in jeweils zwei authentischen Seminarsitzungen getestet und die Umsetzbarkeit und Machbarkeit hin überprüft. Dazu wurden insgesamt mehr als 120 Stunden Videomaterial mittels der automatisierten Software kodiert und es wurden pro Videobild Wahrscheinlichkeitswerte extrahiert zu den diskreten Emotionen Freude, Angst und Ärger. Diese Wahrscheinlichkeitswerte wurden anschließend pro Person umgerechnet in aggregierte Prozentwerte über die jeweilige Sitzung hinweg sowie in Häufigkeitswerte von sogenannten „Peak-Expressions“ (Spitzen-Ausdruck), ebenso über jeweils eine Sitzung hinweg. Die Ergebnisse zeigen zum einen, dass eine synchronisierte Aufzeichnung des Gesichtsausdruck multipler Interaktionsteilnehmerinnen und -teilnehmer mit anschließender automatisierter Analyse des Gesichtsausdrucks nicht nur möglich ist und zum anderen, dass es große Unterschiede gab zwischen den Lehrpersonen und den Studierenden in der Häufigkeit emotionaler Gesichtsausdrücke während den aufgezeichneten Sitzungen sowie zwischen den drei analysierten diskreten Emotionen. Außerdem zeigten sich bei allen teilnehmenden Personen eine hohe Dynamik und Wechselhaftigkeit in der nonverbalen emotionalen Expressivität. Dieser Teil der vorliegenden Arbeit zeigte damit zum ersten Mal,

dass es nicht nur möglich ist, mehrere Personen in einer authentischen Gruppeninteraktion simultan auf Video aufzuzeichnen und anschließend mittels automatisierter Software zu analysieren, sondern auch dass dieser neue methodische Ansatz wertvolle und interessante Erkenntnisse über den nonverbalen Emotionsausdruck von Interaktionspartnerinnen und -partnern in echten und authentischen Situationen liefern kann.

Abschließend werden die Ergebnisse der Arbeit und das methodische Vorgehen in einer allgemeinen Diskussion zusammengefasst und kritisch diskutiert. Auf methodischer Ebene erscheint die neu entwickelte und validierte Selbstberichtsskala ein intern und extern valides sowie reliables und ökonomisches Instrument zur Erfassung der emotionalen Ansteckbarkeit mit positiven und negativen Emotionen zu sein. Die neu entwickelte und evaluierte video-basierte Methode, bestehend aus multiplen synchronisierten Videokameras und automatisierter Software zur Erkennung von Gesichtsausdrücken auf der Basis einzelner Videobilder, erscheint zudem ein vielversprechender und höchst innovativer Ansatz zur Erforschung interpersoneller Prozesse in authentischen Gruppeninteraktionen außerhalb des Labors zu sein.

Auf inhaltlicher und theoretischer Ebene liefern die Ergebnisse der vorliegenden Arbeit Hinweise darauf, dass Personen, die sich mit negativen Emotionen anstecken lassen, eine höhere Wahrscheinlichkeit aufweisen für das Erleben negativer Emotionen sowie für das Erleben psychischer Probleme, z.B. Angst, Depression und Stress, während Personen, die sich mit positiven Emotionen anstecken lassen höhere Werte in verschiedenen Bereichen des sozialen Miteinanders aufweisen, z.B. Geselligkeit, Mitgefühl und Vertrauen. In Bezug auf den nonverbalen Emotionsausdruck in authentischen Gruppeninteraktionen im Klassenzimmer liefern die Ergebnisse der vorliegenden Arbeit neue wertvolle Erkenntnisse über die Häufigkeit und die zeitliche Dynamik von Gesichtsausdrücken und über die emotionale Expressivität von Lehrpersonen und Studierenden in realistischen Lehr-Lern-

Situationen. Zusammenfassend leistet die vorliegende Dissertation wichtige Beiträge zur Erforschung der emotionalen Ansteckung im psychologischen Kontext und erweitert sowohl deren theoretisches Fundament als auch deren methodisches Repertoire in signifikanter Weise.

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Appendices

Appendix A: Information on the Research Project "FEEL"

Basic Information

Title: Projekt FEEL – Forschung zum Emotionalen Erleben im Lehr-Lern-Kontext

English Title: EmoCont – Emotional Contagion in the Classroom

Principal Investigators:

- Prof. Dr. Anne C. Frenzel, University of Munich (LMU), GER
- Prof. Dr. Corinna Reck, University of Munich (LMU), GER
- Prof. Dr. Reinhard Pekrun, University of Essex, UK

Funding:

- Deutsche Forschungsgemeinschaft (DFG), Project number 282833022
- Funding period 2016 – 2019 (36 months)

Pilot Studies

Pilot Study 1 "Teacher Pilot Study":

- Project Leader/Manager: Anton Marx, Nathania Klauser
- Data: Questionnaire data (paper-pencil-questionnaires)
- Sample: Teachers ($N = 257$) in different German states (mostly Bavaria)

Study 2 "Video Pilot Study":

- Project Leader/Manager: Anton Marx
- Data: Video recordings, Facial expression data
- Sample: University lecturers ($N = 13$) and their students (N=69)

Pilot Study 3 "Online Pilot Study":

- Project Leader/Manager: Anton Marx
- Data: Online survey data (using Sosci Survey, www.soscisurvey.de)
- Sample: Online sample ($N = 253$), recruited via Clickworker (www.clickworker.com)

Main Studies

Main Study "Questionnaire Study":

- Project Leader/Manager: Anton Marx, Katarina Kosovac
- Data: Questionnaire data (paper-pencil-questionnaires) at four time points
- Sample: Teachers ($N = 102$) and their students ($N > 1400$ students)

Main Study "Video Study":

- Project Leader/Manager: Anton Marx, Katarina Kosovac
- Data: Video recordings, Facial expression data
- Sample: Subsample of the teachers ($N = 19$) and their students ($N > 200$ students)

Appendix B: Preregistration of the Systematic Review of Measures of SEC

ASPREDICTED

Wharton University of Pennsylvania CREDIBILITY LAB
(http://credlab.wharton.upenn.edu)

You are logged in as: **anton.marx@psy.lmu.de**

HOME (index.php) See List (see_list.php)

Change my AsPredicted email (update_email1.php) Log out (logout.php)

As Predicted:"*Review of measurement of susceptibility to emotional contagion*" (#30634)

Created: 11/07/2019 08:15 AM (PT)

Author(s)
Anton Marx (University of Munich (LMU)) - anton.marx@psy.lmu.de
Anne Frenzel (University of Munich (LMU)) - frenzel@psy.lmu.de

1) Have any data been collected for this study already?
No, no data have been collected for this study yet.

2) What's the main question being asked or hypothesis being tested in this study?
(1) What self-report measures of susceptibility to emotional contagion (SEC) have been published in psychological research or related disciplines?
(2) What specific items are used in these measures to assess individuals' SEC and do they relate to positive or negative emotional experiences?
(3) What theoretical conceptualizations of SEC act as foundations for the development and construction of these measures?

3) Describe the key dependent variable(s) specifying how they will be measured.
Susceptibility to Emotional Contagion (SEC) is defined as a trait-like disposition of how susceptible a person is to catch others' emotions (e.g. Mehrabian & Epstein, 1972; Hatfield et al., 1994).

4) How many and which conditions will participants be assigned to?
No conditions.

5) Specify exactly which analyses you will conduct to examine the main question/hypothesis.
A. Literature Search / Methods to identify potentially relevant publications:
(1) Searching multiple bibliographic databases (PsycINFO, PSYNDEX, PubMed, ERIC): Search terms include all possible combinations of the terms "emotional", "emotions", "contagion", "contagious", "transmission", "transfer", "crossover", "susceptibility", "measurement", "measure", "scale", "questionnaire", "index", and "self-report".
(2) Scanning reference lists of existing reviews and eligible studies
(3) Contacting scholars in this area of research
(4) Broadly searching the internet and academic social networks

B. Inclusion Criteria / Inclusion and exclusion criteria to select publications for further analyses:
(1) At least one of the items used in the measure is related to SEC.
(2) The focus of the publication lies on either scale development or scale validation and/or the reported measure could be and is intended to be used beyond a single study. This is indicated by either reports on content validity, construct validity, criterion validity, or norms, or by instructions on how to use the measure, calculate scores, and/or what specific items are used.
(3) There are no constraints regarding the publication date or the country of origin.

C. Data Extraction / Analysis:
The selected publications will be reviewed and analyzed regarding their year of development or publication, target group(s), theoretical background/conceptualization, subscales, response scale, and the number of items related to SEC in total, SEC of positive emotions, SEC of negative emotions, and general SEC.

6) Describe exactly how outliers will be defined and handled, and your precise rule(s) for excluding observations.

See 5)

7) How many observations will be collected or what will determine sample size?
No need to justify decision, but be precise about exactly how the number will be determined.
n.a.

8) Anything else you would like to pre-register?
(e.g., secondary analyses, variables collected for exploratory purposes, unusual analyses planned?)
Nothing else to pre-register.

Appendix C: Additional Material of Chapter 4 – Study 1

C.1 Full list of assessed variables

Part I

1) Teacher self-efficacy
2) Teacher burnout
3) Teaching enthusiasm
4) Control and value components of teaching goals
5) Emotional labor

Part II

1) Information on a randomly selected class (class 1)
2) Teaching enthusiasm (class-specific items) in class 1
3) Teacher emotions (class-specific items) in class 1
4) Susceptibility to emotional contagion (class-specific items) in class 1
5) Emotion regulation capacities (class-specific items) in class 1
6) Teacher class perception (class-specific items) in class 1
7) Teacher self-efficacy (class-specific items) in class 1
8) Control and value components of teaching goals (class-specific items) in class 1
9) Teacher-class-relationship (class-specific items) in class 1
10) Teaching flexibility (class-specific items) in class 1

Part III

1) Information on a second randomly selected class (class 2)
2) Teacher emotions (class-specific single-item scales) in class 2
3) Teacher class perception (class-specific single-item scales) in class 2
4) Emotion regulation capacities (class-specific single-item scales) in class 2
5) Teacher-class-relationship (class-specific single-item scale) in class 2

Part IV

1) Information on a third randomly selected class (class 3)
2) Teacher emotions (class-specific single-item scales) in class 3
3) Teacher class perception (class-specific single-item scales) in class 3
4) Emotion regulation capacities (class-specific single-item scales) in class 3
5) Teacher-class-relationship (class-specific single-item scale) in class 3

Part V

1) Attachment style
2) Attachment insecurity
3) Emotion regulation capacities
4) Susceptibility to emotional contagion
5) Socioeconomic variables

C.2 Factor matrix of the 10-item version of the SEC scale

Factor Matrix of the 10-Item Version of the SEC Scale

	Factor 1	Factor 2
It cheers me up to be around a jolly person.	.69	
It fills me with joy to be around happy people.	.83	
I get carried away when someone is euphoric.	.59	.12
I let myself be infected by someone's enthusiasm.	.76	
I get cheerful when I am surrounded by cheerful people.	.71	.17
I depresses me when people around me are gloomy.	.10	.49
I get nervous when others around me are nervous.		.65
I get angry when I am surrounded by enraged people.		.51
I tense up when I hear people fighting.		.68
I get stressed when I am around stressed people.		.85

Note. Only factor loading >.1 are displayed

Appendix D: Additional Material of Chapter 4 – Study 2

D.1 Preregistration (aspredicted.org-template)

ASPREDICTED

Wharton University of Pennsylvania CREDIBILITY LAB
(http://credlab.wharton.upenn.edu)

You are logged in as: **anton.marx@psy.lmu.de**

HOME (index.php) See List (see_list.php)

Change my AsPredicted email (update_email1.php) Log out (logout.php)

As Predicted:"*Susceptibility to contagion of positive and negative emotions*" (#26597)

Created: 08/07/2019 07:53 AM (PT)

Author(s)
Anton Marx (University of Munich (LMU)) - anton.marx@psy.lmu.de
Anne Frenzel (University of Munich (LMU)) - frenzel@psy.lmu.de

1) Have any data been collected for this study already?
It's complicated. We have already collected some data but explain in Question 8 why readers may consider this a valid pre-registration nevertheless.

2) What's the main question being asked or hypothesis being tested in this study?
Objectives:
First, we present a new, elaborated measure which assesses susceptibility to positive emotions, on the one hand, and negative emotions, on the other. We aim to investigate the psychometric properties, internal consistencies and factor structure of our newly developed self-report scale to measure individuals' SEC (internal validity).
Second, regarding external validity, we aim to investigate relations of self-reported SEC (through positive and through negative emotions) with other relevant and emotion related constructs and to explore diverging patterns in the relations of positive and negative SEC with these constructs.

Research questions:
1/ Is our newly developed scale a reliable instrument to assess self-reported positive SEC and negative SEC (internal consistency)?
2/ Are positive SEC and negative SEC clearly separable, yet positively correlated constructs as measured by our newly developed scales?
3/ Is our newly developed scale an internally valid measure to assess self-reported positive SEC and negative SEC, as documented by confirmatory factor analysis (CFA) showing that the two-factor model fit the data better than the unidimensional model?
4/ Is our newly developed scale a valid measure to assess self-reported positive SEC and negative SEC in terms of construct validity, divergent validity, and criterion oriented validity?

3) Describe the key dependent variable(s) specifying how they will be measured.
Variables: Susceptibility to Emotional Contagion (newly developed scale), Positive and negative affect (PANAS), Big Five Personality traits (BFI-2), Perceived Stress (PSS), Life Satisfaction (SWLS), Health Symptoms (CHIPS), Depressivity (EDS), General Anxiety (PHQ-ADS), Empathy (AMES), Empathy (IRI), Social desirability (KSE-G), Theory of mind (RME)

4) How many and which conditions will participants be assigned to?
None

5) Specify exactly which analyses you will conduct to examine the main question/hypothesis.
1/ Item analysis: Variances, means, standard deviations, item discrimination index, item difficulty index, item-total correlations, scatter plots, density plots
2/ Scale analysis / summary statistics: Variances, means, standard deviations, skewness, kurtosis, normal distribution of scales, scatter plots, density plots
3/ Reliability (internal consistencies): Cronbach's alpha
4/ Internal validity: Item inter correlations, Confirmatory factor analysis
5/ Construct, convergent, divergent, criterion-oriented validity: Correlational analyses, also controlling for social desirability

6) Describe exactly how outliers will be defined and handled, and your precise rule(s) for excluding observations.

Exclusion criteria: Time spent filling out the online questionnaire < 5 minutes

7) How many observations will be collected or what will determine sample size?
No need to justify decision, but be precise about exactly how the number will be determined.
Sample size: N = 250
A priori power analysis: Statistical power = 1 for medium and large effect sizes

8) Anything else you would like to pre-register?
(e.g., secondary analyses, variables collected for exploratory purposes, unusual analyses planned?)
All data has been collected (on 01/23/2018) using an online survey provider (soscisurvey.de) and crowd-based recruiting services (clickworker.com). However, until today, this data has not been analyzed yet.

Further exploratory analyses: Relations of global SEC with PosSEC, NegSEC, positive and negative affectivity, Big-5 personality traits, perceived stress, depressivity, anxiety, health symptoms, life satisfaction, and theory of mind.

See https://osf.io/gx7ew/ for a more detailed version including background information, hypotheses, and the original items of our newly developed scale.

D.2 Extended Preregistration (osf.io-template)

Preregistration @ aspredicted.org

Working title:
Susceptibility to contagion of positive and negative emotions – Psychometric properties, reliability, and validation of a newly developed self-report instrument

Authors:
Anton K. G. Marx, LMU Munich (anton.marx@psy.lmu.de)
Anne C. Frenzel, LMU Munich

Date:
2019/08/07

Background:
The transmission of emotions between two or more individuals is thought to be a contagious process and the idea of such emotional contagion (EC) was already described over a century ago (Le Bon, 1896; Lipps, 1907). Since then, it has been investigated in various research contexts (Elfenbein, 2014) and a number of terms have been used to describe similar processes, including contagion, transmission, and mirroring of emotions (Dezecache, Jacob, & Grezes, 2015).
In 1993, Hatfield, Cacioppo, and Rapson defined "primitive emotional contagion" as an automatic, unintentional and partly unconscious process of two or more individuals converging emotionally through nonverbal mimicry and synchronization.
Alongside this interactional process of contagion, they also proposed a trait-like disposition of how susceptible a person is to catch others' emotions (Hatfield et al., 1993, 1994; see also Hatfield, Bensman, Thornton, & Rapson, 2014): the individual susceptibility to emotional contagion (SEC).
Originally, SEC is theoretically conceptualized as unidimensional and global construct (Doherty, 1997). However, previous empirical studies have predominantly focused on the contagion of negative emotions and the experience of negative affect and mental health problems, such as burnout (e.g. Bakker, Schaufeli, Sixma, & Boseld, 2001; see also Siebert, Siebert, & Taylor-McLaughlin, 2007).
Additionally, Murphy and colleagues (Murphy et al., 2018) recently pointed out that contagion of positive emotions and contagion of negative emotions differ substantially in terms of internal and external validity. They conclude that emotionally contagious processes should not be seen as unidimensional phenomena and call for new and more fine-grained self-report measures with higher internal and external validity.
As of yet, the specific role of SEC of positive and negative emotions for an individual's emotional experience remains unclear and suitable scales to assess such positive and negative SEC separately are lacking.
Within the present contribution, we present a new, elaborated measure which assesses susceptibility to positive emotions, on the one hand, and negative emotions, on the other. We aim to investigate the psychometric properties, internal consistencies and factor structure of our newly developed self-report scale to measure individuals' SEC (internal validity).
Additionally, regarding external validity, we aim to investigate relations of self-reported SEC (through positive and through negative emotions) with other relevant and emotion related constructs and to explore diverging patterns in the relations of positive and negative SEC with these constructs.

1/ What's the main question being asked or hypothesis being tested in this study?

Objectives:
First, we present a new, elaborated measure which assesses susceptibility to positive emotions, on the one hand, and negative emotions, on the other. We aim to investigate the psychometric properties, internal consistencies and factor structure of our newly developed self-report scale to measure individuals' SEC (internal validity).

Second, regarding external validity, we aim to investigate relations of self-reported SEC (through positive and through negative emotions) with other relevant and emotion related constructs and to explore diverging patterns in the relations of positive and negative SEC with these constructs.

Research questions:
1/ Is our newly developed scale a reliable instrument to assess self-reported positive SEC and negative SEC (internal consistency)?

2/ Are positive SEC and negative SEC clearly separable, yet positively correlated constructs as measured by our newly developed scales?

3/ Is our newly developed scale an internally valid measure to assess self-reported positive SEC and negative SEC, as documented by confirmatory factor analysis (CFA) showing that the two-factor model fit the data better than the unidimensional model?

4/ Is our newly developed scale a valid measure to assess self-reported positive SEC and negative SEC in terms of construct validity, divergent validity, and criterion oriented validity?

Confirmatory hypotheses:
A. Construct validity:
PosSEC and NegSEC are positively correlated (medium-sized).

B. Internal validity:
The two-factor model fits the data better than the unidimensional model.

C. Convergent validity:
1/ Correlations with affectivity on a trait-level as measured by the PANAS

	NegSEC	PosSEC
Negative affectivity (PANAS)	*medium-sized positive correlation*	*small-sized negative or no correlation*
Positive affectivity (PANAS)	*small-sized negative or no correlation*	*medium-sized positive correlation*

2/ The affective empathy subscale of the AMES empathy measure is positively related to NegSEC and not or negatively related to PosSEC.

D. Divergent validity:
1/ Neither NegSEC nor PosSEC is substantially related to the Big5 personality traits. Largest positive correlations are expected for NegSEC with neuroticism and for PosSEC with agreeableness and extraversion.

2/ Neither NegSEC nor PosSEC is substantially related to the subscales of the IRI empathy measure. Largest positive correlations are expected for personal distress and NegSEC and empathic concern and PosSEC.

3/ Neither NegSEC nor PosSEC is substantially related to the subscales cognitive empathy and sympathy of the AMES empathy measure.

E. Criterion-oriented validity:

	NegSEC	PosSEC
Perceived stress	*medium-sized positive correlation*	*small-sized negative or no correlation*
Depressivity	*medium-sized positive correlation*	*small-sized negative or no correlation*
Anxiety	*medium-sized positive correlation*	*small-sized negative or no correlation*

Health symptoms	*medium-sized positive correlation*	*small-sized negative or no correlation*
Life satisfaction	*small-sized negative or no correlation*	*medium-sized positive correlation*

F. Exploratory analyses:
Relations of NegSEC and PosSEC with a measure of theory of mind or social cognition capacities (RME) and potential subsections thereof (positive and negative).

2/ Describe the key dependent variable(s) specifying how they will be measured.

Variable 1: Susceptibility to Emotional Contagion
Measure: (SEC)
Source: self-developed
Response scale: 1 to 5
Subscales: Positive SEC, negative SEC, global SEC
Scoring: Sum/mean scores for all three subscales and sum score over all items
Items: 15 (5 per subscale)

Variable 2: Positive and negative affect
Measure: PANAS
Response scale: 1 to 5
Subscales: Positive affect, negative affect
Scoring: Sum/ mean scores for both subscales separately
Items: 20 (10 per subscale)
Source: Krohne, H.W., Egloff, B., Kohlmann, W. & Tausch, A. (1996). Untersuchung mit einer deutschen Version der „Positive and Negative Affect Schedule“ (PANAS). *Diagnostica, 42*, 139-156.

Variable 3: Big Five Personality traits
Measure: BFI-2
Response scale: 1 to 5
Subscales: Neuroticism, Extraversion, Openness, Agreeableness, Conscientiousness
Scoring: Sum/mean scores over all 5 subscales
Items: 60 (12 per subscale)
Source: Danner, D., Rammstedt, B., Bluemke, M., Treiber, L., Berres, S., Soto, C., & John, O. (2016). Die deutsche Version des Big Five Inventory 2 (BFI-2). Zusammenstellung sozialwissenschaftlicher Items und Skalen. doi:10.6102/zis247

Variable 4: Perceived Stress
Measure: PSS
Response scale: 1 to 5
Subscales: none
Scoring: Sum/mean scores
Items: 10
Source: Cohen S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. Journal of Health and Social Behavior, 24, 385-396

Variable 5: Life Satisfaction
Measure: SWL
Response scale: 1 to 7
Subscales: none
Scoring: Sum/mean scores
Items: 5
Source: Glaesmer, H., Grande, G., Braehler, E., & Roth, M. (2011). The German Version of the Satisfaction with Life Scale - Psychometric Properties and Population ased norms. European Journal of Psychological Assessment, 27 (2), 127-132.

Variable 6: Health Symptoms
Measure: CHIPS
Kurzung der Originalskala (33 Items) auf 8 Items.
Response scale: 1 to 5
Subscales: none
Scoring: Sum/mean scores
Items: 8
Source: Hall, N. C., Chipperfield, J. G., Perry, R. P., Ruthig, J. C., Goetz, T. (2006): Primary and secondary control in academic development: Gender specific implications for stress and health in college students. *Anxiety, Stress, and Coping*, *19*(2), 189-210.

Variable 7: Depressivity
Measure: EDS
Response Scale: 0 to 3
Subscales: none
Scoring: Sum/mean scores
Items: 10
Source: Matthey, S., Barnett, B., Kavanagh, D.J., & Howie, P. (2001). Validation of the Edinburgh Postnatal Depression Scale for men and comparison of item endorsement with their partners. Journal of Affective Disorders, 64, 175-184.
Cox, J.B., Holden, J.M., & Sagovsky, R. (1987). Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. British Journal of Psychiatry; 150: 782-6. DOI: 10.1192/bjp.150.6.782

Variable 8: General Anxiety
Measure: GAD-7 (PHQ-ADS)
Response scale: 0 to 3
Subscales: none
Scoring: Sum/mean scores
Items: 7
Source: Kurt Kroenke, Jingwei Wu, Zhangsheng Yu, Matthew J. Bair, Jacob Kean, Timothy Stump, and Patrick O. Monahan (2016). The Patient Health Questionnaire Anxiety and Depression Scale (PHQ-ADS): Initial Validation in Three Clinical Trials. Psychosom Med.; 78(6): 716-727. doi:10.1097/PSY.0000000000000322.

Variable 9: Empathy
Measure: AMES
Response scale: 1 to 5
Subscales: Affective empathy, cognitive empathy, sympathy
Scoring: Sum/mean scores for all subscales
Items: 12
Source: Vossen, H.G.M., Piotrowski, J.T., Valkenburg, P.M. (2015). Development and Validation of the Adolescent Measure of Empathy and Sympathy (AMES). *Personality and Individual Differences, 74*, 66-71.

Variable 10: Empathy
Measure: IRI (SPF)
Response scale: 1 to 5
Subscales: Empathy concern, Fantasy, Personal distress, Perspective taking
Scoring: Sum/mean scores for all subscales
Items: 12
Source: Davis, M. H. (1980). A multidimensional approach to individual differences in empathy. JSAS Catalog of Selected Documents in Psychology, 10, 85.
Paulus, C. (2009). Der Saarbrücker Persönlichkeitsfragebogen SPF(IRI) zur Messung von Empathie: Psychometrische Evaluation der deutschen Version des Interpersonal Reactivity
Index. http://hdl.handle.net/20.500.11780/3343

Variable 11: Social desirability
Measure: KSE-G
Response scale: 0 to 4

Subscales: Positive qualities, negative qualities
Scoring: Sum/mean scores
Items: 6 (3 per subscale)
Source: Kemper, C. J., Beierlein, C., Bensch, D., Kovaleva, A., & Rammstedt, B. (2014). Soziale Erwunschtheit-Gamma (KSE-G). Zusammenstellung sozialwissenschaftlicher Items und Skalen. doi:10.6102/zis186

Variable 12: Theory of mind (social cognition capacities)
Measure: RME
Response scale: n.a.
Subscales: none
Scoring: Sum/mean score
Items: 36
Sources: Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., and Plumb, I. (2001). The "Reading the Mind in the Eyes" test revised version: a study with normal adults, and adults with Asperger syndrome or high–functioning autism. J. Child Psychol. Psychiatry 42, 241-251. doi: 10.1111/1469-7610.00715
Warrier V., Bethlehem R.A., Baron-Cohen S. (2017) The "Reading the Mind in the Eyes" Test (RMET). In: Zeigler-Hill V., Shackelford T. (eds) Encyclopedia of Personality and Individual Differences. Springer, Cham.
Marcello Vellante , Simon Baron-Cohen , Mariangela Melis , Matteo Marrone , Donatella Rita Petretto , Carmelo Masala & Antonio Preti (2013) The "Reading the Mind in the Eyes" test: Systematic review of psychometric properties and a validation study in Italy, Cognitive Neuropsychiatry, 18:4, 326-354, DOI: 10.1080/13546805.2012.721728

3/ How many and which conditions will participants be assigned to?
Study design: Cross sectional self-report study with no conditions or manipulations.

4/ Specify exactly which analyses you will conduct to examine the main question/hypothesis.

Scale validation of our newly developed SEC scale:

Item analysis: Variances, means, standard deviations, item discrimination index, item difficulty index, item-total correlations, scatter plots, density plots

Scale analysis and summary statistics: Variances, means, standard deviations, skewness, kurtosis, normal distribution of scales, scatter plots, density plots

Reliability (internal consistencies): Cronbach's alpha

Internal validity: Item inter correlations, Confirmatory factor analysis

Construct, convergent, divergent, criterion-oriented validity: Correlational analyses, also controlling for social desirability

5/ Any secondary analyses?
N.A.

6/ How many observations will be collected or what will determine sample size? No need to justify decision, but be precise about exactly how the number will be determined.
Sample size: *N* = 250
A priori power analysis: Statistical power = 1 for medium and large effect sizes (see appendix B)
Exclusion criteria: Time spent filling out the online questionnaire < 5 minutes

7/ Anything else you would like to pre-register? (e.g., data exclusions, variables collected for exploratory purposes, unusual analyses planned?)
Exploratory analyses: Relations of global SEC with PosSEC, NegSEC, positive and negative affectivity, Big-5 personality traits, perceived stress, depressivity, anxiety, health symptoms, life satisfaction, and theory of mind.

8/ Have any data been collected for this study already?
Yes, all data has been collected (on 01/23/2018) using an online survey provider (www.soscisurvey.de) and crowd-based recruiting services (www.clickworker.com). Until today, this data has not been analyzed yet.

Additional comments:
All materials will be made openly available online in an OSF repository (osf.io/2wrce/).

