From the Eye to the Heart: Eye Contact Triggers Emotion Simulation

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ABSTRACT
Smiles are complex facial expressions that carry multiple meanings. Recent literature suggests that deep processing of smiles via embodied simulation can be triggered by achieved eye contact. Three studies supported this prediction. In Study 1, participants rated the emotional impact of portraits, which varied in eye contact and smiling. Smiling portraits that achieved eye contact were more emotionally impactful than smiling portraits that did not achieve eye contact. In Study 2, participants saw photographs of smiles in which eye contact was manipulated. The same smile of the same individual caused more positive emotion and higher ratings of authenticity when eye contact was achieved than when it was not. In Study 3, participants' facial EMG was recorded. Activity over the zygomatic major (i.e. smile) muscle was greater when participants observed smiles that achieved eye contact compared to smiles that did not. These results support the role of eye contact as a trigger of embodied simulation. Implications for human-machine interactions are discussed.

ACM Classification Keywords
H.1.2 Models and Principles: User/Machine Systems—Human factors; H.5.2 Information Systems: Information Interfaces and Presentation: User-centered design; H.5.3 Information Systems: Information Interfaces and Presentation—Synchronous interaction

General Terms
Experimentation, Human Factors

Keywords
Eye contact, smile, facial expression, embodied simulation

1. INTRODUCTION
There is a road from the eye to the heart that does not go through the intellect.
-G. K. Chesterton

Understanding the subtle meaning of facial expression is a daily challenge, and the smile might be the most challenging of expressions. While it is true that prototypical smiles are universally recognized as signs of joy [11, 15, 22], suggesting that this expression is easily interpreted, other research [1, 13] attests to its complexity.

How do people understand a smile? This question is addressed in the Simulation of Smiles Model (SIMS), recently proposed by Niedenthal, Mermillod, Maringer, and Hess [30]. The present research was conducted in order to test a specific hypothesis generated by the SIMS, namely that eye contact is a sufficient trigger for embodied simulation of smiles.

1.1 The Simulation of Smiles (SIMS) Model
The SIMS model integrates social psychological research with recent findings in neuroscience in order to propose how the specific meaning of a smile is arrived at. According to the SIMS, three operations can be used to process smiles: perceptual analysis (matching the smile to representations of prototypical smiles), top-down application of beliefs and stereotypes, and embodied simulation.

Embodied simulation refers to partial *reenacting* of a corresponding state in the motor, somatosensory, affective and reward systems. This reenacting represents the meaning of the expression to the perceiver [17, 10, 29] *as if* he/she was in the place of the smiling person. The perception of a smile is therefore accompanied by the bodily and affective states associated with the production of this facial expression. In addition to affective state, an important part of the embodied simulation of a smile is facial mimicry. We define facial mimicry as the visible or non-visible use of facial musculature by an observer to imitate another person's facial expression [30].

The important role of the facial mimicry was suggested by the findings of Stel & van Knippenberg [37]. They showed that inhibiting facial mimicry decreased the speed of judging facial displays as expressing positive or negative emotion. In another study, Maringer et al. [26] showed that inhibition of facial mimicry impaired the distinction between genuine and nongenuine smiles. A recent study by Neal and Chartrand [28] further bolsters this conclusion, showing that amplifying facial mimicry improves one's ability to read others' facial emotions.

Although parts of embodied simulation, such as facial mimicry, appear to be helpful in forming an accurate understanding of facial expression, what is less clear are the conditions under

Gaze-In'12, October 26, 2012, Santa Monica, California, USA.

which embodied simulation occurs. According to the SIMS model, a sufficient though not necessary trigger for embodied simulation is the achievement of eye contact with the individual displaying the expression.

1.2 Eye Contact as a Trigger to Simulation

Both developmental research [14, 19, 25], and work on intimacy [21, 34] provide hints of the role of eye contact in embodied simulation of emotion. This role is more explicitly indicated by the findings of Bavelas, Black, Lemery, and Mullett [6] on the perception of pain expressions. There, a confederate faked the experience of pain and expressed the pain facially. Further, he made eye contact with some of the participants but not others. Eye contact significantly affected participants' reactions: they mimicked the confederate's expressions most clearly when eye contact with the confederate was made. Relatedly, Schrammel and colleagues [35] showed that participants' zygomatic major muscle activity was stronger when viewing happy faces than neutral faces, and, most importantly, facial expression had an effect only under conditions of eye contact. These results suggest a close link between eye contact and facial mimicry.

