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KINEMATIC CHARACTERIZATION OF SPONTANEOUS AND POSED FACIAL EXPRESSIONS OF HAPPINESS AND SURPRISE

Kinematic characterization of spontaneous and posed facial expressions of happiness and surprise

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ABSTRACT

The relationship between emotions and facial expressions has been largely studied. However, most studies have focused on static and posed facial displays. Research on dynamic spontaneous facial expressions is still needed to understand how humans move their face to genuinely express emotion. Therefore, we conducted a study in which spontaneous and posed facial expressions of six basic emotions (happiness, sadness, anger, fear, disgust, and surprise), were recorded. Spontaneous facial expressions were recorded while participants watched emotion-eliciting videos, specifically selected to elicit the list of target emotions. Posed facial expressions, instead, were recorded while participants were instructed to reproduce a specific facial display while watching static pictures of that display. This thesis consists of an overview about emotion, facial expressions and measuring techniques, and a complete analysis and comparison of facial expressions of happiness and surprise. In particular, we considered the role played by the facial horizontal axis (i.e., the axis dividing the lower and upper parts of the face) in emotion expression. I found different dynamic properties between spontaneous and posed expressions for happiness and surprise. I also found that the upper and lower parts of the face are involved to different degrees in expressions of happiness and surprise. My study provides important evidence to overcome the bias introduced by research that for years has not considered spontaneous expressions or dynamic aspects, and further knowledge that is key for real life applications in clinical, security, and forensic fields.

" ...Facial movement of expression (which) impresses us through its changes, through its melody. The characteristic of the person will always be the way they move, the melody of the expression; this can never be caught in snapshots... "

(Sir Ernst Gombrich, cited by Jonathan Miller, 1983)

INTRODUCTION

The correspondence between emotions and facial expressions has been thoughtfully studied in the field for psychology (Namba et al., 2017). Both emotions and faces are key aspects in human's daily life. In fact, authors of Ancient Greece and Rome, like Aristoteles or Cicero, already noticed a relationship between the two and considered the face as a window into the human soul (which in the present days would also include the mind) (Barrett et al., 2019).

Human beings are a social species that continuously engage in complex interactions to survive and to maintain an appropriate daily life functioning. A dynamic exchange of information is required in social interactions to achieve a mutual understanding between people (Jack and Scyhns, 2015). The face is one of the most powerful tools in social communication, thus it is not surprising that humans are experts at identifying and getting information from faces practically from birth. Faces contain an incredible amount of information that an observer can decode apparently effortlessly in just a glance: gender, age, race, sexual orientation, physical health, attractiveness, emotions, personality traits, deception, social status (ibid., Jack and Scyhns, 2015). Humans can also transmit their own emotions or states to others through their facial expressions, body posture, voice, gestures, etc. In addition, faces are ubiquitous in our daily life: we have face to face conversations with people both in the real world or through computers and phones; we continuously take pictures of ourselves or the people around us, which we often send to others or print to put up in our homes; even when we are alone or not directly interacting with other human beings, we entertain ourselves with movies, series or by scrolling of other people's social media profiles.

However, the history of the study of emotions through facial expressions still carries the weight and influence of the beginnings of this field, which is the reason why so many studies still use or analyze static and posed faces. In addition, the dynamic properties of facial expressions, still need to be better understood, because the face, as a transmitter of multiple and complex social categories, comprises a high-dimensional, dynamic information space (ibid. Jack and Scyhns, 2015).

Therefore, in the present study the kinematic characteristics of both spontaneous and posed facial expressions of emotion, specifically of happiness and surprise, are analyzed. This approach is necessary to understand how humans spontaneously express emotion and also to reinterpret possibly biased results introduced by past studies that focused on posed expressions (Namba et al., 2017), and live up to the growing demand of assessing of emotions through facial displays, not only in the field of psychology and neuroscience, but also for clinical, security, forensic, and even commercial applications in industries such as artificial intelligence and entertainment (Parks et al., 2020).

The present thesis consists of a first chapter about emotion and the main different theories that try to explain and study this broad concept, that has created such controversy in the field of psychology. The second chapter consists of an overview about facial expressions of emotion, and addresses several key topics related to my research: the universality of facial expressions, the importance of their dynamic properties, the difference between spontaneous and posed displays, how facial expressions of emotion are produced and identified, and the concept of facial mimicry. The last two points of this chapter focus on the smile and on surprise, which are the two facial expressions that were further analyzed in this study. The third chapter addresses the main techniques used to study and measure facial expressions of emotion, and their respective pros and cons: electromyography, qualitative techniques, and quantitative techniques. In the fourth and last chapter, is presented the study carried out with kinematic analysis, in which different dynamic properties between spontaneous and posed expressions for happiness and surprise were found. Finally, in the discussion, some real-life and future applications of this study are briefly presented.

1. EMOTION

Emotions are fundamental to human life; they are key to adapt to the environment, to communicate, to learn and to maintain health (Kvajo, 2016). However, despite the importance of emotion in human functioning, scientists have been unable to reach a consensus on a definition or on the constructs underlying emotional phenomena and experiences (Gu et al., 2019).

The two main approaches of emotional studies have been based on two theories: Basic Emotional Theory (also called Natural Kind or Discrete Theory) and Dimensional Theory of Emotion (also referred to as Conceptual Construction Theory), that for years have been seen as contradictory and have sometimes been said to be in the *100-year war* (Lindquist et al., 2013). The main difference is the conceptualization of emotions as either discrete or independent entities. Both theories will be shortly presented, followed by an integrative theory, that proposes that these two theories are not necessarily incompatible (Fox, 2018; Gu et al., 2019).

1.1 BASIC EMOTION / NATURAL-KIND THEORY

Basic emotion theory proposes that human beings have a limited number of emotions that are basic both biologically and psychologically (Wilson-Mendenhall et al., 2013), and are manifested through patterns of organized and recurrent behavioral elements (Gu et al., 2019). Basic emotions have biological and social functions essential for evolution and adaptation (Izard, 2007) and therefore have been preserved to handle fundamental life situations or tasks (Gu et al., 2019). There are several hypotheses about the existing number of basic emotions, however in our study we adopted Ekman's (1992) 6 basic emotions (happiness, sadness, anger, fear, surprise, and disgust; see Figure 1), which he considered could be combined to form complex or secondary emotions.

The reasons to focus on these six basic emotion categories are mainly two: first, they represent common beliefs and, therefore, a clear and strong test about emotions and their expressions, and second, they have been the focus of years of research and provide the largest set of scientific evidence than can be analyzed and interpreted (Barrett et al., 2019). Lastly, production studies of spontaneous facial expressions, like our own, rarely include categories beyond these six. The choice of happiness, sadness, anger, fear, disgust, and surprise was therefore necessary to be able to make reliable, specific, robust, and generalizable conclusions, which is essential in this period of time in which these characteristics are closely judged in the psychological field (Barrett et al., 2019).

Figure 1. Ekman's facial expressions of 6 basic emotions. Top row from left to right: happiness, sadness, anger. Bottom row from left to right: fear, disgust, surprise.

Basic emotion categories are assumed to reflect natural kind categories when they elicit changes in cognition, judgement and perception, experience (i.e., recognition of an experienced emotion), behavior and physiology (Lindquist et al., 2013). In fact, human beings need the category labels of these emotions to communicate to other human beings a personal experience that might be key for social interaction or for survival (Izard, 2007).

In other words, in this view, emotions can prompt adaptive behaviors in whoever experiences them and when transmitted to others, the perception of someone else's emotional expression can elicit adaptive actions in the perceiver. Therefore, emotions can both be shaped by and shape social situations (Fox, 2018).

This is a stimulus-response approach of emotion, in which an external or internal process elicits an emotion, which consequently triggers a change in cognition, physiology, action or subjective experience (Lindquist et al., 2013). These changes or reactions caused by the emotion are thought to be independent from it, in fact they are thought to be the elements to objectively measure (i.e., heart rate, facial expressions, body movement, vocalizations, etc.) and to establish the presence of an emotion.

Natural kinds are considered so when specific instances share some common elements (analogy) or some common causal mechanism (homology) (Barrett, 2006). Thus, in this approach emotions are considered to be natural kinds because the specific reactions triggered by each discrete emotion category are hypothesized to appear in specific recurrent patterns and because even when the patterns of reactions differ, the emotions are thought to be triggered in specific situations (i.e., fear in a dangerous situation) (Lindquist et al., 2013). They exist in nature and should only be discovered or identified by humans, in fact basic emotions are assumed to be biologically primitive and therefore, to be present in animals and to be universal in humans, constituting the essential entities of emotional life (Lindquist et al., 2013).

Those who support this approach (like Ekman or Panksepp) and believe that emotion categories have real boundaries in nature, criticize that laboratory studies cannot trigger emotions intensely enough to have significant biological markers or changes, and that the methods to measure the reactions (face, body, nervous system, etc.) triggered by these 'blunted' emotions are not accurate enough to find the real way of expressing emotions. These scientists believe that better designed studies, more accurate measures, and more precise definitions of emotion might allow us to better understand what emotions are and how they are expressed (Barrett, 2012). Therefore, the importance of understanding the dynamic and temporal aspects of spontaneous facial expressions of emotions, which we addressed in our study, is shown again.

1.2 DIMENSIONAL / CONCEPTUAL CONSTRUCTION THEORY

The hypothesis that basic emotions are discrete and exist as natural kinds was compromised by the dimensional approach, which proposed that emotion was controlled by two independent dimensions: hedonic (pleasure-displeasure) and arousal (rest/low-activated/high). In fact, all emotions can be located in a circle called circumplex, with one axis for each dimension, that controls the position of each emotion on each quadrant, characterized by different amounts of hedonic and arousal properties (see Figure 2) (Russell, 1980; Russell and Barrett, 1999).

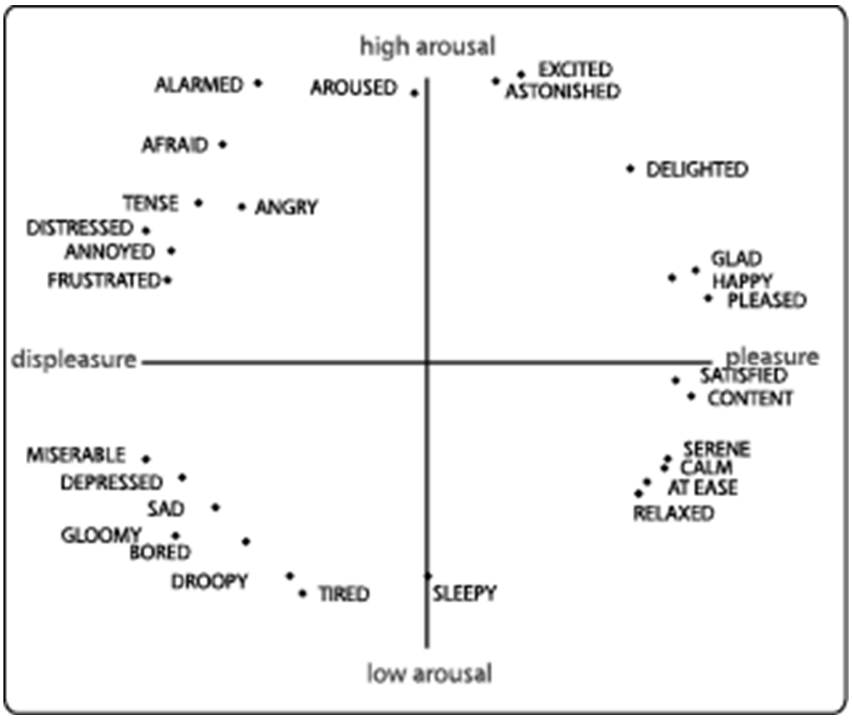


Figure 2. Russell, 1980. Circumplex of Emotions.

As a consequence of conceiving emotions like dimensional rather than discrete entities, this view questions the existence of emotions as natural kinds. From this approach, emotions are not considered as biologically and universally existing in nature, since language and categorization are assumed to shape emotion and its' experience (Russell and Barrett, 1999). Barrett further explains this hypothesis first in her "conceptual act theory" (Barrett, 2006) and later in the actualized "theory of constructed emotion" (Barrett, 2017), where she proposes that what humans perceive and experience as discrete emotions, rather than being biologically given, are conceptual constructions that emerge from our categorization of a more basic psychological process called 'core affect'. This background 'core affect' or mood is determined and experienced along the general dimensions of valence and arousal, and these states are then categorized into discrete emotion categories based on a cognitive appraisal of the current context (ibid. Fox, 2018).

Therefore, in this approach, emotions are thought to be constructed by basic psychological operations, unspecific to emotion, with which the brain interprets and makes sense of the information coming both from external world and internal subjective events and signals (Barrett, 2017). Evidence supporting this approach relies on the subjective experiences of emotions analyzed through self-reports and on neuroimaging studies that have shown that during emotional experiences of different emotion categories, several interacting brain regions, involved in both affective and non-affective functions, activate. This implies that discrete emotions cannot be pinpointed to localized brain areas (Lindquist et al., 2013).

1.3 INTEGRATIVE APPROACH

Discrete vs. Dimensional or Natural kinds vs. Constructivist approaches have confronted each other for years, however recently some researchers and theorists who consider that they are not necessarily contradictory, are trying to reconcile both points view by proposing integrative approaches (Fox, 2018; Gu et al., 2019). In fact, not only is the integration possible, but it should be necessary to fully understand emotional expression and experience (Fox, 2018).

One of the main differences between the two approaches is the consideration of emotions as discrete or dimensional entities. The dimensional approach proposes that each emotion has a different hedonic and arousal value and therefore a different 'core affect'. This core affects are key and present in every emotion, even the basic emotions, that the discrete approach considers separately from the others. In this perspective, all emotions can be located in the circumplex (see Figure 3), with the special characteristic of basic emotions being positioned on the axis of the dimensions and therefore, controlled by mainly one core affect, which might be an explanation for why they are considered basic (Gu et al., 2019).

