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Facial Feedback in Implicit Sequence Learning

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Abstract

There is continuous debate how closely or loosely emotion is linked to behavior and especially to facial expressions. In strong versions of the so-called facial feedback hypothesis, it is assumed that facial activity can intensify, modulate and initiate emotions. The hypothesis has been largely investigated with various emotions, however, surprise was tested only in a few studies. Additionally, it has been discussed frequently how obtrusively manipulations of facial feedback as well as the dependent measures are. Thus, in the present experiment we analyzed whether unobtrusive facial feedback of surprise versus no-surprise can modulate reactions following deviations in an implicit sequence learning task. Participants had to quickly and accurately press keys which corresponded to one of four letters appearing at the screen. After several blocks in which a standard sequence (consisting of a predefined order of 12 letters) was repeated, standard sequences and deviation sequences (i.e. one element differed from the standard sequence) were intermixed. The results confirmed our hypothesis: Participants of the surprise face condition showed longer reaction times to deviation sequences than to standard sequences. In contrast, participants of the no-surprise face condition did not show this difference in reaction times. Results were discussed with respect to implicit learning as well as to theories on emotion and facial feedback taking the special status of surprise into account.
Key words: facial feedback, emotion, surprise, implicit sequence learning, embodied emotions, embodiment, implicit measures.

Eeny, meeny, miny, moe,
Catch the tiger by the toe.
If it hollers let him go,
Eeny, meeny, miny. Ho!

If you are familiar with this rhyme, most likely, you are a little bit bemused due to the unexpected ending. If you would have observed your face, perhaps you might have noticed some slight changes of your mimic, too. The encountering of some kind of deflection from an expected pattern, rule, or schema results in specific cognitive as well as physiological processes and is accompanied by several behavioral indicators. The phenomenal experience going along with these processes is most often the feeling of surprise. Physiologically, various changes are elicited by surprising events, for example, temporary slowing of heart rate, often subsumed under the term “orienting-response” (e.g., Reisenzein & Meyer, 2009). Examined from a behavioral position, surprise can be

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accompanied by a vast number of different indicators: ongoing activities are interrupted, slowed down or delayed, the sense organs are oriented to the surprising event, investigative activities (e.g., visual search, questioning others) are started, processing resources were reallocated, exclamations of surprise are verbalized, and characteristic facial expressions are shown –eyebrows are raised, eyes are widened, pupils are dilated, mouth is opened (e.g., Reisenzein & Meyer, 2009). Obviously, these reactions seem to be very adaptive when arguing in terms of evolutionary advantages of fast acting preparedness in front of surprising events. Thus, related to the cognitive-psychoevolutionary model of surprise (Meyer, Reisenzein, & Schützwohl, 1997) the evolutionary function of surprise is first, to detect events which are incompatible or discrepant to existing schemas, rules, or expectancies, second, to interrupt ongoing activities and to reallocate processing resources, third, to evaluate the event, and fourth, if necessary, to update the existing schema. However, especially in the case of surprise, the subjective feeling, behavioral indicators including facial expressions, and physiological changes are only associated loosely with one another. For example, Reisenzein, Bördgen, Holtbernd, and Matz (2006) induced surprise by first establishing a specific expectancy and then disconfirming this expectancy. They found evidence for strong dissociations between self-reports of surprise and facial surprise expressions in most of their participants. In contrast, participants most often believed that they had shown strong facial expressions of surprise.