Appendix:
A/ Items of the SEC-Scale (German and English versions)
B/ Power analyses using G*Power
C/ Questionnaire as used in the data collection (online survey)

Sources:
Bakker, A. B., Schaufeli, W. B., Sixma, H. J., & Bosveld, W. (2001). Burnout contagion among general pracitioners. *Journal of Social and Clinical Psychology, 20*(1), 82-98.
Dezecache, G., Jacob, P., & Grezes, J. (2015). Emotional contagion: its scope and limits. *Trends in Cognitive Sciences, 19*(6), 297-299. doi:10.1016/j.tics.2015.03.011
Doherty, R. W., (1997). The Emotional Contagion Scale: A measure of individual Differences. *Journal of Nonverbal Behavior, 21*(2).
Elfenbein, H. A. (2014). The many faces of emotional contagion: An affective process theory of affective linkage. *Organizational Psychology Review, 4*(4), 326-362. doi: 10.1177/2041386614542889
Hatfield, E., Cacioppo, J. T., & Rapson, R. L. (1993). Emotional contagion. *Current Directions in Psychological Sciences, 2*(3), 96–99.
Hatfield, E., Cacioppo, J., & Rapson, R. L. (1994). *Emotional contagion*. New York: Cambridge University Press.
Hatfield, E., Bensman, L., Thornton, P. D., & Rapson, R. L. (2014). New perspectives on emotional contagion: A review of classic and recent research on facial mimicry and contagion. *Interpersona, 8*(2), 159-179.
Le Bon, G. (1896). *The Crowd – A Study of the Popular Mind*. Retrieved from https://archive.org/details/LeBonGustaveTheCrowdAStudyOfThePopularMindEN1896129P/
Lipps, T. (1907). Das Wissen von fremden Ichen. In T. Lipps (Ed.). *Psychologische Untersuchungen, Bd. I*. Leipzig: Verlag von Wilhelm Engelmann. Retrieved from http://ophen.org/pub-103553/
Murphy, B. A., Costello, T. H., & Lilienfeld, S. O. (2018). Is empathic contagion helpful or harmful? Overlooked heterogeneity in the empathy index. Psychological Assessment, 30, 12, 1703-1708. http://dx.doi.org/10.1037/pas0000641
Siebert, D. C., Siebert, C. F., & Taylor-McLaughlin, A. (2007). Susceptibility to Emotional Contagion, *Journal of Social Service Research, 33*(3), 47-56. doi:10.1300/J079v33n03_05

D.3 Transparent Changes Document

In this document, we describe all reasonable changes to the preregistered hypotheses and analysis plan, following a template available from the Open Science Framework (https://osf.io/yrvcg/).

1. Description of change:

We specified the hypotheses regarding the Big-Five personality traits Extraversion, Agreeableness, and Emotional Instability (Neuroticism). These hypotheses are labeled "additional hypotheses".

1.1 Rationale:

The BFI-2 measure provides subfacets for each of the personality traits which represent relevant dependent variables for investigating criterion-oriented validity more precisely than the personality traits itself.

1.2 Effect of change on study results:

The results are expected to be more accurate and fine-grained in terms of criterion-related validity.

2. Description of change:

We omitted two of the Big-Five personality traits from our analyses: Openness and Conscientiousness.

2.1 Rationale:

These two personality traits are of no interest for the evaluation of the external validity of our scale.

2.2 Effect of change on study results:

None expected.

3. Description of change:

We specified the hypotheses regarding the AMES sympathy subscale and the IRI empathic concern subscale. These hypotheses are labeled "additional hypotheses".

3.1 Rationale:

These two scales rather reflect individuals' capacities regarding interpersonal and social functioning as well as other-oriented and prosocial tendencies instead of empathy; thus representing an important criterion for our scales external validity.

3.2 Effect of change on study results:

The results are expected to be more accurate and fine-grained in terms of criterion-related validity.

D.4 Power Analysis

Power analyses using G*Power

1/ Small effect sizes (one-/two-tailed)

t tests - Correlation: Point biserial model

Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	One
	Effect size |ρ|	=	0,1
	α err prob	=	0,01
	Power (1-β err prob)	=	0,95
Output:	Noncentrality parameter δ	=	3,9746673
	Critical t	=	2,3287376
	Df	=	1562
	Total sample size	=	1564
	Actual power	=	0,9500022

t tests - Correlation: Point biserial model

Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	Two
	Effect size |ρ|	=	0,1
	α err prob	=	0,01
	Power (1-β err prob)	=	0,95
Output:	Noncentrality parameter δ	=	4,2247467
	Critical t	=	2,5786177
	Df	=	1765
	Total sample size	=	1767
	Actual power	=	0,9500095

2/ Medium effect sizes (one-/two-tailed)

t tests - Correlation: Point biserial model

Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	One
	Effect size |ρ|	=	0,3
	α err prob	=	0,01
	Power (1-β err prob)	=	0,95
Output:	Noncentrality parameter δ	=	4,0150815
	Critical t	=	2,3497321
	Df	=	161
	Total sample size	=	163
	Actual power	=	0,9510229

t tests - Correlation: Point biserial model

Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	Two
	Effect size |ρ|	=	0,3
	α err prob	=	0,01
	Power (1-β err prob)	=	0,95
Output:	Noncentrality parameter δ	=	4,2658882
	Critical t	=	2,6031120
	Df	=	182
	Total sample size	=	184
	Actual power	=	0,9506344

3/ Large effect sizes (one-/two-tailed)

t tests - Correlation: Point biserial model

Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	One
	Effect size |ρ|	=	0,5
	α err prob	=	0,01
	Power (1-β err prob)	=	0,95
Output:	Noncentrality parameter δ	=	4,1231056
	Critical t	=	2,4048918
	Df	=	49
	Total sample size	=	51
	Actual power	=	0,9536553

t tests - Correlation: Point biserial model

Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	Two
	Effect size |ρ|	=	0,5
	α err prob	=	0,01
	Power (1-β err prob)	=	0,95
Output:	Noncentrality parameter δ	=	4,3588989
	Critical t	=	2,6682160
	Df	=	55
	Total sample size	=	57
	Actual power	=	0,9505322

D.5 Bivariate correlations of all measures with social desirability

Bivariate Correlations of All Measures With Social Desirability in Study 2

	SD - Positive Qualities		SD - Negative Qualities	
	r	*p*	*r*	*p*
Positive SEC	.20	.0017	-.16	.0098
Negative SEC	-.35	.0000	.19	.0033
AMES Cognitive Empathy	.28	.0000	-.12	.0700
AMES Affective Empathy	-.22	.0006	.09	.1774
AMES Sympathy	.18	.0053	-.20	.0012
IRI Perspective Taking	.46	.0000	-.13	.0410
IRI Fantasy	.15	.0210	-.01	.8318
IRI Empathic Concern	.32	.0000	-.22	.0006
IRI Personal Distress	-.31	.0000	.09	.1848
PANAS Positive Affect	.30	.0000	.30	.0000
PANAS Negative Affect	-.11	.0835	.08	.2259
BFI2 Sociability	.15	.0164	.00	.9866
BFI2 Assertiveness	.26	.0000	.01	.9066
BFI2 Activity/Energy Level	.27	.0000	-.06	.3120
BFI2 Compassion	.32	.0000	-.34	.0000
BFI2 Trust	.23	.0003	-.24	.0002
BFI2 Respectfulness	.33	.0000	-.40	.0000
BFI2 Emotional Volatility	-.46	.0000	.32	.0000
BFI2 Depression	-.28	.0000	.18	.0039
BFI2 Anxiety	-.32	.0000	.16	.0135
EDS Depression	-.20	.0015	.14	.0272
GAD7 Anxiety	-.23	.0003	.19	.0024
PSS Stress	-.20	.0016	.22	.0004
CHIPS Physical Symptoms	-.22	.0006	.20	.0018
SWLS Life Satisfaction	.24	.0002	-.14	.0293

D.6 Model fit and factor matrix of the 10-item version of the SEC scale

Model Fit (CFA) of the 10-item version of the SEC scale in study 2

Test statistic = 1.189

CFI = .893

TLI = .859

SRMR = .072

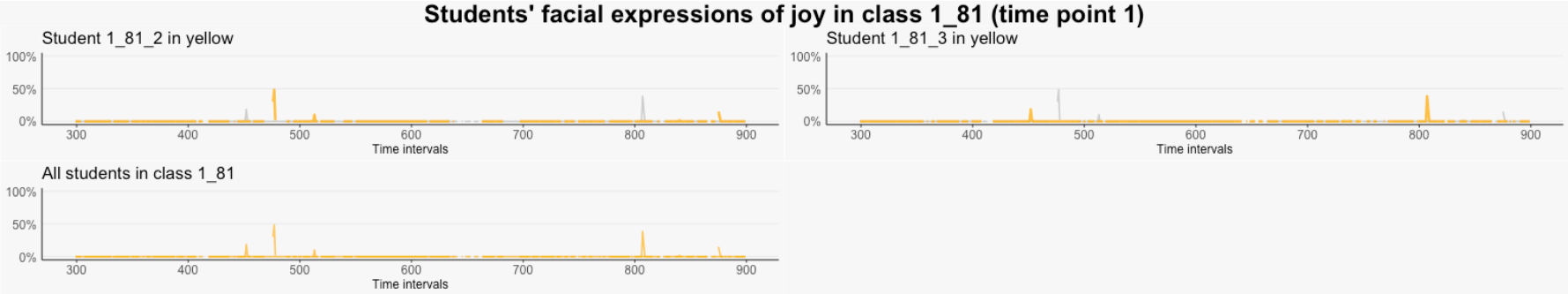
RMSEA = .112 (90% CI [.091, .133])

Factor Matrix (CFA) of the 10-item version of the SEC scale in study 2

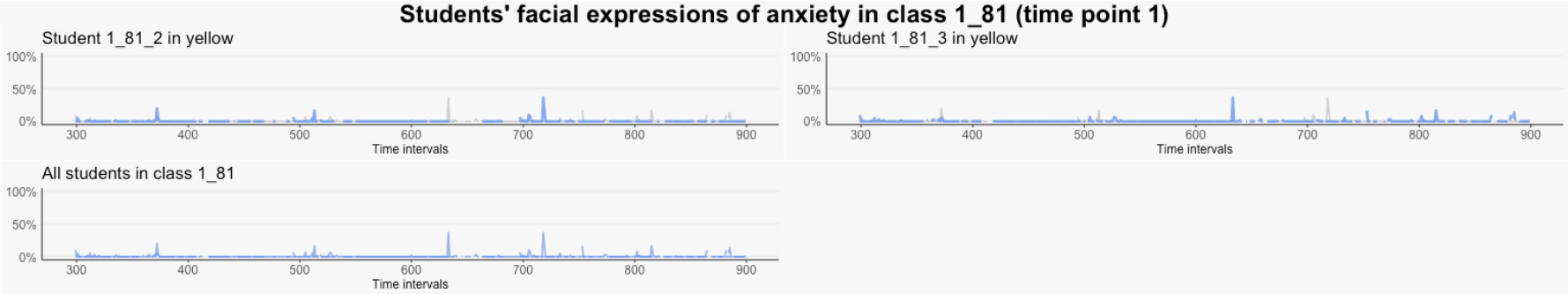
	Factor 1	Factor 2
It cheers me up to be around a jolly person.	.652	
It fills me with joy to be around happy people.	.779	
I get carried away when someone is euphoric.	.629	
I let myself be infected by someone's enthusiasm.	.746	
I get cheerful when I am surrounded by cheerful people.	.772	
I depresses me when people around me are gloomy.		.542
I get nervous when others around me are nervous.		.720
I get angry when I am surrounded by enraged people.		.637
I tense up when I hear people fighting.		.734
I get stressed when I am around stressed people.		.859

Appendix E: Additional Material of Chapter 5

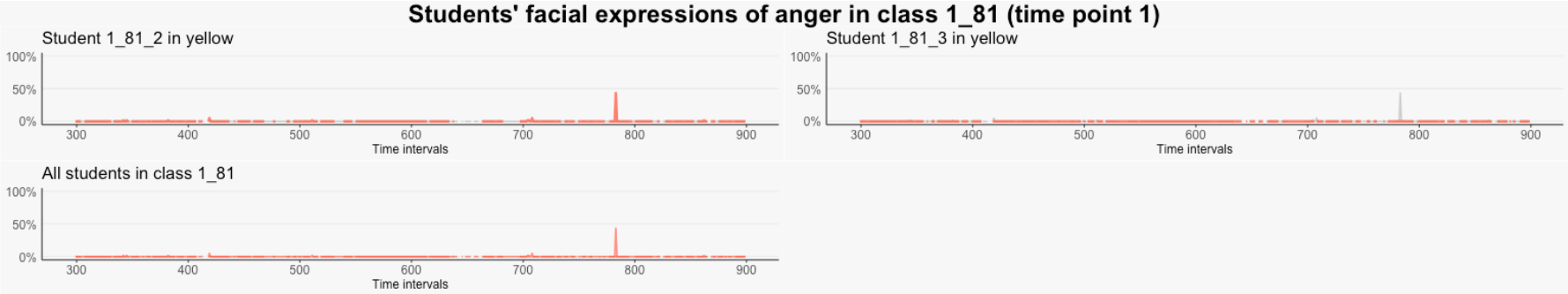
E.1 Time series graphs of all students in their classes (time point 1)



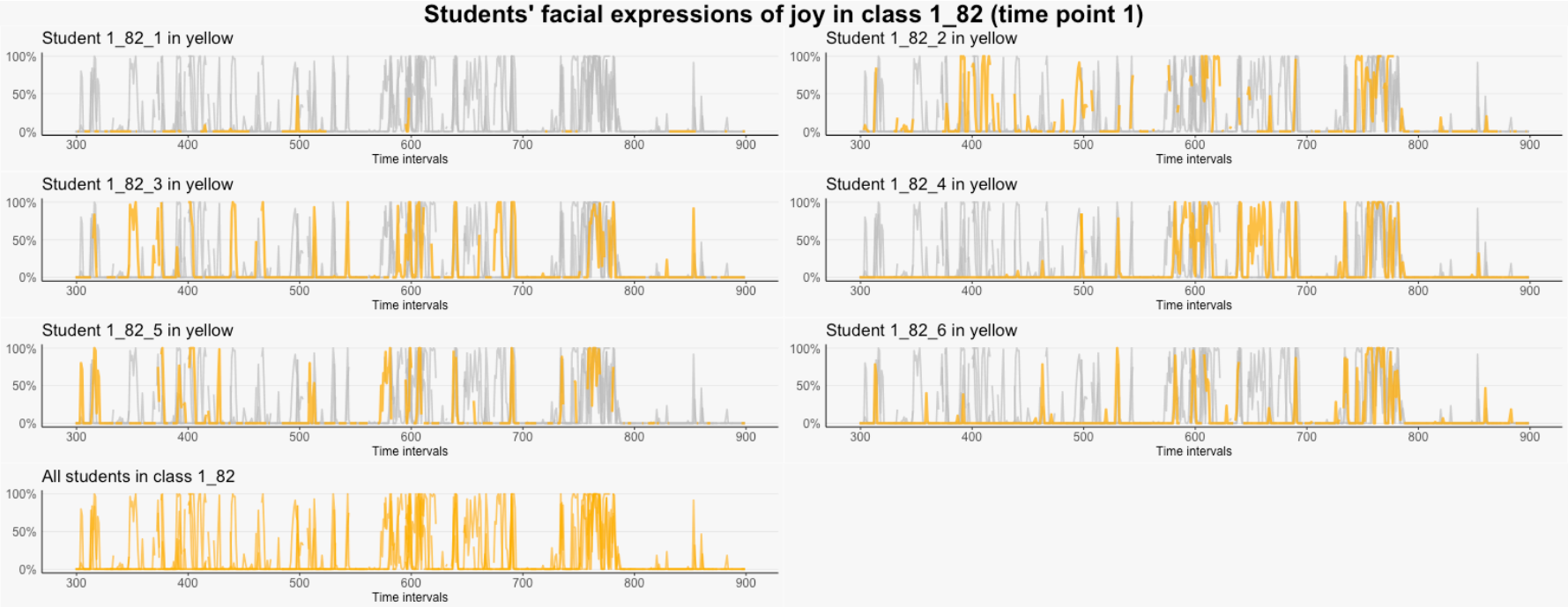
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



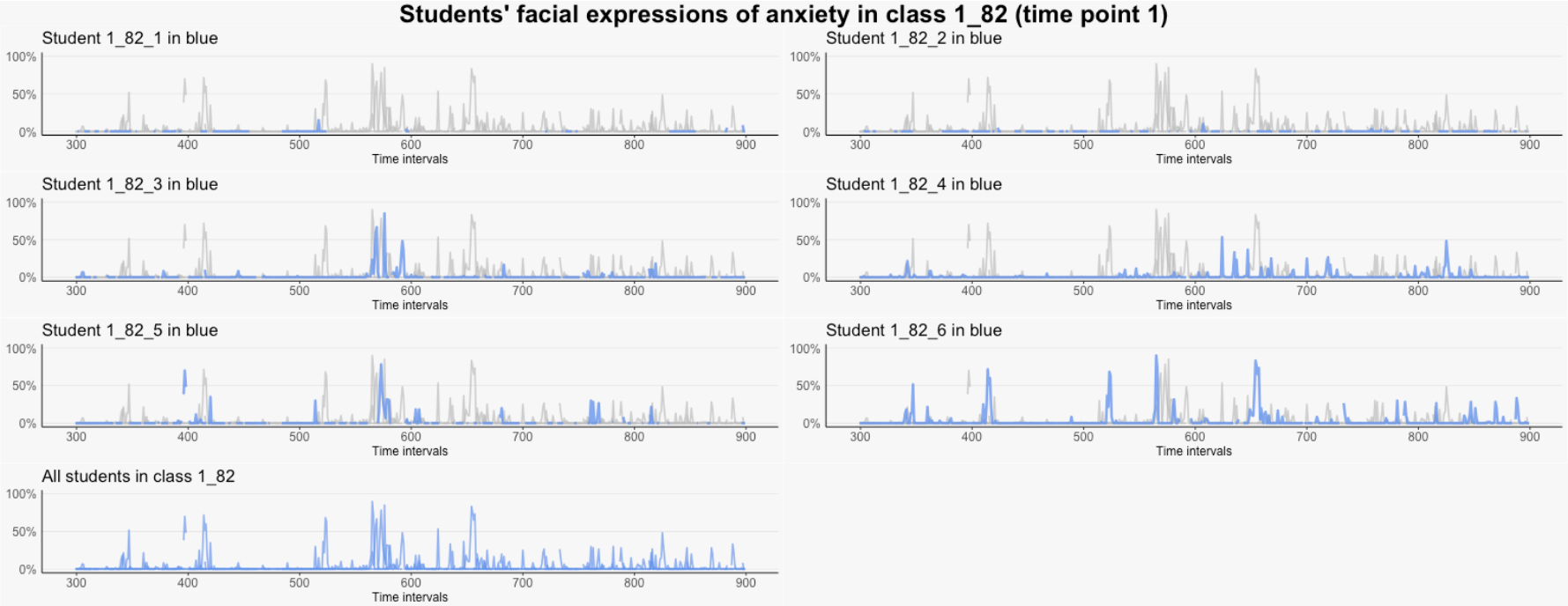
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



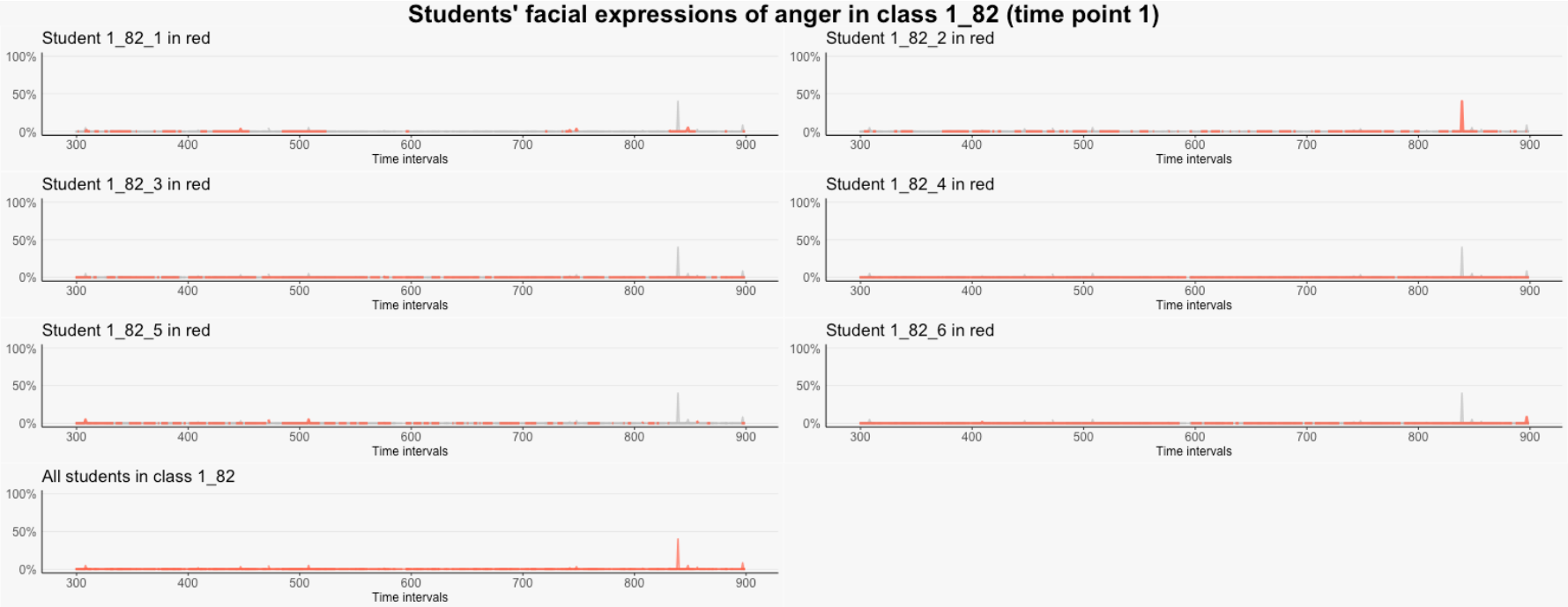
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



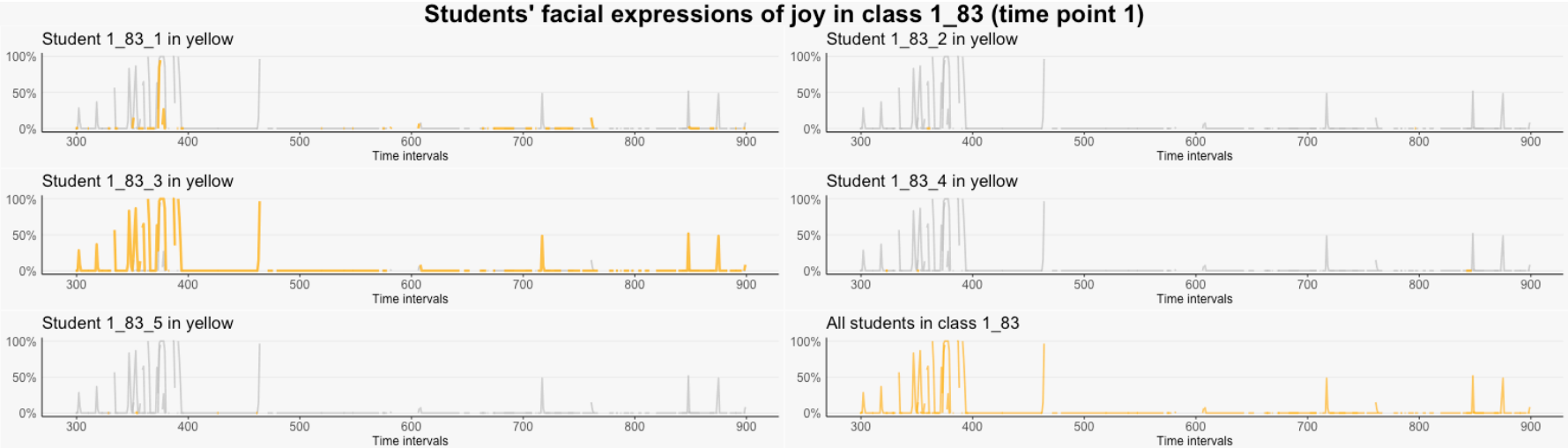
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



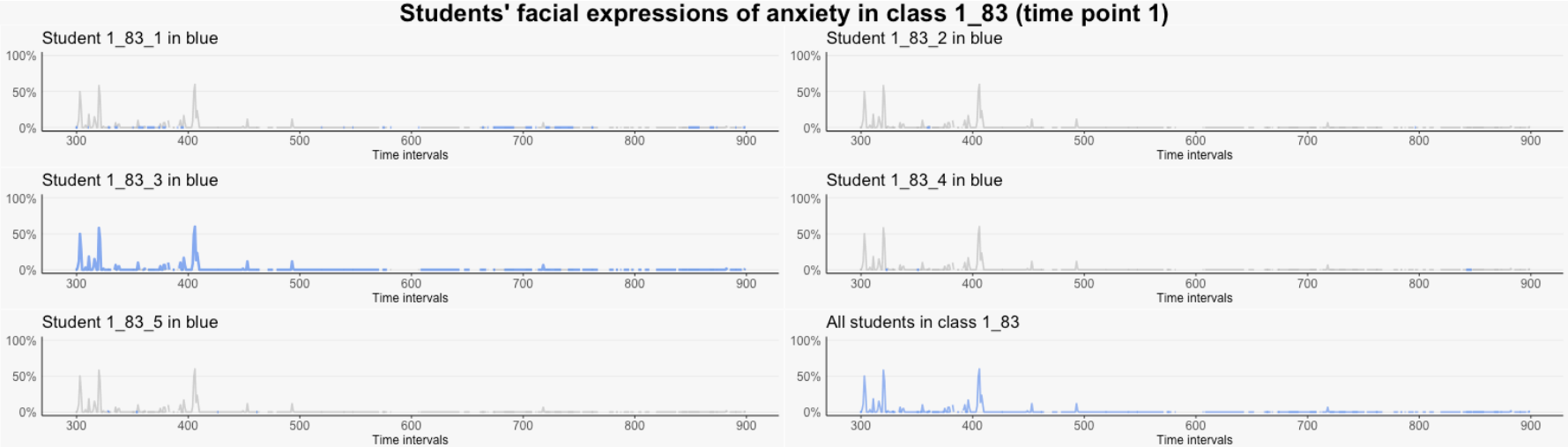
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



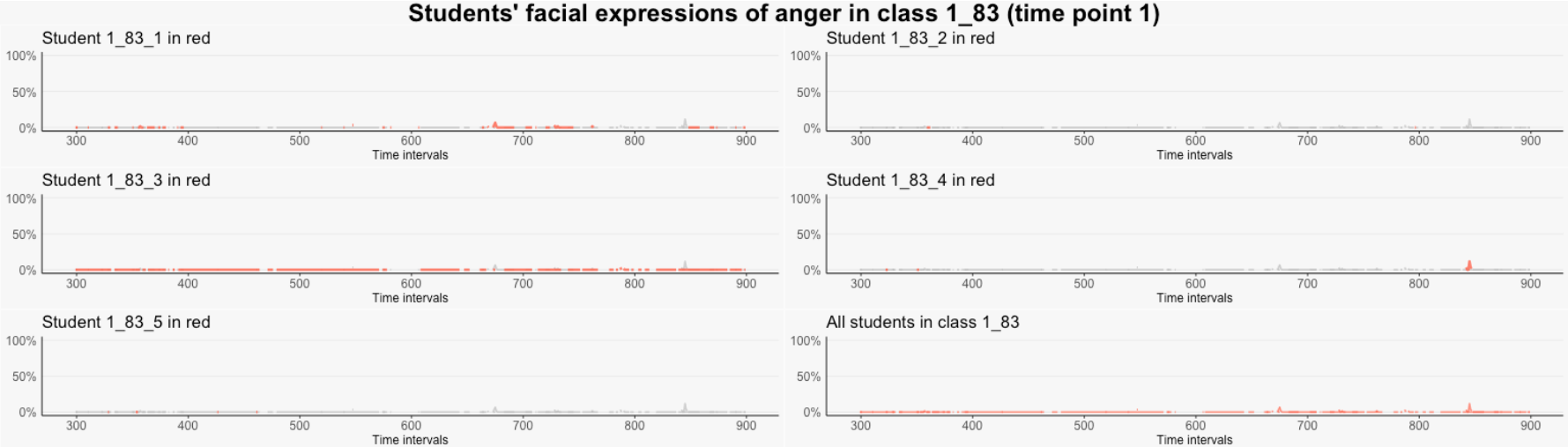
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



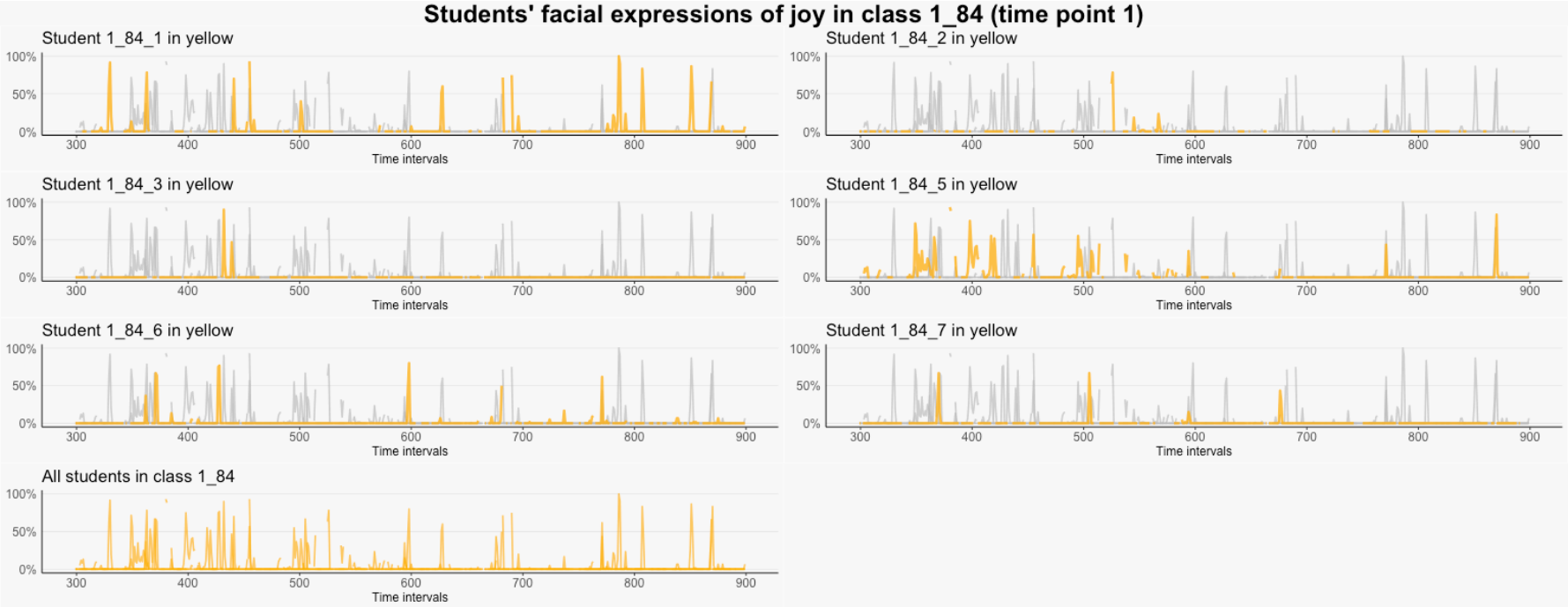
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