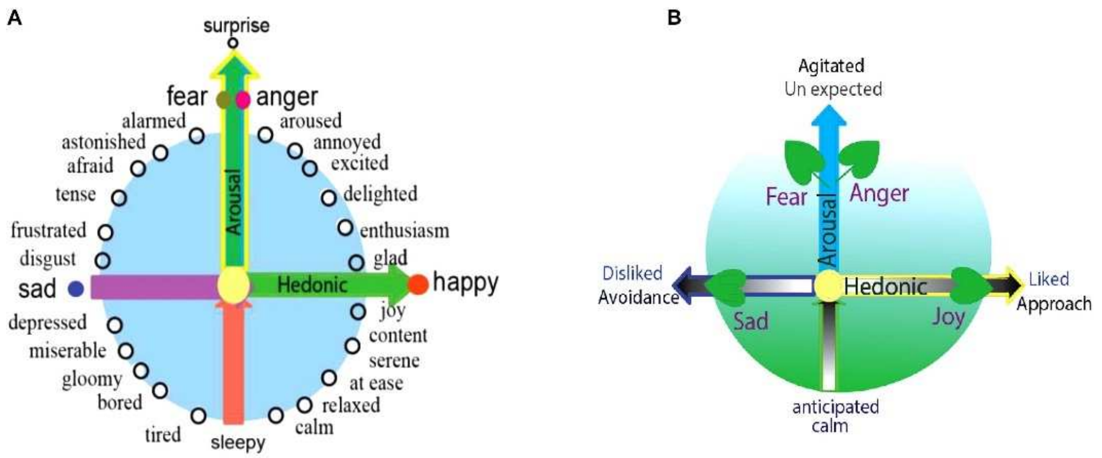


Figure 3. Gu et al., 2019. Integration of basic emotions in the circumplex. Panel A) All emotions, including the basic ones can find their place in the circumplex. Different emotions have specific arousal or hedonic properties, while basic emotions are determined by only one or the other type of property. Panel B) The behavioral responses evoked by the emotion can be approach (determined by hedonic value) and agitation (determined by arousal value), which vary depending on the expectedness and hedonic value of the stimuli that caused them.

This integrative approach, in which complex emotions surround the circumplex with basic emotions in its' axis, suggests that if basic emotions exist, there might be four, like proposed by Jack and colleagues (2014): fear-anger, which are determined mainly by the arousal and the safety value of the situation, and joy-sadness, which are influenced by the hedonic value of the context (Gu et al., 2019). The two remaining emotions that Ekman considered basic and that we used in our study are disgust and surprise. Disgust, which shares some facial characteristics with anger (wrinkled nose), and surprise, which has some similar facial characteristics to fear (raised eyebrows), are still very close or practically on the axis. However, their differences of disgust and surprise to anger and fear respectively, are hypothesized to have appeared later in evolution favoring social functions rather than survival (Mansourian et al., 2016, cited by Gu et al., 2019).

The other main difference in between these two approaches is the conception of emotions as natural reactions to the world or as psychological constructions of it. Fox (2018) proposes a model to reconcile both approaches. Basic emotions are thought to be biological, universal, and highly adaptive mechanisms that automatically and rapidly trigger specific actions or responses to react or adapt in a certain situation. In addition, they alter the background core affect or mood of an individual (on the dimensions of arousal and valence), which is what human beings are able to subjectively perceive. Fox (2018) proposes that humans cannot be consciously aware of the functioning and reactions of primitive emotional systems, however, the additional mood alteration induced by emotions can be detected and defined. Therefore, what is experienced and reported by humans are broad emotion categories or words (in line with the constructivist approach), however, underneath lay primitive and discrete emotion systems (natural-kinds approach) (Fox, 2018).

In Fox's words (ibid., 2018): "if the function of an emotion concept is to enable the categorization of sensory information using synchronized body and brain states that occur in a specific context to predict what is likely to happen next and to mobilize action plans, then the definition (…, of constructivists) seems very close to what other affective scientists – coming from a discrete emotions perspective – would call 'affective systems' (Panksepp, 1998) or 'emotions' (Izard, 2007; Scherer, 2005) or 'emotion states' (Adolphs, 2017)".

Finally, Barrett (2012) emphasizes the importance of asking the right questions in order to make progress in the study of emotion. Too vague or confusing questions like "are emotions real?” or “what are emotions?” have partly led to the confrontation and the division of opinions of theorists and scientists of the field. She proposes replacing these types of questions with others like “how do emotions become real?” which shift the focus on more precise and objective points of research like our own: the dynamic properties of facial expressions of emotion.

2. FACIAL EXPRESSIONS OF EMOTION

The ability to recognize faces seems to be one of the first competencies newborns have right after birth. It has been proposed that infants have a biologically determined preference for high contrast spatial configurations, which mediates the development of a very early facial recognition capacity. In the following months, this general capacity, tunes in so that babies become experts at identifying faces of those belonging to their same species and even race (Valenza and Turati, 2019). Early in life, infants are capable of distinguishing broad affect categories related to facial displays (positive or negative) and it is only later, with the acquisition of concept categories, that young children develop the ability to perceive and express discrete emotion categories from facial expressions (Barrett, 2006). This early attunement and expertise show the key role that faces play in human communication, socialization, and survival (Valenza and Turati, 2019).

However, facial expressions and emotions do not have a one-to-one correspondence; one facial expression can transmit several different emotions depending on the context and vice versa. Facial expressions and emotions do not have unidirectional relationship; they share a bidirectional link, since an emotion can evoke a facial expression, but like the facial feedback hypothesis (Laird, 1984) proposes, facial expressions can also evoke the emotion that they are linked to. The strong association that is established throughout experience, is the argument to explain this bidirectional relationship proposed by the embodied cognition approach, which considers the body to influence cognitive and affective processes through sensorimotor processes (Caruana e Borghi, 2013).

Despite this complex connection between emotions and facial expressions, which have a low referential specificity and informational value (Barrett, 2006), humans can easily and efficiently transmit and perceive emotions through facial displays. In fact, facial expressions play an important role in expressing internal emotions and intentions and are one of the most significant non-verbal ways in daily social interactions and communication of emotions. This information helps us navigate the world and guides our actions, emotions, and decisions (Barrett, 2017).

Nowadays, there is an increasing demand for improving performance in facial expression production and recognition, due to the broad set of its potential applications, such as clinical, security, human-computer interaction, and communication, even in real-time. (Nonis et al., 2019). However, facial expressions are not produced by all-or-non mechanisms. Instead, they are composed of highly dynamic and graded movements, creating patterns from which complex social or emotional meanings can be inferred (Jack et al., 2014). This, summed with the low informational value and referential specificity of facial expressions makes research on temporal dynamics, which cannot be consciously controlled, key for understanding how humans spontaneously transmit and decode information through the face and for the development of real-life applications (Barrett, 2006).

2.1 ARE FACIAL EXPRESSIONS OF EMOTION UNIVERSAL?

The different approaches of emotion that were presented in the previous chapter are at the basis of several other discussions that have been going on for years, like whether facial expressions are universal or specific to each culture. In 1872 Darwin proposed facial expressions of emotion to be universal. He argued that they probably developed to fulfill biologic and adaptive functions and thanks to evolution, facial expressions ended up being transmitted and inherited through generations in association to emotion. Some universalists like Tomkins (1962) believe that facial expressions are innate but learned cultural differences might be at the root of variability of expressions, and relativists like LaBarre (1947) and Birdwhistell (1970) have proposed that facial expressions are culture-specific, and that emotional state cannot have universal symbols.

The neuro-cultural theory proposed by Ekman (1972) considers both factors that influence facial expressions and contribute for universality and cultural differences respectively. He explained that:

- "Neuro": the universal (or at least partly) correspondence between a particular set of facial movements and basic emotions is due to a facial affect program, which can be activated quite automatically, due to its' biological and adaptive function.
- "Cultural": differences are due to the fact that the events that elicit emotions, the rules about how to control facial expressions in certain social contexts, and the consequences of emotional arousal and expressivity vary amongst cultures. These culture-related factors are learned and can contribute to the variability found in the facial expression of emotions.

Therefore, the study of facial expressions of emotion should consider that differences in expressivity of emotion might be due to the fact that a same situation can elicit different types of emotions in different cultures or contexts. This implies that it is not the facial expression of an emotion that varies, but the emotion elicited and experienced in a specific context that differs. In Ekman's words: "what is universal in facial expressions of emotion is the particular set of facial muscular movements triggered when a given emotion is elicited" (Ekman, pp. 216, 1972) even though cognitive processing, habits in facial movements, and expectations about the expression of emotion can alter the automatic universal muscular movements linked to an emotion.

There are several types of evidence that supports Ekman's view. The first set of evidence relies on cross-cultural studies (Ekman and Friesen, 1971; Frank and Stennett, 2001) which have shown the ability of members of a culture to recognize with a similar accuracy the facial expressions of basic emotions of members from a different culture. Some of the evidence comes from studies carried out on members of tribes that lived isolated and had barely been in contact with the rest of the world (like the Fore living in the mountains of Papua New Guinea, visited by Ekman, Sorenson, and Friesen in 1969), which further support the existence of universal facial expressions. The second set of evidence relies on studies carried out with participants that despite being congenitally blind and never having seen a human face, produce similar facial expressions to people who have (Galati et al., 1997; Matsumoto and Willingham,2009).

Nevertheless, and in line with the culture-related component of facial expressions proposed by Ekman himself, even if emotions can be recognized universally, there seems to be an in-group advantage, and therefore higher accuracy, when emotions are expressed and perceived by members of the same group (ethnic, national, and even regional). It also seems that the more group members are exposed or in contact with members of other groups, the lower is this advantage, probably because of familiarity or shared rules and habits (Elfenbein and Ambady, 2002).

In conclusion, Jack (2013) proposed that the modern human being presents a combination of some facial expressions of basic emotions that can be universally recognized, since they are linked to more primitive biological and adaptive functions, and more complex cultural-specific expressions of emotion that might have developed over time to fulfill a growing complexity of social interactions and new communication needs. Consequently, modern facial expressivity includes a set of primitive and universal signals that make the communication of some emotions possible across cultures and elements developed due to cultural diversification and further expertise (Jack, 2013).

2.2 DYNAMIC CHARACTERISTICS OF FACIAL EXPRESSIONS

Facial expressions are a highly dynamic set of changing configurations due to underlying muscle activity (Krumhuber et al., 2013). Specific patterns of facial movements evolved over time as a system to transmit and identify information key to support biological and social needs. Dynamic facial expressions of emotion sequentially and hierarchically transmit a series of signals that allow detecting emotions, creating a highly sophisticated communication system (Jack et al., 2014). The early phases of dynamic displays of facial expressions convey biologically basic information, linked to a few primitive categories like arousal and pleasure, while later stages include more complex information that allows identifying a series of socially specific emotions (Jack et al., 2014). In fact, Jack and colleagues (2014) proposed that the dynamics of facial expressions, in particular the confusions in the early stages between emotion categories (-happy, -sad, -fear and surprise, -disgust and anger), provide further evidence for the theory that the emotions and their related facial expressions that the modern human can produce and identify today, probably evolved from a simpler system of communication, with less emotion categories.

The dynamic properties embedded in the temporal sequence of facial movements, like their direction, quality, speed, and duration provide further diagnostic information about the sender and the context to the perceiver. Some key characteristics are the onset, which is the time from the start of a movement, like a smile, until its maximum intensity; the apex, which is the time duration before this peak intensity starts decreasing; and the offset, which is the time from the end of the apex until the facial display disappears (Krumhuber et al., 2007). These durations, together with distance changes of facial landmarks, allow calculating further parameters like velocities and accelerations.

These dynamic properties can help transmit and identify emotions, but also provide information about their authenticity, intensity, and a person's intention to act (Krumhuber et al., 2013). For example, in the case of smiles, shorter durations and more irregular onset actions have been associated with judgements of politeness (rather than amusement), and lower genuineness and spontaneity, while longer durations have showed increased verbal responsiveness in children and more favorable decisions or more cooperative choices in adults (ibid., Krumhuber et al., 2013).

Therefore, temporal dynamics of facial expressions provide information that is both useful to judge the subjective experience of emotions and to guide a perceiver's actions and intentions (Krumhuber et al., 2013).

In addition to the sequential and hierarchical transmission of signals dynamically in time, facial movements are asymmetrical, which refers to the differences in the expression intensity of the right or left side of the face due to hemispheric lateralization. The left side of the face seems more activated in emotional expressions since the right cerebral hemisphere appears to be more involved in emotional experiences. Furthermore, horizontal differences can be observed in upper and lower facial muscles, which seem to be controlled by independent motor regions in the brain, specifically during spontaneous facial expressions (Park et al., 2020). In fact, facial expressions appear to be organized behaviorally across the upper-lower hemiface and only secondarily across the right-left hemiface. (ibid., Ross et al., 2013).

2.3 SPONTANEOUS VS. POSED FACIAL EXPRESSIONS

Facial expressions are not an all-or-non phenomenon since they have a specific temporal dynamic and differences both on the vertical and horizontal hemifaces. They are also all-or-non, since they can be produced spontaneously or they can be posed, they can be genuine or they can be fake, and these are just poles of a spectrum, in which a great number of ways of expressing emotions can exist.

Most research differentiates facial expressions as spontaneous or posed depending on the way and the context in which they are produced. Posed facial expressions are those displayed intentionally by participants who pretend to transmit a specific emotion, while spontaneous facial expressions are those elicited by stimuli that contain certain emotional content and usually correspond to a more genuine emotional experience (Namba et al., 2017; Zloteanu and Krumhuber, 2021).