In the present three studies, our aim was to test the SIMS model's specific hypothesis that eye contact is a trigger of embodied simulation of the smile. The first study relied on existing portraiture paintings. We selected portraits of subjects who achieved different degrees of eye contact with the viewer, and who expressed smiles. Participants saw each portrait twice. On one exposure the participant viewed the full portrait; on the other exposure the eyes of the portrait subject were obscured. The indicator of embodied simulation was the participant's rating of the emotional impact of the painting. Since embodied simulation is related to affective change, the more a smile is embodied in the self, the more the viewer should report an emotional response to the portrait. If the eye-contact-as-trigger hypothesis is correct, then the emotional impact of the portrait should be significantly greater when the eyes are unmasked versus masked, and this should be particularly true if the viewer achieves eye contact with the portrait on the unmasked trial. In contrast, if participants were using a perceptual analysis for decoding the smile, then seeing the eyes per se would be important, but level of eye contact would be irrelevant to personal feelings of emotion.

2. STUDY 1

2.1 Method

2.1.1 Participants

Undergraduates (101 female, 13 male) from two medium-size universities participated in exchange for course credit. Data from 6 participants were discarded because they were incomplete or because they failed to follow instructions.

2.1.2 Stimuli

Paintings were selected from art archive internet sites by a research assistant who was blind to the hypotheses. Criteria that guided the selection of potential target portraits included that the portrait showed a frontal and not profile view, and that the eyes were clearly visible. Neither portraits of celebrities nor very famous portraits were included in the final set. The 16 target portraits were selected based on a pilot study involving 39 undergraduate students (27 female, 12 male) from a medium-sized university. Participants saw 32 smiling portraits and rated the extent to which they were certain that the subject of the portrait was actually smiling. Responses were made on scales from 0 (not at all sure) to 100 (very sure). The 16 portraits selected as targets were those for which the average ratings of certainty that the displayed expression was a smile were the highest (M = 73.22, SD = 13.07). Among the 16 targets, the level of eye contact varied substantially (see examples in Figure 1).

Figure 1. Portraits achieving eye contact (left) and not achieving eye contact (right), in unmasked (top row) and masked (bottom row) conditions.

72 paintings from the 16th through 20th centuries, 56 distractors and 16 target portraits, constituted the final stimulus set[1]. The distractors (portraits, landscapes, and still life works) were included to minimize demand characteristics.

A mask (pattern: small checkerboard, colors: 98, 92, 56 and 181, 188, 146 RGB) obscured the eyes for one presentation of all 32 portraits (i.e., both target and distractor portraits; Fig. 1, bottom panel). Four mask sizes (128 by 22 pixels, 158 by 22 pixels, 189 by 45 pixels and 242 by 60 pixels) were used, depending on the face area proportions. Masks did not systematically cover any particular portion of the eye area but always obscured eye gaze, and they were applied randomly to the landscape and still life paintings.

2.1.3 Procedure

Participants were tested in pairs, but worked independently at individual computer stations. They were seated approximately 0.5 m from the screen (20", display resolution: 1280 x 768). The experiment was programmed in E-Prime Version 1.2 (1996-2006 Psychology Software Tools).

Each of the 72 paintings was presented twice (once masked and once unmasked) in a random order, with the constraint that one exposure occurred in the first, and the other in the second half of the trials. Stimuli were displayed on a black background. The inter-trial interval was 800 ms, during which participants saw a black screen.

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[1] Stimuli are available on-line at : https://www.dropbox.com/s/q48il7ti6cse7ui/Study%201.zip

For masked and unmasked presentations, target portraits were accompanied by the question, presented simultaneously at the bottom of the screen, “How emotional is the impact of the painting?” Participants responded by positioning a cursor on a bar ranging from 0 (no emotion) to 100 (a lot of emotion). Positive emotion was not mentioned in the question in order to minimize demand characteristics. For half of the distractors, a filler question appeared and the other half was presented without a question.

In the second part of the experiment, participants saw the 16 target portraits again. This time they rated the amount of perceived eye contact (“How much eye contact does the subject establish with you as the viewer?”) using the scale described above (cursor bar ranging from 0, no eye contact to 100, a lot of eye contact). At the end of the session the experimenter debriefed the participants and probed for suspicion.