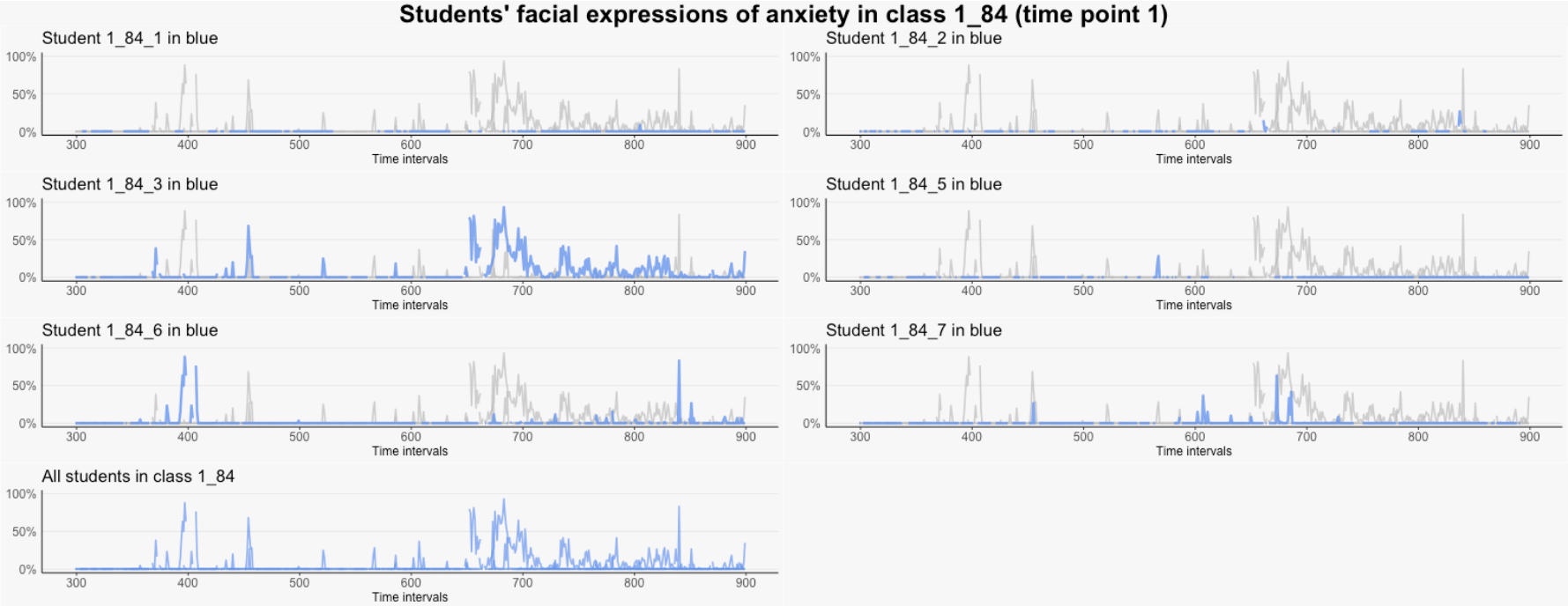
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



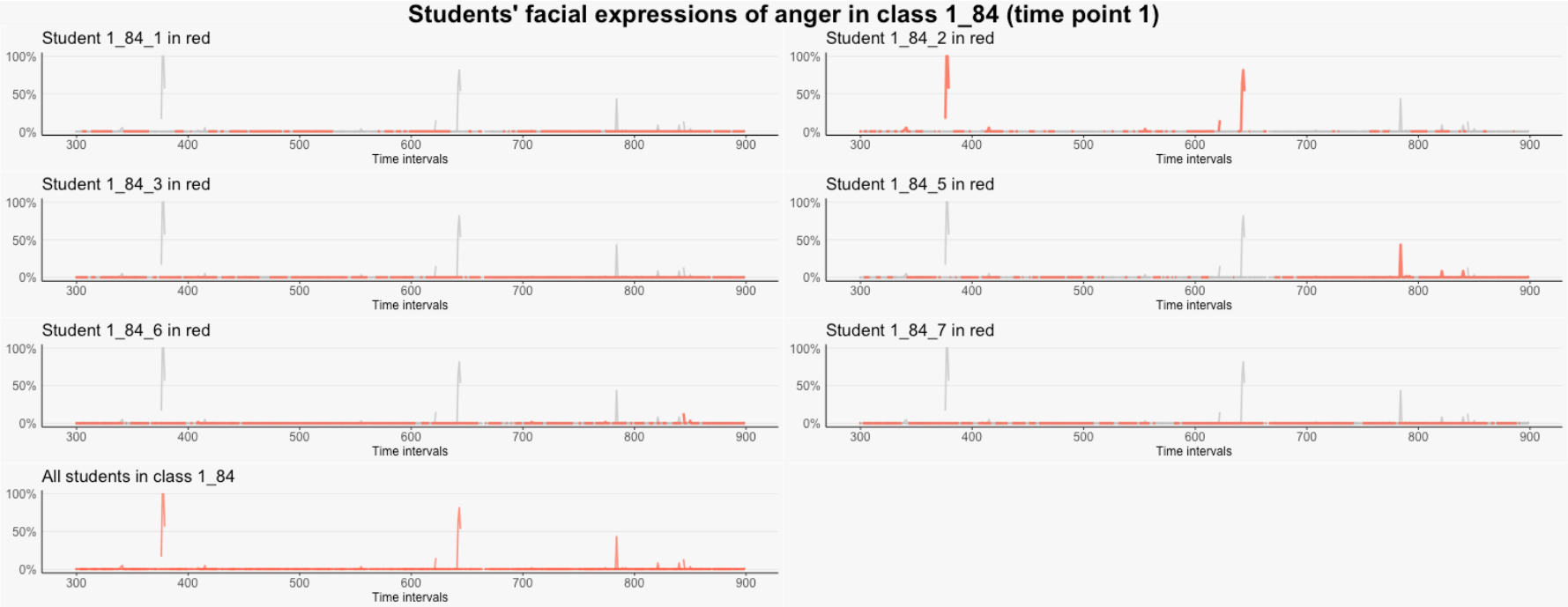
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



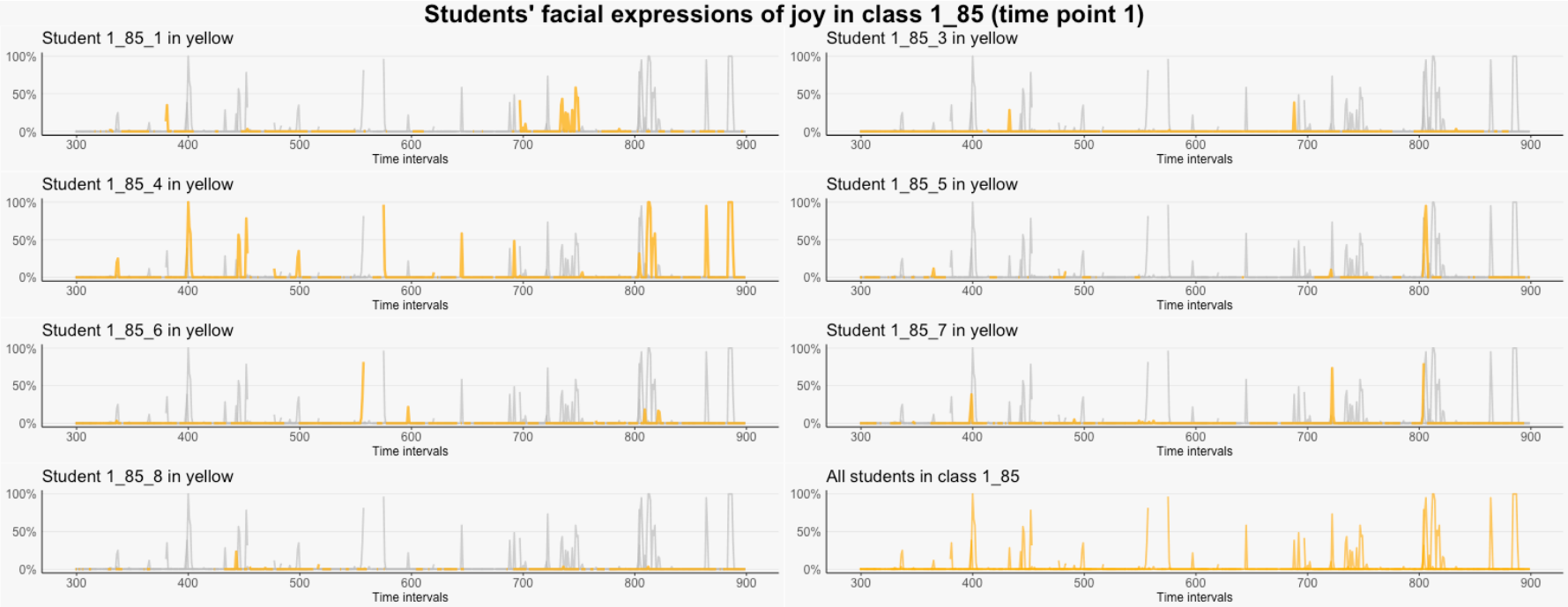
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



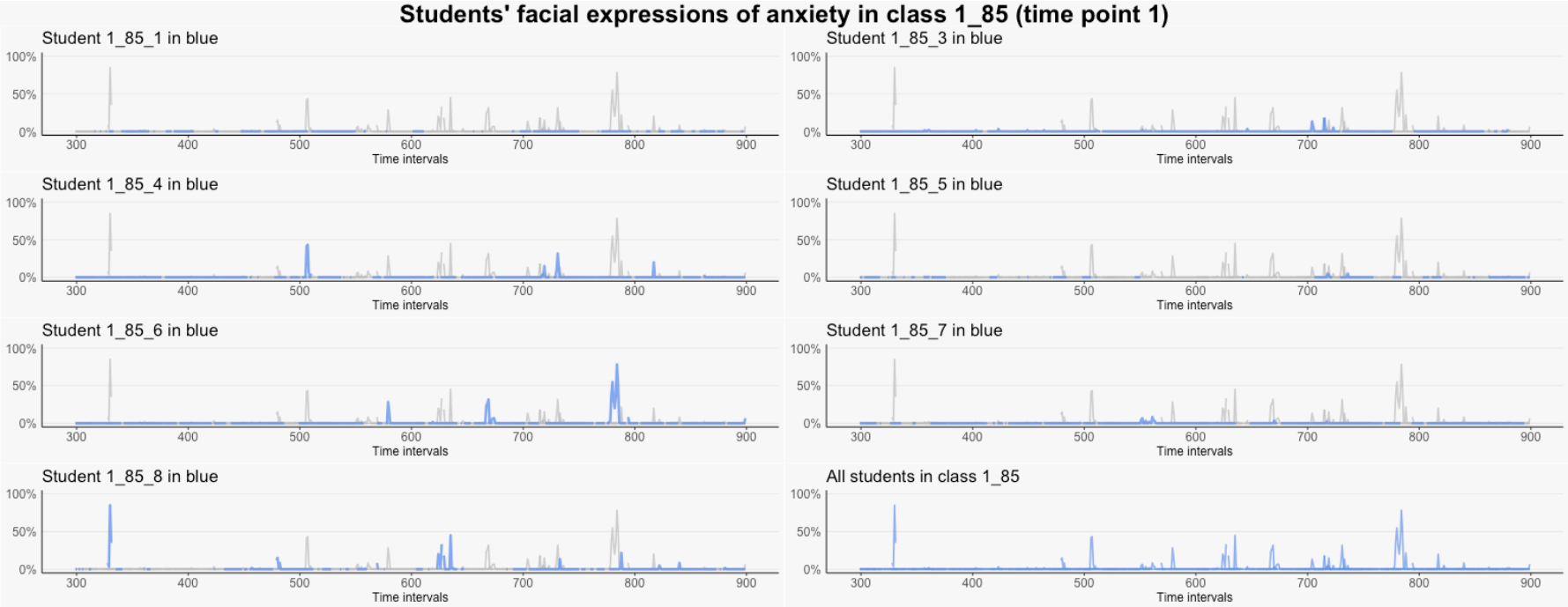
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



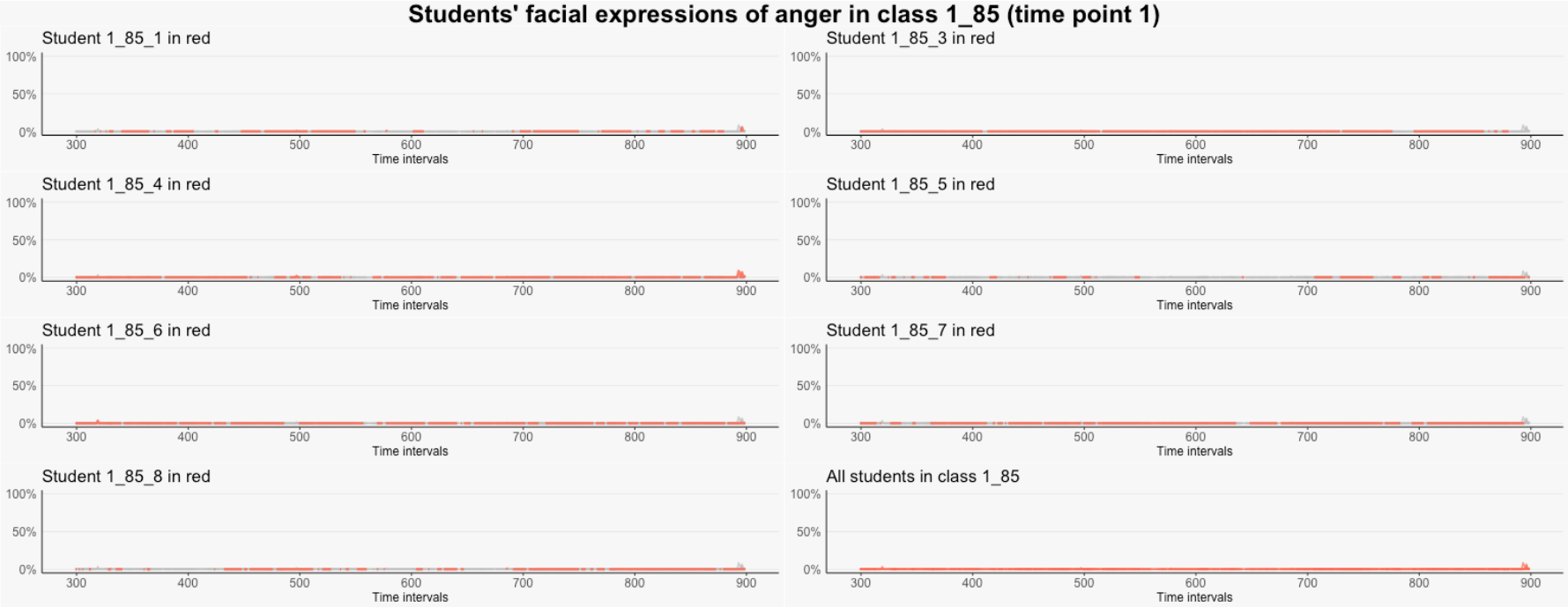
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



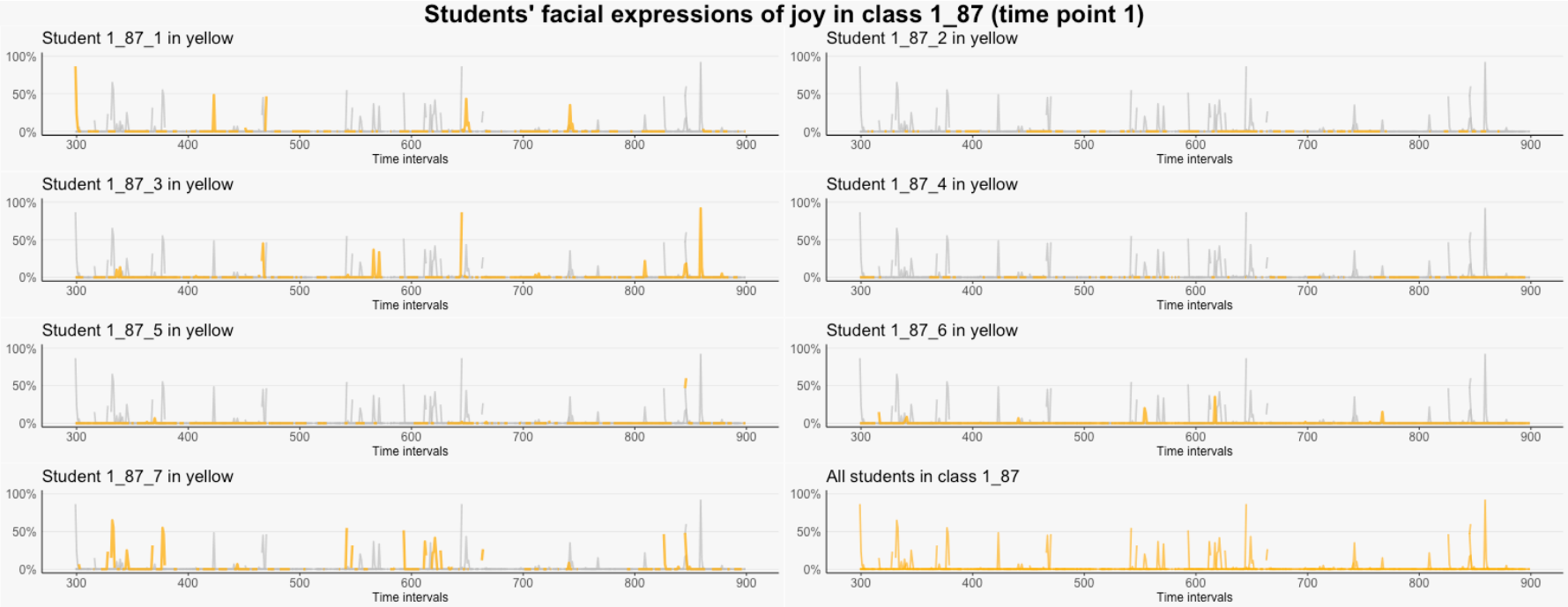
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



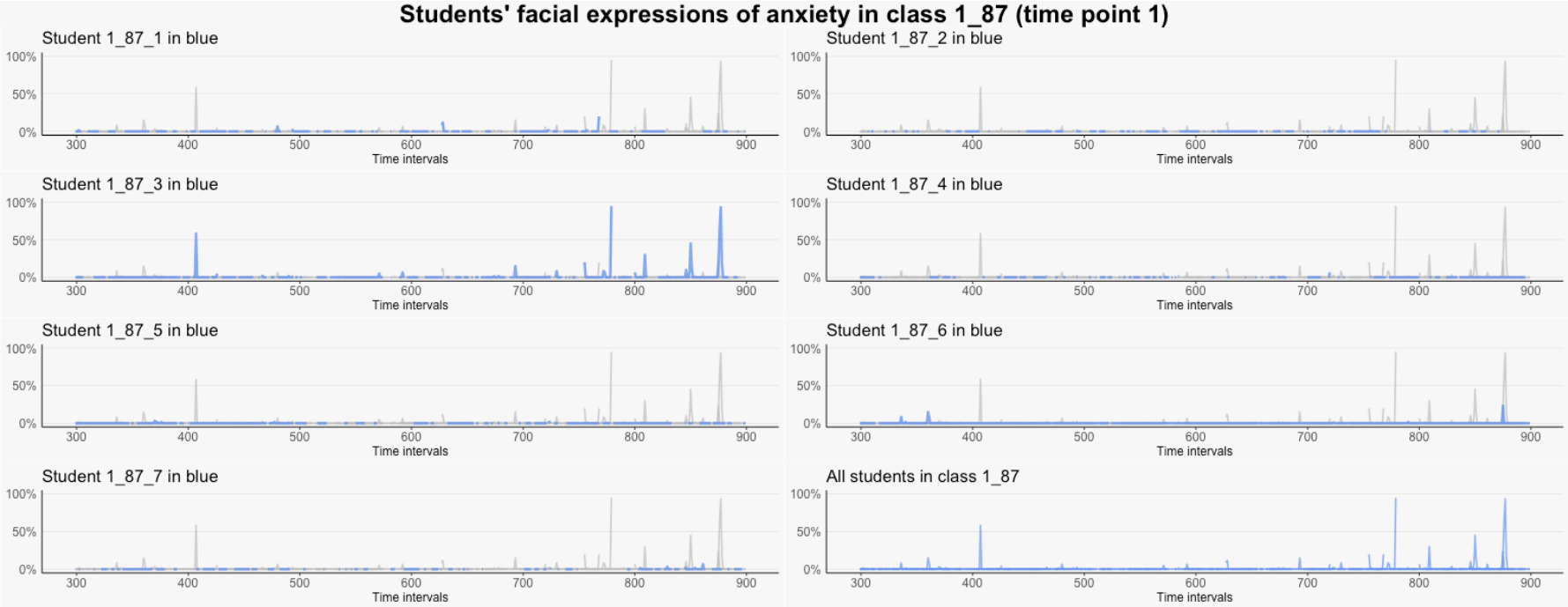
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



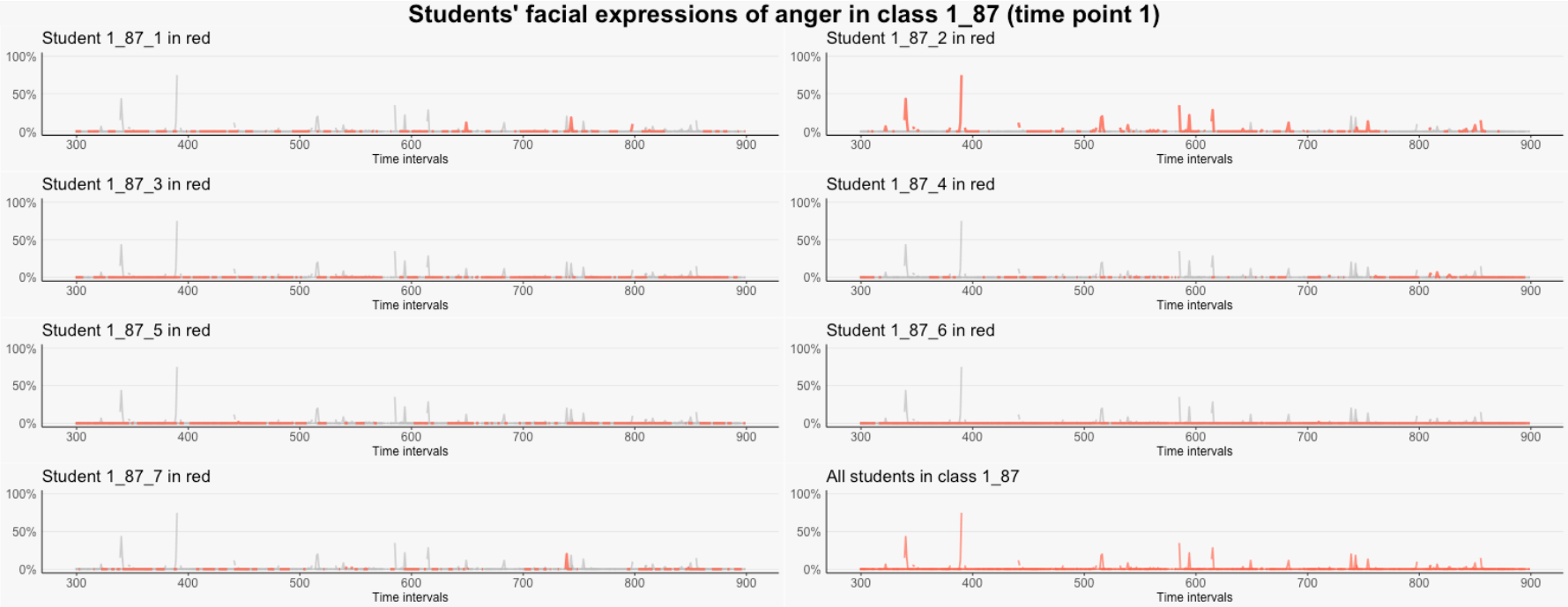
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



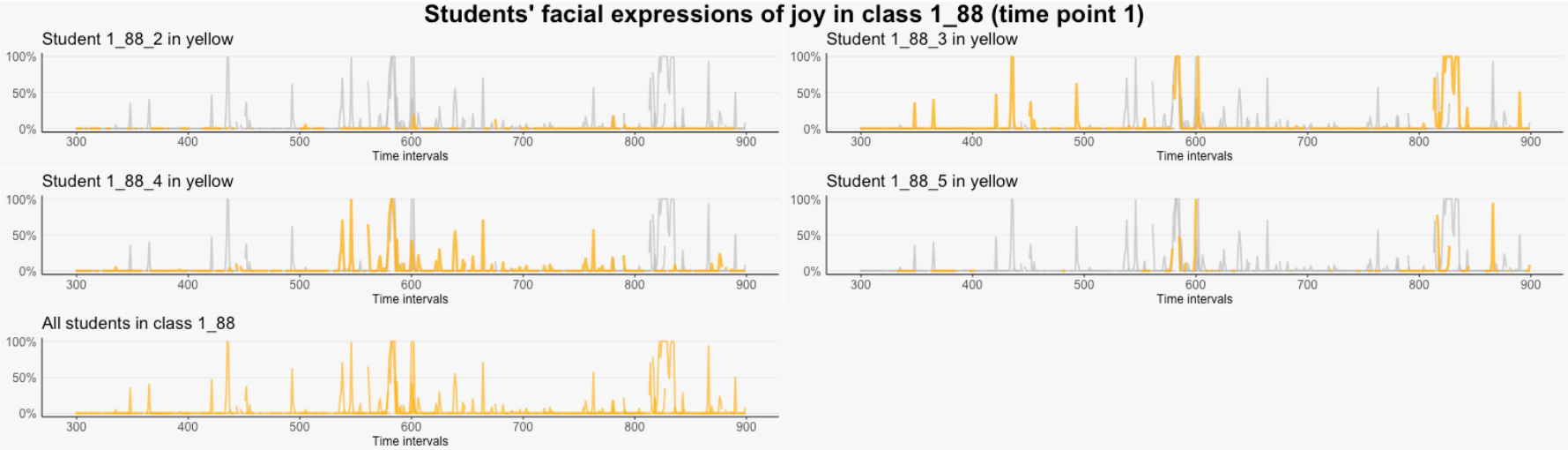
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



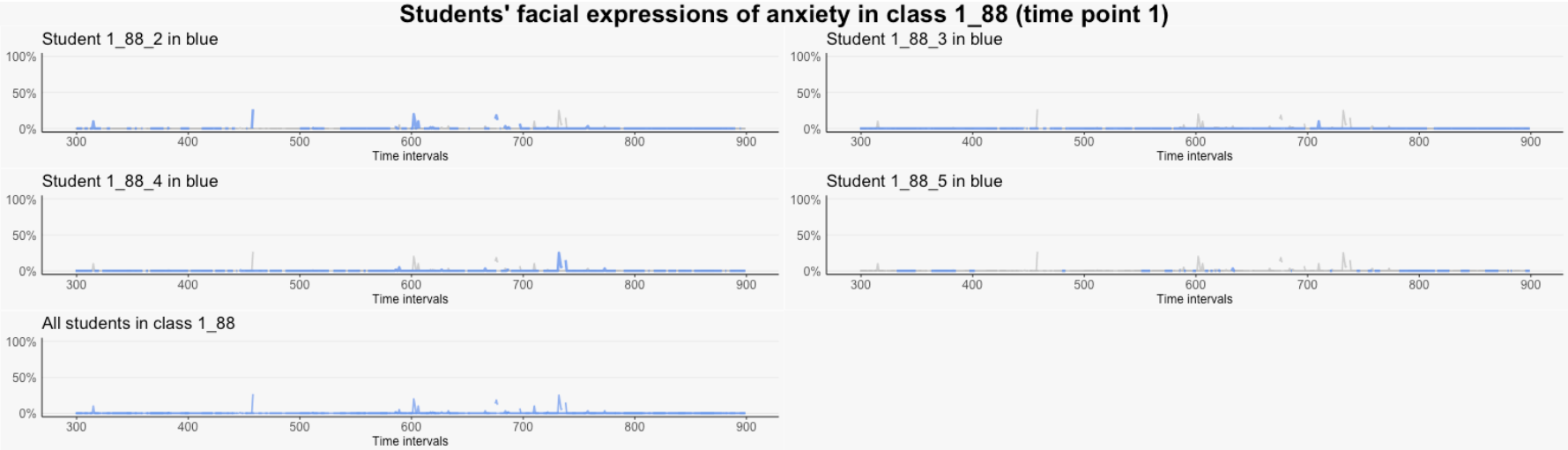
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