2.3.1 APPROACHES FOR STUDYING FACIAL EXPRESSIONS

The *appearance-based* approach, which focuses on the presence or absence of facial markers and dynamic properties, has been the most common used approach in expression authenticity research. In this approach strong assumptions based on preselected criteria are made on which facial expressions present elements that are representative of spontaneity or not. This approach allows clear and categorical judgements, however it is greatly observer-dependent and doesn't consider all the different options that an expression may contain, for example looking authentic but not being genuine (which can be the case of some posed expressions) (Zloteanu and Krumhuber, 2021).

The *elicitation-based* approach focuses on the methods used to elicit facial expressions rather than on the expressions and the facial appearance themselves. The focus is on the congruence between the eliciting stimulus and the observed behavior, which can present a big number of variations, differently from the previous approach in which a facial expression prototype is expected for each emotion. This approach is key in research interested in understanding the diversity of facial expressions of emotion, the influence of the context or specific factors, and that tries to mirror the emotional inferences made from facial expressions in real life (Zloteanu and Krumhuber, 2021). Therefore, it is the approach that was adopted in the present study since my goal was to understand the characteristics of spontaneous and genuine expressions of emotion, produced differently using two sets of stimuli and instructions.

2.3.2 POSED FACIAL EXPRESSIONS

Posed facial expressions are those displayed intentionally by a person who pretends to transmit a specific emotion (Namba et al., 2017). For example, a smile can happen genuinely when hearing a joke, seeing something pretty or feeling happy. However, people sometimes try to smile when they are feeling angry, scared, tired or embarrassed, to hide these rather unpleasant emotions in contexts in which they are either inappropriate or in which they could be an obstacle for a person's intentions or interests.

Ekman (1972) proposed that humans pose facial expressions based on the following four processes:

- Intensifying: amplifying or exaggerating facial expressions to match other people's expectations (e.g., exaggerating a smile when receiving a present).
- Desintensifying: minimizing or inhibiting facial expressions to maintain a favorable or positive context or relationship with other people (e.g., smiling less to disguise happiness or a positive mood when people around are not in the same positive state, for example when passing an exam when your friends haven't).

- Masking: replacing the facial expression of the emotion that is being experienced with a different one considered to be more appropriate or useful (e.g., smiling while feeling scared to not scare or worry others).
- Neutralizing: avoiding facial expressivity even though an emotion is being subjectively experienced (e.g., the so-called *poker face* during card games, to maintain the situation unknown for the opponent).

Differences between spontaneous and posed facial expressions could also be explained by people's ideas and representations about their own actions, which often represent stereotyped movements and behaviors that do not necessarily correspond to how they behave in real life (Robinson and Clore, 2002).

2.3.3 SPONTANEOUS FACIAL EXPRESSIONS

Spontaneous facial expressions are those elicited by stimuli that contain certain emotional content and usually correspond to a more genuine emotional experience (Namba et al., 2017). They are not uniform or fixed, instead, they are mosaic entities that have the potential for dynamically displaying over time motorically independent and graded expressions on the upper-lower and right-left face (ibid., Ross et al., 2019).

Spontaneous facial expressions developed to fulfill several functions key for evolution, therefore they should be characterized by certain elements that differentiate them from posed facial expressions of emotion. Ekman (2003) proposed four types of characteristics that can allow to identify a spontaneous expression of emotion:

- Morphology: it is thought that when a genuine emotion is experienced, the expression of this emotion cannot be totally inhibited or modified (Baker et al., 2016), since like Darwin (1872) already proposed, there are certain facial muscles that cannot be voluntarily controlled and consequently provide evidence of the emotion being experienced. These muscles that don't respond to conscious control were called "reliable facial muscles" by Ekman (2003), who considered them to be trustworthy signs of genuine facial expressions of emotion. For example, the *Zygomaticus Major* appears in both genuine and posed smiles, however the additional involvement of the *Orbicularis Oculi* usually provides a cue for genuine smiles.

- Symmetry: genuine expressions tend to be more asymmetrical than posed ones, which are voluntarily controlled. In fact, in human beings, facial expressions are mainly organized across the horizontal axis (upper and lower hemiface) and secondarily across the vertical axis (left and right hemiface) (Ross et al. 2013). Differences in between the upper and lower part of the face are more evident in spontaneous facial expressions (Park et al., 2020). This is due to the fact that motor control of spontaneous facial expressions depends on different motor regions for each horizontal hemisphere, M1 and vlPMC (located on the posterior-ventrolateral surface of the frontal lobes) for the lower region and M2, M3 and M4 (located on the posterior-medial surface of the frontal lobes) for the upper region of the face (Ross et al, 2019).
- Duration: genuine facial expressions tend to last from 0,5 to 6 seconds, consequently expressions that have shorter or longer durations tend to be posed.
- Onset: genuine expressions appear, evolve, and disappear gradually in a time span of a few seconds, while posed ones have more abrupt onsets and offsets.

However, in everyday life, people are not accurate at judging whether facial expressions are genuine or posed. This could be due either to the tendency of people to trust others and their expressions of emotion, since their nature relies in building trustworthiness that allows establishing a successful social interaction (Namba et al., 2018), or due to the inability to focus and process the signs that are useful to distinguish a genuine expression from a posed one (Bond and DePaulo, 2006; ten Brinke et al., 2019). In addition, most emotion research has used stimuli that present posed or static emotions (Namba et al., 2017; Zloteanu e Krumhuber, 2021), created by asking participants to move certain facial muscles without them knowing which emotion they were representing (e.g., Ekman and Friesen's FACS images from 1978) or by asking actors to express an emotion while thinking of a situation of their own life that made them feel like this and would help them represent it (Stanislavskij, 1938; 1957). The first types of stimuli are totally void of emotional content and the second type of stimuli, despite containing some emotional background, remain expressions produced by actors who are intentionally representing an emotion and therefore can only be considered semi-spontaneous (Barrett et al., 2019).

Therefore, creating a dataset of genuine facial expressions and analyzing the elements that characterize them, like temporal dynamics, is key to overcome the limits of emotion research and further develop our understanding of facial expressions of emotion. Some recent studies, like Snowden and colleagues' (2021) and our own, are trying to do so by using videos which have been shown to be able to elicit emotions, be ecologically valid stimuli and easy to apply (Gross e Levenson, 1995). A different approach uses artificially dynamized facial stimuli, by morphing neutral to emotional expressions (Calvo et al., 2018).

2.4 PRODUCTION OF FACIAL EXPRESSIONS OF EMOTION

Humans have 43 facial muscles (see Figure 4), with which they can produce up to 10.000 different expressions, making the human face one of the most powerful communicative tools our species has (Rinn, 1984).

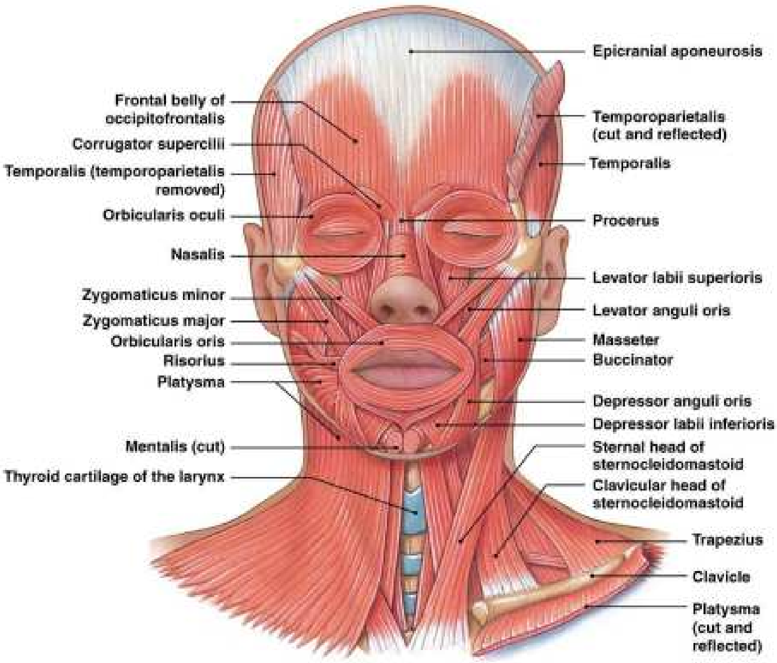


Figure 4. Martini et al., 2018. Facial Muscles.

The cranio-facial muscles that control facial expressions are innervated by two parallel effector systems, which are anatomically and functionally different (Tschiassny, 1953; Frank et al., 1993) (see Figure 5). The involuntary or extrapyramidal pathway sends motor projections from the subcortical areas of the brain (specifically, the ventral limbic system, the basal nuclei, and the hypothalamus) to the facial muscles that automatically produce facial expressions. The voluntary or pyramidal pathway sends projections from the motor areas of the posterior frontal lobe to facial muscles passing through the cerebellum.

The first pathway is involved in spontaneous facial expressions and the second one in posed expressions. The existence of these two different routes has also been proved at the clinical level due to the presence of double dissociations in patients with cerebral lesions (Tschiassny, 1953). Patients with unilateral facial paralysis caused by lesions in the descendant projections of the motor areas, are unable to voluntarily move the facial muscles of the contralateral hemiface of the lesion but are able to produce involuntary and symmetrical facial movements in response to emotional stimuli. The opposite pattern can be observed in patients with emotional facial paralysis: they can produce voluntary facial movements but are not able to spontaneously express emotions through the face (Tschiassny, 1953).

Movements controlled by the extrapyramidal motor pathway are synchronized, precise and symmetrical, while movements controlled by the pyramidal motor pathway are less characterized by these properties. This could be a possible explanation to the fact that some spontaneous facial expressions, like smiles, have a more fluid dynamic pattern with a lower onset and offset velocity compared to posed smiles (Frank et al., 1993).

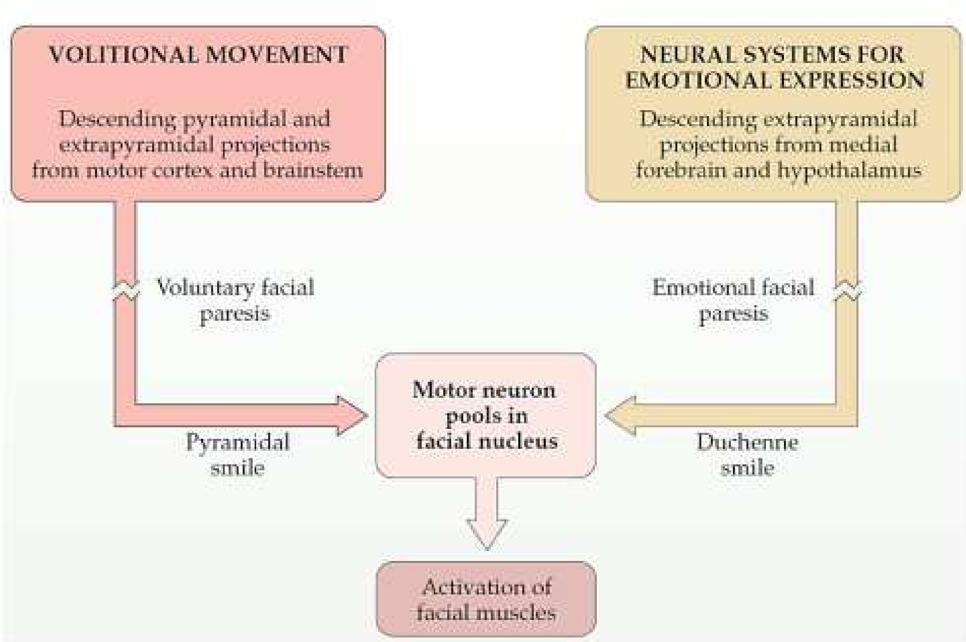


Figure 5. Purves, 2018. Two effector pathways and specific deficits related to each one of them.

2.5 RECOGNITION OF EMOTION IN FACIAL EXPRESSIONS

Recognizing emotions in facial displays is a very complex process, however people seem to do it effortlessly and automatically. Humans are constantly moving their faces, but somehow perceivers are not only able to discriminate certain movements and facial configurations but also to categorize them and attach a meaning to them (Barrett, 2019). This categorization might simply involve action identification, which is labeling facial movements (like a smile), or mentalizing, which involved inferring a mental state or situation that caused the actions (like a state of happiness) (Barrett, 2019).

A personal characteristic that has been closely linked to positive social interactions and therefore also to emotion recognition is empathy. Empathy, which is the capacity of sharing ("I feel what you feel"), called emotional empathy or empathic concern, and understanding ("I understand what you feel"), called cognitive empathy or perspective taking, the emotions of others (Seibt et al., 2015; Holland et al., 2021) allows not only to predict and understand others' emotions but also their motivations, intentions, and actions, facilitating the creation of affective bonds and pushing human beings towards social interaction and interpersonal solidarity, which would be the prosocial concern (Zaki and Ochsner, 2012) component of empathy that some authors consider (Vignemont and Jacob, 2012).

Self-report questionnaires are the most common technique to measure empathy. One of the most used batteries is the Interpersonal Reactivity Index (IRI) (Davis, 1980), which was the questionnaire used in the present study. IRI is composed of 28 questions to be answered on a 5-point Likert scale, that goes from "Doesn't describe me well" to "Describes me very well". Each question corresponds to one of the 4 sub-scales that compose the component of empathy (Davis, 1983):

- Perspective taking (PT): tendency to take the point of view of others. Example item: "I believe there are two sides to every issue, and I try to consider them both".
- Fantasy (FS): tendency to identify oneself with the feelings and actions of fictional characters of books or movies. Example item: "when I read an interesting book, I imagine how I would feel if the events of the story were happening to me".
- Empathic Concern (EC): evaluates the feelings of sympathy and worry towards others. Example item: "I often feel affected by things that happen".
- Personal Distress (PD): evaluates self-oriented feelings of stress or uneasiness in tense interpersonal interactions. Example item: "Finding myself in a tense emotional situation scares me".

