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# Dissecting the smile: a spatio-temporal study

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## 1. Introduction

The smile, an exquisite expression of human emotion, transcends cultural boundaries and speaks a universal language of warmth and connection. The facial expression of a smile is universally recognised as a signal of happiness or positive emotion in various cultures. Beyond its physiological manifestation, notably the release of endorphins and the reduction of stress hormones, which contribute to improved well-being (Dufner et al. 2010), the smile possesses immense psychological power, capable of lifting spirits, easing tensions and forging links between individuals. In history, art and literature, the smile has been celebrated as a timeless emblem of the human experience, immortalised in countless works of art and treasured souvenirs. At its core, the smile embodies the beauty of human connection and the resilience of the human spirit. But certain types of damage can disrupt the smile and the social function of those affected. Smile is most commonly analysed clinically in deficit situations, with facial palsy being the most prevalent pathological condition. Peripheral facial palsy refers to the partial or total loss of function in certain facial muscles due to damage to the facial nerve, which can have various aetiologies. Current methods of facial movement analysis rely on clinical assessment, but quantitative methods such as motion capture have been developed on an experimental basis (Sarhan et al. 2023). Several studies have attempted to overcome the lack of objective, reproducible, and sensitive measures for facial movement assessment using these methods

(Hontanilla et al., 2008; Sforza et al., 2010). After a validation of our method for the normalized displacement as feature of interest for healthy volunteers and patient follow-up (Sarhan et al. 2023, Marcellin et al. 2023, Rodriguez et al. 2023), the objective of our research is now to focus on time spatiotemporal parameters of facial mimicry and more precisely here to the smile to study if there are similarities between healthy subjects.

## 2. Methods

Twenty-three healthy subjects (7 men and 16 women) aged  $24 \pm 8$  years were recruited for this study. They were equipped with 105 Vicon passive markers (1.5 mm  $\varnothing$ ) placed all over the face. Participants performed the smile movement without tempo instructions in front of a 10-camera Vicon Vantage V16 system recording at 100Hz. After labelling the points, including the labial commissure point (Dagnes et al., 2018), with reference to x,y and z displacements curves, the frame of the beginning of the movement (when the marker begins to move), the end of contraction (when the marker reaches its maximum amplitude), beginning of relaxation (the moment when the marker begins its return to its starting position), and the end of the movement (when the marker returns to its starting position) were marked on the Vicon Nexus timeline for each subject. The movements were normalized from 0 to 100% of a smile cycle using cubic spline interpolation. The mean and standard deviation of the time at which contraction ended and relaxation began were calculated

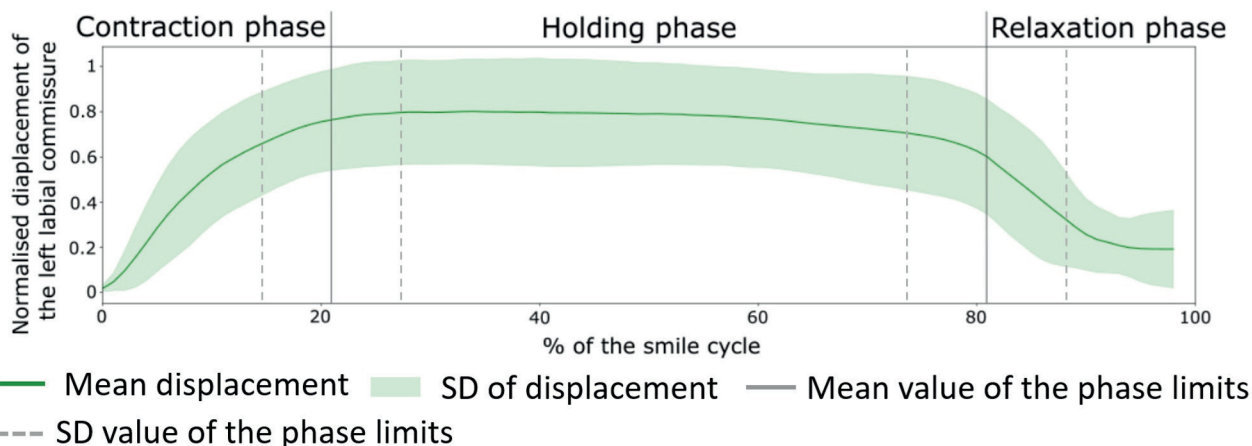


Figure 1. Mean displacement and phase limits for the smile

and expressed as a percentage. The mean and standard deviation of normalised displacement of markers in amplitude and time was calculated. Finally, a distribution frequency analysis was carried out.

### 3. Results and discussion

Table 1. Distribution frequency analysis for the end of contraction phase and beginning of relaxation phase.

% of smile cycle	14	16	18	20	22	24	26	28	30	32	34	36					
End-of-contraction frequency	2	2	1	3	6	1	4	0	1	2	1	0					
% of smile cycle	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90
Frequency of onset of relaxation	1	0	0	0	0	0	1	0	2	1	1	4	3	3	4	1	2

The mean value for the end of contraction phase is  $22,4 \pm 5,7 \%$  and  $80,39 \pm 7,2\%$  for the beginning of relaxation phase (Figure 1). Concerning the frequency of distribution, we can see that for the contraction phase, the highest frequency is at 22% of smile cycle and for relaxation there is equality between 80% and 86% (Table 1).

We can see that the three phases of the smile have the same length for the smile despite the fact that there were no tempo instructions when the movement was performed.

For the 23 volunteers studied, the standard deviations for the limit of these phases were 6% and 7% of the smile cycle, showing little difference between volunteers.

This result is in line with Özsoy et al. 2024. This work shows the same duration for the phase than us.

At present, we have not found any other references on the spatiotemporal analysis of smiles.

Despite the fact that the smile requested is not constrained to a tempo, it might be interesting to try to record a spontaneous smile from the subject during the acquisitions to compare it with our “on command” smile. To reinforce our study, we could extend the parameters of interest to the speed of movement and also to the order in which the markers are activated. Taken together, these parameters will give us comprehensive information about the temporality of smiling in healthy volunteers, and could be compared with pathological data, enabling patients to be better managed.

### 4. Conclusions

In this study, we describe the analysis of smile cycle using motion capture. This spatio temporal information coupled with displacement data can increase knowledge of facial mimicry and continue to improve the management of patients suffering from facial pathologies leading to motor problems on the face. It would be interesting to analyse velocity and the order in which the markers are activated, and to apply this method to other movements and also to pathological movements to study the differences with the healthy reference. Overall, this study provides promising insights into the use of biomechanical analysis to follow-up patients with facial palsy. Finally, this study gives us promising prospects for studying the biomechanics of facial mimicry, which is a highly complex part of the human body but which may show similarities in the healthy population.

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## Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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