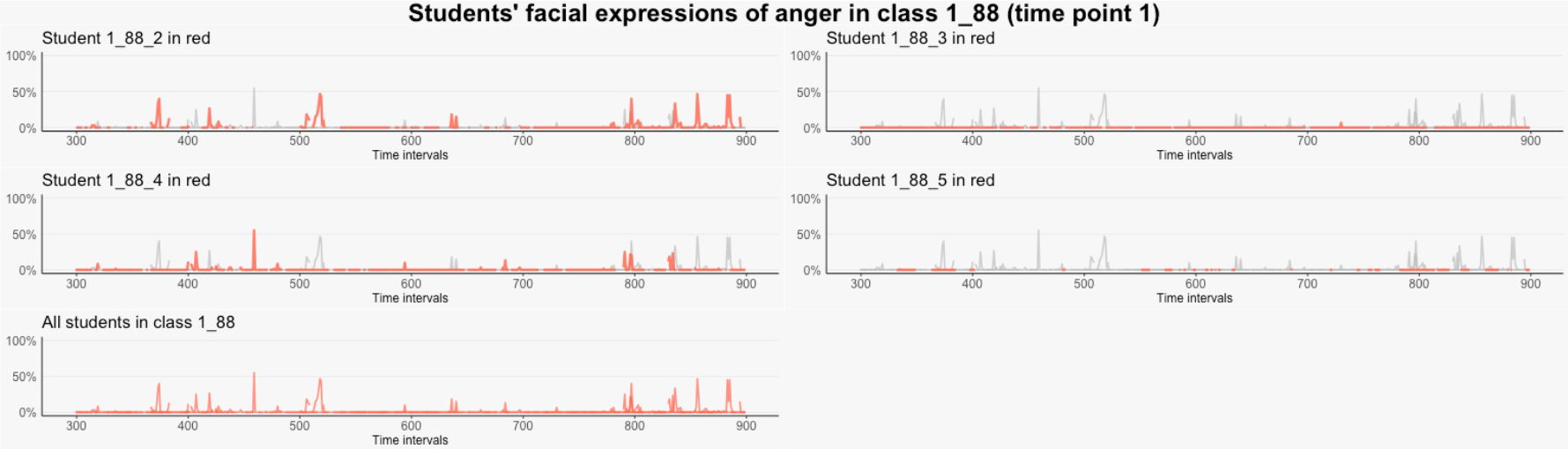
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



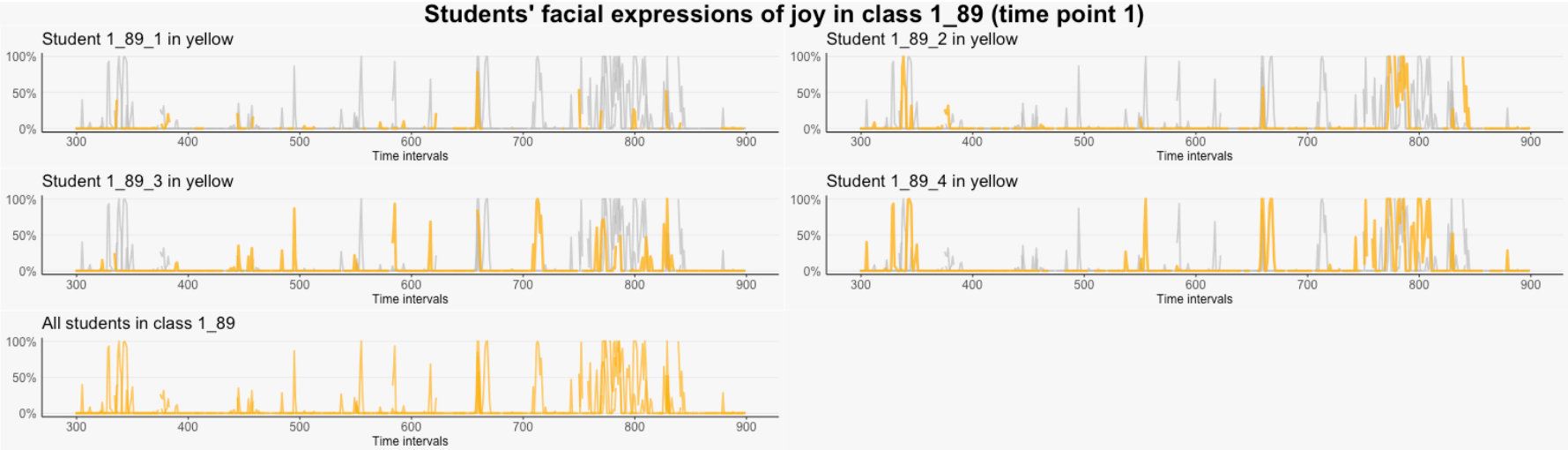
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



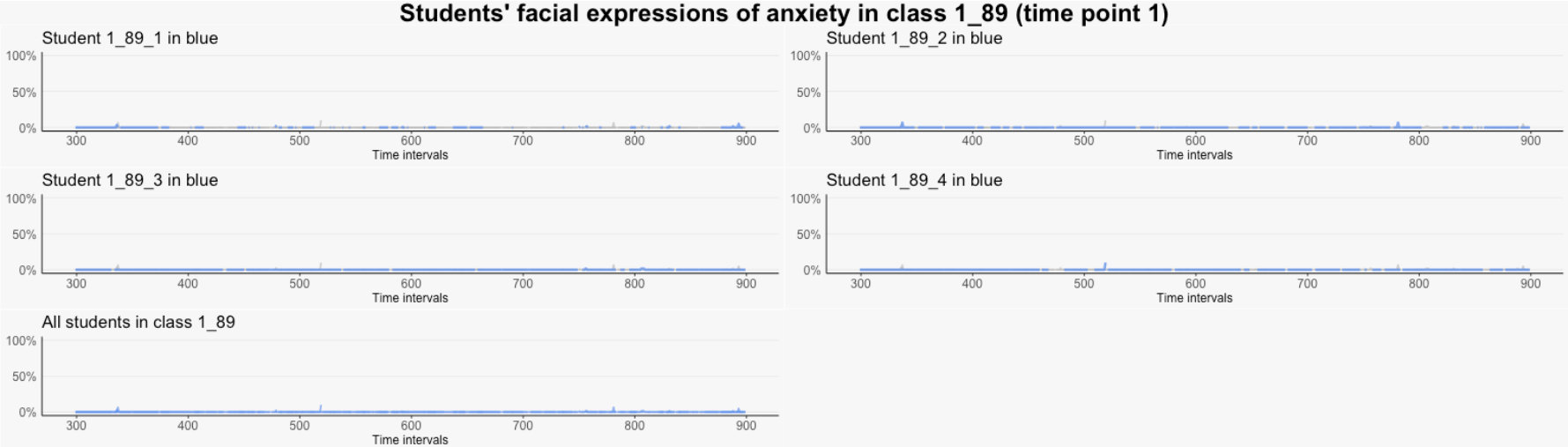
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



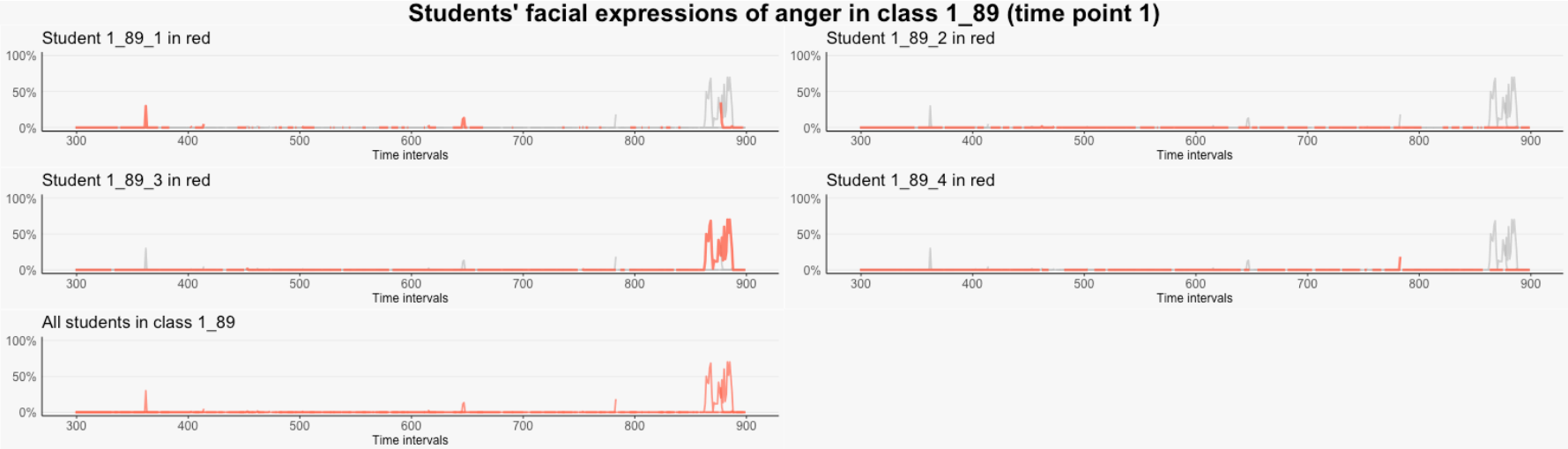
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



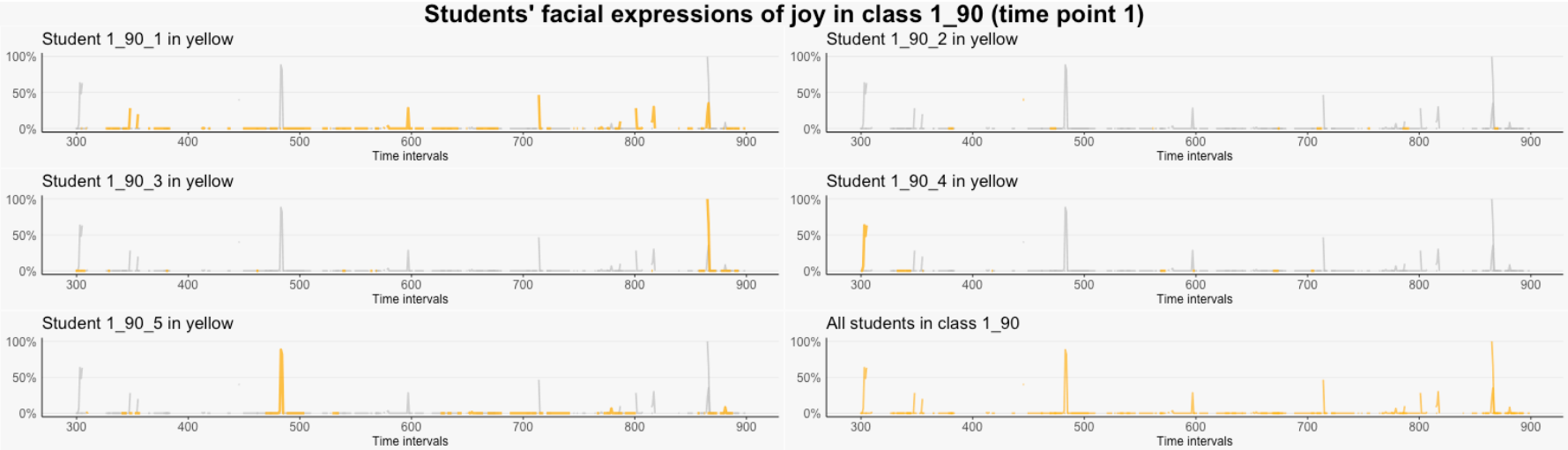
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



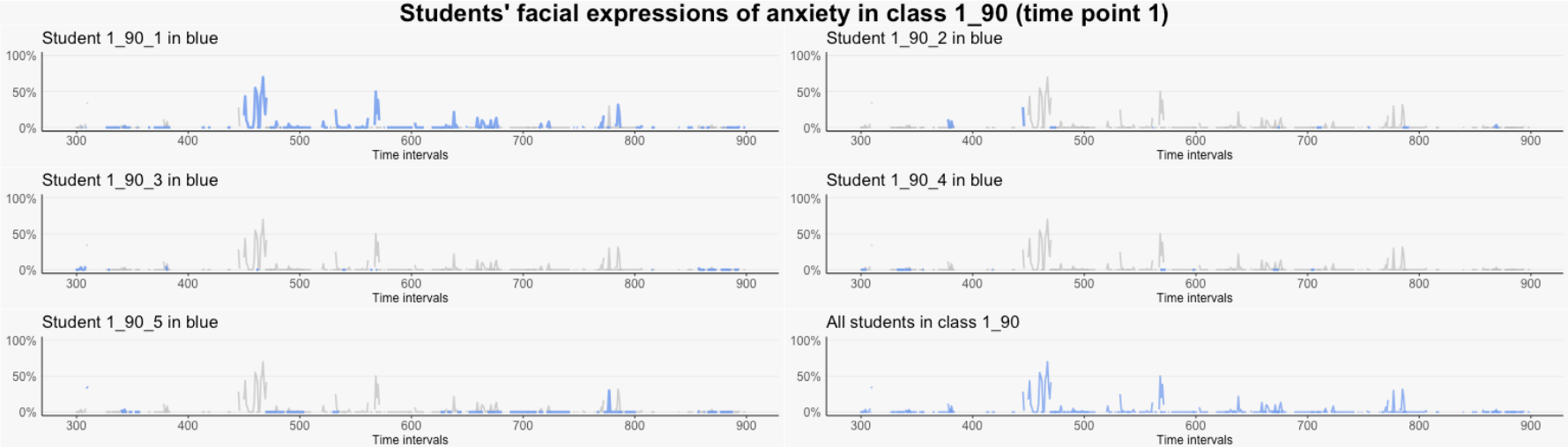
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



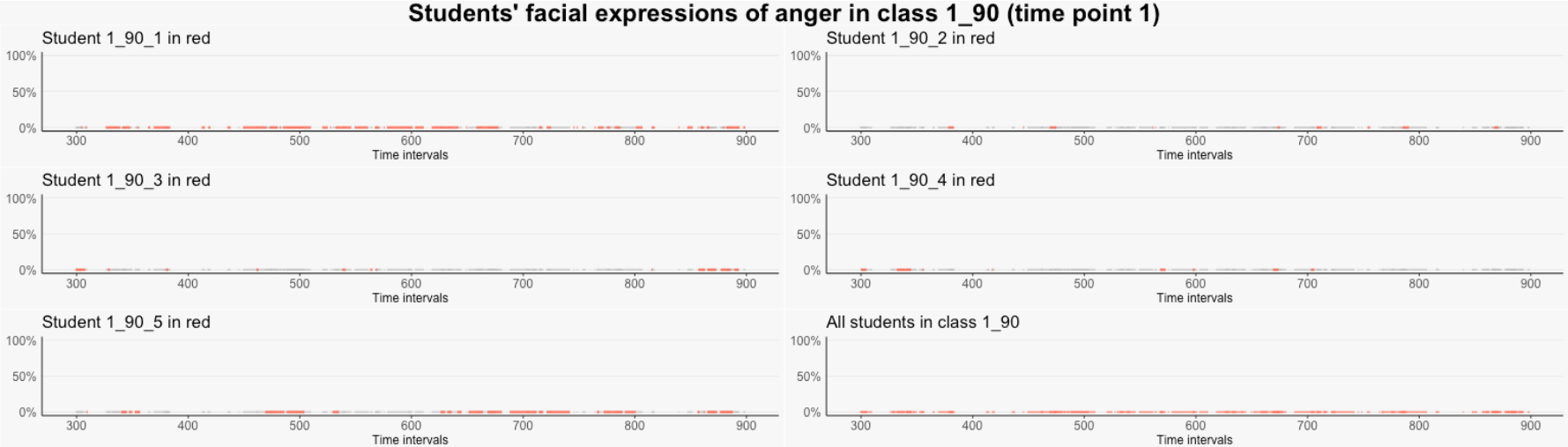
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



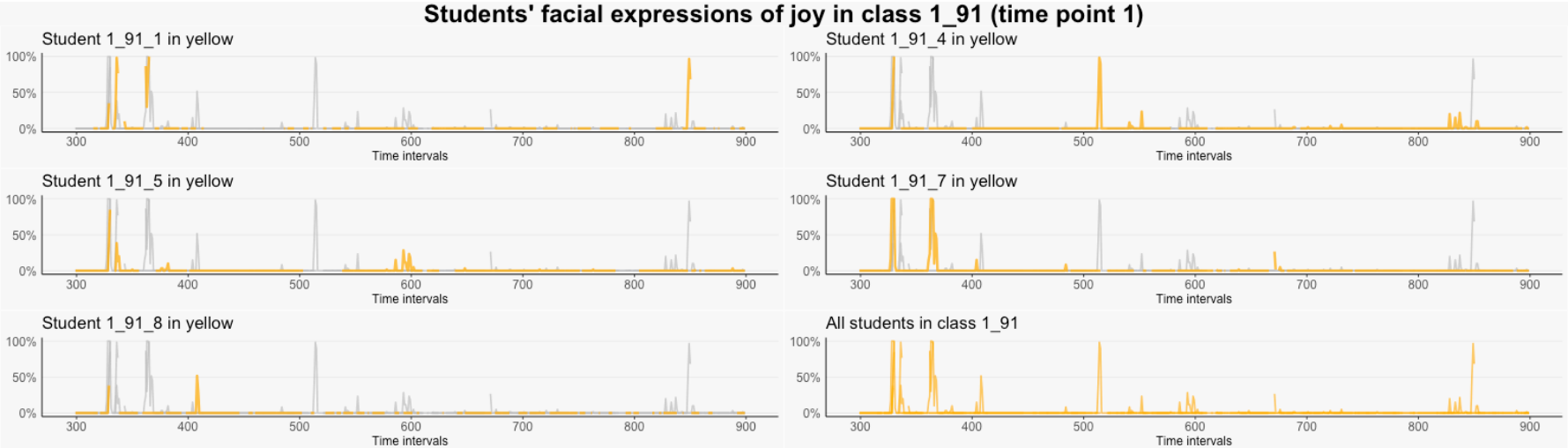
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



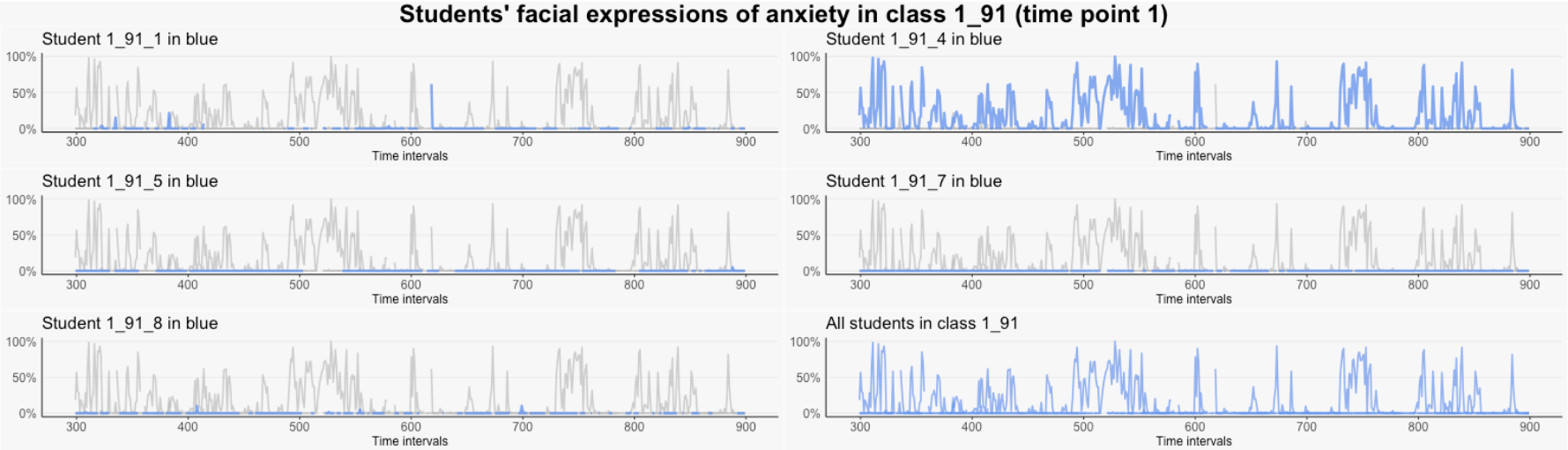
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



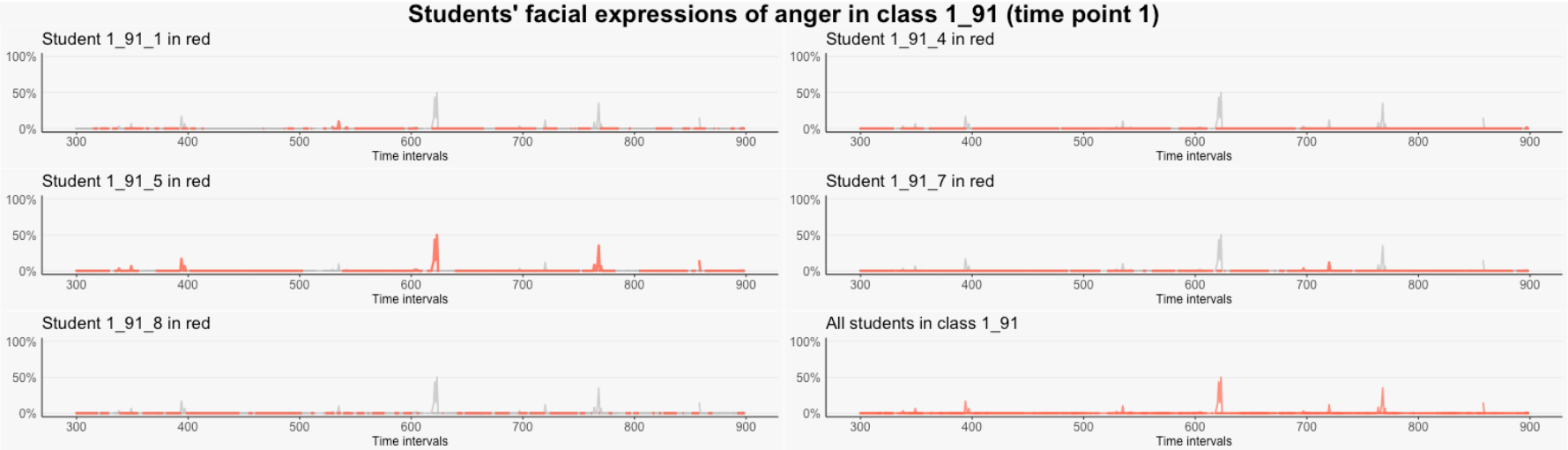
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



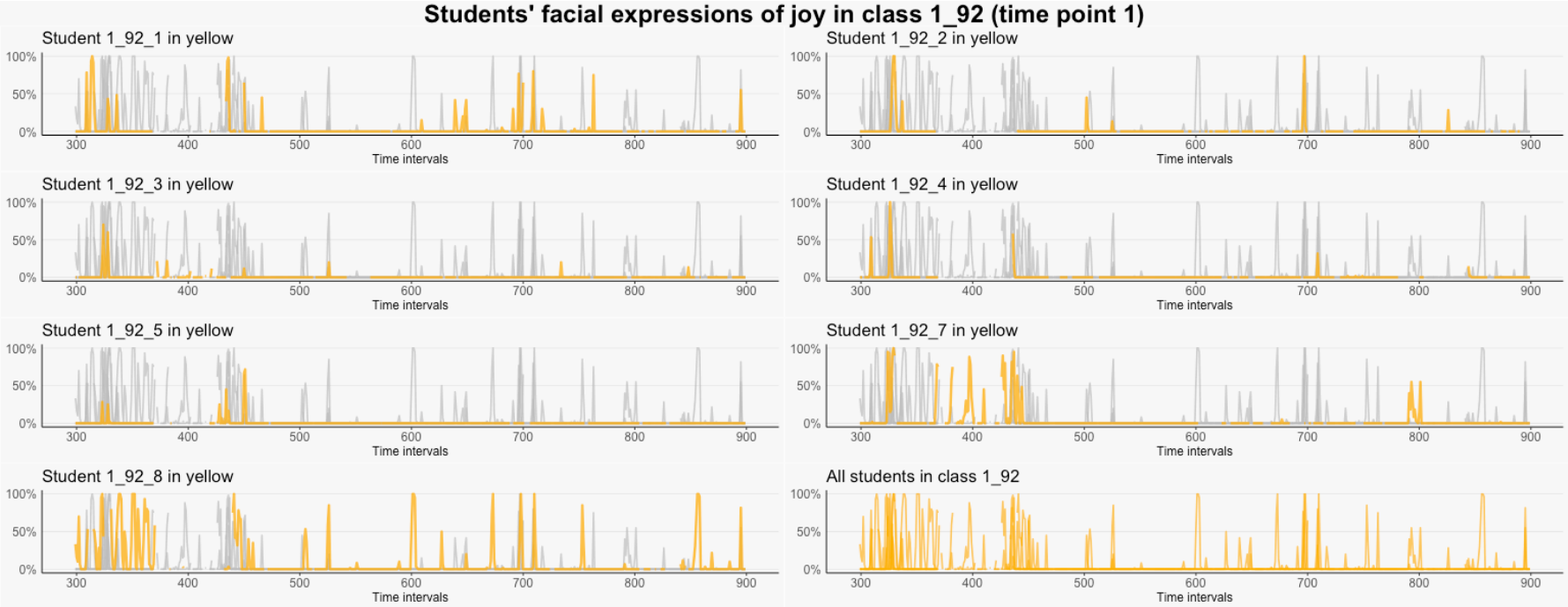
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



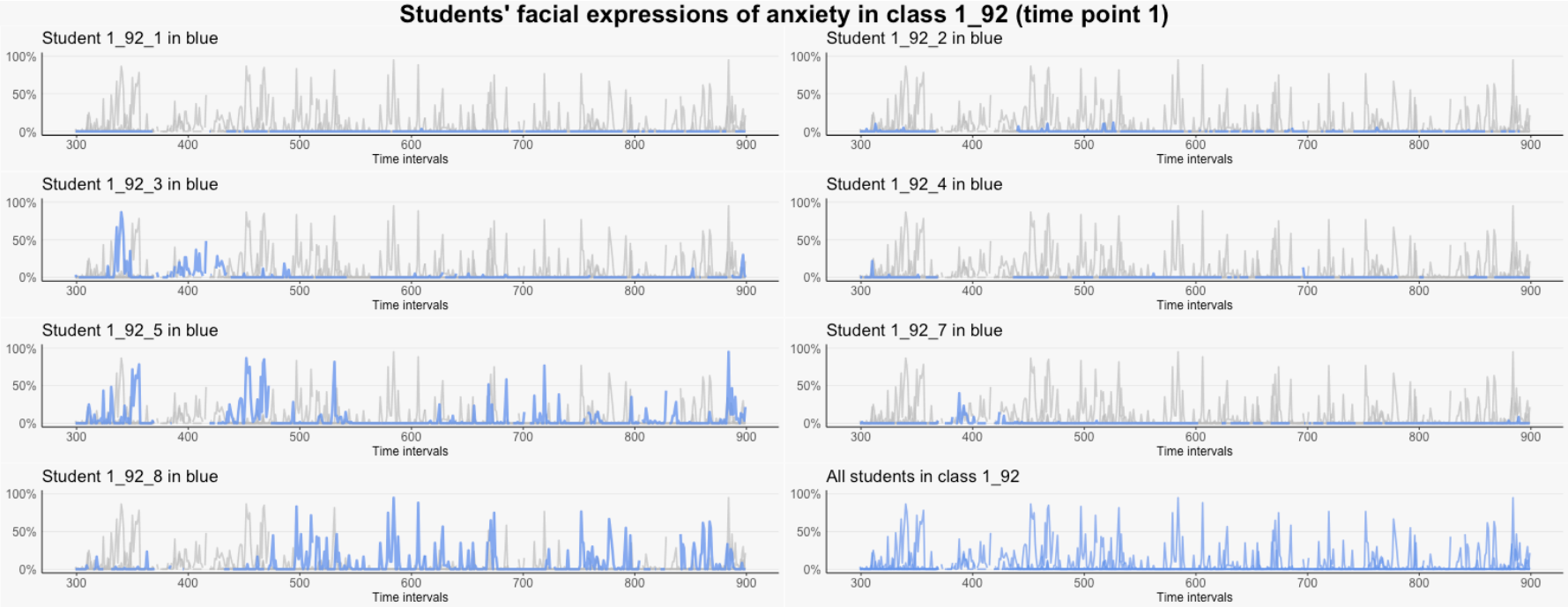
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