PT and FS subscales measure the cognitive aspects of empathy, while EC and PD subscales measure the emotional aspects.

2.6 FACIAL MIMICRY

Faces are extremely important in social interactions, which is why humans have become such experts at decoding the information a facial expression can transmit. However, someone who perceives another person producing a facial expression doesn't do this passively. A perceiver actively makes inferences about the emotions or intentions of the other person and often involuntarily tends to reproduce their facial display. This tendency to imitate other people's facial expressions of emotion is called facial mimicry, which reflects humans' sensitivity to the emotional meaning of faces (Holland et al., 2021). The importance and power of facial mimicry is supported by studies that have found it to appear as early as in 5-month infants (Isomura and Nakano, 2016; Vacaru et al., 2019) and studies that have shown that facial mimicry can even be elicited by artificial agents, since quite simple gestures or expressions are enough to trigger it (Hofree et al., 2014)

Facial mimicry seems to be linked to empathy: people high in emotional empathy should be more likely to show facial mimicry, because they feel with the other, and because they are motivated to show their concern; on the other hand, facial mimicry may enable cognitive empathy, by working as a feedback mechanism about the other person's emotional state (ibid., Seibt et al., 2015). Although empathy is an important modulator of facial mimicry, there are several other factors that are important in social interactions that also play a role. They can be related to personal characteristics like attachment style, social anxiety, gender, and age; to the perceiver like the mood; to the relationship between people like familiarity, attitude, interdependence, or group membership; and to the information itself like modality (dynamic vs. static) or intensity of stimuli (Rymarczyk, 2016; Seibt et al., 2015).

A neural explanation of facial mimicry is provided by the mirror-neuron system (MNS), which is a set of brain regions activated both by the enactment and observation of motor actions (ibid., Holland et al., 2021). The MNS would activate that motor action representation in the perceiver, favoring its' physical movement through imitation, which could further elicit some subjective experience connected to that action, like the emotion of a facial expression. Therefore, the MNS mechanism provides evidence for the interpersonal sharing of emotional or other subjective experiences just by interacting with other people, and consequently, for understanding facial expressions or other actions (Holland et al., 2021). In fact, studies that blocked facial mimicry have shown participants to take longer in detecting when a facial expression of an emotion shifted to a different emotion category and participants to be less accurate at distinguishing genuine or not genuine smiles. These studies provide further evidence that facial mimicry facilitates the recognition of emotions in facial expressions (Krumhuber et al., 2013).

2.7 THE SMILE

Smiles are one of the most important human displays of emotion, in fact they appear very early in development and through the lifespan become one of the most common and key expressions for social interaction (Schmidt et al., 2003). A smile can be plainly thought of as a simple way to universally express happiness or joy, however smiles are much more complex (Niedenthal et al., 2010). They can happen in different contexts, serve different functions, and therefore have different configurations or dynamic properties.

The smile that is considered a universal expression of joy, is spontaneous and quick facial expression with upturned lip corners due to the contraction of the *Zygomaticus major* (Ekman, 1992). The *Orbicularis oculi* muscle, which is also called the Duchenne marker, causes a wrinkling of the skin around the eyes, and is considered a sign of an authentical smile or felt positive affect (Schmidt et al., 2003). According to the appearance-based approach, these are the main facial muscles involved in a smile, even though some others might be active while trying to modify or mask the appearance of a smile (Schmidt et al., 2003). In addition to this general morphological configuration, the elicitation-based approach and new study techniques consider spontaneous smiles as evolved social signs that share a consistent onset, offset, duration, and other dynamic properties (like velocities and accelerations). For example, it has been reported that a smile can appear as fast as 0,30 to 0,40 seconds after seeing another smile, that the smile onset can last up to 0,7 seconds, and that usually 3 to 4 seconds pass until a smile fades away (Schmidt et al., 2003).

These consistent properties, together with a stereotyped (upturned lip corners), redundant (around three smiles per minute during social interactions), and marked pattern of smiles, provide a reliable signal that is easily recognized across individuals and contexts, offering an efficient way of interpersonal communication (Schmidt et al., 2003). However, the diversity of appearance and dynamics of spontaneous smiles still requires a better understanding of a smile's properties and patterns, to determine what features or temporal parameters are key in transmitting information and how they variate in different contexts (Schmidt et al., 2003).

2.7.1 SPONTANEOUS VS. POSED SMILES

A spontaneous or authentic smile has been defined as an involuntary display of positive affect, while posed or *false* smiles have been defined as voluntary displays used to communicate that a positive emotion is being felt, even if it was not (in a social interaction or being asked to produce a specific expression) (ibid., Niedenthal et al., 2010).

Facial expression research has been mostly carried out focusing on morphological features, like the Duchenne marker. dynamic properties and differences between genuine and deliberate smiles (Zloteanu and Krumhuber, 2021). The Duchenne marker, which involves the *Orbicularis oculi*, the muscle around the eyes that causes the cheeks to lift, wrinkles around the eyes, and the eye opening to narrow, has been the morphological feature most frequently used to identify a true smile. Combined with the contraction of the *Zygomaticus major*, an experience of spontaneous and authentic positive affect is usually inferred (Niedenthal et al., 2010).

However, more recent evidence than Duchenne's studies (1862), has found that smiles with the Duchenne marker might not always be linked to self-reported enjoyment, that its' importance can vary with culture, and that it can be observed in situations in which a non-Duchenne smile would be expected (Niedenthal et al., 2010). Therefore, new research, focuses on dynamic features of smiles, like symmetry, smoothness, duration, and synchrony which has been found to be more accurate and efficient in understanding and judging smiles (Niedenthal et al., 2010).

The relative fast onset of spontaneous smiles may provide evidence for an automatic movement (upturn of the lip corners), which is programmed to reach a goal without interruption, leading to a progressive and stable course and a consistent link between the speed and the amplitude of the movement (Schmidt et al., 2003). In contrast, compared to spontaneous smiles, posed smiles seem to have shorter onset and offset durations, longer overall duration, and less smooth, more irregular, and rather abrupt movement patterns. They also seem to have less consistent temporal characteristics and be larger in amplitude, maybe because expressions are exaggerated since they are not actually experienced (Krumhuber et al., 2007).

These dynamic characteristics allow each smile to transmit a specific subjective experience, which can be identified by a perceiver, who can make different judgements and inferences of the smile itself and of the expresser (Krumhuber et al., 2007).

2.7.2 FUNCTIONS OF SMILES

Differences in smile dynamics and depending on the context could be due to the fact that smiles can serve different functions. Here we present the three types of smiles mainly reported by authors (Niedenthal et al., 2010; Rychlowska et al., 2017) according on their function and their meaning:

- Enjoyment or reward smiles are those that express happy or pleasurable feelings, and that have the function to reinforce the actions or situations that initially elicited them. Communicating positive emotion through smiles is key for learning and for encouraging desirable behaviors (Niedenthal et al., 2010).
- Affiliative smiles are those that express positive social motives and fulfill the function of establishing and maintaining social relationships, without necessarily being related to joy or pleasure. Some examples are smiling when greeting someone, when reconciling with someone or when feeling embarrassed (Niedenthal et al., 2010).
- Dominance smiles are those that reflect social status or control. For example, the smile related to the feeling of pride or to a defiant attitude, that communicate superiority (Niedenthal et al., 2010).

The function served by smiles is a factor that might influence not only the appearance but also the dynamic properties of the movement and should be considered in future research and real-life applications (Rychlowska et al., 2017).

2.7.3 FACIAL MIMICRY OF SMILES

Smiles are one of the most powerful social signs, one of the most common facial expressions seen in everyday interactions and one of the first expressions to be observed through development. Observing someone else smile automatically and rapidly triggers a smile in the perceiver. Seibt and colleagues (2015) pointed out several reasons for this strong facial mimicry of smiles, which can indicate happiness but also any other positive affect. First, genuine smiles are social rewarding and tend to evoke a return of the reward through mimicry. Second, smiles communicate a desire to establish a successful interaction that could be the basis for a meaningful interpersonal relationship and confirm the authenticity of the sender, consequently reinforcing affiliative motivation. And lastly, returning a smile, independently of doing it intentionally or not, doesn't cost anything and doesn't tie the sender to any compromise. In fact, returning a smile is so easy that human beings have developed the habit to do so in most situations (Seibt et al., 2015). Thus, since smiles are omnipresent, the focus of research should try to understand the specificities of smiles depending on their nature, context, and intention.

2.8 SURPRISE

Surprise is the emotion experienced when someone is confronted with an unexpected event or a schema-incongruent situation (Noordewier et al., 2016). Surprise is characterized by unexpectedness, which is inherently negative, since it reflects the inability to effectively predict or anticipate the future, which can be frustrating and risky. The valence of the surprise is only positive or negative once a person has made sense of the event after the initial surprise reaction (Noordewier et al., 2019). In our experiment, we had videos eliciting positive surprises.

The discrepancy between the expected and the real outcome or between a mental representation and an unfitting event can elicit the feeling of surprise (Noordewier et al., 2016). Behaviorally, surprise can show itself in several ways like the interruption or delay of ongoing motor activities; and orienting response, including bodily changes like slowing of heart rate and increase activity of sweat glands, and orienting of the sense organs to the surprising event; investigative activities such as visual search or questioning others; spontaneous vocalizations; and a characteristic facial expression consisting, in a full-blow form, of eyebrow-raising, eye-widening, and mouth-opening/jaw drop (ibid. Reisenzein, 2012).

Even though surprise is one of the six basic emotions and considered universal by some, the facial expression linked to it has been found particularly dissociated to the experience of emotion (Reisenzein et al., 2013). In fact, Reisenzein and colleagues (2006) found the full-blown facial expression of surprise consisting of raised eyebrows, widened eyes, and opened mouth/jaw drop, to be present in only 4-25% of participants (with variability depending on the study), even though the subjective reports and behavioral indicators suggested the presence of surprise. Furthermore, most of the observed expressions consisted of eyebrow raising only; the full, three-component display was never seen (ibid., Schützwhol and Reisenzein, 2012).

Surprise expressions are not only variable, depending on their authenticity, context, and on the intensity of the felt emotion, but based on past evidence, they are also weakly connected to the subjective experience of surprise. Therefore, research on the dynamic properties of spontaneous surprise expressions is key and still required to determine what elements are common or differ in between expressions and contexts, and ultimately better understand facial expressions of emotion in humans.

2.8.1 SPONTANEOUS VS. POSED SURPRISE

Facial expressions of surprise are mainly associated with eyebrow and eyelid movements, since the mouth opening of the stereotypical expression has rarely been found in relation to surprise (Schützwhol and Reisenzein, 2012; Namba et al., 2021). This upper face activation can be considered the main component of a spontaneous expression of surprise, since this part of the face is mainly activated by the subcortical system that controls spontaneous responses (Namba et al., 2021).

For years, research has used posed facial expressions of surprise rather than spontaneous ones. Recent evidence shows that spontaneous and posed expressions have different dynamic properties. In a study using deep learning-based tracking of facial landmarks, Namba and colleagues (2021) confirmed the key role of the movement of raising the eyebrows and eyelids both in spontaneous and posed expressions; found that posing surprise while mimicking another person's facial expressions, both eyebrows and eyelids move faster than in spontaneous conditions; and found the movement of eyelids and eyebrows to be more strongly coupled in posed expressions and more weakly coupled in spontaneous ones (Namba et al., 2021)

2.8.2 FUNCTIONS OF SURPRISE

According to cognitive consistency theories and personal control perspectives, human beings have the need for living in a predictable and coherent world (Noordewier et al., 2019). To fulfill these needs, people's actions, thoughts, and perceptions are largely controlled by schemas, which are complex and organized sets of theories or beliefs (ibid. Reisenzein et al., 2012). For schemas to fulfill their function, they must be approximately correct. However, since we don't know everything about the world and what we know might change, these schemas need to be constantly monitored and updated with new information (Reisenzein et al., 2017).

The cognitive-evolutionary model of surprise proposes that the surprise mechanism has a key role in this process (see Figure 6). In this view, surprise is an innate information processing mechanism that unconsciously compares new information with personal schemas about the world. A discrepancy between an existing schema and an ongoing event is unexpected, and if the discrepancy is intense enough, a surprise reaction occurs (Reisenzein et al., 2017). The feeling of surprise elicits the interruption of the ongoing processing of information and the reallocation of processing resources to the unexpected event, allowing a further analysis, and if needed, an immediate reaction or an update of the schema that unconsciously caused the feeling of surprise (Reisenzein et al., 2017).

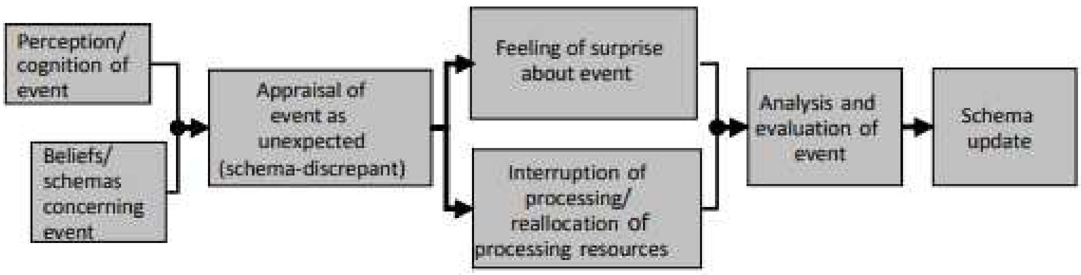


Figure 6. Reisenzein et al. (2012). A Cognitive-Evolutionary Model of Surprise.