2.1.4 Results

We first divided the target portraits into two groups, based on a median split of the eye contact ratings averaged across subjects: portraits achieving eye contact and portraits not achieving eye contact.

Ratings of emotional impact were then submitted to a 2 (mask: masked vs. unmasked) x 2 (eye contact: achieved or not achieved) repeated-measures ANOVA. Unsurprisingly, there was a main effect of mask, $F(1,107) = 92.05$, $p < .001$, such that emotional impact was higher for unmasked ($M = 54.02$, SD = 16.83) than for masked portraits ($M = 42.97$, SD = 15.64, $d = 0.93$). Emotional impact also varied as a function of eye contact, $F(1,107) = 117.80$, $p < .001$, such that portraits that achieved eye contact had more emotional impact on the observer than portraits that did not achieve eye contact ($M = 53.63$, $SD = 15.84$, $M = 43.36$, $SD = 15.93$, $d = 1.04$). However, as predicted, mask interacted with eye contact, $F (1,107) = 17.76$, $p < .001$, such that the difference between the emotional impact of masked and unmasked trials was higher for portraits achieving eye contact ($M = 13.09$, $SD = 12.57$) than for smiles that did not achieve eye contact ($M = 9.00$, $SD = 13.39$, $d = 0.41$).

The dichotomization of continuous variables is a controversial practice, which decreases the statistical power [7]. We therefore reanalyzed the data using eye contact as a continuous variable.

Since participants rated the emotional impact of each of the 16 target portraits twice, impact ratings could not be considered independent. Therefore, we used hierarchical modeling (HLM software, version 6.06) [26] with portraits as the level-1 units and participants as level-2 units. There were a total of 1728 observations. The intercept was allowed to vary randomly. Mask and eye contact were specified as predictors.

Analysis of the main effects revealed the expected effect of mask, $t(107) = 9.93$, $p < .001$, such that the emotional impact of unmasked portraits was higher than the impact of masked portraits. Also, emotional impact significantly increased with eye contact, $t(1726) = 11.18$, $p < .001$. Most importantly, mask interacted with eye contact, $t(1726) = 4.43$, $p < .001$, such that the difference between masked and unmasked trials was greatest for portraits achieving high levels of eye contact.

2.1.5 Discussion

Our results are consistent with the hypothesis that eye contact triggers embodied simulation of smiles, estimated by the reported emotional impact of portraiture painting. This impact was greater when the subject’s eyes were visible, versus when masked. More importantly, the difference was significantly greater when eye contact was achieved. Facial mimicry and the production of a corresponding emotional state are two components of embodied simulation. Our finding complements other results in the literature that demonstrate eye contact is associated with greater facial mimicry [6, 35].

A limitation of Study 1 was that although we experimentally manipulated whether or not the eyes were visible, we did not manipulate eye contact. Further, we used one indicator of simulation – emotional impact. In Study 2 we tried to address these limitations by manipulating eye contact and using a different measure of embodied simulation, namely, ratings of positivity and genuineness of smiles. We were inspired by past research showing that smiles judged as genuine are related to greater facial mimicry and positive feelings in the perceiver [12, 36]. If eye contact is a trigger of embodied simulation, ratings of positivity and genuineness of smiles should be higher under conditions of achieved eye contact.

3. STUDY 2

3.1 Method

3.1.1 Participants

41 undergraduates (40 females, 1 male) from a medium-sized university took part in exchange for course credit. Data from 4 participants were discarded from further analyses due to their failure to follow instructions.

3.1.2 Materials

72 photographs of smiles were developed for the study. 12 models (6 female, 6 male) were photographed by a professional photographer in the presence of an expert on facial expression of emotion. The expert used standard instructions [12] for eliciting Duchenne and non-Duchenne smiles. Each model was photographed smiling with three levels of eye contact: direct gaze (high eye contact), left averted and right averted gaze (see Figure 2).

3.1.3 Procedure

Participants were tested in pairs, but worked independently. They were exposed to each of the 72 photographs[2] (screen size: 20", display resolution: 1280 x 768, picture size: 380 by 475 pixels) for 1500 msec. Their task was to rate the degree to which they perceived the smile to be genuine on a scale ranging from 0 (*not genuine at all*) to 100 (*very genuine*), and the degree to which they perceived the smile to be positive on a scale ranging from 0 (*not at all positive*) to 100 (*very positive*).