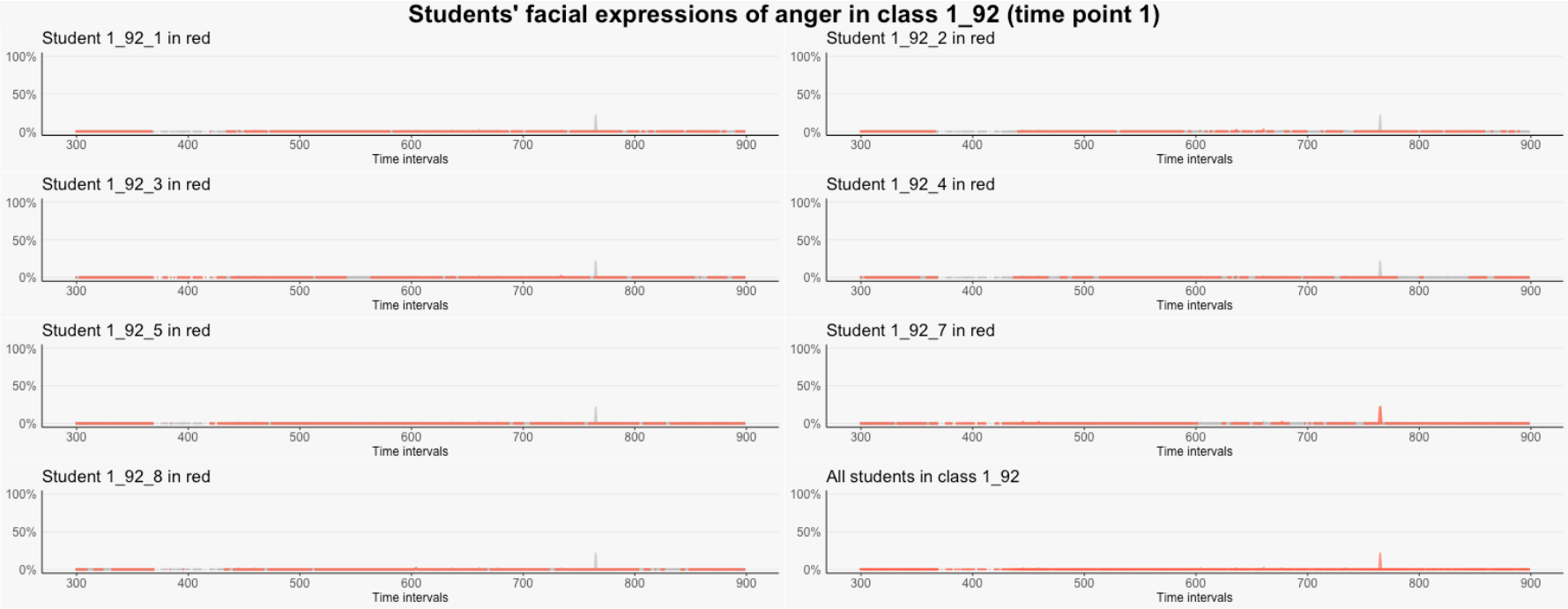
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



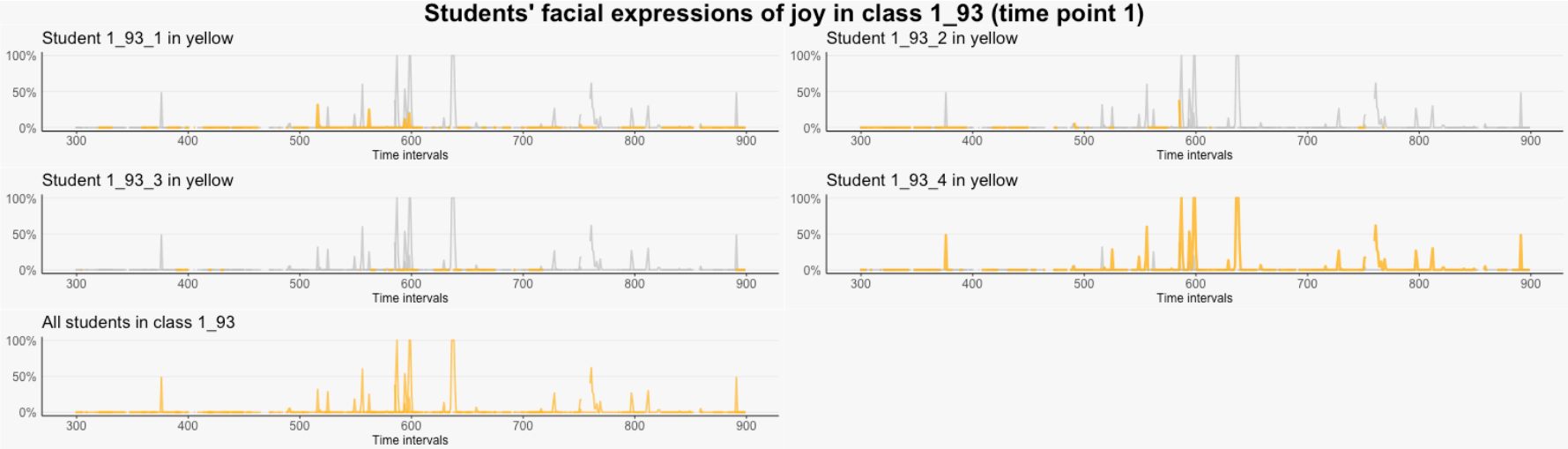
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



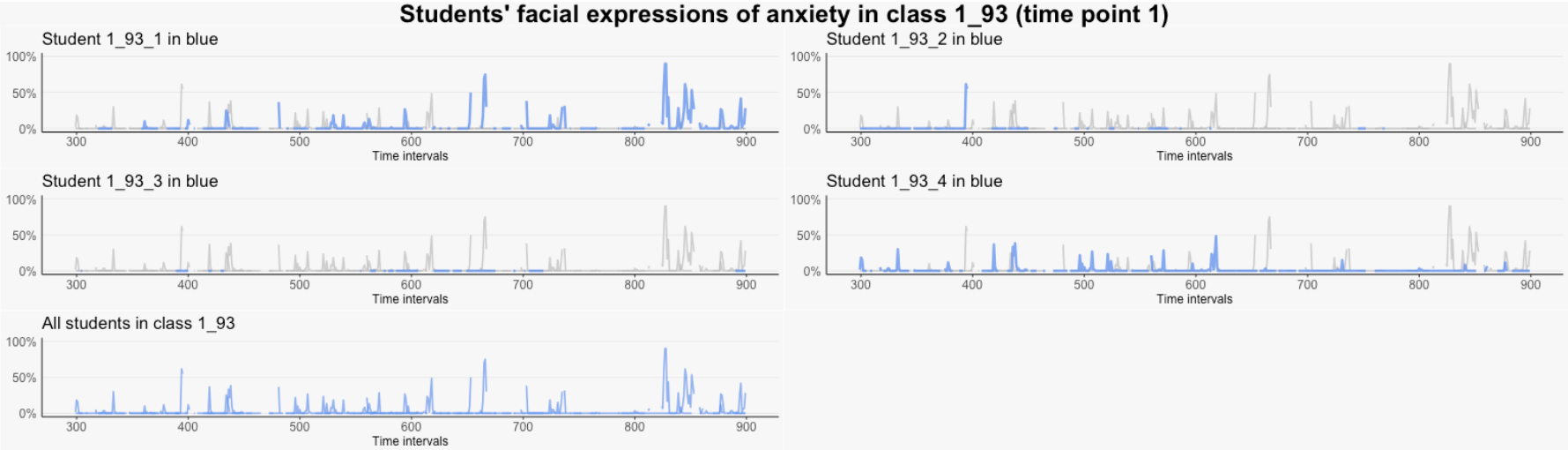
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



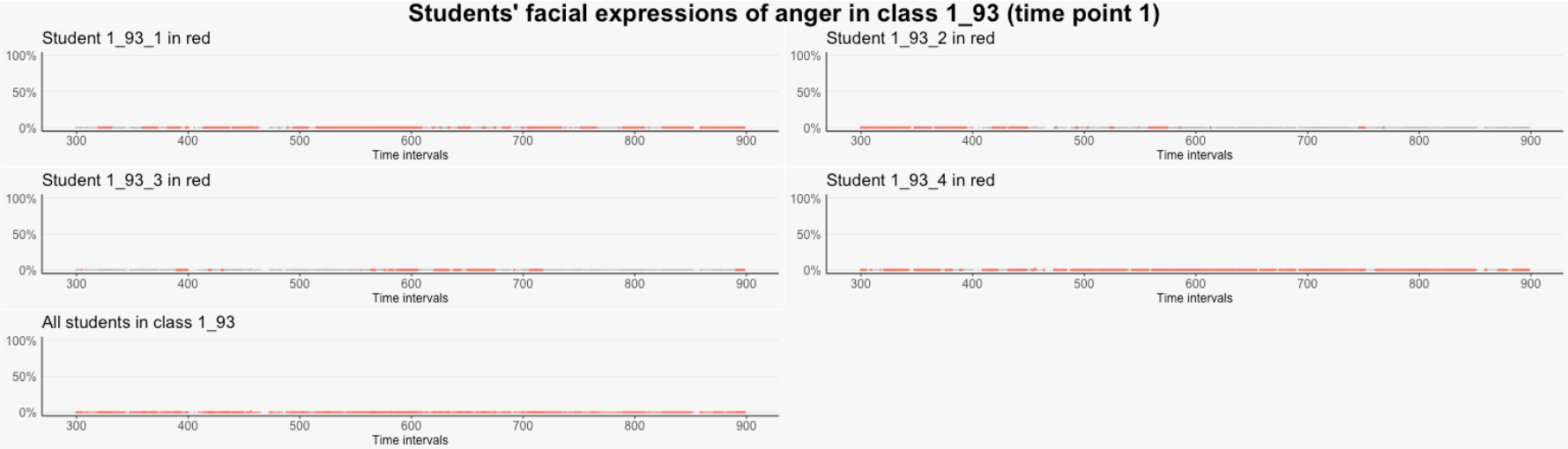
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



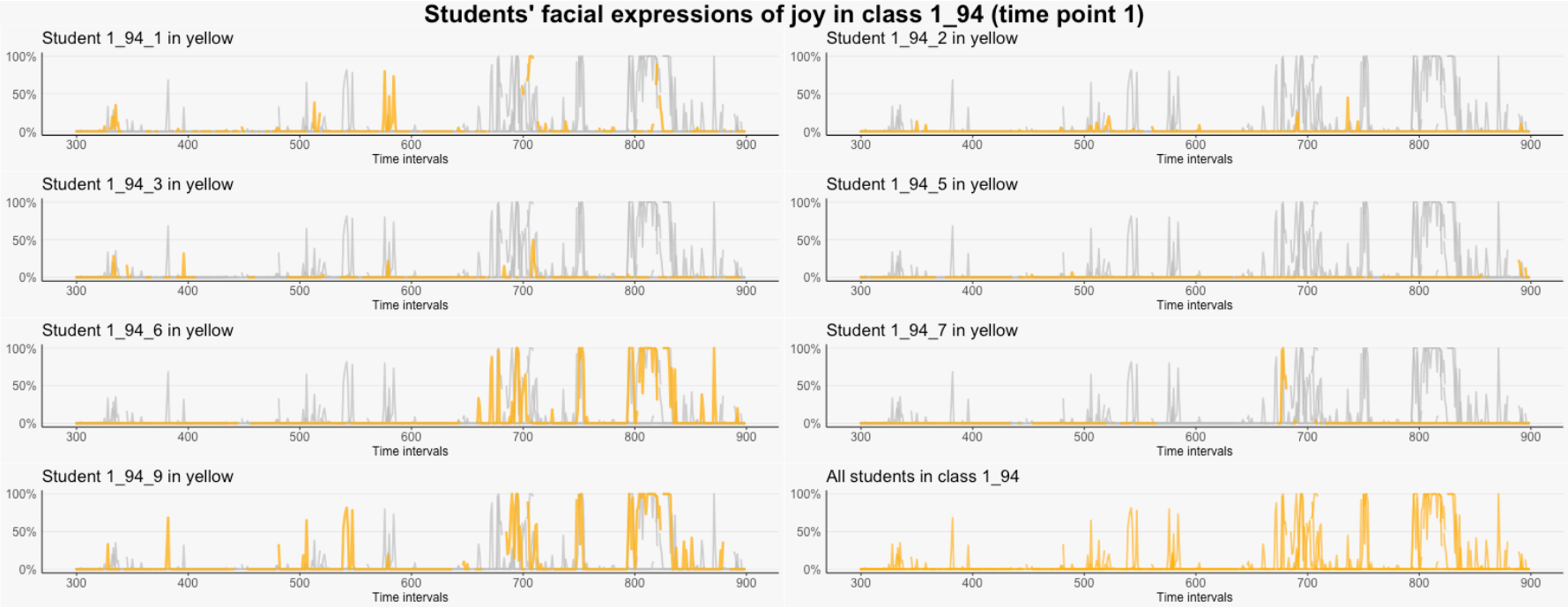
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



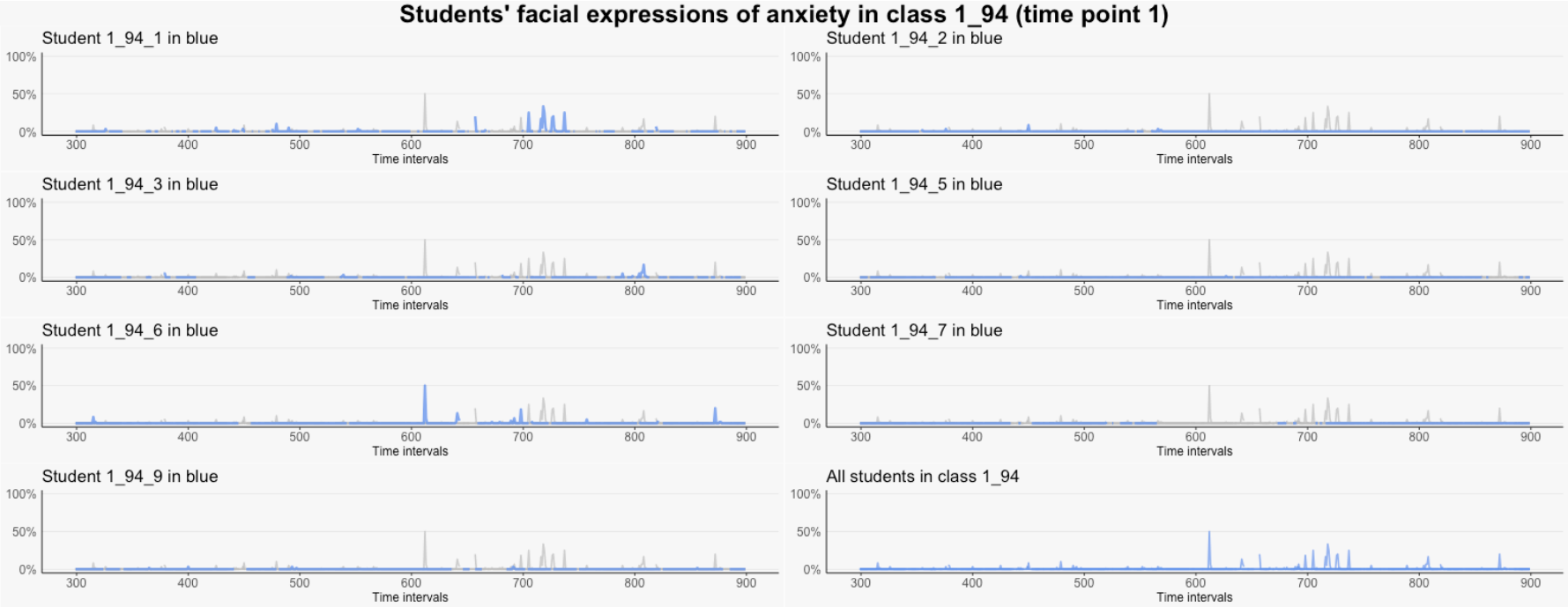
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



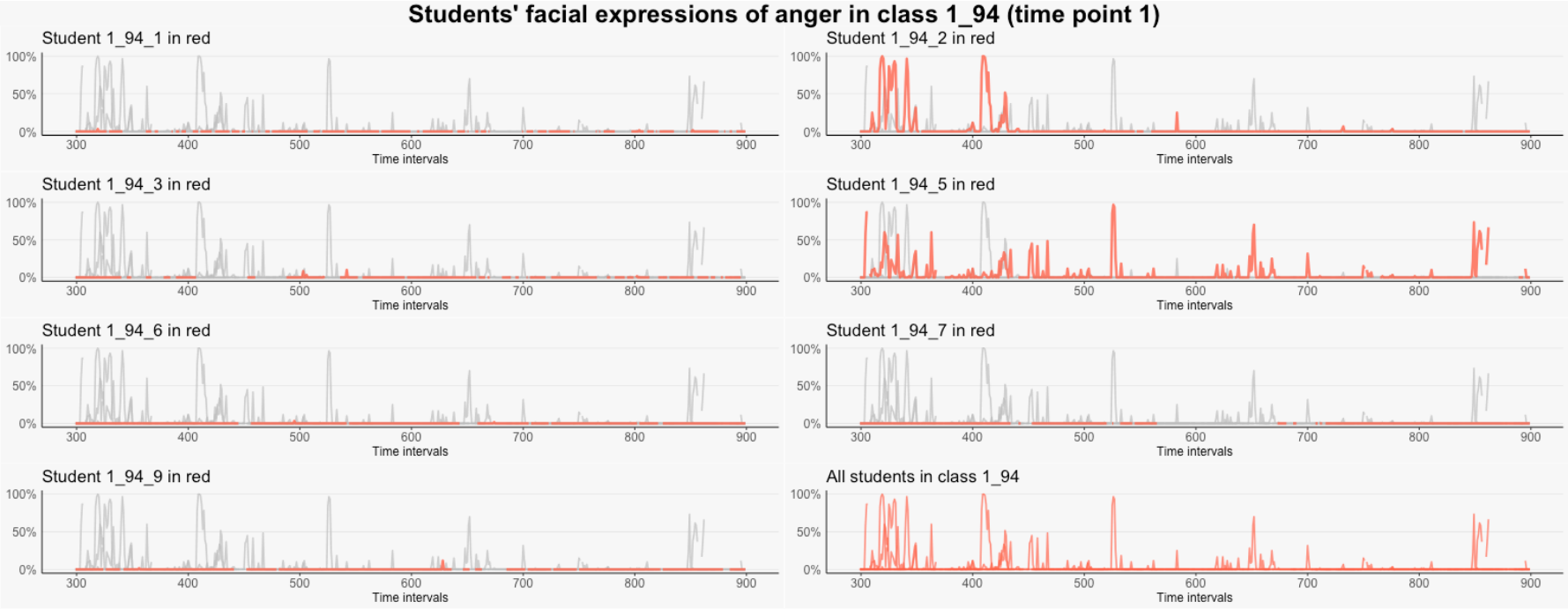
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).

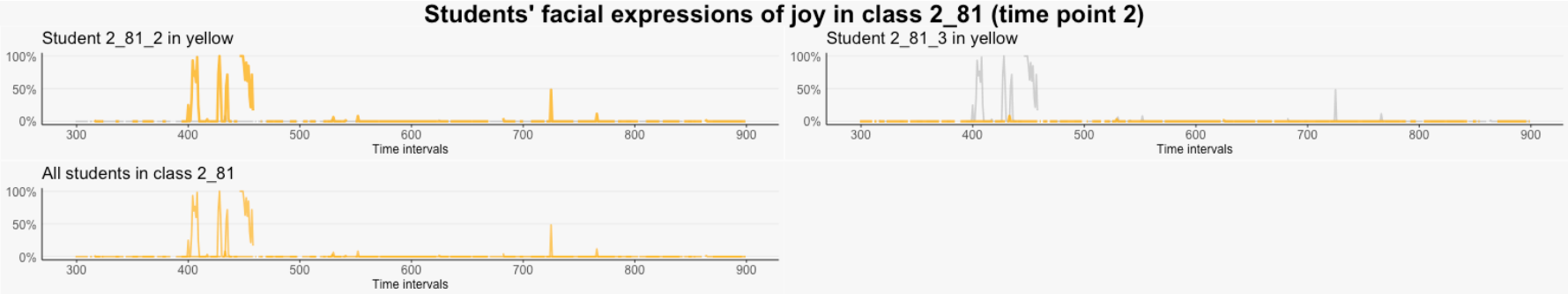


Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).

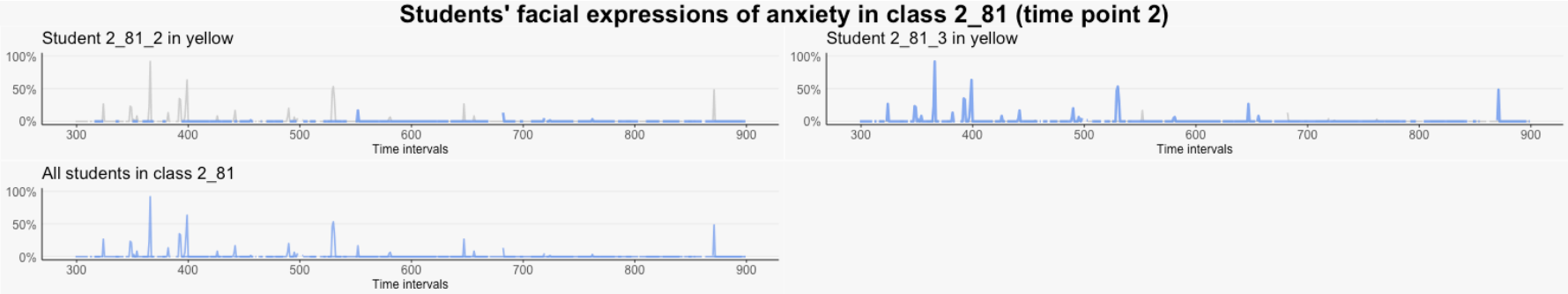


Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).

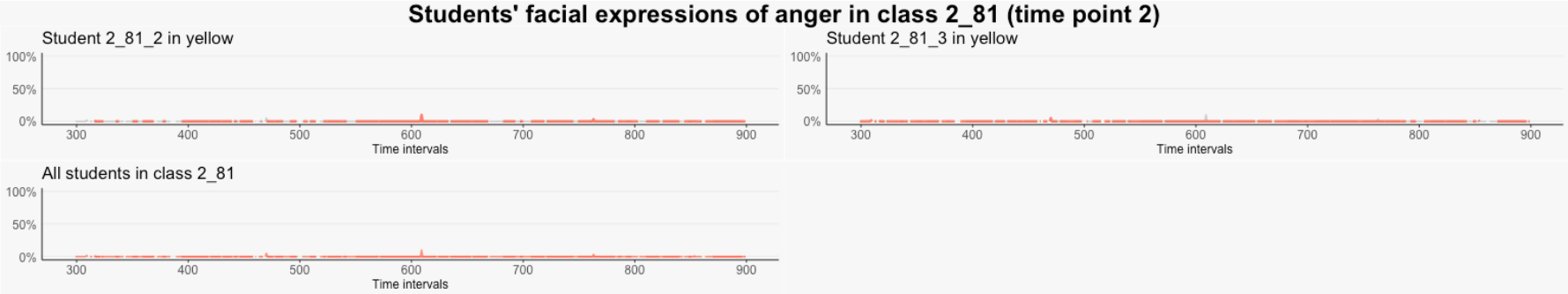
E.2 Time series graphs of all students in their classes (time point 2)



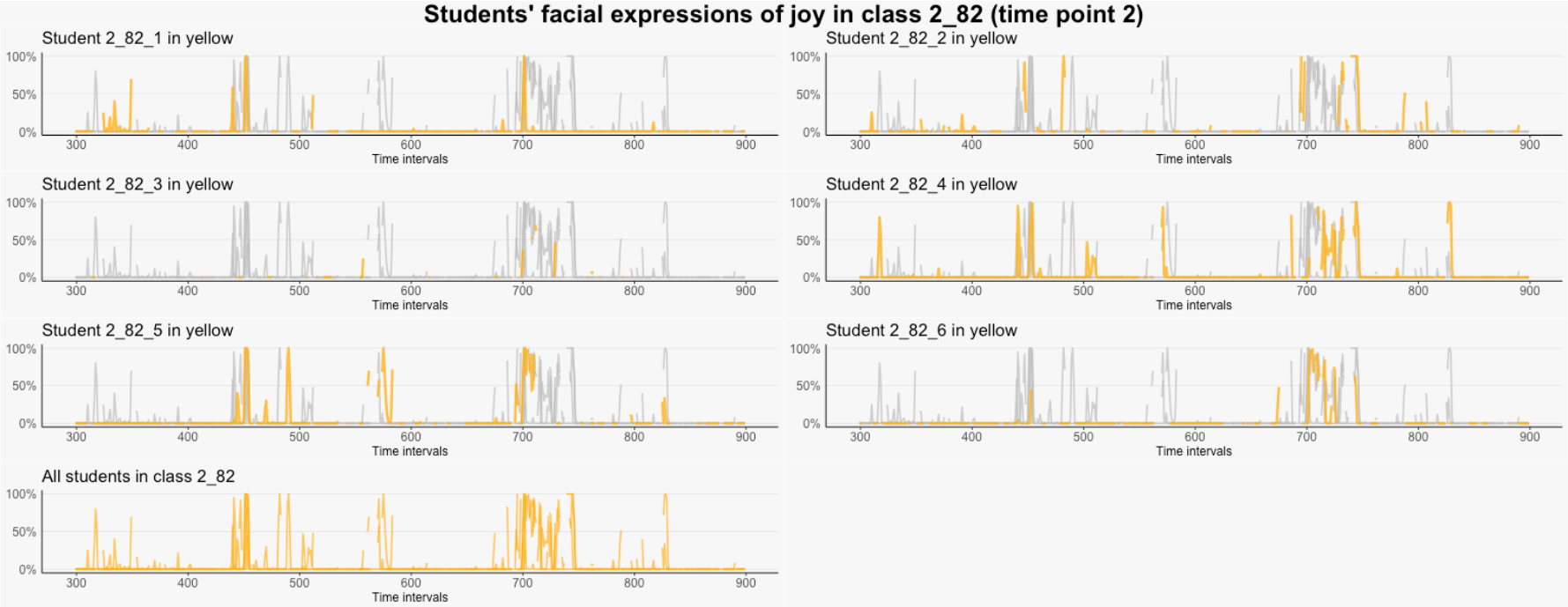
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



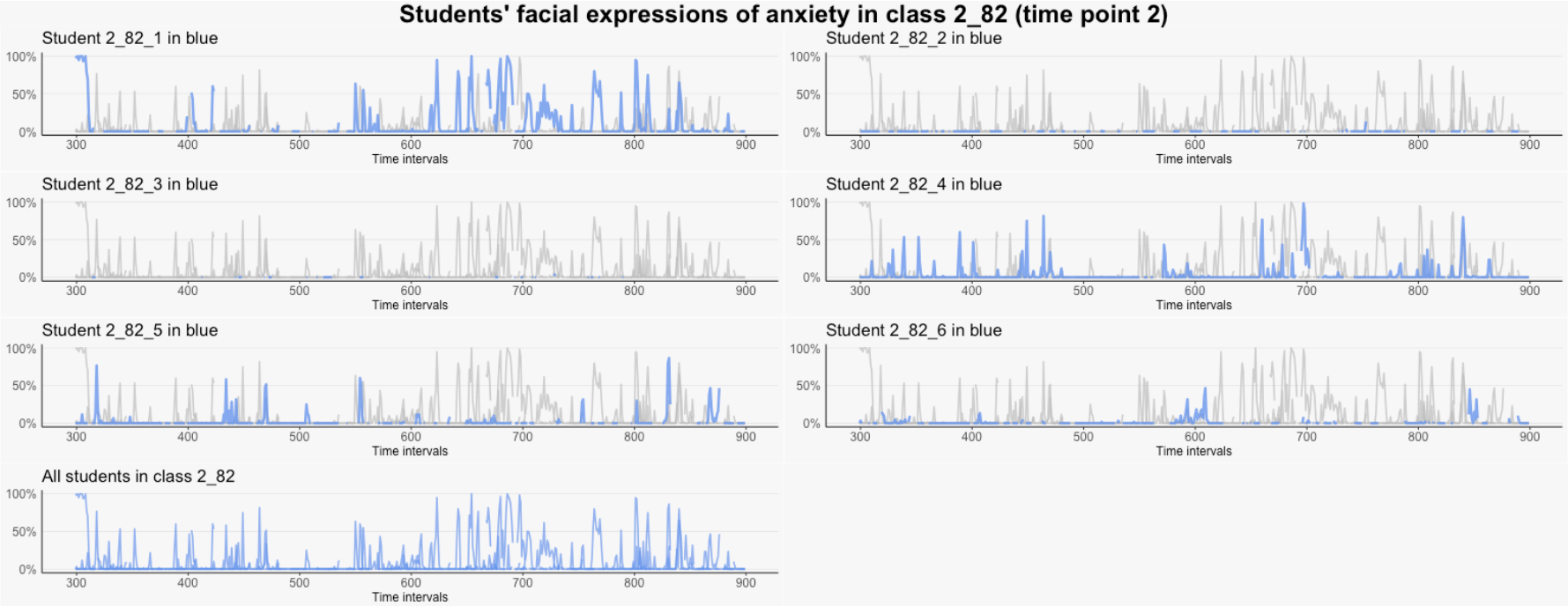
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