2.8.3 FACIAL MIMICRY OF SURPRISE

Surprise appears to be an emotion and a facial expression more related to personal survival than to interpersonal affiliative interests or desires, like smiles. Facial mimicry seems to be closely related to empathy and to play a key role in understanding others' emotions and even sharing or feeling them, through emotional contagion (Olszanowski et al., 2019). Therefore, facial mimicry, which is considered by some as a valid signal of desire for affiliation (Kavanagh et al., 2016), is likely to occur more consistently in facial expressions if emotion with affiliative or social functions, like happiness. In fact, facial mimicry occurs more consistently in the presence of an audience (Barrett, 2006). This statement is in line with the scientific evidence (Reisenzein et al., 2006) that has found a dissociation between subjectively feeling surprised and expressing or mimicking it through the face.

However, mimicry is also considered to be caused by a learning process that helps to produce appropriate physical and emotional responses to relevant social situations (ibid., Kavanagh et al., 2016). In fact, intentional imitation is one of the most important ways to learn about and interiorize something (from riding a bike, to speaking, to a whole culture), and it usually involves acquiring actions and skills, associated with nonverbal communication and emotion. Since both the learning process and the outcomes are implicit, the tendency to mimic can be difficultly controlled or inhibited (Kavanagh et al., 2016). This proposal would explain the facial mimicry of expressions like surprise, that seemingly do not serve a social function.

3. STUDYING FACIAL EXPRESSIONS OF EMOTION: METHODS AND TECHNIQUES

The face of a healthy human being has 34 muscle groups, 17 on each side, that can be contracted and relaxed in different ways. Sometimes these movements can be visible to the naked eye due to changes in position or distance between facial features or due to wrinkling or change in color of the skin. However, facial movements or specific details about them are cannot always be perceived by the naked eye, due to individual differences in carrying out a facial movement, or because they are too subtle, like the dynamic components (velocity, acceleration, angle, duration, etc.) (Barret et al. 2019).

Furthermore, facial movements should be measured in conjunction with the subjective emotional experience of the participants, to confirm the type of emotion or mood that they feel while viewing a video eliciting a specific target emotion and a specific facial expression (Namba et al., 2017). According to Barrett and colleagues (2019) there are different ways to measure the emotional state of a person (see Figure 7):

- Subjective measures: consist of the feelings and impressions of participants who report them in self-report questionnaires, of judgements of external observers, blind to the condition who infer the emotion experienced by participants, or of researchers themselves who base their judgements on specific criteria to identify emotional experiences.
- Behavioral measures: consist in analyzing the changes that happen in facial expressions, vocalizations, body movements or gestures.
- Objective measures: consist in analyzing changes of physiological indices like electric and hemodynamic activity of the brain, heart rate, blood pressure, respiratory volume and/or rate, body temperature, skin conductance, etc.

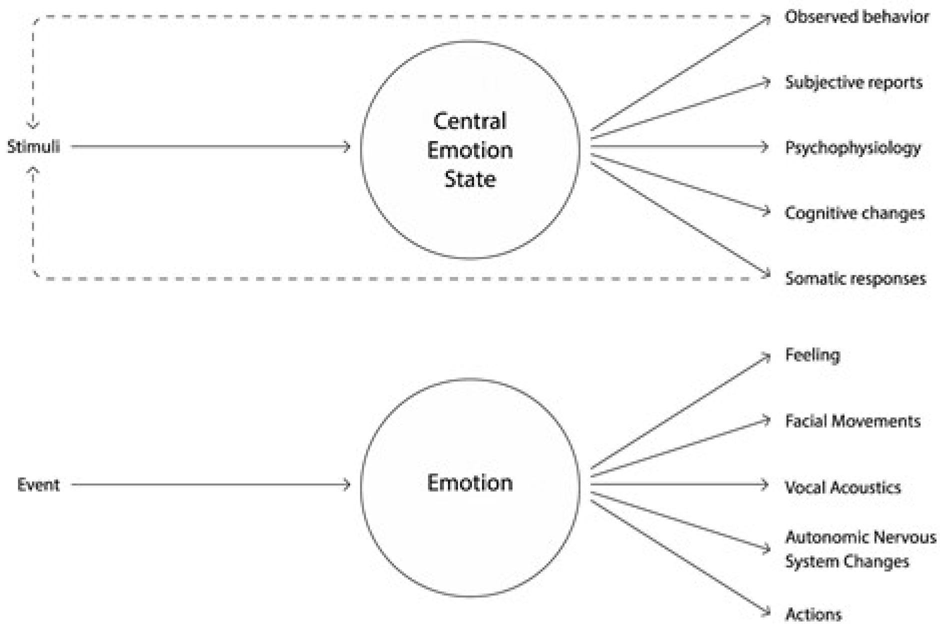


Figure 7. Barrett, 2017.Top: Adapted from Anderson and Adolphs (2014). Bottom: Adapted from Barrett (2006).

In our study we implemented one measure of each type, since in addition to recording changes of facial movements (behavioral measure), which was the main goal of the experiment, we recorded the heart rate with an electrocardiogram (objective measure) and the participants' self-reports of their emotional experience (subjective measure). The different ways in which facial movements can be studied in a scientific experiment, which are mainly three, will be presented: electromyogram, qualitative techniques, and quantitative techniques.

3.1 ELECTROMYOGRAPHY

Electromyography (EMG) is a technique that measures the muscle's electrical activity related to facial movements and can thus be used to study facial expressions. EMG can measure facial movements that are not visible to the naked eye and independent both to the perceiver and to the participant's subjective emotional experience, or even when facial expression is not necessarily congruent to the perceived or expressed emotion. Despite being the most objective and sensitive measure of facial movements, it is rarely used due to its impracticality (Barrett et al., 2019). EMG requires placing electrodes on participants' faces (limited positions, see Figure 8), which is technically complex, uncomfortable for the participants, and thus, inappropriate for measuring facial expressions in naturalistic or everyday life situation (Wolf, 2015). In fact, a review done by Barrett (2019) showed the scarceness of published articles that reported using facial EMG and the limited number of muscles that had been studied in non-ecological contexts.

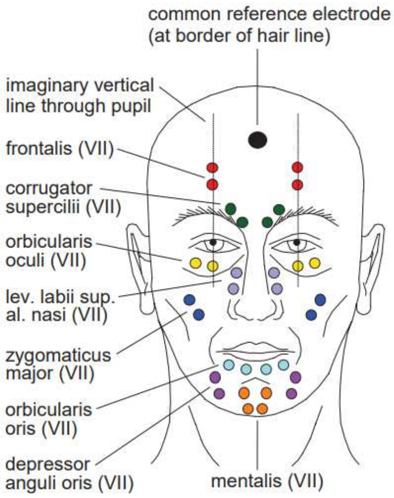


Figure 8. Van Boxten (2010). Electrode locations for measuring EMG activity.

3.2 QUALITATIVE TECHNIQUES

Qualitative techniques are based on a visual analysis of facial muscles and configurations. These techniques use videos or pictures that are analyzed by experts of a specific coding system or through computer methods like analysis of facial features or facial textures. The most known and used qualitative technique is Facial Action Coding System (FACS), (Ekman and Friesen, 1978). FACS is a systematic approach based on muscle contractions and anatomy to describe visible facial movements, which are called action units (AUs) (Namba et al. 2017). There are a total of 46 AUs, which presence and intensity is evaluated, and which are coded and analyzed as independent elements and hypothesized to correspond to a specific facial configuration, which consequently corresponds to a specific emotional experience (Barrett et al., 2019) (see Figure 9). For example, the movement of the *zygomaticus major* muscle to pull the lip corners up (AU12) and the contraction of the *orbicularis oculi* which wrinkles the skin around the eyes, diminishes the eye-opening and raises the cheeks, are the AUs involved in a smile, which imply the feeling of happiness (Namba et al., 2017).

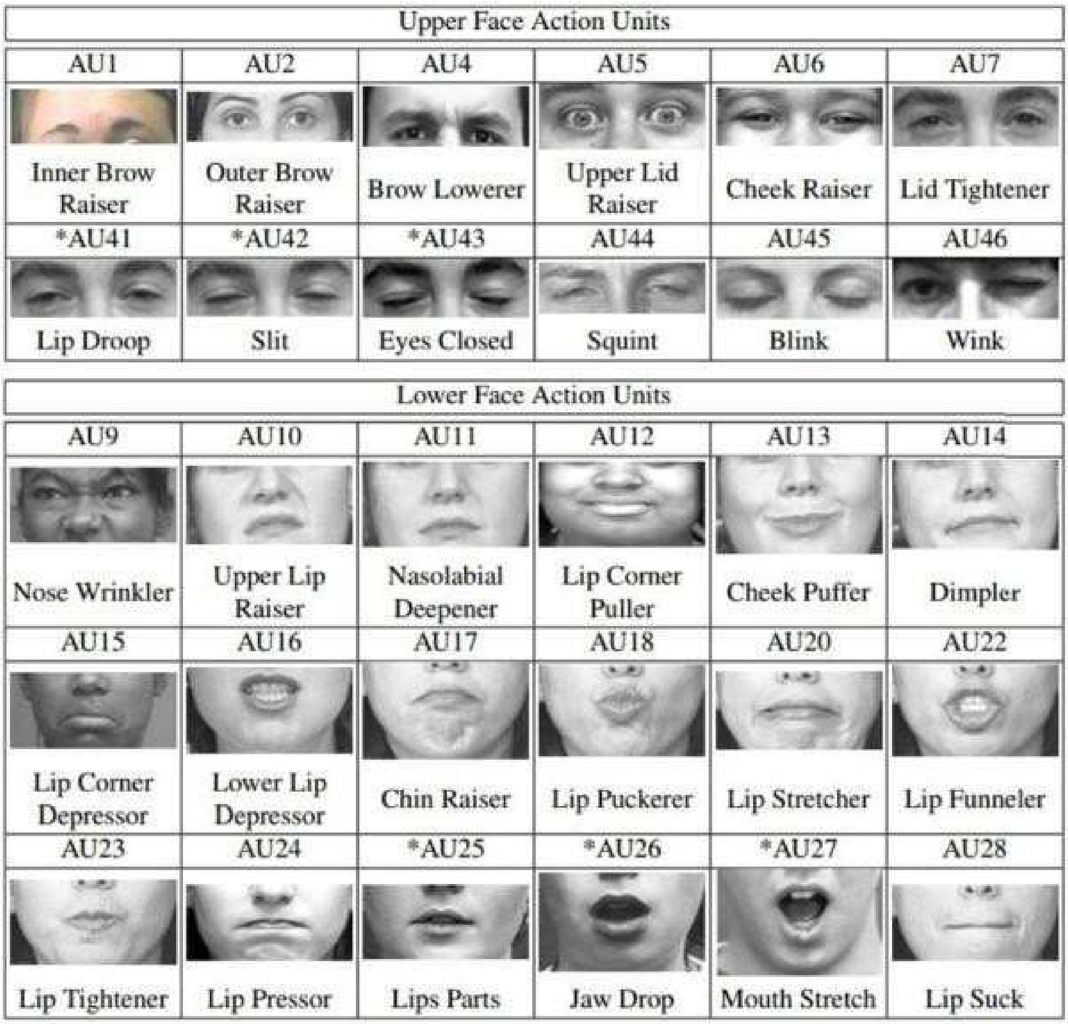


Figure 9. Action units (AUs) of FACS (Ekman and Friesen, 1978)

FACS is a complex perceiver-dependent method that requires an intense and specific training for human coders to identify the presence or absence of facial movement while viewing videos or pictures of participants (Barrett et al., 2019). It is a slow process, since several weeks are required for the training of the experts and the amount of time needed to decode a video depends on the complexity and quantity of the facial expressions present in a video.

To address this issue, automated FACS algorithms for some AUs have been developed using computer-vision systems. These automated algorithms are slightly more accurate than human coders, which reach an inter-judge accuracy of 80% compared to 90% of computers. However, the accuracy of algorithms drops when used to analyze everyday life facial configurations, which are not stereotypical or controlled. Even though these algorithms still need to be fully developed, they present a much more practical option for the future, since they can be also used with human judges to speed up the process of studying facial expressions in everyday life (Barrett et al., 2019).

However, this technique focuses on stereotypical categories and facial configurations, leaving out important aspects of facial movements, like dynamics, that can be key in better understanding facial expressions (Namba et al., 2017).

3.3 QUANTITATIVE TECHNIQUES

Quantitative techniques allow the study of facial dynamics, which are a key aspect of facial expressions, and therefore for expressing and recognizing emotion (Sowden et al., 2021). Temporal and spatial patterns of facial expressions of emotion can be studied with kinematic analysis or machine learning techniques. Quantitative techniques can detect and analyze movement not visible to the naked eye. They thus present the advantage of providing specific information that could not be picked up by humans otherwise.

3.3.1 KINEMATIC ANALYSIS

Kinematic analysis is the study of movement independently of the internal and external forces that cause it (Castiello, 1995). The most typical kinematic parameters of the face and body include speed, acceleration, angle, distances, etc. which are highly correlated.

The first kinematic analysis where very rudimentary and consisted of a series of photographs each representing a sequence of an action. From these first chronophotographic studies, technology has helped to progressively developed more sophisticated methodologies to study kinematics, like cinematography, television, or multiple exposure techniques (Bonfiglioli and Castiello, 2005). Optoelectronic techniques, bring together optics and electronics, to study movement by placing on the participant reflective markers, that can be active or passive. The movement of these markers is then picked up by a series of cameras connected to a computer (Popat et al., 2009). These "marker-based tracking systems" are one of the newest and most used techniques. In fact, a passive marker tracking system was the technique used in the present thesis research.

- Passive marker-based systems: use markers (up to 35, with diameter ranging from 2 to 10 mm) that reflect infrared light that is generated by cameras surrounding the participant. The cameras can be adjusted so they only pick up the light reflected by the markers (although shiny or metallic material should be avoided, since it could create confounding reflections). Each marker's 3D location in space is later calculated by an algorithm that coordinates the different positions recorded by cameras (minimum of 2), that are previously calibrated based on a known space reference system (Popat et al., 2009).