Not only specifically for surprise, but also for emotions in general, there is continuous debate how closely or loosely emotion is linked to behavior and especially to facial expressions (e.g., Ekman, 1992; Niedenthal, 2007; Russell & Fernández-Dols, 1997). Therein, a prominent theoretical approach represents the *facial feedback hypothesis*. The facial feedback hypothesis (for reviews see e.g., Adelmann & Zajonc, 1989; McIntosh, 1996), or much broader, the *peripheral feedback hypothesis* (e.g., Adelmann & Zajonc, 1989; Flack, 2006) could be dated back to early philosophers as Aristotle (e.g., Russell & Fernández-Dols, 1997) but also Hegel as well as early physiologists and/or psychologists, for example Piderit, Gratiolet, Darwin, and James (e.g., Adelmann & Zajonc, 1989). James (1884, 1890/1950) described the possibility of a causal role of bodily states in the experience of emotion. His assumption was that first the body changes, and the subjective feeling of an emotion follows. In more recent theories with a neuroscience perspective on emotion, the causal relationship between expression and experience was again revived (Damasio, 1999; LeDoux, 1996). James (1884) did not distinguish between facial musculature and skeletal musculature as source of feedback in emotional experience. However, all of James' illustrations for his hypothesis included references to facial efference (see e.g., Adelmann & Zajonc, 1989). In Tomkins (1962) theory on emotions, the face got a primary role for expressing affect which provides feedback for others and for the self. At the latest since research and theories by Paul Ekman (e.g., Ekman, 1992, 1993; Ekman, Friesen, & Ancoli, 1980; Levenson, Ekman, & Friesen, 1990), the prominent role of the face in emotional responding was cemented. Reisenzein and Studtmann (2007) summarized the results of 25 years of intensive research on the facial feedback theory: Facial feedback may have an intensifying effect on the feelings caused by the emotion-related facial expression. Facial feedback modulates ongoing emotions, and is able to initiate them (McIntosh, 1996). However, facial feedback seems to be most likely not necessary for emotional experience (McIntosh, 1996; Reisenzein & Studtmann, 2007). In recent theoretical discussions, findings and assumptions regarding facial/body feedback are integrated into larger theoretical frameworks of embodiment (e.g., Niedenthal, 2007).

The facial feedback hypothesis was tested by either directly asking participants to simulate an emotion by showing facial expressions for specific emotions or by unobtrusively manipulating specific facial muscles (e.g., the *zygomaticus major* muscles) involved in the production of emotion specific expressions (e.g., smiling). Since methods in which participants are directly instructed to simulate emotions has been largely criticized due to methodological problems, by now, unobtrusive methods are most often seen as standard methods for investigating the facial feedback hypothesis. Most often, facial feedback is used in research on pleasant or unpleasant affect, that is, emotions as happiness, joy, or amusement versus sadness, anger, disgust, or distress are investigated. The well-known experiment of Strack, Martin, and Stepper (1988) represents a milestone within this research for pleasant affect. Essentially, participants were instructed to hold a pen with their lips only or with their teeth only, either contracting the *orbicularis oris* muscle which is incompatible with contracting the muscles that are used in smiling or contracting the muscles associated with smiling (i.e., the *zygomaticus major* or the *risorius* muscles), respectively. To cover the real goal of the experiment and to direct subjects' attention away from their own expressions, the crucial task was embedded in several tasks investigating psychomotoric coordination. The dependent variable of interest was the subjective rating of a cartoons' funniness. The results confirmed the hypothesis: Subjects rated the cartoons to be more amusing while holding the pen with their teeth facilitating smiling than by fixing the pen with their lips inhibiting smiling.

Related to unobtrusive tests of the facial feedback hypothesis for unpleasant affect, the contraction of the brow muscles plays an important role. For example, Larsen, Kasimatis, and Frey (1992) attached two golf tees to the subjects' brow region and asked them to touch the tips of the tees together (i.e., experimental condition) or to hold the golf tees still (i.e., control condition). Touching the tips together was only possible by contracting the *corrugator supercilii* muscles which are involved in the implementation of a sad emotional facial expression. The authors covered the task as a divided-attention experiment. In one part of the experiment, participants saw several pictures and were asked to rate them for "how it makes you sad". The results represent further support for the facial feedback hypothesis: Participants rated the pictures as more sadness releasing when they had to pull the golf tees together (i.e., facilitation of frowning) than when they had to hold the golf tees still (i.e., inhibition of frowning).