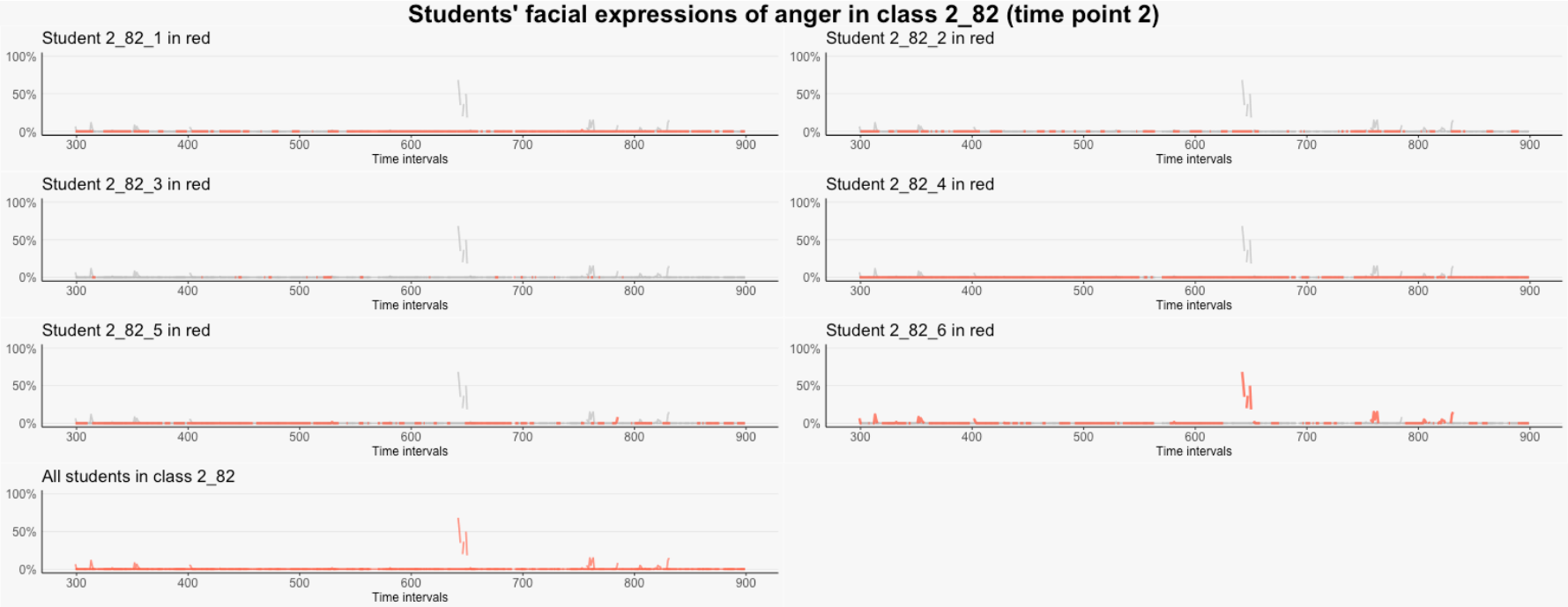
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



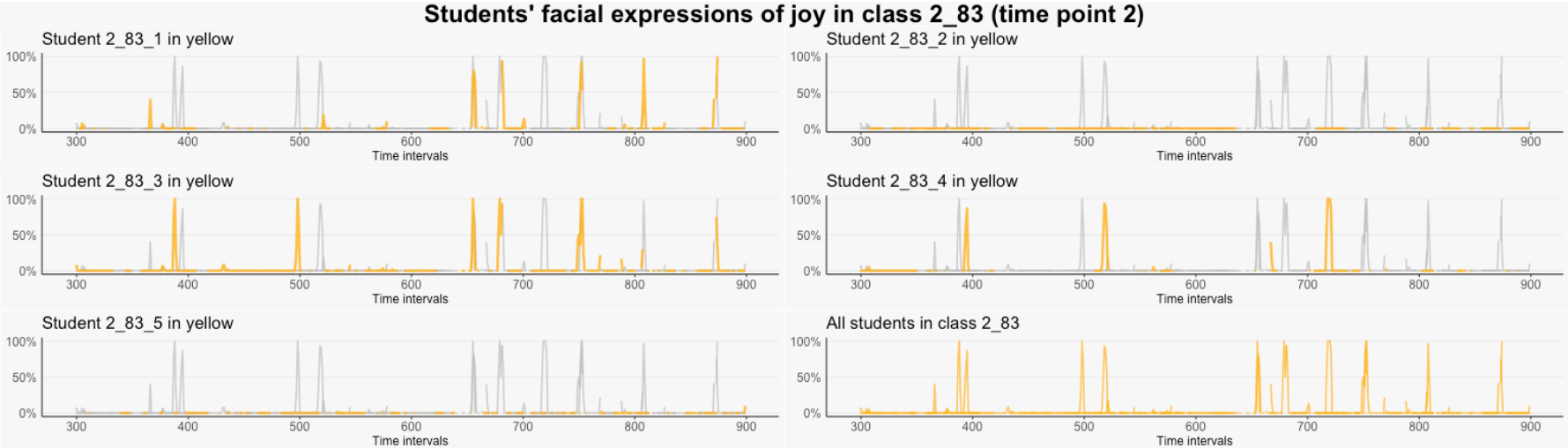
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



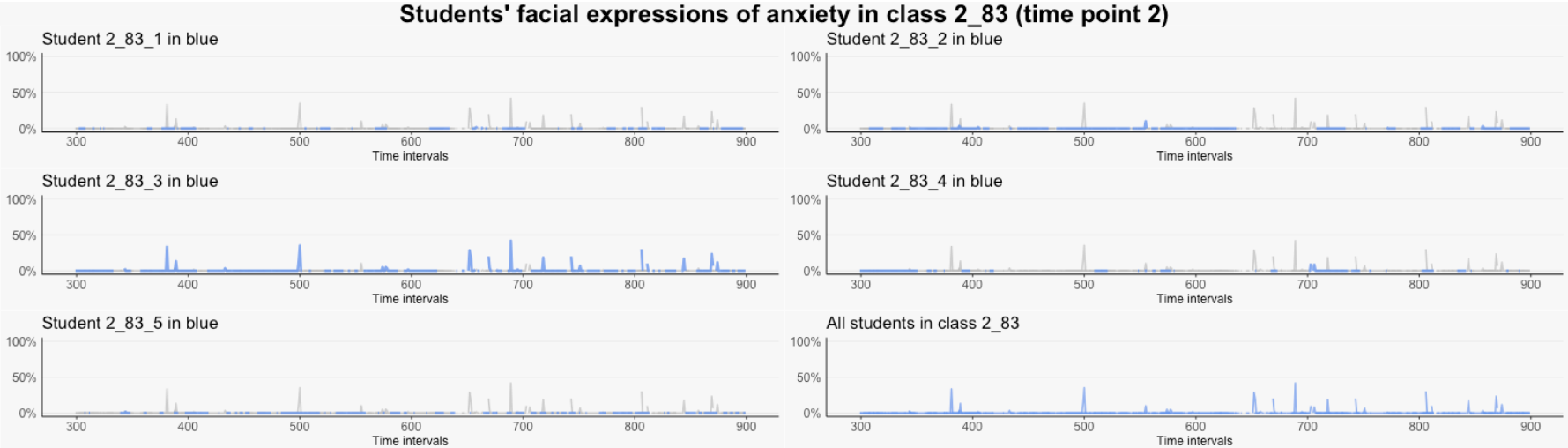
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



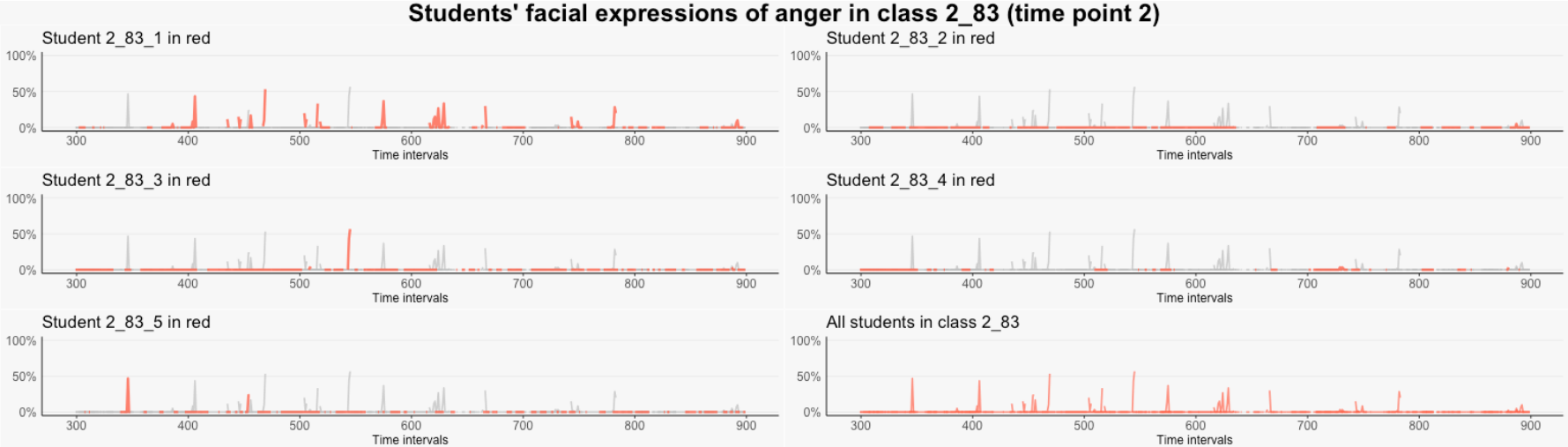
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



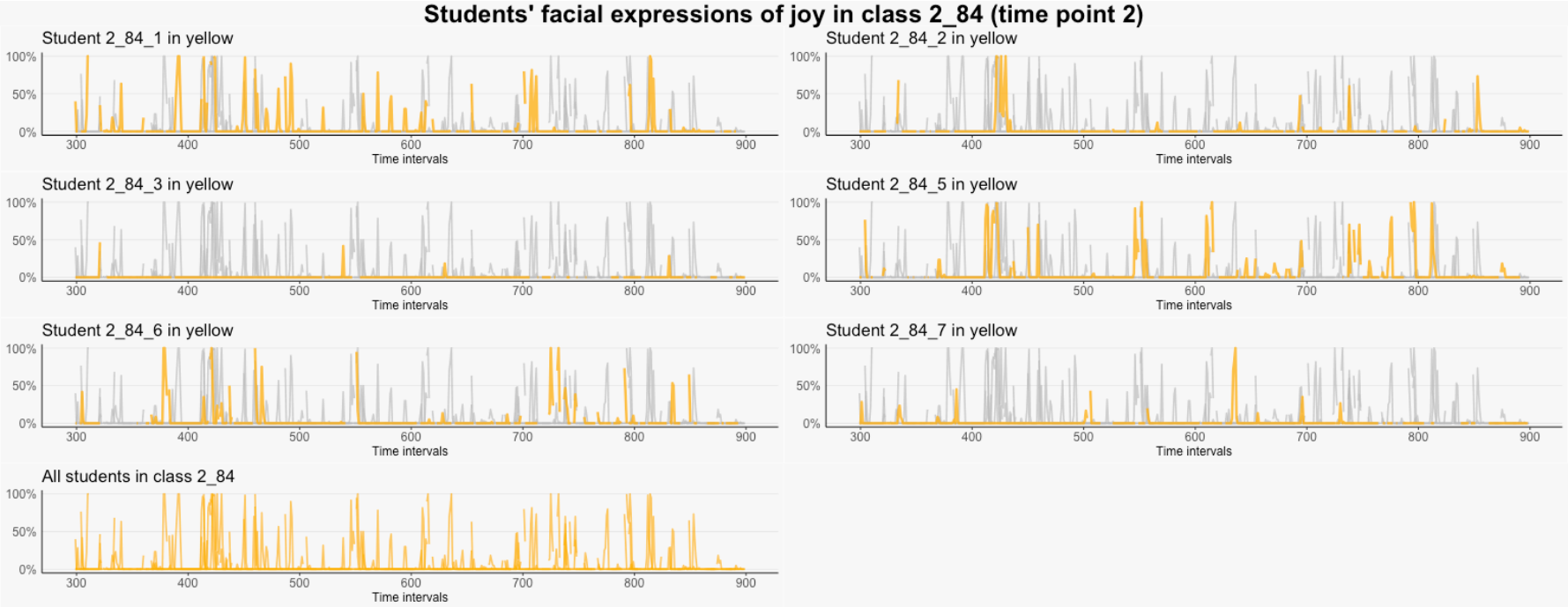
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



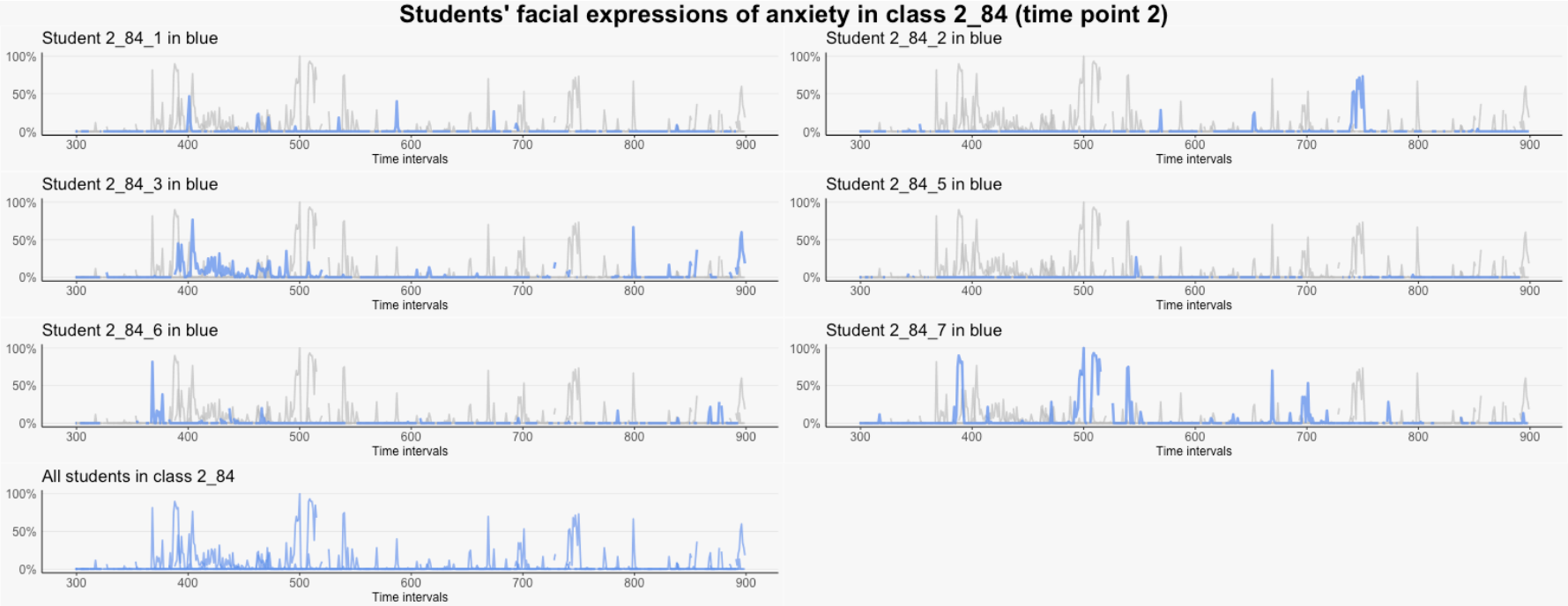
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



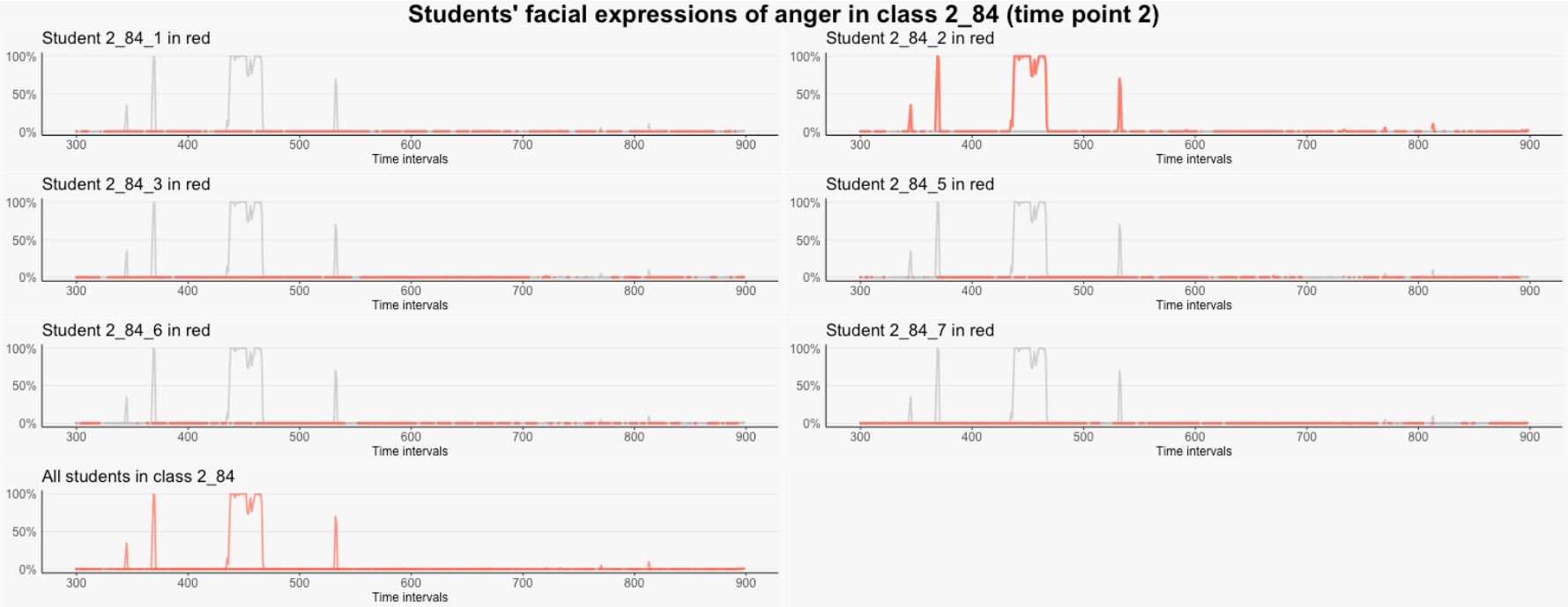
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



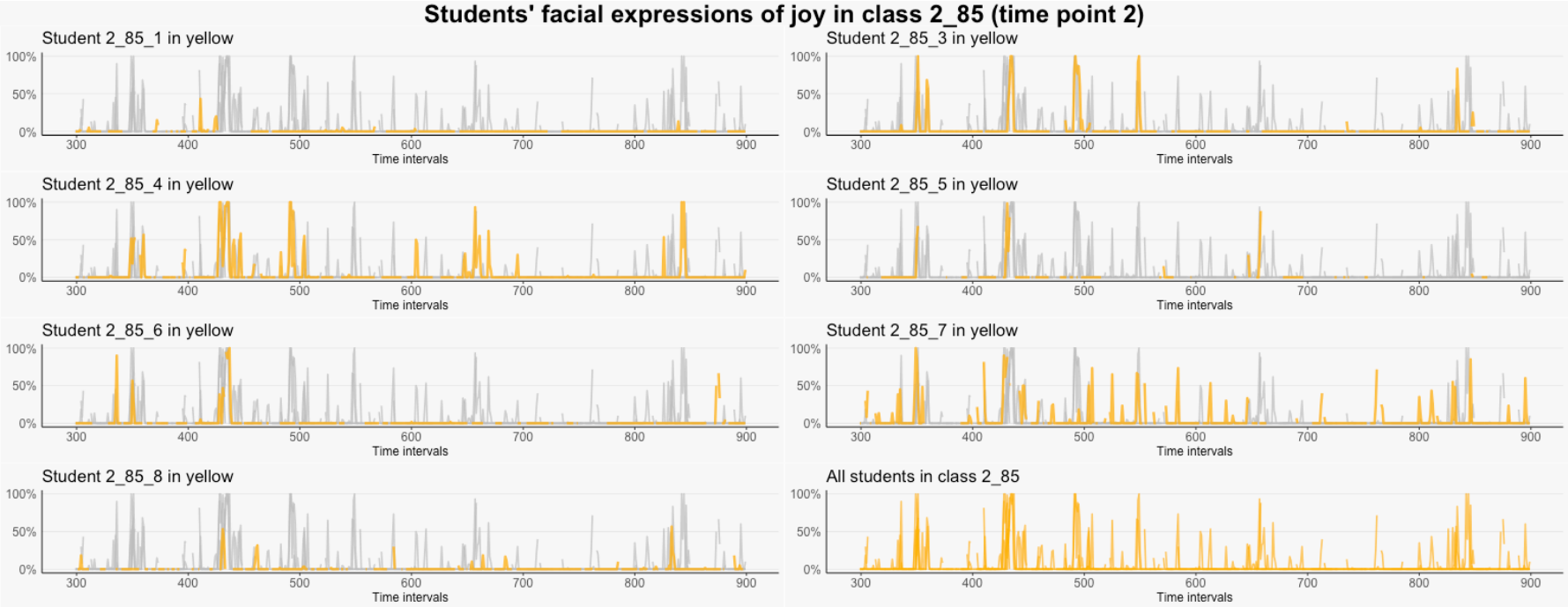
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



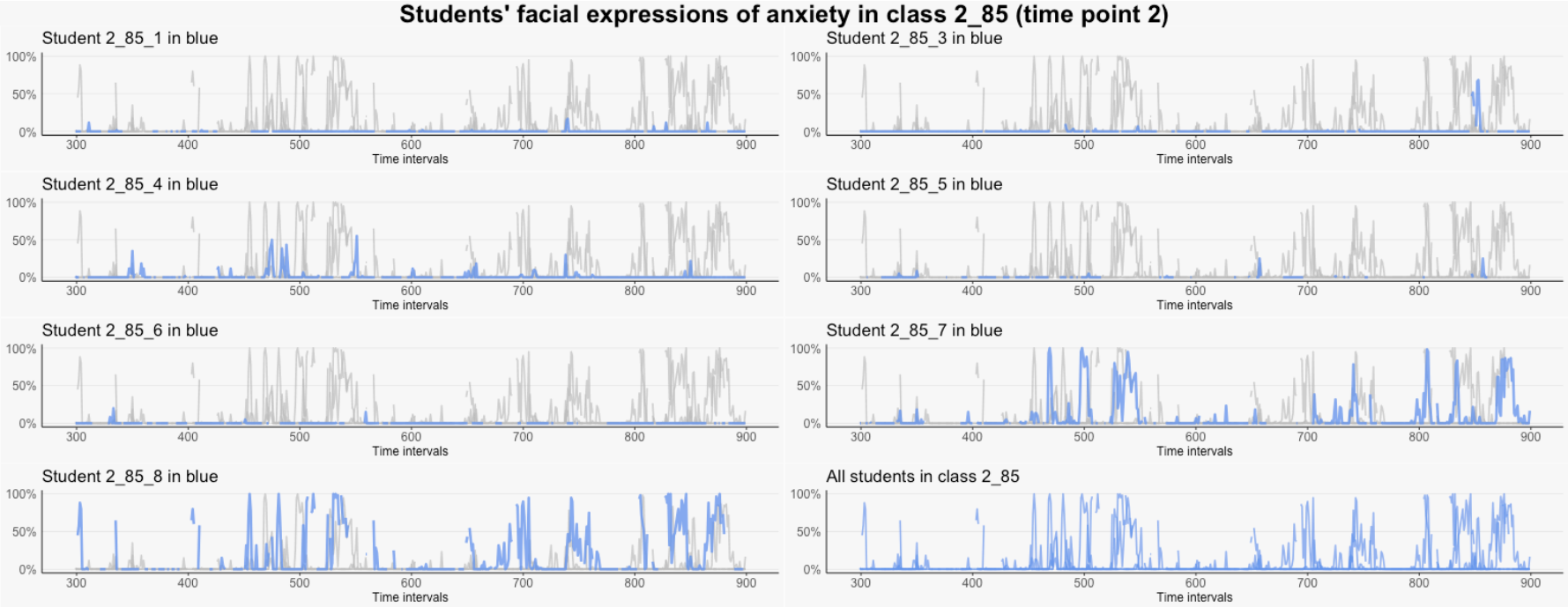
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



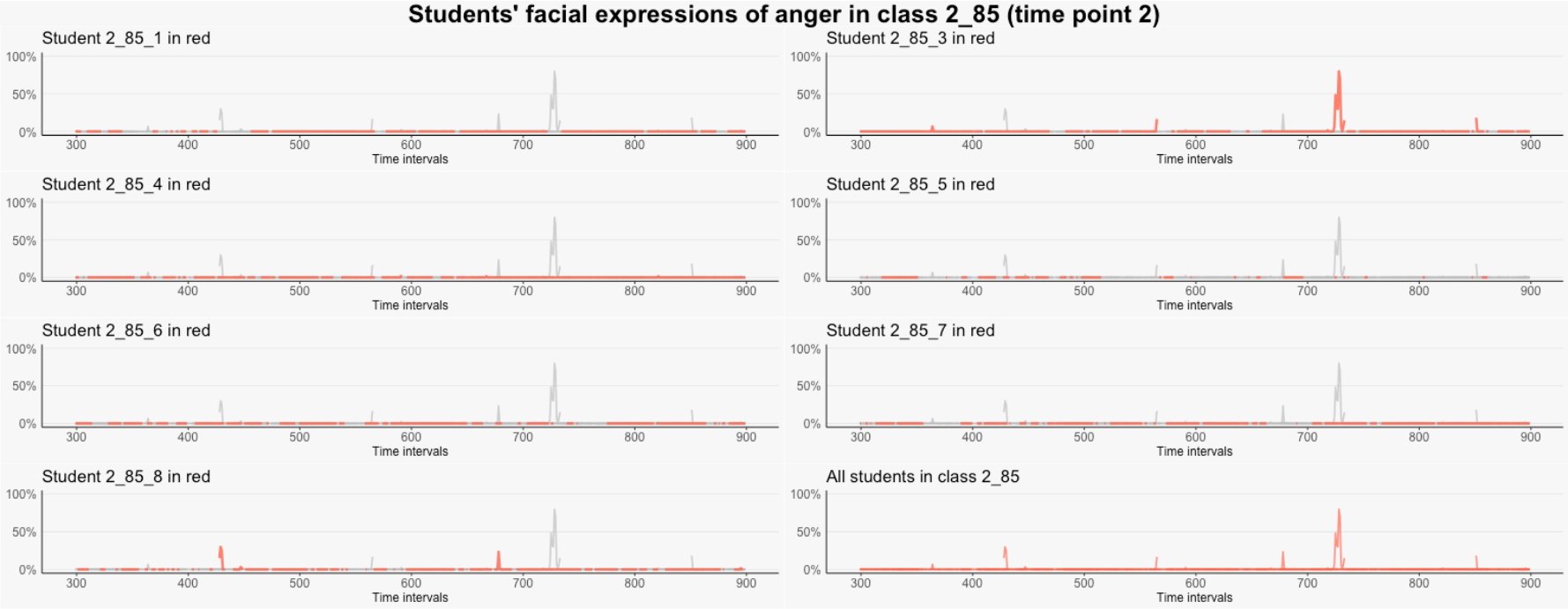
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



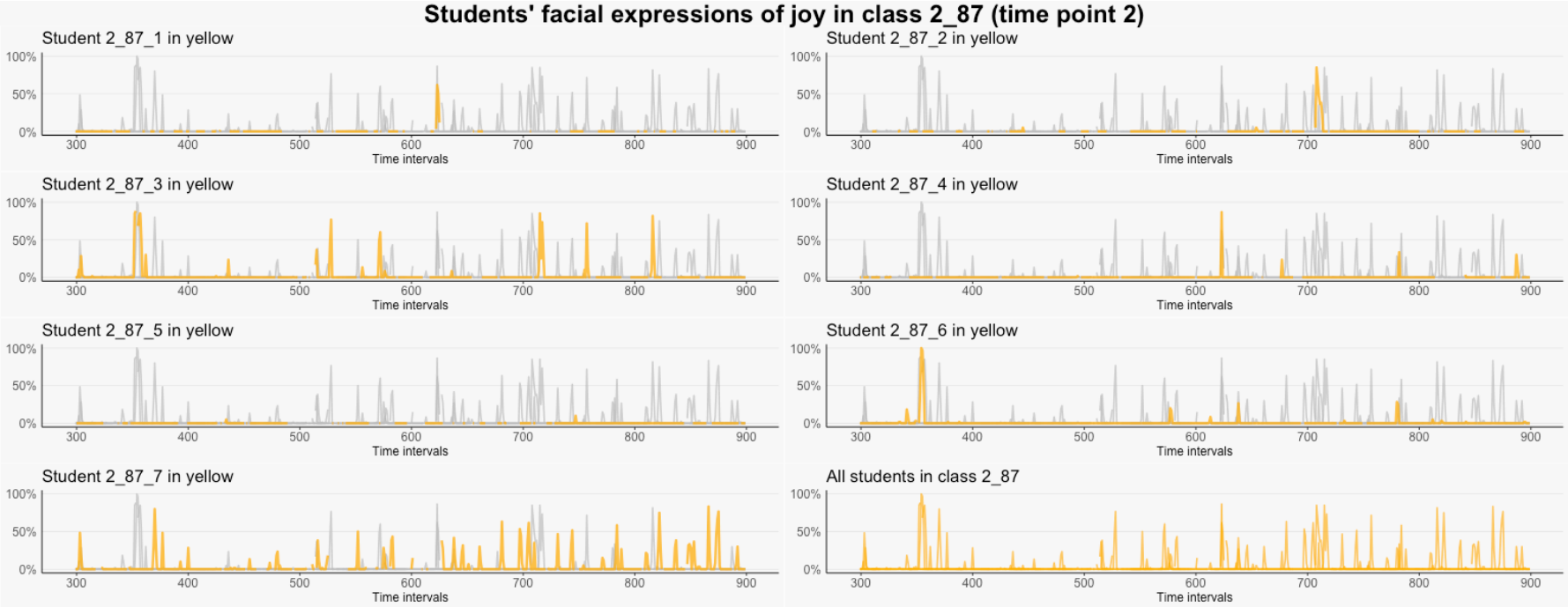
Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



Time series graphs of facial expressions as recognized by automated coding software (percentage of recognized frames in time intervals of 60 frames or 2 seconds).