- Active marker-based systems: used markers that are connected to LEDs, producing their own infrared signal, which is then used to calculate the position of the marker by a computer. The advantage of these systems is that each marker is recognized as a single entity, which gives a continuous and instantaneous signal of the movement, minimizing the post-processing of landmark positions. However, differently from passive markers, active markers have to be connected to a power source through wires, that can be uncomfortable for the participant and could introduce biased data (Popat et al., 2009).

Marker-based systems are simple to apply and quite comfortable for the participants, due to the markers' small size (invisible to the participants once they are placed on their face) and to the fact that the skin fast gets desensitized to the friction of the adhesive material. New marker free techniques are being developed to try to cancel the small error introduced by changes in the placement of landmarks in between sessions (Popat et al., 2009). These techniques can allow more specific analyses of facial movement and characterization of specific facial movement profiles. However, the implementation and use of these computerized systems is much more complex and requires further development to be able to apply them in regular experimental settings.

3.3.2 MACHINE LEARNING

Machine learning is a field that through statistics and artificial intelligence, uses computational algorithms to create usable models out of empirical data (Edgar and Manz, 2017). These systems have the capacity to learn from problem specific training data to solve associated tasks by using an automated built analytical model (Janiesch et al., 2021).

Facial Expression Recognition (FER) is a computer-based technology that analyzes faces of videos or pictures based on mathematical algorithms, which perform the analysis following three steps: face detection, facial landmark detection and facial expression and emotion classification (Nonis et al., 2019). The last step studies the movement of facial features to classify them into attitude or emotion categories, which shows the importance of better understanding and studying the dynamics of the face with techniques like kinematics. This automatic process has a lot of potential since it could analyze not only facial expressions to recognize emotion, but also data from verbal expression, body movement, gestures, or physiological indices.

Face recognition research and systems can focus on 2D or 3D data of the face. Systems that work on 2D images of the face, fail to solve difficult problems due to changes in position or illumination, which can be overcome by 3D approaches. Using both models conjunctly makes 2D + 3D multi-modal FER a promising approach for real-life applications (Nonis et al., 2019).

Deep learning algorithms, which are a type of machine learning technique, are being applied in the past years. Some of the most used models are Convolutional Neural Networks (CNN) and the Recurrent Neural Networks (RNN) (Nonis et al., 2019). Much research is being carried out on this field, but deep learning still has a long range of development, since compared to machine learning it requires a larger amount of labeled data and processing power (Nonis et al., 2019). However, this presents an advantage in facial expression recognition and emotion classification tasks. Human beings can move their faces and show their feelings in very different ways or contexts, thus, the big amount of data that can be processed by deep-learning algorithms' makes it a much more powerful and efficient tool to solve this task.

4. RESEARCH

4.1 RESEARCH GOAL

Most past studies on facial emotional expressions have been based on posed or acted static facial displays, like the faces from FACS. Even new and powerful techniques like machine learning base most of their learning and classification processes on FACS, therefore maintaining the bias that these static and posed faces might introduce.

However, understanding the relationship between facial expressions and experienced emotions, requires the study of spontaneous facial expressions under controlled circumstances and the measurement of the dynamic aspects of facial movements together with the participants subjective experience of specific emotion (Namba et al., 2017).

Therefore, the present experiment and thesis have the goal to study the patterns and differences in between spontaneous and posed facial expressions of emotion through kinematic analysis, focusing on six basic emotion types (happiness, sadness, fear, anger, disgust, and surprise), and on happiness and surprise for a further the analysis, of facial movements.

4.2 METHODS

4.2.1 PARTICIPANTS

30 university students (21 females and 9 males, M_{age} = 23, SD = 2.155, range = 19-29) voluntarily participated in this study. They were all native or bilingual Italian speakers with normal or corrected-to-normal (glasses or lenses) vision and presented no evidence of neurological or psychiatric conditions. The experiment was approved by the Ethics Committee of the University of Padua (No 4539) in accordance with the declaration of Helsinki (Sixth revision, 2008). All participants signed their written informed consent prior to the beginning of the experimental session.

The experiment was carried out in the months of November and December 2021 in the Laboratory of Kinematic Analysis of the University of Padua, Department of General Psychology, respecting the security rules and indications to contain the epidemiologic COVID-19 crisis.

4.2.2 MATERIAL AND SETTING

A 15-inch screened computer was used to carry out the experiment, constructed on E-Prime. A webcam, centered to record the faces of participants, was placed on top of the main screen, and connected to a laptop that was hidden behind the setting and not visible to the participants.

A high precision infrared optoelectronic system was used to record the kinematics of facial expressions. The system used, called SMART-DX© (BTS Bioengineering Corp.), consists of:

- 6 infrared cameras placed in a semicircle at about 1 meter distance and in front of the sitting position of the participants.
- 8 passive reflective semispherical-shaped markers with a diameter of 6 mm and one 3 mm diameter marker, positioned manually by the experimenter on the participants face by using double-sided single use stickers appropriate for the skin.

Figure 10. Experimental Setting.

The infrared reflection of the markers is recorded as a bright point by the six cameras, allowing the system to construct a 3D image by combining the 2D images from each single camera through a triangulation procedure. In this way, the three-dimensional position of each marker in any point of time can be reconstructed.

A system calibration, in which the six cameras are synchronized and other parameters (like brightness, orientation, position, etc.) are set, is performed before each session, or set of sessions. The calibration steps to obtain an optimal data acquisition are:

1. Setting of the cameras. Position, angle, zoom, focus, brightness, and threshold are set. These parameters were determined at the beginning of the experiment and stayed constant throughout all participants.
2. Static Calibration (or Axis Sequence). An orthogonal tern, which is a structure consisting of three carbon fiber bars, is positioned in the center of the space, approximately where the participant will be sitting. Each of the three bars, has several spheric markers located in pre-defined positions, to establish a global cartesian reference system.
3. Dynamic Calibration (or Wand Sequence). The y axes bar is extracted from the orthogonal tern, obtaining a wand with three spheric markers located at a known distance the one from the other. The wand is moved inside the area of interest for the experiment, to establish the total volume of space in which the participant will eventually move and to re-calculate with higher precision the parameters calculated during the static calibration.

This allows a correct 3D estimation and reconstruction of the position and of the movements of the reflective markers located in the participant's face and registered simultaneously by at least two infrared cameras.

4.2.3 STIMULI

The videos used in this experiment were selected in a previous study done on Qualtrics, in which participants rated a total of 50 videos. The ones with the highest scores for each emotion were kept, for a total of 18 videos, 3 for each target emotion. The duration of the videos was from 15 to 59 seconds (M = 45 seconds). The duration of each trial was standardized to 60 seconds by adding a gray screen at the end of each video until the first rating scale appeared.

Many other emotion-elicitation techniques exist and have been used in previous studies, like exposure to emotional slides, music, pictures, autobiographical recollection, mental imagery, facial or respiratory feedback, real-life techniques, etc. (Schaefer et al. 2010; Sowden et al. 2021). However, throughout the years, videos have been the technique most widely used as stimuli to study the relationship between facial expressions and emotions. They present several advantages in the laboratory setting: they are simple to apply, they can elicit strong subjective and physiological changes, and their dynamic nature provides a good artificial model of reality, without the ethical and practical problems of other methods (Gross and Levenson, 1995; Schaefer et al. 2010).

Several well-known video-sets used in previous studies for emotion induction may be outdated or be extracted from movie scenes, presenting actors who do not express emotions in a spontaneous manner but act them out instead. Therefore, for our study, contemporary videos picked out from the internet or from TV, all containing sound and enough context to understand the situation presented. The face is clearly visible in all videos, which is key for emotion recognition in others and later in oneself.

4.2.4 PROCEDURE

After positioning the markers on participants' faces (see Figure 11), they were seated in front of the computer screen and the surrounding cameras. Participant's facial expressions and (upper body movement) were recorded during two conditions in the following order:

1. Spontaneous: participants watched a total of 18 emotion-induction videos (3 for each target emotion, duration: 15-59 seconds), which were previously selected and validated. The mean duration of the videos for each target emotion was: 48.67s happiness, 42.7s surprise, 43.7s sadness, 51s anger, 43.7s fear, and 38.3s disgust.
2. Posed: participants watched six Ekman pictures of faces corresponding to the six target emotions and imitated the facial expression following the instruction to move from neutral to peak facial expression and back to neutral until the face disappeared from the screen (1 minute).

The order of recording condition, first spontaneous and then posed (to avoid possible bias due to posed facial expressions), was the same for all participants. The order of emotions was pseudorandomized for the spontaneous condition (6 order sequences were possible, and in none of them the same emotion appeared in sequence) and randomized for the posed condition.

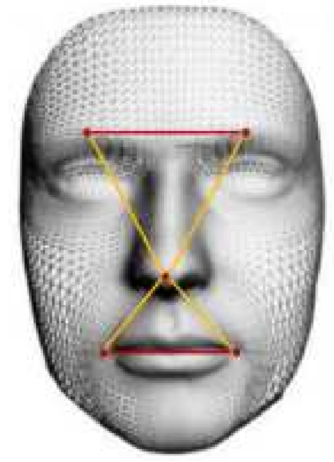
Position Marker	Description	
Middle Eyebrow (eyeb)	Middle point of the eyebrow (right and left)	
Cheilion (ch)	Mouth commissures, angle between the lips (right and left)	
Nose tip	Nose tip (reference point)	

Figure 11. Marker Position.

Each video / picture was followed by rating scales (see Appendix, Figures 1-3), where like in Sowden et al. (2021), participants were required to answer, in the following order:

- Arousal level (calm / activated).
- Valence (positive / negative).
- Emotion level: how happy, angry, sad, disgusted, surprised, and fearful they felt (thus rating the target emotion and all the other target emotions).

The scoring was made on 9-point Likert scale, where 1 indicated not at all and 9 indicated very much. In the spontaneous condition, after these scales, an additional question was added in which participants had to answer whether they had seen or not that video before (to control for possible familiarity effects). The instructions changed depending on the condition, asking how they felt while watching the video in the spontaneous condition and how they felt while reproducing the facial expression in the posed condition.

Throughout the whole duration of the experiment, participants remained seated but could move and react freely and had no other constraints set by the experimenter.

4.2.4 KINEMATIC DATA PROCESSING

The optoelectronic SMART-DX© system is equipped with several computerized software that are adapted for each phase of the kinematic data processing:

- SMART-DX Capture© software: used in the data acquisition phase allows the calibration of the telecameras and acquisition of kinematic data in real time.

- SMART-DX Tracker© software: raw data is reconstructed three dimensionally. In this phase, each marker is assigned a specific trajectory (3D tracking), and each trajectory is given a name (labelling), based on a 3D model previously created (see Figure 12). Specifically in this experiment, the face of the participant and the 3D positions of markers throughout time have been reconstructed.
- SMART-DX Analyzer© software: used for the processing and analysis of the data of interest. In this phase, an analysis protocol specifically constructed for the 3D model and for the data is applied, allowing the calculation of specific kinematic parameters: distances, angles, speeds accelerations, setting of events of interest, duration of movement, etc. (see Figures 12 - 15).

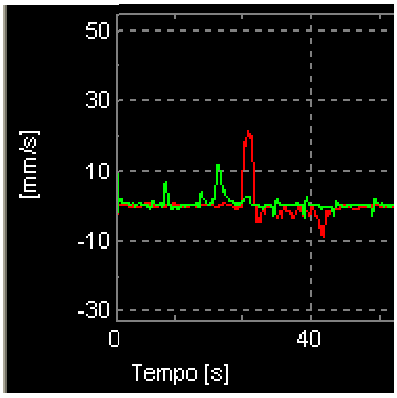


Figure 12. Time sequence Surprise (**curves**: green-eyebrows, red-mouth)

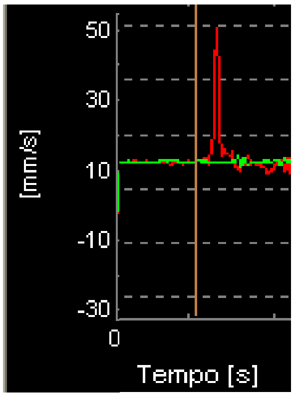


Figure 13. Time sequence Happiness (**curves**: green-eyebrows, red-mouth)

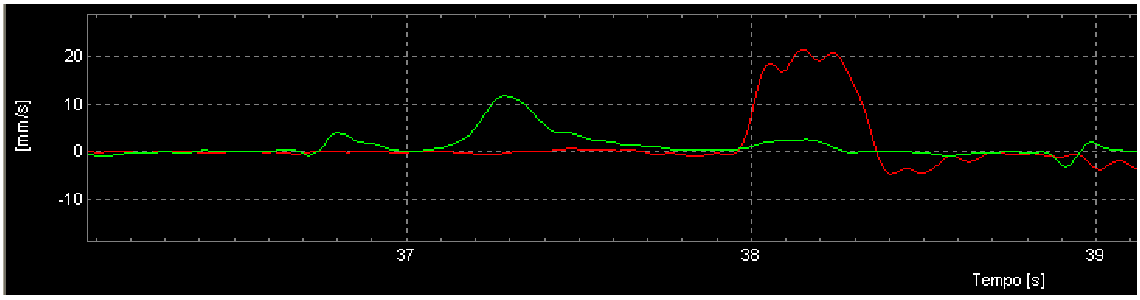


Figure 14. Zoomed Time sequence Surprise (**curves**: green-eyebrows, red-mouth)

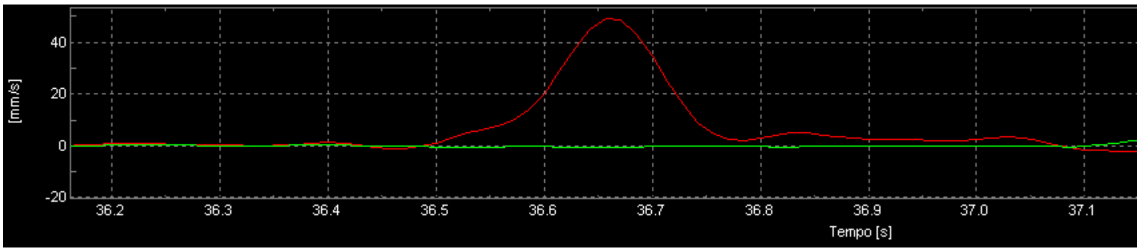


Figure 15. Zoomed Time sequence Happiness (**curves**: green-eyebrows, red-mouth)

Our 3D model and protocol to perform kinematic analysis of facial expressions of happiness and surprise were done considering markers on the corner of the lips (Rch and Lch) and in the middle point of the eyebrows (Reyeb and Leyeb), which are the most relevant points for expressing these emotions (see Figure 16).