In the tradition of the experiments by Strack *et al*. (1988) and Larsen *et al*. (1992) a lot of studies were conducted which are concerned with further testing the facial feedback hypothesis with other methods and/or other emotions. Regarding surprise, until now there is only one study in which the facial feedback hypothesis is tested. Reisenzein and Studtmann (2007, Experiment 1) told their participants that the study was concerned with "effects of the size of the visual field on perception". The main task of the participants was to quickly indicate whether a dot appeared above or below a string of signs. Additionally, participants were asked to either widen (surprise face group) or narrow (surprise-incompatible face group) their visual field during some of the trials. Participants in the surprise group were told that the visual field is large if one "opens one's eyes widely" by rapidly and widely opening the eyes with raising eyebrows and upper lids plus opening the mouth which was demonstrated by the experimenter. Participants in the surprise-incompatible group were told that the visual field is small when "one focuses one's eyes on a point" which could be reached best when the eyebrows are contracted and the eyelids are partially closed which was demonstrated by the experimenter. Again, this represents an unobtrusive manipulation as the instructions are not related to any description of emotion but lead to surprise-like expressions as a by-product. At the end of each trial of the dot-location task, participants were asked to rate their mood on one mood item which was sometimes concerned with surprise. Crucially, after a series of baseline trials serving to establish certain expectancies, there were two trials during the course of the experiment in which surprise was induced by an unexpected salient change of the colors in these trials. Essentially, the authors found no evidence for influences of different facial feedback neither on subjective surprise ratings in surprise as well as baseline trials nor on the delay in reaction times to surprise trials compared to baseline trials. In Experiment 2 and 3, the authors changed the facial manipulation to a still less obtrusive task. Facial expressions were manipulated by asking participants to look up or look down while simultaneously saying "aa" or "oo", for surprise and surprise-incompatible, respectively. The results replicated those of the first experiment or (Experiment 3) were contrary to the facial feedback hypothesis as they showed that subjects of the surprise group felt less surprised by the stimulus changes than subjects of the control group.

As Reisenzein and Studtmann (2007) used a rather obtrusive task to cause surprise, there is another prominent task –namely implicit sequence learning (e.g., Clegg, DiGirolamo, & Keele, 1998; for overviews see, e.g., Frensch & Rünger, 2009; Shanks, 2005) within serial reaction time tasks– in which the deflection from an expected pattern was measured, however, in implicit ways as participants most often do not have an explicit representation of the pattern or of the deflection. Implicit sequence learning refers to the finding that the repetition of a specific sequence (for example a specific order of letters on which participants had to react one after the other) lead to decreasing reaction times (RTs) during practice over the course of the experiment but to a dramatic increase of RTs when the repeating sequence is modified in any of several ways (e.g., Ferdinand, 2008). It is important to note that participants often are not aware of the repeating sequence, the deflections, and that learning occurred at all. The concrete processes involved in implicit sequence learning (e.g., Dennis, Howard, & Howard, 2006; Gheysen, Gevers, De Schutter, Van Waelvelde, & Fias, 2009; Gureckis & Love, 2005; Weiermann, Cock, & Meier, 2010) and the extent to which the learning is really implicit (e.g., Destrebecqz & Cleeremans, 2001; Haider & Frensch, 2009) are continuously discussed. Further, it is discussed whether the (preconscious) detection of some kind of deflection from the expected pattern could be seen as conflict monitoring which causes the slowing in response times after the occurrence of the deflection and eventually causes the adoption of adjustments in response to that conflict (e.g., Jiménez, Lupiáñez, & Vaquero, 2009). It seems undisputed that implicit sequence learning can be used as an implicit measure for the reactions to deflections and the following orienting responses indicated by slowed reaction times. In turn, behavioral orienting responses with slower reactions in response to deviations from an expected pattern represent crucial indicators of surprise. Therefore, the use of implicit sequence learning tasks seems a promising tool for studying processes of surprise on a nonverbal, preconscious, or implicit level independent of subjects' (miss-)attributions and explicit statements. Thus, the main problems of earlier studies in which participants had to rate the extent of their feelings can be prevented. Especially in the case of surprise, an implicit measure could be desirable as Reisenzein *et al*. (2006) showed that different aspects of surprise (especially subjective feeling and facial expression) are only loosely associated. Perhaps, in implicit measures completely without explicit surprise ratings, the influence of different facial expressions (i.e., surprise *vs*. no-surprise) can show its differential effects on crucial aspects of surprise more strongly.