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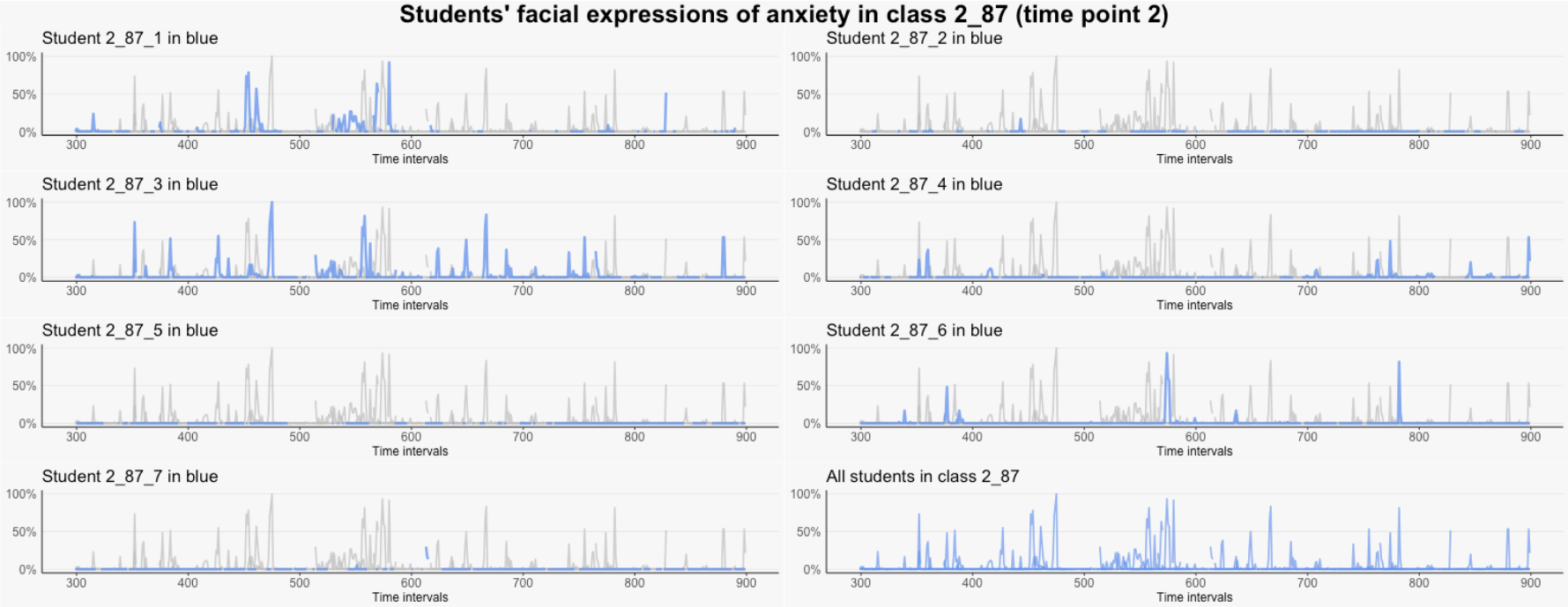

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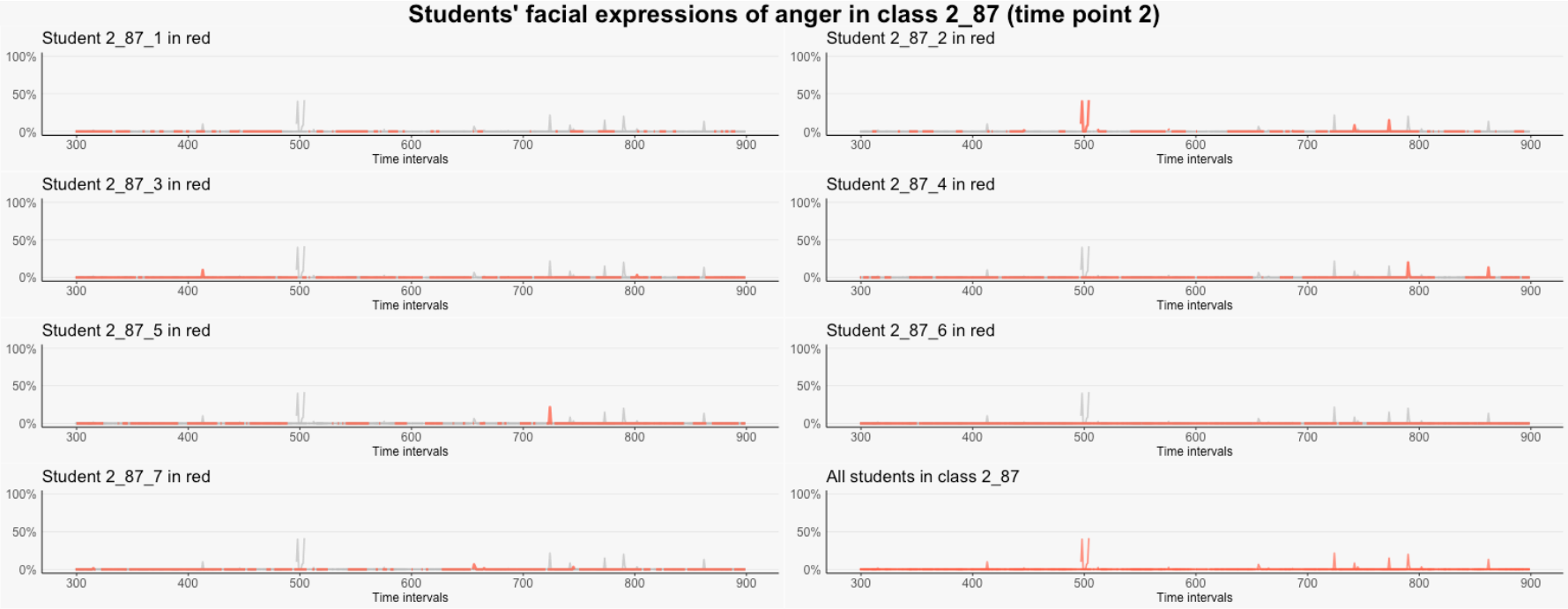

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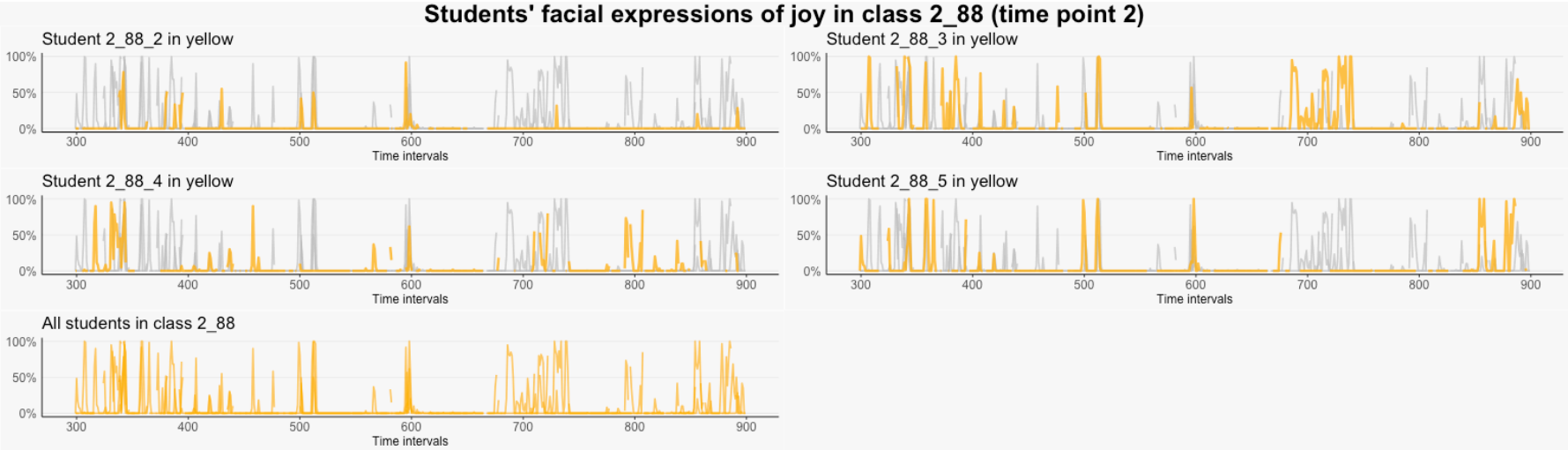

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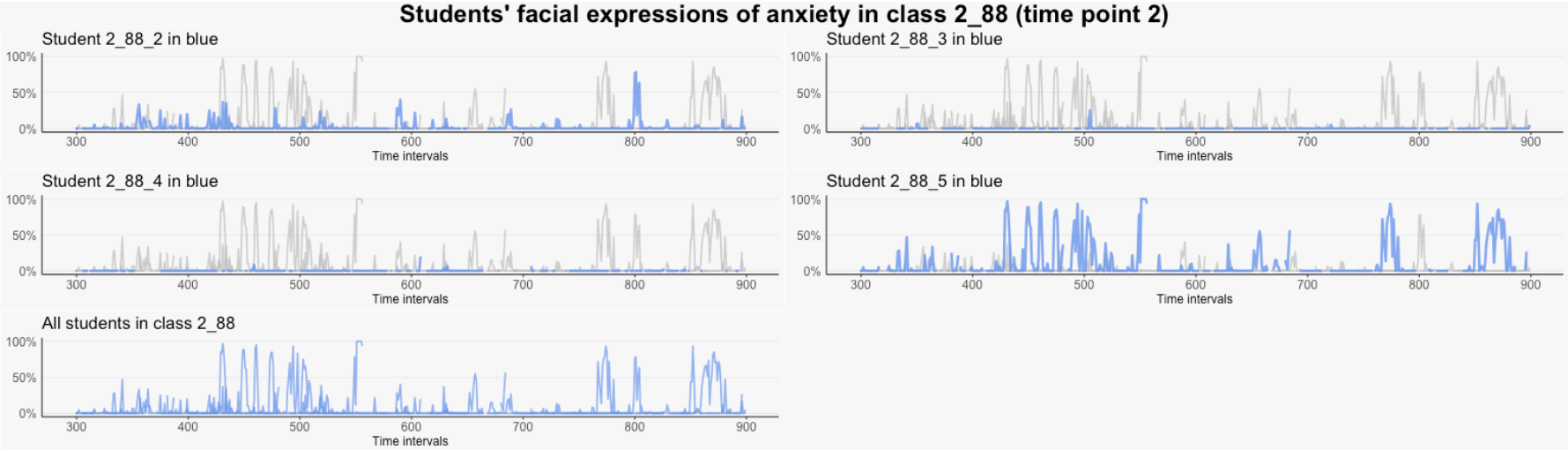

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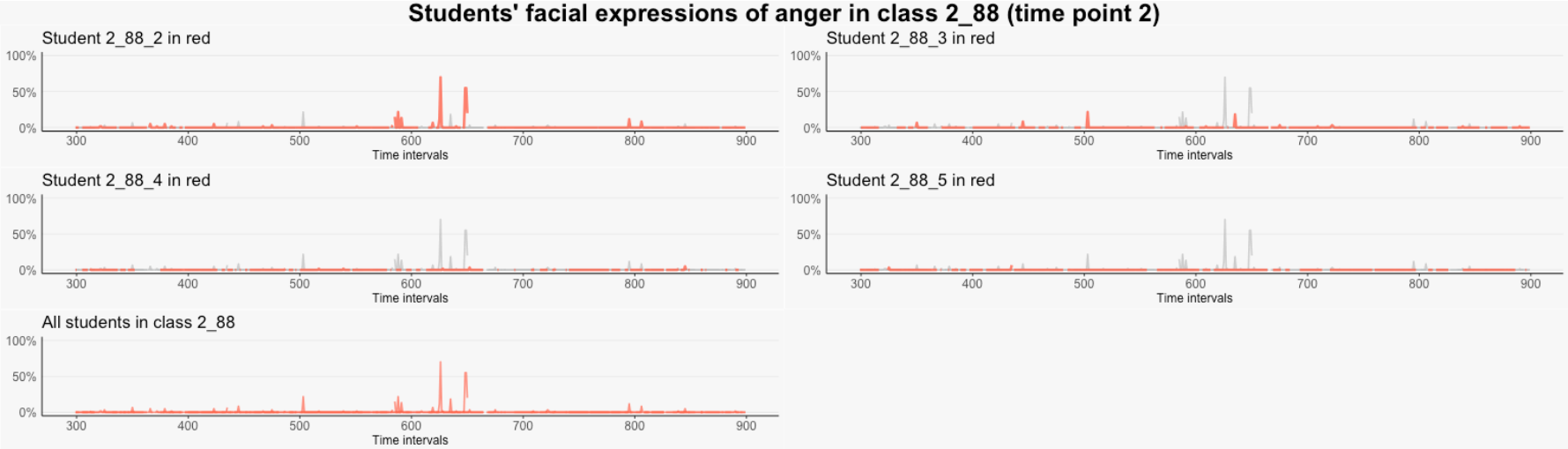

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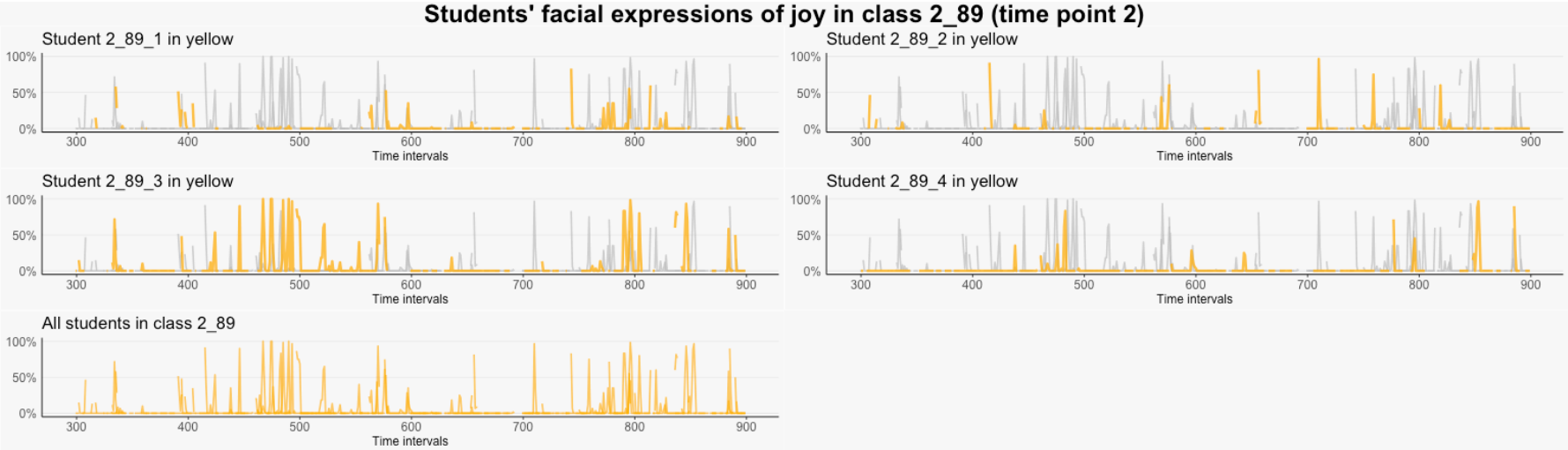

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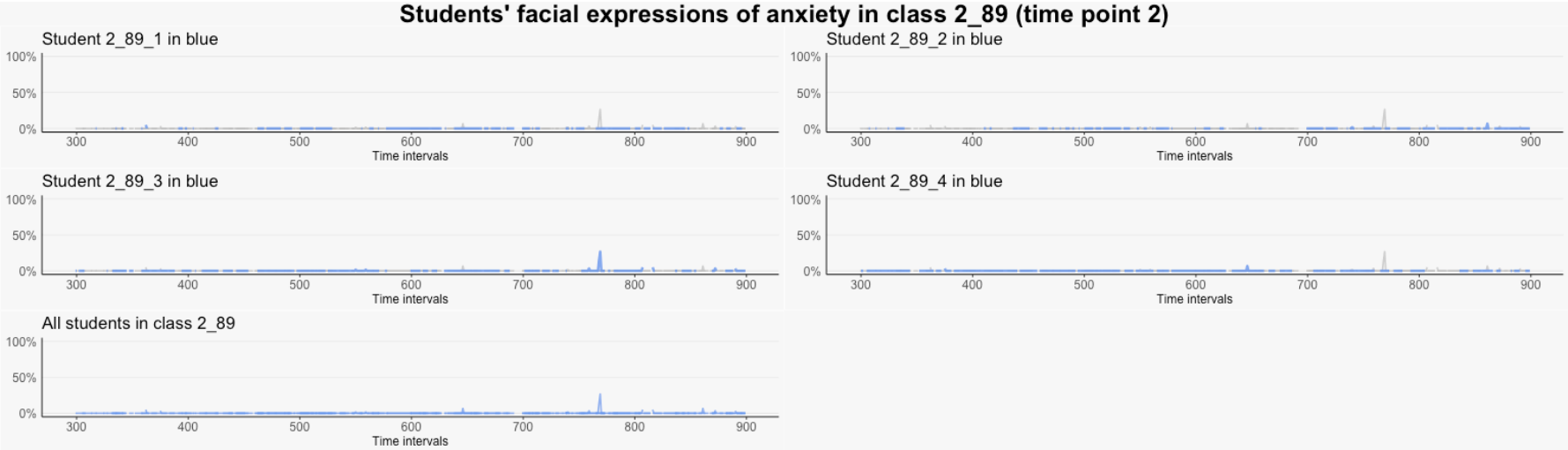

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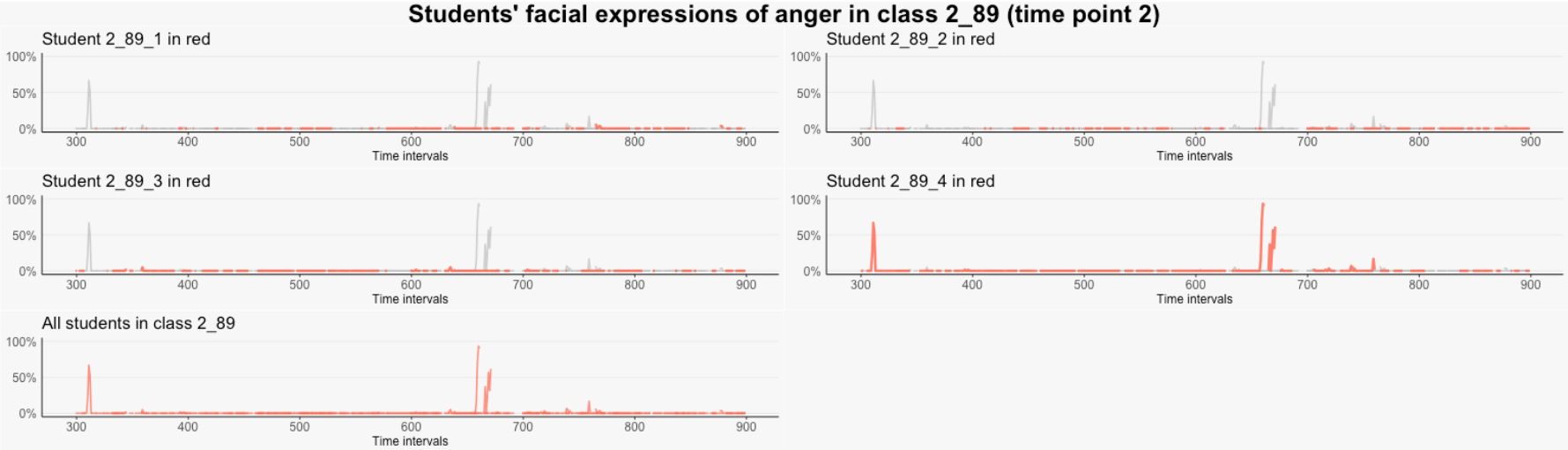

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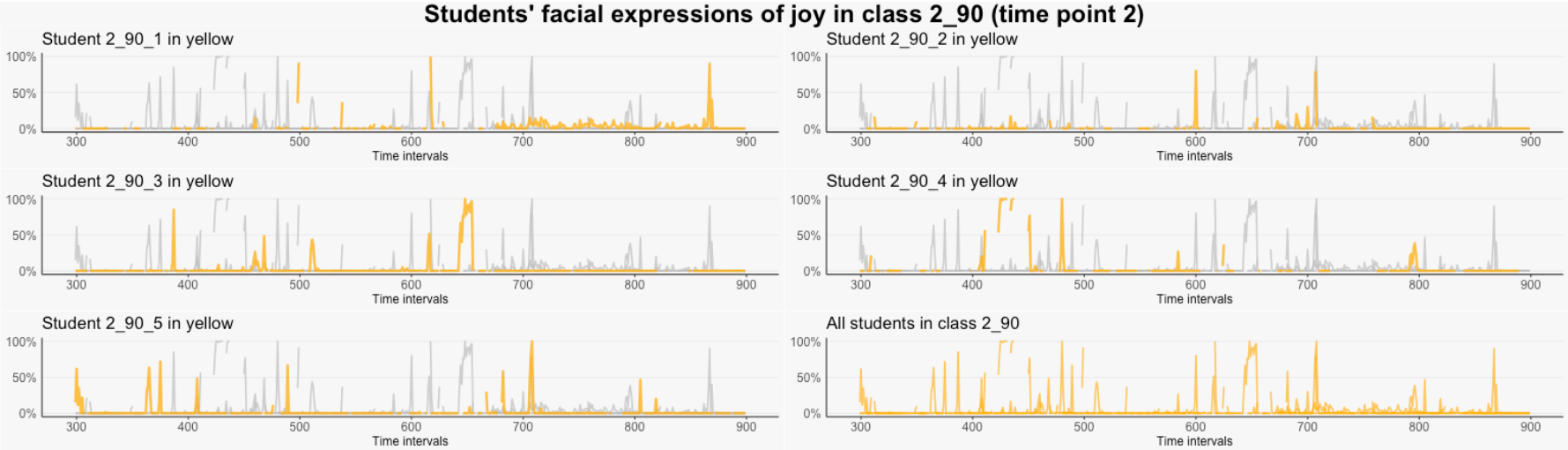

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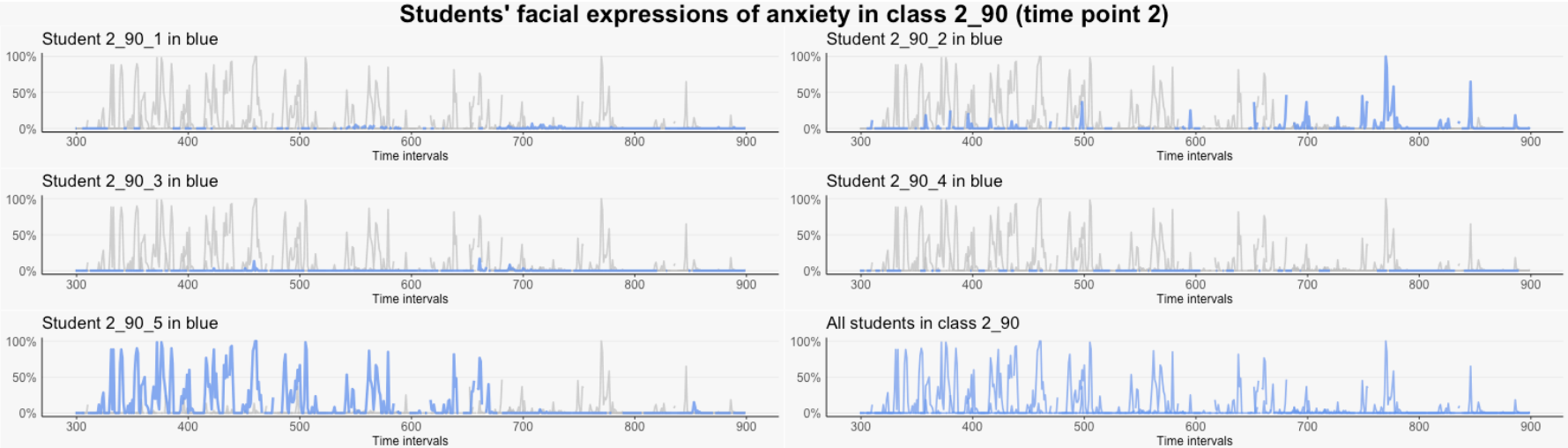

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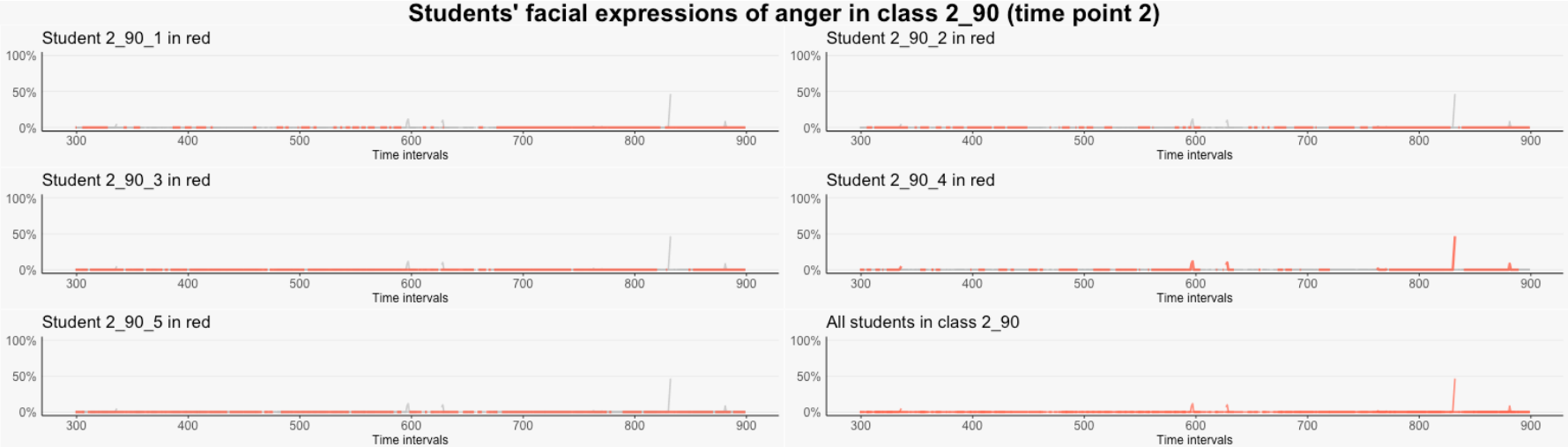

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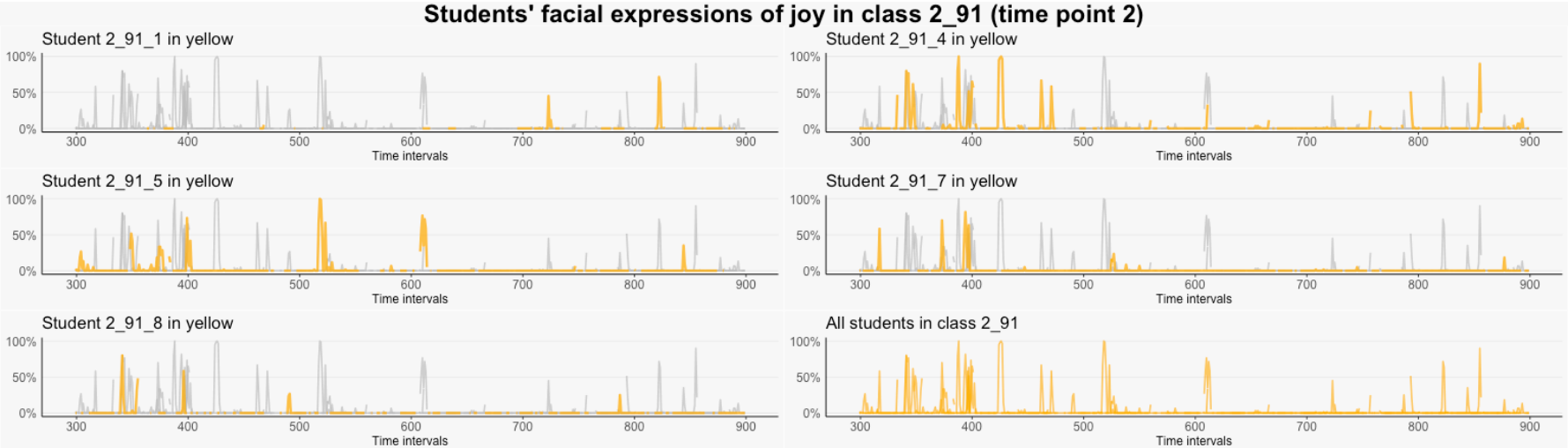