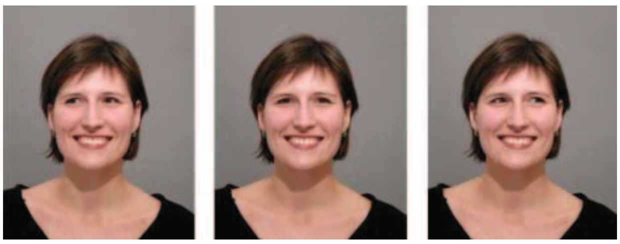

Figure 2. Smile with achieved eye contact and gaze averted to the left/right

[2] Stimuli are available on-line at : https://www.dropbox.com/s/wvoead207bhljc9/Study%202.zip

3.1.4 Results

Two one-way ANOVAs were conducted with gaze (eye contact or averted) as the independent variable, and genuineness and positivity as the dependent variables. There was a main effect of gaze on ratings of genuineness such that smiles with eye contact were judged as more genuine (M = 60.99, SD = 11.21) than smiles with averted gaze (M = 58.93, SD = 10.08), $t(36)$ = 2.47, p = .018, d = 0.42. This was also true for positivity: smiles that achieved eye contact were rated as significantly more positive (M = 64.29, SD = 11.68) than smiles with averted gaze (M = 60.54, SD = 10.31), $t(36)$ = 4.76, p < .001, d = 0.81. Mediational analyses indicated that the effect of eye contact on genuineness disappeared when controlling for positivity, $F(1,34)$ = 1.73, p > .1. However, the effect of eye contact on positivity was still significant over and above the differences in ratings of genuineness, $F(1,34)$ = 16.19, p <.001. This is consistent with complete mediation, such that the increased perceived genuineness of smiles that make eye contact was largely determined by the increased feelings of positive emotion generated by such smiles.

3.1.5 Discussion

The present study used an experimental manipulation of eye contact and found that eye contact was related to higher ratings of both positivity and genuineness, for both Duchenne and non-Duchenne smiles. In light of past findings on the extent to which "genuine" smiles produce physiological, bodily, and experiential signs of positive affect, we suggest that the present positivity ratings can be one valid indicator of emotional simulation. In our experiment ratings of positivity fully mediated the relationship between eye contact and perceived genuineness. This result suggests that judgments of the genuineness of smiles may not be based only on perceptual features of the smile, but also on the affective experience of the perceiver.

A limitation of these two studies is that only self-reported indicators of embodied simulation - emotional impact and ratings of positivity - were used. The aim of Study 3 was to address this limitation by adding a measure of facial mimicry. Participants' EMG activity was recorded while they were observing smiles in which eye contact was manipulated. If eye contact is a sufficient trigger of embodied simulation, smiles should be mimicked more when eye contact is achieved than when it is not.

4. STUDY 3

4.1 Method

4.1.1 Participants

A total of 27 female undergraduate students from a medium-size university participated in the experiment. They were recruited on campus and received 10 € compensation.

4.1.2 Materials

Experimental stimuli were prepared according to the parameters described in Study 2. This time, participants saw photographs of 6 models (3 female, 3 male) displaying facial expressions (neutral or smiling) and two levels of eye contact (eye contact achieved, and averted gaze – no eye contact) for a total of 24 facial stimuli[3].

4.1.3 Procedure

Participants were tested individually. Facial stimuli were presented on a computer screen (screen size: 17", display resolution: 1024 x 768, picture size: 760 by 950 pixels) for 8 s. Each stimulus appeared three times in a random order, with the constraint that two photographs of the same face never occurred in succession. The inter-trial interval was 500 ms. Presentations began with a screen prompting participants to press the space bar when ready. Participants were told to imagine real interactions with models of the photographs.

Activity of the zygomatic major (ZM) muscle was recorded on the left side of the face, according to the established guidelines [16] and using bipolar 10 mm Ag/AgCl surface-electrodes filled with SignaGel (Parker Laboratories Inc.). As a pretext for the placement of electrodes used to record ZM activity, participants were told that their brain waves would be recorded - and a dummy electrode was also placed in the center of the forehead.