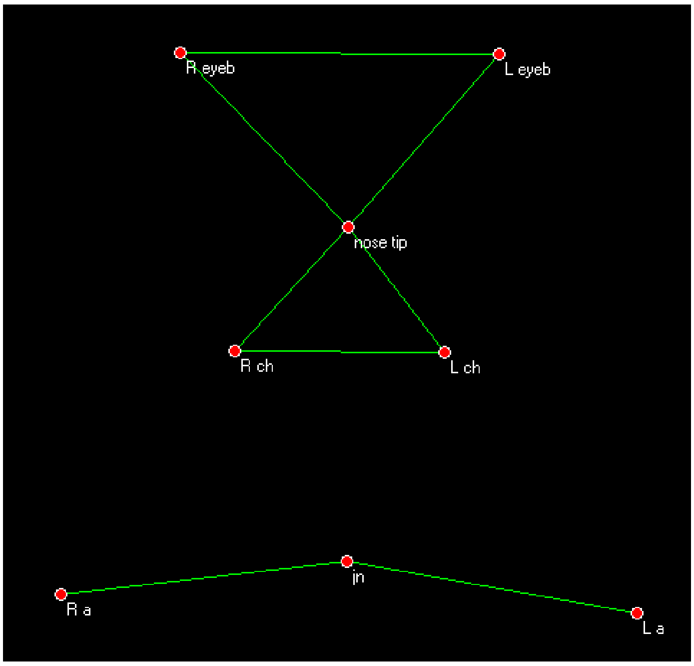


Figure 16. Face Model for 3D data reconstruction and kinematic analysis.

The parameters selected for the kinematic analysis are:

- Maximum Distance (MD): maximum distance between the markers of the mouth (MDM) and of the eyebrows (MDE) (unit of measurement: mm). This parameter can be influenced by the variable anatomical characteristics of facial landmarks. To correct this bias, the maximum distance for the corners of the mouth (DM) and the eyebrows (DE) was also calculated subtracting the minimum distance from it.
- Maximum Velocity (MV): maximum reached speed by the angles of the mouth (MVM) and the eyebrows (MDE) (unit of measurement: mm/s).
- Time to Maximum Velocity (TMV): time interval between onset and peak in which two points reach the maximum speed (unit of measurement: ms).
- Time to Maximum Distance (TMD): time interval between onset and peak in which two points reach the maximum distance (unit of measurement: ms).
- PTMV: percentage time between onset and peak in which two points reach the maximum speed (unit of measurement: %).

- PTMD: percentage time between onset and peak in which two points reach the maximum distance (unit of measurement: %).

4.2.5 STATISTICAL ANALYSIS

The data calculated with SMART-DX Analyzer© was exported to an Excel document and the statistical analysis was performed with JASP 16.0 © (2018). The chosen statistical test was Linear Mixed Effect Models with a significant threshold $\alpha = 0{,}05$. The data of some participants had to be left out of the analysis due to the absence of facial expressions to analyze. For this reason, the analysis of happiness was carried out on a total of 25 participants and the analysis of surprise was carried out on a total of 11 participants.

4.3 RESULTS

4.3.1 HAPPINESS

The Linear Mixed Effect Models revealed a significant effect for Condition with an increase of the smile amplitude and speed when the participants performed a posed smile, compared to when they smiled spontaneously (see Figure 17 and Figure 18): MDM: $F_{(1,24)} = 55.241$, $p < 0.001$, VS-MPR = 203200.396; MVM: $F_{(1,24)} = 133.321$, $p < 0.001$, VS-MPR = $5.476e^{8}$. This was not the case for the distance of the eyebrows, which initially weas found to be significantly different in between conditions: MDE: $F_{(1,24)} = 10.278$, $p = 0.004$, VS-MPR = 17.424, but corrected for anatomical distance, this parameter did not significantly differ in between conditions anymore: DE: $F_{(1,24)} = 1.404$, $p = 0.248$, VS-MPR = 1.064. The speed of the eyebrows did not significantly differ in between conditions either: MVE: $F_{(1,48)}$[1] = 1.032, $p = 0.315$, VS-MPR = 1.011.

The percentage time that the corners of the mouth took to reach the maximum velocity was also significantly different in between conditions, with a decreased amount of time to reach the maximum speed when posing smiles compared to spontaneous expressions (see Figure 19): PTMVM: $F_{(1,24)} = 5.661$, $p = 0.026$, VS-MPR = 3.916. This was not the case for the distance of the mouth corners, or for neither the speed nor the amplitude of

[1] Model fit is singular. Specified random effects parameters (random intercepts and random slopes) cannot be estimated from the available data. Carefully reduce the random effects structure, but this practice might inflate the reported p-value, and invalidates the analysis.

the eyebrows: PTMDM: $F_{(1,48)}$[2] = 0.213, p = 0.646, VS-MPR = 1.00; PTMDE: $F_{(1,24)}$ = 1.775, p = 0.195, VS-MPR = 1.153; PTMVE: $F_{(1,24)}$ = 0.211, p = 0.650, VS-MPR = 1.00.

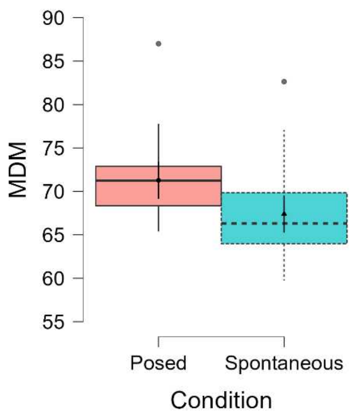


Figure 17. MDM Happiness

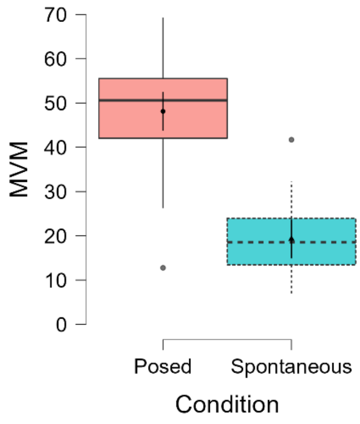


Figure 18. MVM Happiness

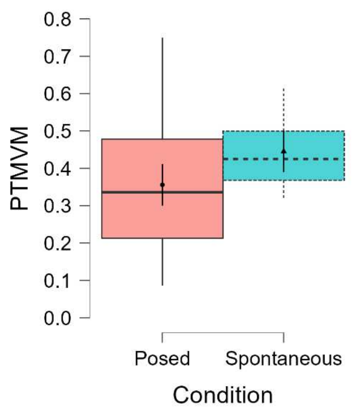


Figure 19. PTMVM Happiness

4.3.2 SURPRISE

The Linear Mixed Effect Models revealed a significant effect for Condition with an increased amplitude and speed of the eyebrows when the participants performed a posed surprise expression, compared to when they expressed it spontaneously (see Figure 20): MDE: $F_{(1,10)}$ = 6.534, p = 0.029, VS-MPR = 3.622. The speed of the eyebrows was not found significant in between conditions: MVE: $F_{(1,20)}$[3] = 3.745, p = 0.067, VS-MPR = 2.027. The time for the eyebrows to reach the maximum distance and speed were not found significantly different between conditions: TMDE: $F_{(1,10)}$ = 0.738, p = 0.41, VS-MPR = 1.00; TMVE: $F_{(1,10)}$ = 0.019, p = 0.893, VS-MPR = 1.00. Neither were the time percentages: PTMDE: $F_{(1,10)}$ = 0.738, p = 0.397, VS-MPR = 1.00; PTMVE: $F_{(1,20}$[4]$)$ = 0.329, p = 0.573, VS-MPR = 1.00.

The amplitude of the mouth corners was found significantly different in between conditions, with a decreased distance when participants posed surprise, compared to when they produced a surprise expression spontaneously (see Figure 21): MDM: $F_{(1,10)}$ = 11.310, p = 0.007, VS-MPR = 10.350. The speed of the corners of the mouth was not found statistically significant in between conditions: MVM: $F_{(1,10)}$ = 1.383, p = 0.167, VS-MPR = 1.044.

2 Idem
3 Idem
4 Idem

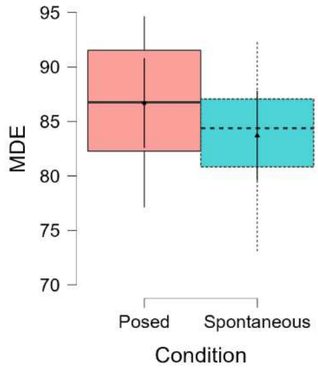


Figure 20. MDE Surprise

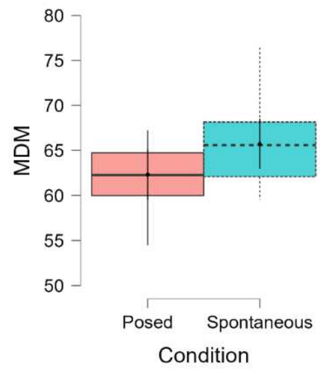


Figure 21. MDM Surprise

Finally, both the times to reach the maximum speed and distance between the corners of the mouth and the time percentages were significantly different, being higher when participants expressed surprise spontaneously compared to when participants posed surprise: (see Figure 22 and Figure 23) TMDM: $F_{(1,20)} = 8.841$, $p = 0.008$, VS-MPR = 9.959; TMVM: $F_{(1,20)} = 17.383$, $p < 0.001$, VS-MPR = 101.474; PTMDM: $F_{(1,20)} = 13.59$, $p = 0.001$, VS-MPR = 38.53; PTMVM: $F_{(1,20)} = 59.597$, $p < 0.001$, VS-MPR = 118551.642.

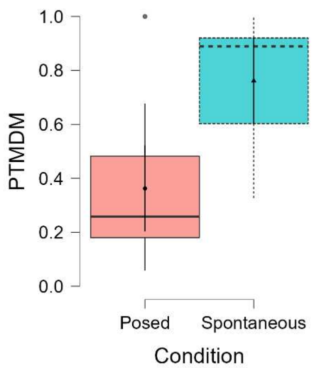


Figure 22. PTMDM Surprise

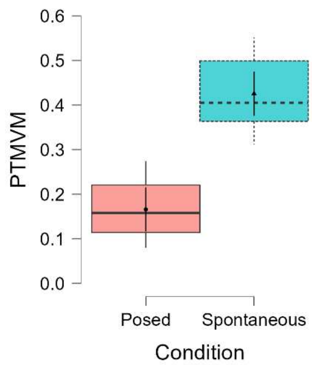


Figure 23. PTMVM Surprise

5. DISCUSSION

The present study provides evidence for the existence of different dynamic patterns of spontaneous and posed facial expressions of happiness and surprise. Spontaneous smiles are programmed to reach a goal without interruption, leading to a progressive and stable course and a consistent link between the speed and the amplitude of the movement (Schmidt et al., 2003). In fact, in the present study, posed smiles had both a higher speed and amplitude than spontaneous smiles, which is consistent with past studies (Krumhuber et al., 2007) that have found posed smiles to have larger amplitudes, rather abrupt, and less smooth movement patterns. Furthermore, the time percentage in which the maximum speed was reached was found to be lower in posed smiles, which is coherent with past findings (Krumhuber et al., 2007; Namba et al., 2017) of shorter onset durations and more abrupt onset in posed smiles compared to spontaneous ones. These differences might be due to exaggeration or personal beliefs that influence posed expressions, which are not coherent with the subjective emotional state or try to mimic the experience of an emotion that is not actually being felt. These results show that the kinematic properties of the mouth are key in the characterization of smiles, which are the facial expression that generally corresponds to happiness, which is in fact, the emotion that participants reported feeling while watching the videos selected to elicit this emotion (see Figure 24).