Thus, in the following experiment, we forced participants to show either a surprise face (i.e., surprise face condition) or we hindered participants from showing a surprise face (i.e., no-surprise face condition) by means of adhesive tapes fixed at relevant parts of the face, respectively. Then, participants worked through several blocks of an implicit sequence learning task. Most of the sequences represent standard sequences with a predefined order of 12 elements. The crucial block was block 3 in which half of the sequences included a deviation at one element from the standard sequence. As the facial expression of surprise should be associated with a larger orienting or irritation response in response to deviations, we expected a larger increase of reaction times to these deviation sequences in relation to the standard sequences for participants of the surprise face condition compared to participants of the no-surprise face condition.

Method

Participants

Forty-one students (33 female; median age: 23 years, range: 19-47; 36 right-handed, 4 left-handed, 1 without dominance of one hand) from the University of Hildesheim participated in the experiment in exchange for course credits. All were native German speakers and reported normal or corrected to normal vision. Participants were randomly assigned to face conditions.

Design

Essentially, we used a 2 (face condition: surprise *vs*. no-surprise) × 2 (sequence: standard *vs*. deviation) design. Face condition was varied between subjects, sequence was varied within subjects and relates to block 3, in which standard as well as deviation sequences were presented. Additionally, we analyzed influences of different kinds of explicit knowledge, thus we separated the group into different sub-groups according to their performance in explicit tests (see below).

Materials

The target stimuli were the letters A, B, C, and D. Each stimulus appeared in white at the center of the black screen in 22-point Courier New font (bold). Participants' task was to quickly and accurately identify each letter by pressing the corresponding key which was assigned as follows: A was assigned to the left middle finger (key F), B was assigned to the left index finger (key V), C was assigned to the right index finger (key N), D was assigned to the right middle finger (key J). A sequence was defined by 12 successive letters. The standard sequence was CDBCABADCBDA, which includes each letter equally often, ensures that each letter follows and precedes each other letter once, and avoids repetition of one letter at successive positions. Deviation sequences were created by exchanging one element of the standard sequence by another letter. Overall, the experiment comprised 12 deviation sequences in which repetitions of letters at successive positions were also not allowed. Over the course of all deviation sequences, each element was exchanged exactly one time, and each of the four letters was equally often used as a deviating element.

Procedure

Participants were individually tested in sound-attenuated chambers. The experiment was run using E-Prime software (version 1.3) with a standard PC and 17' CRT monitors with a refresh-rate of 75 Hz. Viewing distance was about 60 cm.

First, participants were asked to read a handout informing them on the supposed purpose of the study. Therein, they were told that we wanted to test influences of different symptoms of hay fever on reactions in simple reaction time studies typically conducted in cognitive psychology. This would be specifically important because results in cognitive psychology show variations over time. Thus, perhaps poorer performance and concentration especially in spring could be related to some symptoms associated with hay fever and the increasing number of persons suffering from hay fever. Participants in the surprise face condition were told that we wanted to test the influence of the symptoms "impairments in the region of the eyes" and "cold associated with a restriction regarding breathing through the nose". Further, for simulating these symptoms we would use adhesive tapes which we would fix over the eye brows, which were meant to stay in a raised position and below the nostrils, so oral breathing got necessary. Participants in the no-surprise face condition were told that we wanted to test the influence of the symptoms "feeling of heaviness in the region of the forehead" and "restrictions in the region of the throat and regarding breathing through the mouth". Further, for simulating these symptoms we would use adhesive tapes which we would fix over the forehead and over the mouth. Overall, participants found this cover story convincing as we got a lot of comments either in the direction whether it would be a problem if someone actually suffers from hay fever or in the direction that participants recommended which other symptoms of hay fever we should also test. After reading these first instructions and information, the experimenter fixed the adhesive tapes as described and as it can be seen in Figure 1. For the surprise face condition, the eye brows were fixed as if