The EMG raw signal was measured with the 16 Channel Bio Amp amplifier (ADInstruments, Inc.), digitized by a 16 bit analogue-to-digital converter (PowerLab 16/30, ADInstruments, Inc.), and stored with a sampling rate of 1000 Hz. Data were filtered with a 10-Hz high-pass filter, a 400-Hz low-pass filter, and a 50-Hz notch filter.

Next, participants saw the 24 photographs once again and rated the degree to which they perceived the facial expression to be positive on a scale ranging from 0 (*not at all positive*) to 100 (*very positive*), identical to the procedure used in Study 2. At the end of the session participants completed a questionnaire that tested their understanding of the task and probed for suspicion. These post-experiment responses indicated that the cover story was persuasive.

4.1.4 Results

4.1.4.1 EMG Activity

The scores of interest were expressed as a difference in the mean activity during the last 500 ms before stimulus onset and the mean activity in the time window 500-1500 ms after stimulus onset. EMG data were subjected to 2 (facial expression: neutral, smile) x 2 (gaze: direct vs. averted) analyses of variance (ANOVA), with both expression and gaze as within subject factors.

Analysis of the main effects showed a significant main effect of expression such that ZM activity was higher for smiles than for neutral expression, $F(1,26)$ = 11.89, p = .002. The interaction between expression and gaze was not significant $F(1,26)$ = 2.32, p > .1, but post-hoc comparisons showed that smiling photographs achieving eye contact elicited higher ZM activity (M = 49.89 mV, SD = 64.78) than photographs with averted gaze (M = 32.11 mV, SD = 52,50), $t(1,26)$ = 2.54, p = .017, d = 0.52, see Figure 3. This difference was not significant for neutral photographs (M_{EC} = 6.04 mV, SD = 33.28, $M_{Averted}$ = 3.63 mV, SD = 42.46), $t(1,26)$ = 0.47, p > .5, d = 0.10.

4.1.4.2 Ratings of positivity

Positivity scores were subjected to 2 x 2 analyses of variance with facial expression and gaze as within subject factors. A significant main effect of facial expression was found, $F(1,26)$ = 547.47, p < .001. Not surprisingly, smiles (M = 83.43, SD = 9.30) were rated as significantly more positive than neutral facial expressions (M = 24.61, SD = 12.84), $t(26)$ = 23.40, p <.001, d = 4.62. Again, the expression-gaze interaction was not significant, $F(1,26)$ = 0.36, p > .5, but post-hoc comparisons showed that ratings of positivity were significantly higher for smiling photographs achieving eye contact (M = 84.93 mV, SD

[3] Stimuli are available on-line at : https://www.dropbox.com/s/he3m6el1mv5lyfe/Study%203.zip

= 8.48) than for smiling photographs with averted gaze (M = 81.93 mV, SD = 11.03), p = .020, d = 0.51. This difference was not significant for neutral photographs (M_{EC} = 25.52 mV, SD = 12.80, $M_{Averted}$ = 23.70 mV, SD = 13.76), $t(1,26) = 1.38$, $p > .1$, d = 0.27.

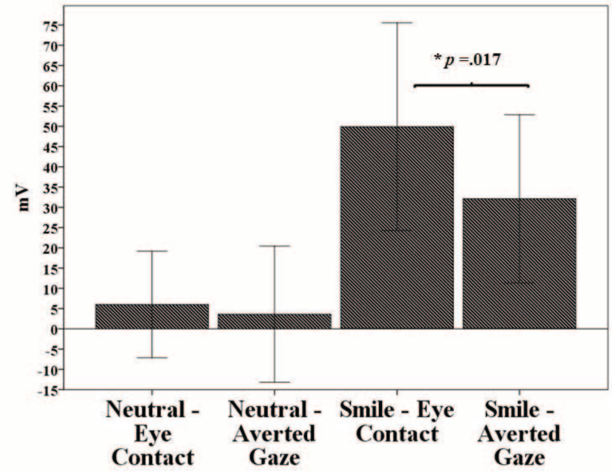

Figure 3. Mean change of zygomatic activity as a function of facial expression and gaze.