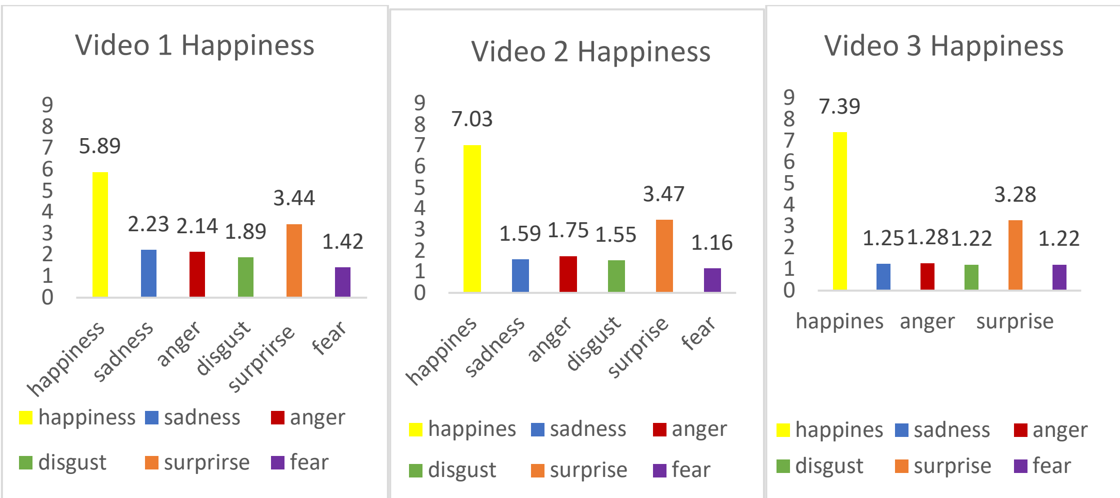


Figure 24. Subjective emotion rating for happiness videos

On the other hand, the facial expression of surprise is particularly dissociated from the subjective experience of the emotion (Resienzein et al., 2013). In fact, in the present study only 37.93% of participants showed surprise expressions. A considerable part of the participants presented surprise expressions mixed with smiling patterns, due to the positive nature of the surprises shown in the emotion-eliciting videos, which received high ratings on both surprise and happiness (see Figure 25). Taking this into account the percentage of participants in our study presenting a full-blown facial expression of surprise consisting of raised eyebrows, widened eyes, and opened mouth/jaw drop, would be close to the 4-25% (depending on the study) proposed in past studies (Resienzein et al., 2006).

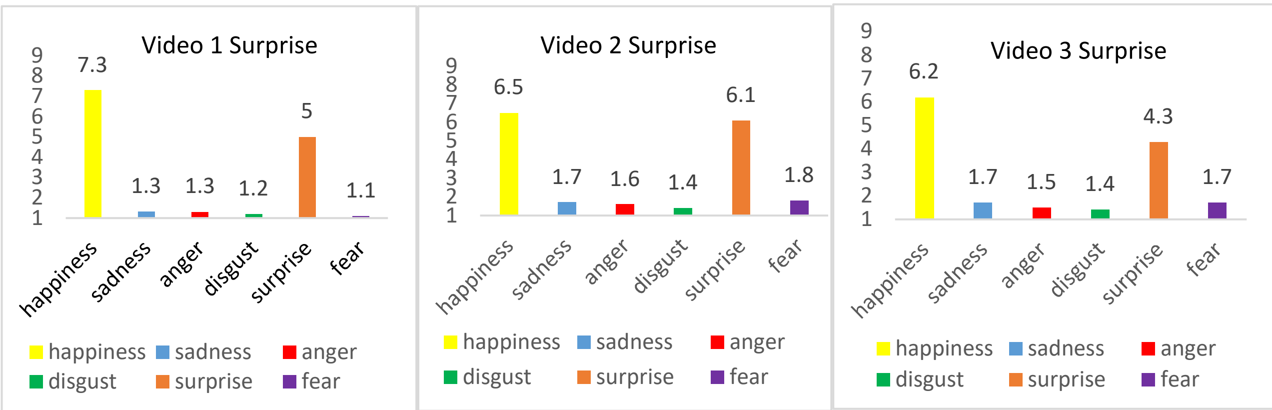


Figure 25. Subjective emotion ratings for surprise videos

This reduced production of facial expressions of surprise even though participants reported feeling surprised, could be due to the fact that surprise is not an emotion with affiliative or social function (at least in a first instance) and therefore facial mimicry is less likely to occur compared to emotions with affiliative functions like happiness (Kavanagh et al., 2016). Therefore, in the present study the kinematic data of 18 of the participants was left out of the analysis due to the absence of surprise facial expressions. The analysis was carried out on 11 participants only, which might be a reason for which several parameters that were expected to be significantly different, like the maximum speed of the eyebrows or the time interval to reach it, were not.

Despite this, the present data provide evidence for higher amplitudes of the eyebrows in posed facial expressions of surprise compared to spontaneous ones. The analyses also revealed a significantly different amplitude of the mouth corners in between conditions, this time, with a higher amplitude for spontaneous surprise expressions. The time to reach the maximum speed of the corners of the mouth and the percentage time was also significantly higher when participants expressed surprise spontaneously. This could be due to the fact that the surprise-eliciting videos were rated very high in subjective-experienced happiness, sometimes even higher than surprise. Therefore, the spontaneous expressions that were produced by participants were often mixed with smiling patterns, which were absent in the posed surprise condition. This difference might have influenced the direction of the effect for these parameters.

5.1 REAL LIFE APPLICATIONS

The assessment of emotions through facial expressions is therefore gaining interest, not only in the field of psychology and neuroscience, but also for several commercial applications in industries such as artificial intelligence and entertainment, and for clinical applications (Parks et al., 2020).

- Security. Classic aspects relating court decisions, FBI agents' investigations, face recognition on cameras, etc. (Barrett, 2017) but also new security challenges like monitoring the state of a person while driving to design safer next generation vehicles (Affectiva.com, 2022).
- Clinical practice. Facial expressions of emotion and emotion recognition are being studied as possible deficits, and therefore biomarkers, to diagnose certain psychiatric or neurological diseases (Park et al., 2020). Spontaneous facial expressivity has been found to be altered in Parkinson's disease (Bologna et al., 2016), autism (Cook et al., 2013), anorexia nervosa (Davies et al., 2016), etc. Atypical kinematic profiles might help explain motor, perceptual, cognitive, and behavioral deficits, linked to higher level social problems in the already mentioned and other conditions like schizophrenia (Edwards, et al., 2002), depression (Anderson et al., 2011), etc.

  This might provide a tool for treatment and rehabilitation programs that could focus on training of emotion recognition capacities based on facial expressions of emotion.
- Education. With the growth of smart-working, online courses, and distance education, the interest in developing platforms and apps that adapt and offer a personalized experience and learning process to each user has grown fast. Software that can track both facial expressions and body movements is trying to

be incorporated into these platforms or virtual spaces to optimize the learning and teaching process (Saneiro et al., 2014; Yang et al., 2018).

- Human-Computer interaction. Facial dynamics should be considered as a key element in the development of facial expression analysis software that can monitor a user's state or intentions and react to it while interacting with a computer (Oliveira Branco, 2006), creating a more sophisticated interaction with the virtual environment (Azad et al., 2014). The creation of robots that can efficiently interact with human beings and produce human-like facial expressions is another of the growing applications in this field (Lazzeri et al., 2018).
- Entertainment. The design of successful videogames and the enhancement of player's experience can be improved by incorporating facial tracking and analysis which captures facial expressions in real-time to appropriately adjust the game difficulty according to a player's expressions and facial dynamics (Akbar et al., 2019).
- Facial treatments. Advances in medicine and chirurgical practice allows an increased number of facial treatments, that should be accompanied by highly sophisticated practices to match the patients or the clients' demands and expectation of natural-looking results (Michaud et al., 2015). Therefore, dynamic aspects of facial expressions are essential in treatments, like facial ageing treatments and post-surgical or post-injury treatments. that focus on the restauration of facial movements or facial appearance.

5.2 LIMITS OF THE STUDY AND FUTURE DIRECTIONS

In the present study I performed a kinematic analysis of spontaneous and posed dynamic characteristics of facial expressions of happiness and surprise. However, a possible limit of the study is that the stimuli used to evoke both types of facial expressions of emotion were inherently different: videos for spontaneous expressions and static pictures for posed expressions. It would be interesting to use more similar types of stimuli to rule out a possible bias due to their different nature. This would be possible focusing on the stimuli of the posed condition, by using videos of people posing the target emotion or even videos of actors, whose facial expressions are pseudo spontaneous (Barrett et al., 2019).

The study of spontaneous facial expressions should aim to create a controlled but also a natural and the closest to real life setting as possible. In our study, in addition to the 6 infrared optoelectronic cameras needed for movement acquisition, participants were recorded by a webcam settled on top of the main monitor. Furthermore, since the experimenter needed to stay in the room to ensure the appropriate development of the session, a dropdown screen was positioned in between the experimenter and the participant so that the latter did not feel directly controlled. Despite these efforts, it is well known that the feeling or the knowledge of being observed can modify human's behavior, therefore, it would be interesting to carry out another experiment in which the participants had no awareness of being recorded and in which the experimenter could be outside of the room to ensure further privacy (Namba et al., 2017). The presence of the experimenter in the room could be an important influencing factor in the facial expressivity of the participants considering that facial mimicry is more likely to happen in the presence of an audience (Barrett, 2006).

In the present study we had a wide range of data that could be interesting to analyze and compare in further studies. It would be interesting to go further in the study of correlations between IRI score, subjective emotional ratings, and kinematic data. The relationship between these factors could be of special interest in populations with difficulties in emotional contagion, empathy, emotional expression, and recognition.

Finally, this study focused on six basic emotions and their relative facial expressions (two in this thesis paper), which for years have accumulated a wide range scientific evidence and research. It would also be interesting to characterize the dynamics of other emotional experiences (i.e., pride, jealousy, frustration, etc.) and mixed emotions, which in the complex world we live in, are as frequent, or even more, than the basic six.

CONCLUSION

This thesis started with an introduction about the construct of emotion, which has been shown to be extremely complex and hard to define. Present and future research should focus on proposing integrative approaches of historically opposing theories of emotion and in asking the right questions. Precise and objective points of research should be the focus of research questions like: “how do emotions become real?” (Barrett, 2012). Only combining these efforts, the field of emotional research will be able to evolve. This is what was done in the present study, since one way in which emotions become real is through facial expressions. Therefore, a kinematic characterization of spontaneous and posed facial expressions of emotion was carried out. Kinematic analysis is an extremely versatile and precise method able to evidence subtle differences in between participants and in between conditions.

Spontaneous and posed facial displays were expected to differ in several dynamic aspects, and so were the key kinematic parameters that would allow to differentiate spontaneous and posed facial expressions for different emotion categories. It was found that the amplitude and speed of the smile is higher when posing happiness, and so is the distance between the eyebrows when posing surprise. This is in line with expected results, in which the main movements and landmarks related to each expression of emotion are exaggerated in the posed compared to the spontaneous condition. The only pattern that went in the opposite direction, was the amplitude of the mouth that was lower while posing surprise. However, this might have been due to the fact that spontaneous surprise expressions were mixed with smiling patterns that might have affected the kinematic pattern. Finally, the time percentages of the speed of the mouth in smiles, and of both the speed and the amplitude of the mouth is surprise, were lower in the posed compared to the spontaneous. These results are also in line with more abrupt onsets of posed facial expressions.

This research is key to overcome biases introduced by years of emotion research that have exclusively focused on static and posed facial expressions. In fact, dynamic patters contain an incredible amount of information that needs to be further studied to understand the real and spontaneous way of expressing emotions through facial expressions. And ultimately, to create datasets of both spontaneous and posed facial expressions to be used in future research. Furthermore, this research provides another key contribution to research, since objective and sensitive information about temporal and spatial properties of facial expressions is still scarce (Barrett et al., 2019). Therefore, this type of data is extremely important to fulfill the future goal of developing a standardized method able to evaluate facial expressivity by using both quantitative and qualitative data.

Finally, and trespassing the importance in the research field, the precise and detailed study, and the understanding of facial expressions of emotion is key in the development of practical real-life applications in several different fields: security, clinical, education, human-computer interaction and artificial intelligence, or entertainment. To reach this goal, psychology, neuroscience, and technology should cooperate closely to better understand the nature and functioning of social communication processes and to apply this knowledge to create tools which are able to improve the life of human beings.

APPENDIX

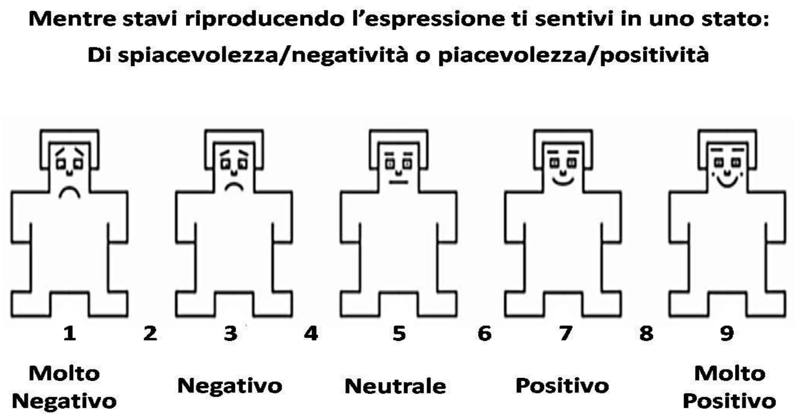


Figure 1. SAM rating scale for valence.

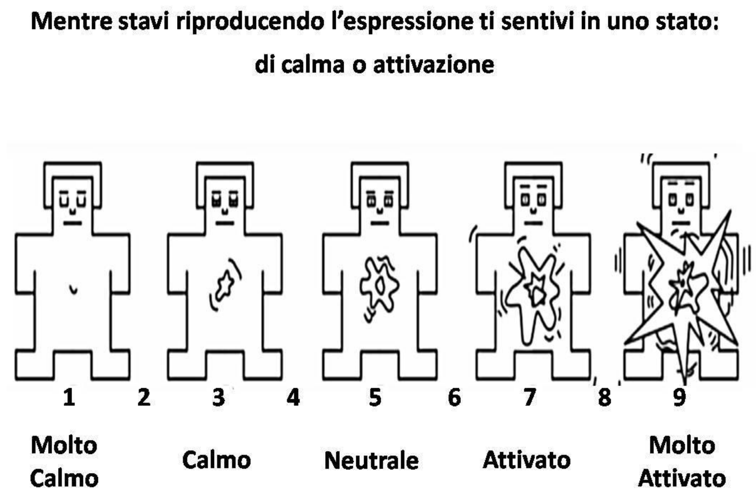


Figure 2. SAM rating scale for arousal.

Figure 3. Question to rate the subjective emotional experience. "While watching the video, how much did you feel each of the following emotions?"

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