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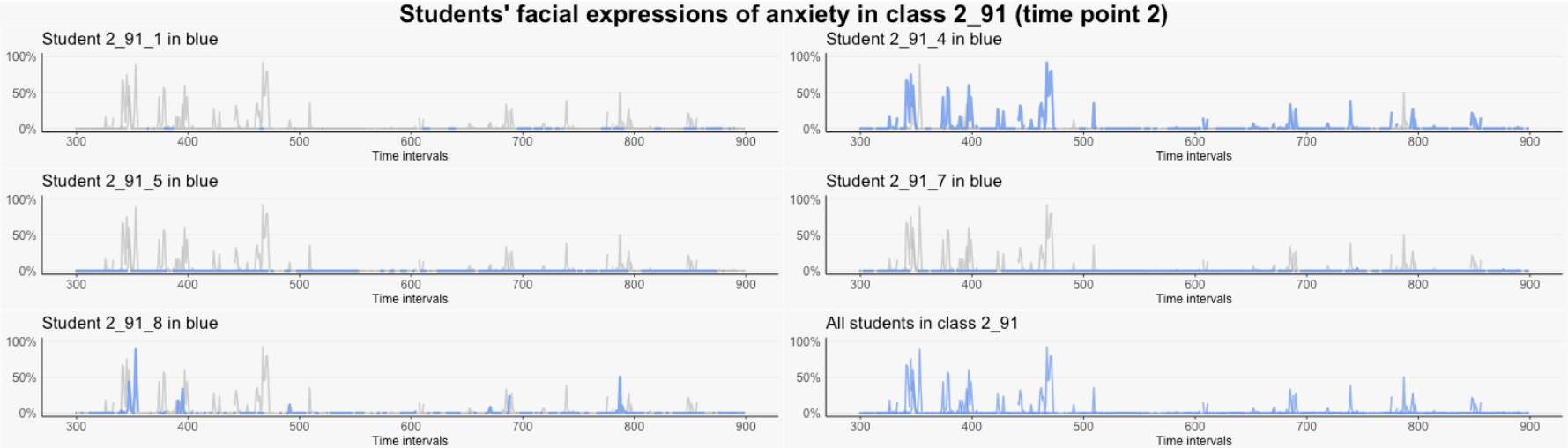

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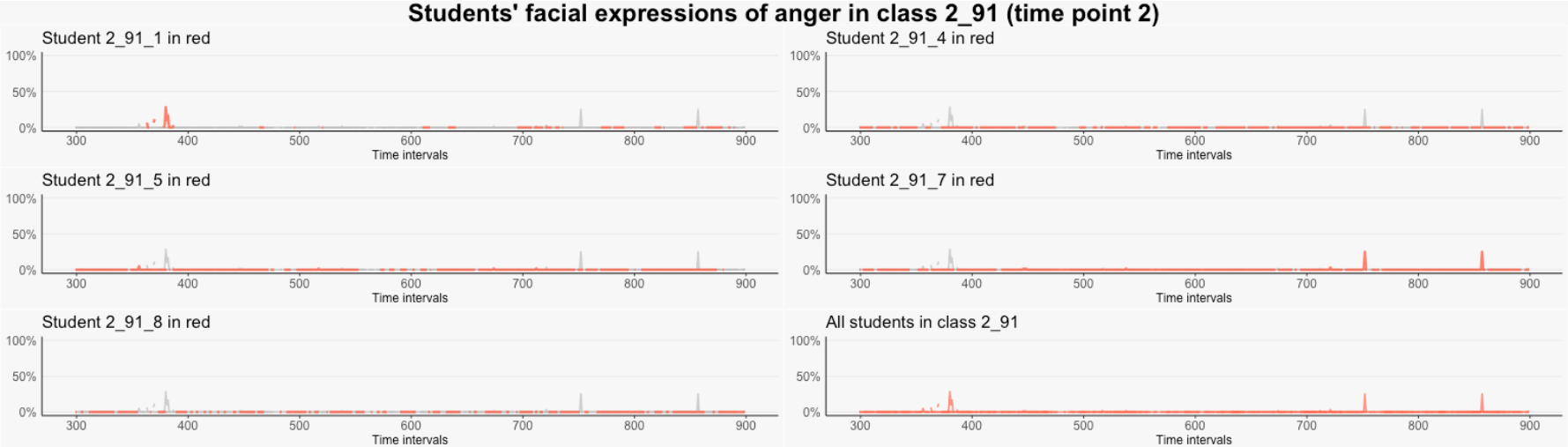

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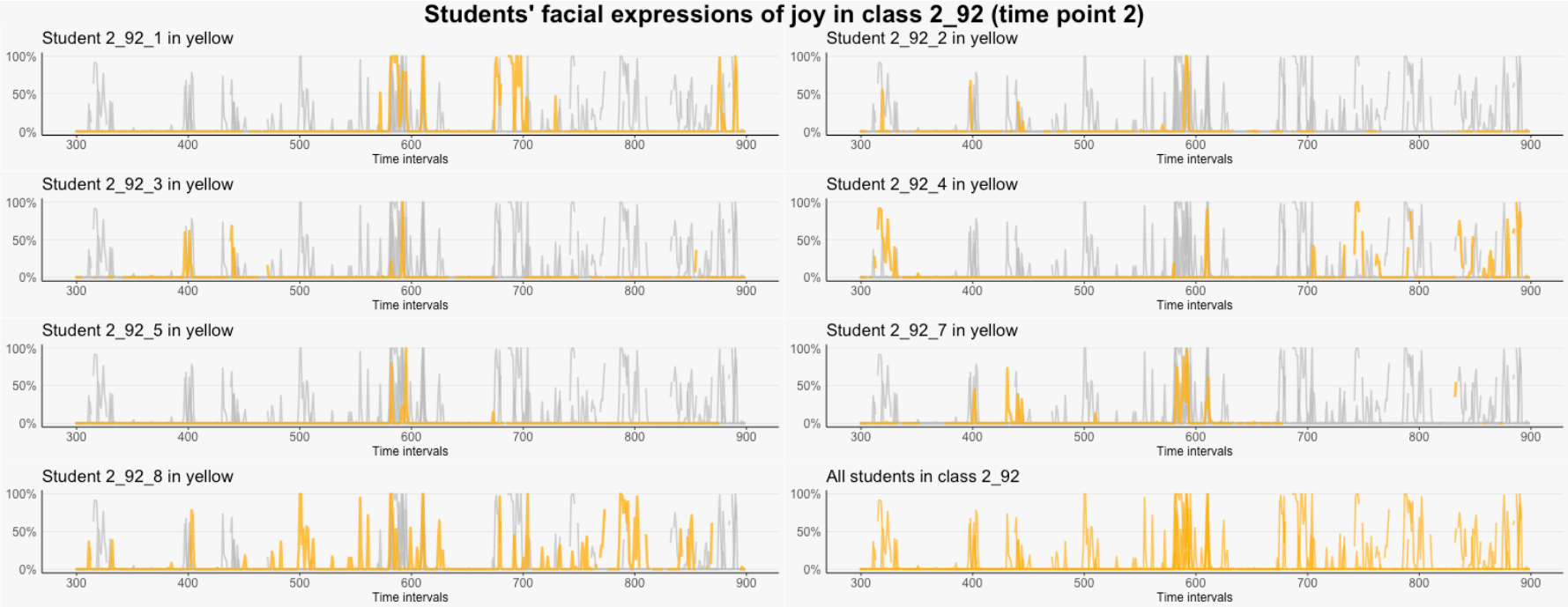

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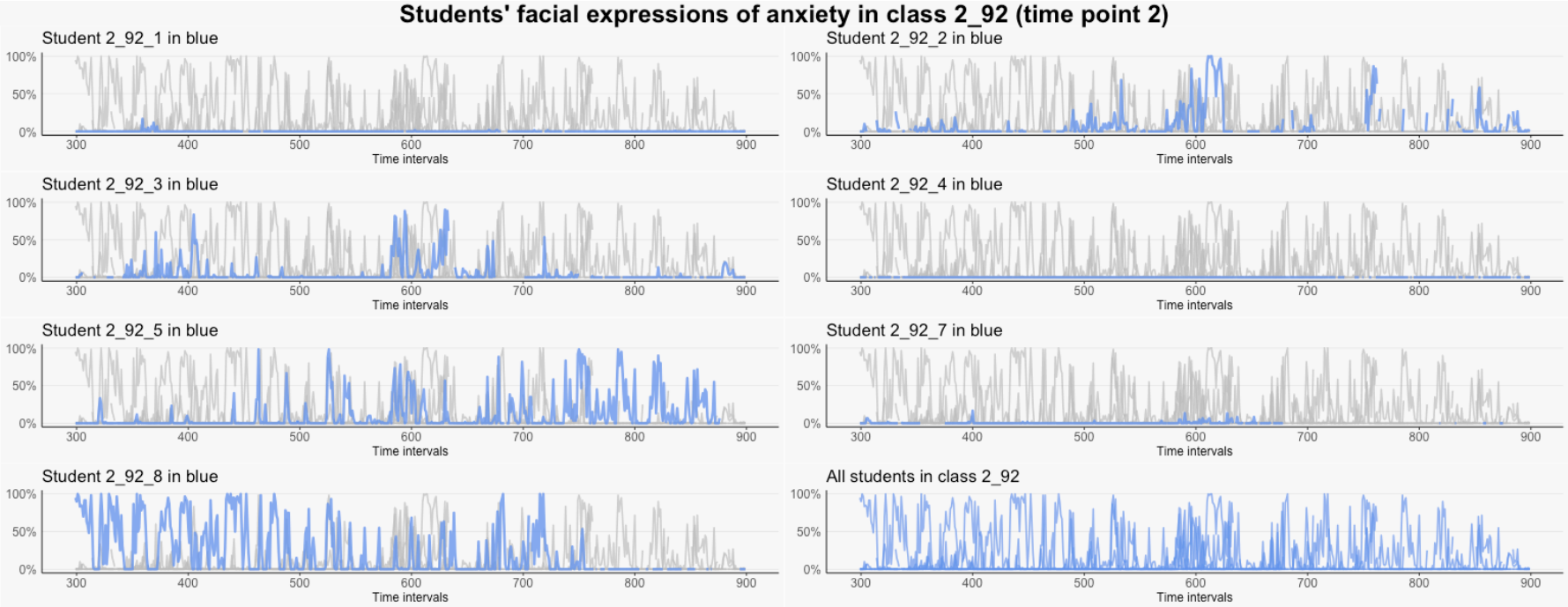

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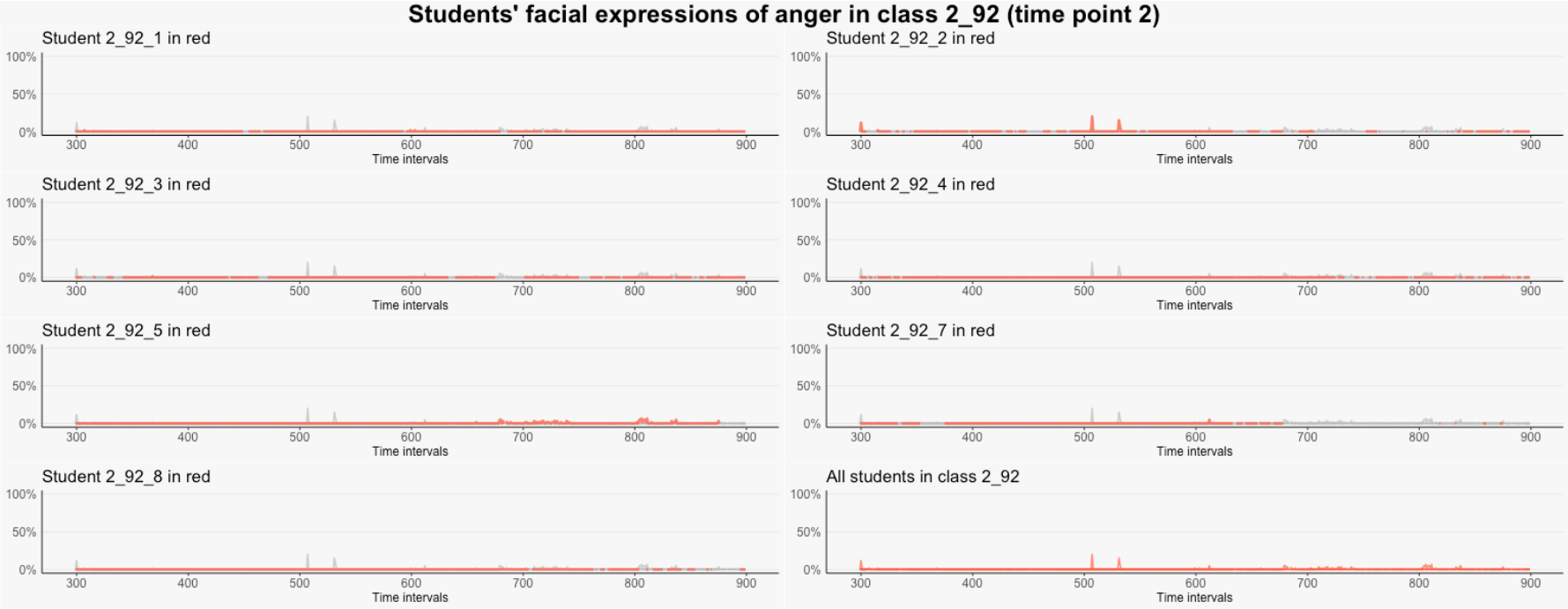

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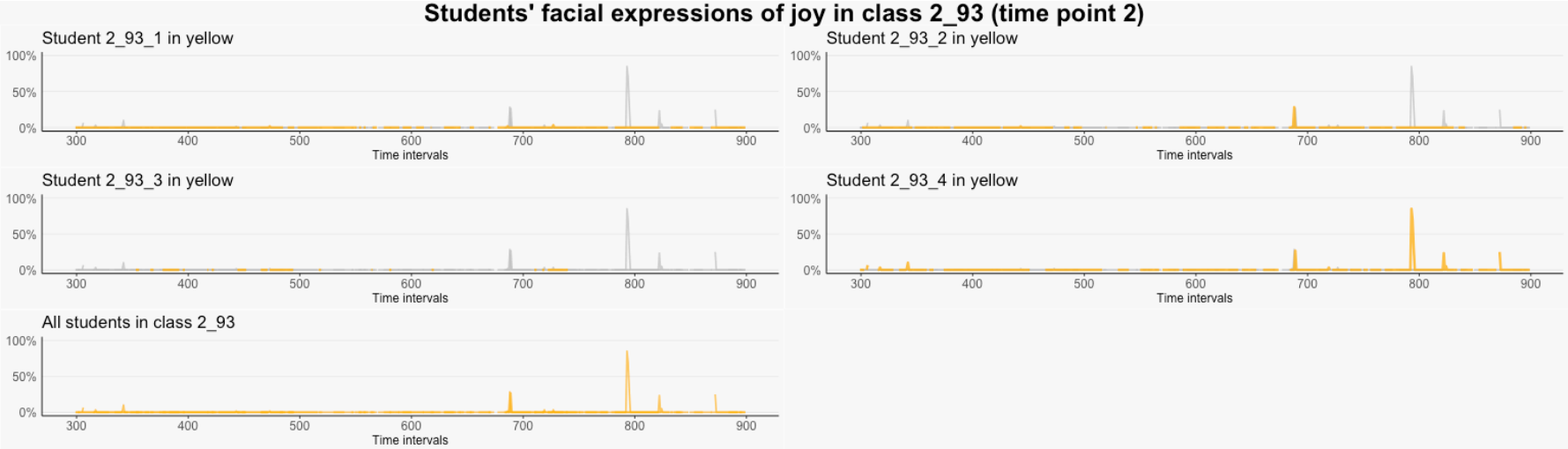

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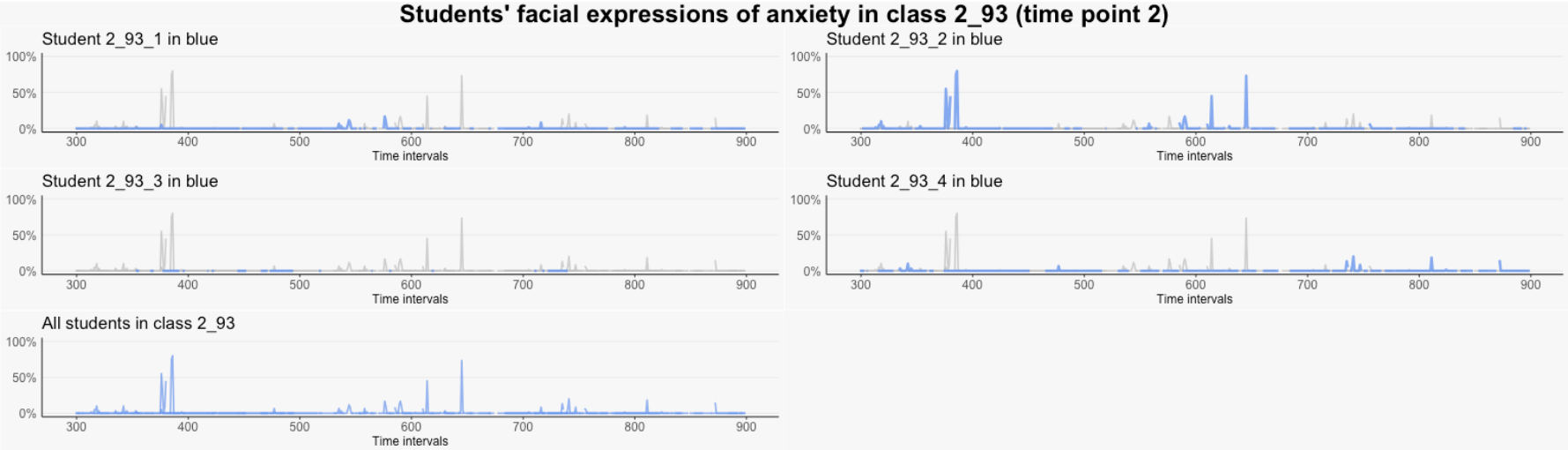

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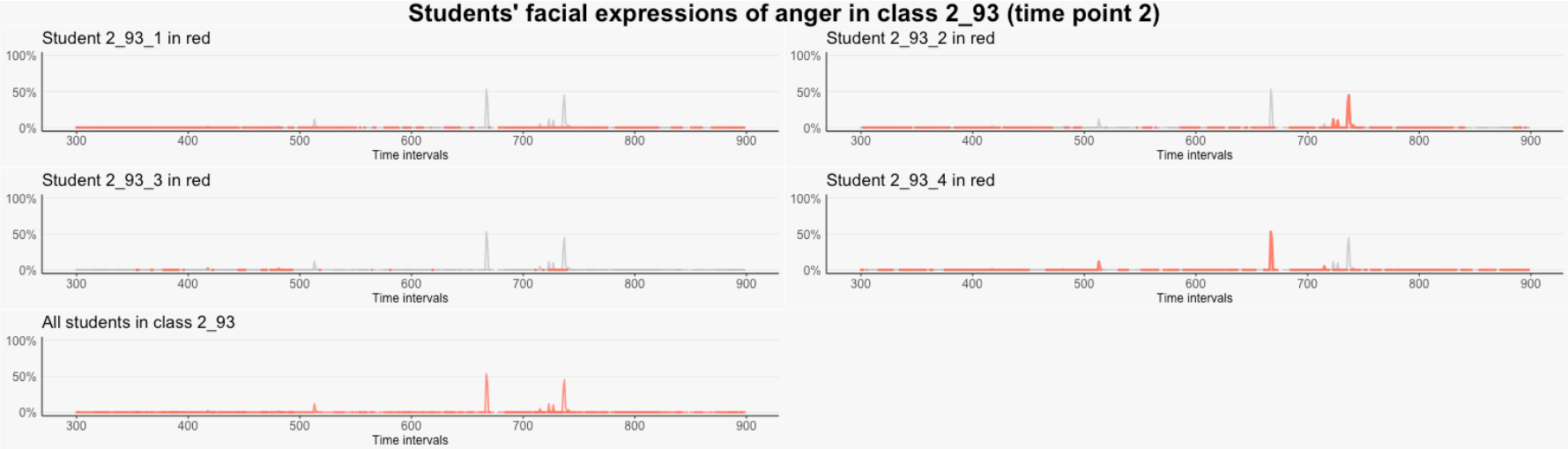

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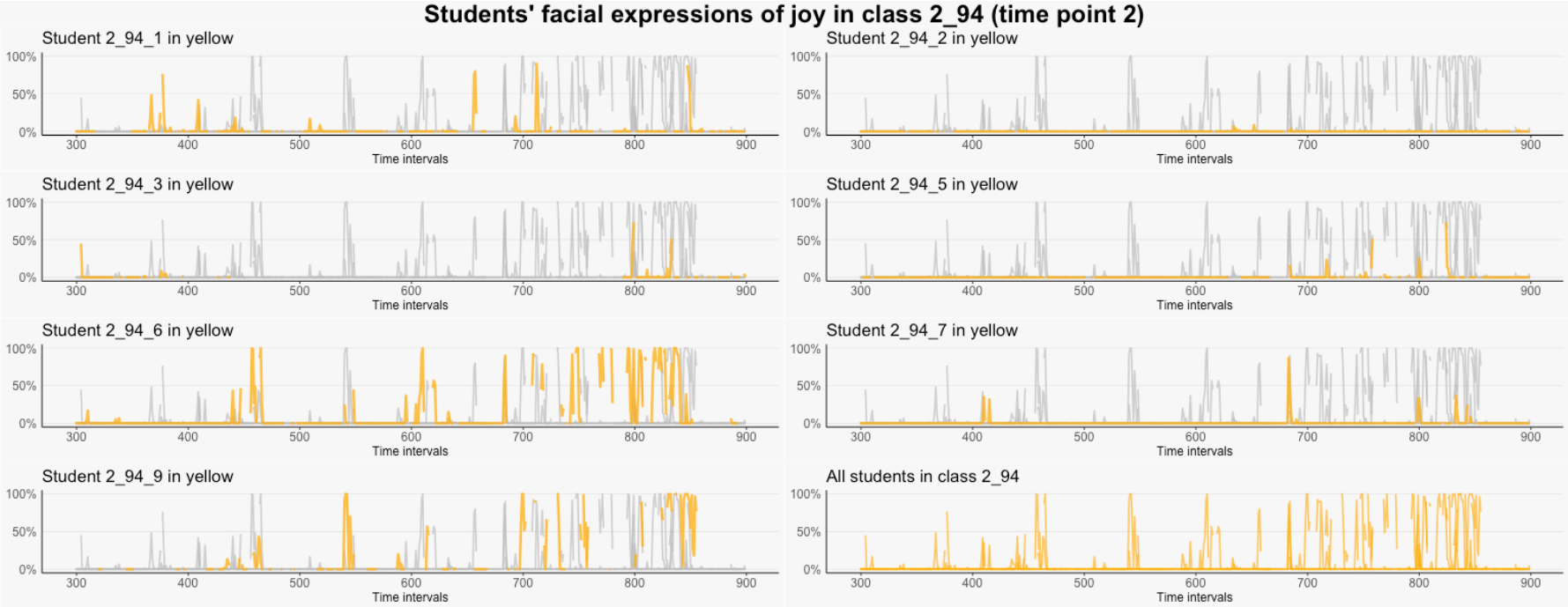

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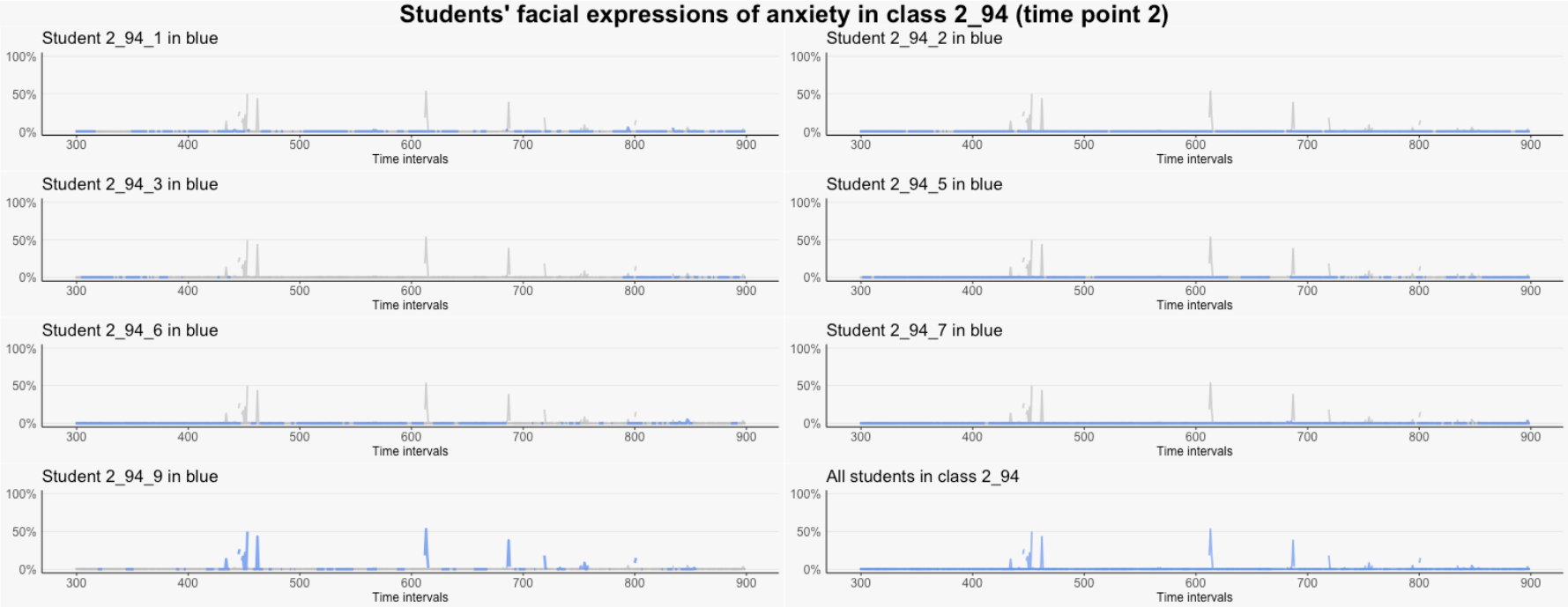

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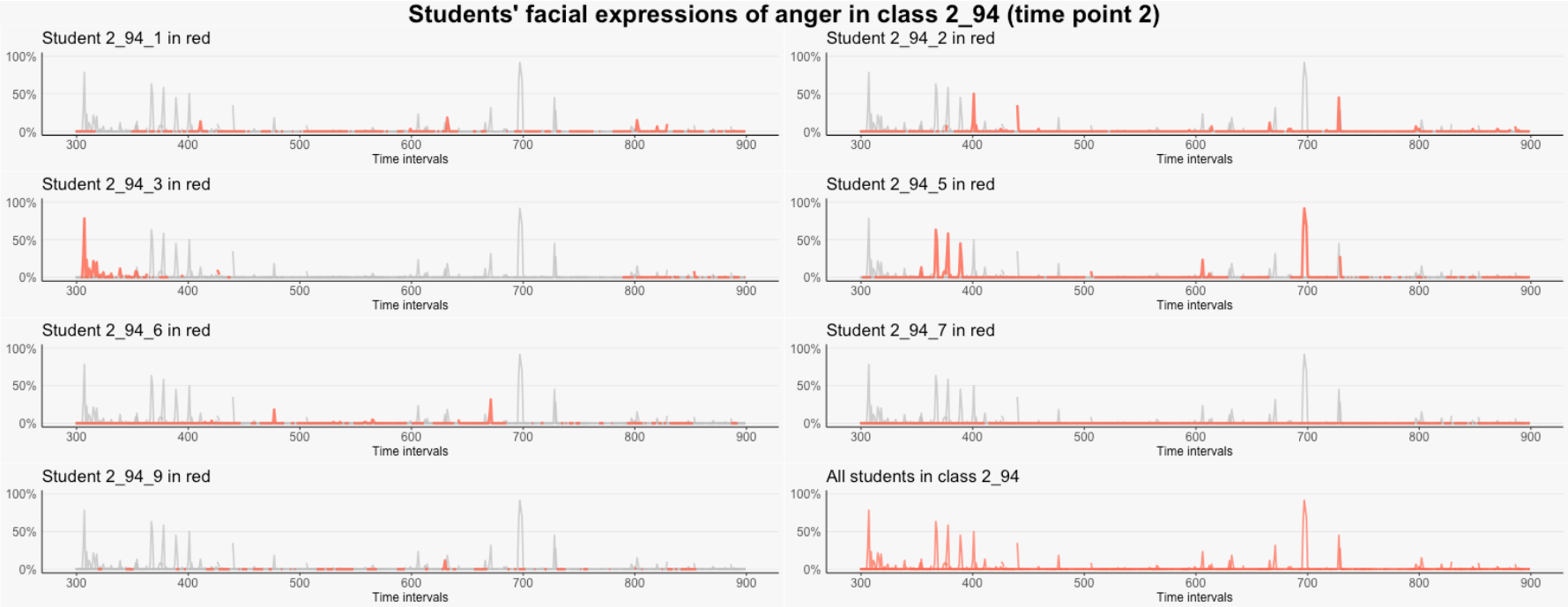

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Versicherung an Eides statt

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(gemäß § 8 Abs. 2 Nr. 4 Promotionsordnung für die Fakultäten 09, 10, 11, 12 und 13 (2016) vom 15. September 2016)

Name, Vorname(n): *Marx, Anton Karl Georg*

Hiermit versichere ich an Eides statt, dass die Dissertation

„Advancing Research on Emotional Contagion"

selbständig und ohne unerlaubte fremde Hilfe angefertigt und keine anderen, als die von mir angegebenen Schriften und Hilfsmittel benutzt wurden. Die den benutzten Werken wörtlich und inhaltlich entnommenen Stellen sind kenntlich gemacht.

München, 16.03.2020, Anton Karl Georg Marx

Ort, Datum, Unterschrift Doktorand/in