4.1.5 Discussion

This study used a psychophysiological indicator of embodied simulation to supplement the self-reported measures used in Study 1 and 2. We found that smiles provoked greater zygomatic major activity under conditions of eye contact compared to averted gaze. These results are in line with the findings of Bavelas et al. [6], where facial expressions of pain elicited greater mimicry in condition of eye contact than when eye contact was not achieved. Also, Schrammel et al. [35] showed that smiles of animated virtual characters had an effect on participants' zygomatic activity only if the character directly turned towards the observer (and thus, when eye contact was achieved). At first pass these results seem contradictory to these obtained by Mojzisch, Schilbach, Helmert, Pannasch, Velichkovsky, & Vogeley [27], where participants smiled both in response to characters who made eye contact and those who were turned away. Note however that in this study mean zygomatic activity was (not significantly) higher for conditions where virtual characters gazed directly at participants, compared to when characters were turned away. It should be also mentioned that only males participated in the research of Mojzisch et al. [27], whereas earlier EMG findings [9] suggest that females show more a pronounced facial mimicry effect than males.

In Study 3, the main effect of gaze was *not* qualified by an interaction with facial expression, as was found by Schrammel et al. [35]. This may be due to the type of stimuli used in the two studies. Note that Schrammel and colleagues used dynamic sequences presenting virtual characters, while in our study participants observed photographs of real persons. Moreover, we specifically manipulated eye contact, while Schrammel et al. [35] varied the character's body orientation. The lack of significant interaction may be also due to an insufficient statistical power. The impact of eye contact on facial mimicry and possible moderations should be investigated in further studies involving more participants.

5. GENERAL DISCUSSION

The present studies were motivated by a prediction [30], that eye contact is a sufficient trigger of embodied simulation of smiles. We used two types of stimuli – portraiture paintings and portrait photography – and three measures of embodied simulation: emotional impact, smile positivity and facial EMG. In the first study, achieved eye contact elicited more emotion than non-achieved eye contact. The second study showed that eye contact increased the perceived positivity and genuineness of smiles. Finally, the third study demonstrated eye contact is associated with greater imitation of smiles than averted gaze. Although our dependent measures are only parts of a complex phenomenon of embodied simulation, findings from these three studies support our prediction and highlight the importance of eye contact in the judgment of smiles. Moreover, these effects of mutual gaze can extend to other facial and bodily expressions [39].

Achieved eye contact is a powerful social signal. When perceiving direct gaze, people allocate their attentional resources to the interaction and engage in intensive processing of their interaction partners' faces [18]. Eye contact has also been proposed to be a signal of approach motivation. For example, Adams and Kleck [2, 3] found that eye contact increased the recognition accuracy and perceived intensity of so-called approach-oriented emotions (i.e., anger and happiness). Such findings are neither completely consistent with, nor contradictory to the present account. We argue however that the effects of eye contact extend beyond mere attention and information, and involve emotional experience along with imitation of the interaction partner.

We believe that deeper understanding of eye contact can inform the design of trustworthy and persuasive robots, helping to solve one of the fundamental questions in building social robots: when is the imitation appropriate [8]? Existing research indicates that mimicry can act like "social glue", fostering prosocial attitudes and cooperation [5, 38, 20]. Consequently, results of the reported three studies suggest that a robot producing or imitating human facial expressions under conditions of eye contact should elicit higher emotional responses than a robot that does not achieve eye contact. It is indeed possible, but the situation is more complex that it seems: recent studies showed that not only people tend to mimic more sympathetic interaction partners [23] but also that being imitated by an outgroup member can have negative consequences and decrease likability [24]. Thus, gaze behavior should vary as a function of the type of the robot, with more likable robots achieving more eye contact. On the other hand, referential gaze and head alignment with the object of interest would be more effective in educational contexts [4].

Another important problem is whether eye contact of strongly humanlike robots, along with a display of smiles, will elicit mimicry and positive emotion or rather feelings of eeriness and discomfort? These questions deserve experimental investigation. We believe that the present research can help in designing robots and agents that "invite" motivated, personal processing of facial expressions [31, 32]. This embodied processing of smiles, frowns or other grimaces can make their impact more visceral and more persuasive.

6. ACKNOWLEDGEMENTS

The authors would like to thank Pierre Chausse and Cyril Bernard for their competent programming, and Sophie

Monceau, Alexandra Buonanotte, Elena Dujour, and Marie Dejardin for their work as experimenters.

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