Figure 1. Fixation of the adhesive tapes in the surprise face condition (left side) and the no-surprise face condition (right side).

participants would frown. Automatically, the eyes were widened. Additionally, the mouth had to be opened slightly due to the impairment of breathing through the nose. For the no-surprise face condition, the forehead was fixed so that participants were no more able to frown. Additionally, due to the tapes over the mouth, participants were not able to open their mouth. Thus, for these participants, at least two typical facial aspects of surprise were prevented.

For the implicit sequence learning task and further questions, all instructions were given on screen. The sequence learning experiment comprised four blocks with 24 sequences each and an additional practice block with 6 sequences at the beginning of the experiment. Blocks 1, 2, and 4 and the practice block exclusively contained standard sequences. Block 3 contained 12 standard sequences and 12 deviation sequences. The order of sequences within block 3 was chosen randomly by the computer. The presentation of each letter was preceded by a fixation cross (+) which was shown for 400 ms. Each letter was presented until a response was given.

After the implicit sequence learning task, participants were asked on screen whether they had noticed something unusual during the course of the experiment. Thereafter, they were specifically asked whether they had noticed that a sequence of letters was repeated permanently during the experiment. The answers were given through mouse clicks at one of two buttons (yes/no). In the case of a "yes"-answer for the first question, participants could type in what they had noticed.

After these questions, participants worked through two explicit tests in which we tested their explicit knowledge regarding the sequence. In the first explicit test (recognition memory test), overall 24 four letter sequences were shown; 12 of these four letter sequences were actually part of the standard sequence, the remaining 12 sequences were not part of the standard sequence. Participants should decide via mouse click on one of two buttons (yes/no) whether each of these sequences was part of the repeating sequence from the main part of the experiment. Each four letter sequence was presented at the center of the screen until a response was given. After each sequence, a blank screen was presented for 750 ms. The order of the four letter sequences was chosen randomly.

In the second explicit test (sequence production task) participants were asked first (inclusion condition), to type in 12 letters as they were repeatedly presented in the main part of the experiment with the following constraint: each of the four possible letters should be used equally often. Participants could react without time pressure and were asked to guess if they do not remember the actual sequence. Then, participants were asked to type in again 12 letters, however now the order should be explicitly and maximally different to the order of the standard sequence (exclusion condition). Again, they should use each of the four letters equally often and they should guess if they are not sure.

At the end of the experiment, five questions regarding the discomfort caused by the adhesive tapes and regarding concentration problems in general during the experiment were asked. Participants answered via mouse click at one of two buttons. Then, the experimenter removed the tapes and thanked the participants for their attendance. Participants were informed that they could get information on the real purpose of the experiment as well as on the results if they were interested in these.

Data analysis

As we were interested in general orienting or irritation processes occurring in deviation sequences compared to standard sequences, we included all responses whether or not it was a correct or an incorrect response into the analyses of the implicit sequence learning task. For each face condition group, mean RTs were calculated for each block (and additionally within block 3 for deviation and standard sequences separately) for each participant, and a group mean was then calculated by averaging individual means in each block as well as for deviation and standard sequences of block 3.

For the recognition memory test, for each participant, the signal detection sensitivity parameter *A'* (see Pollack & Norman, 1964; Pollack, 1970) was calculated. To this end, hits were correct identifications of four letter sequences which had been presented within the standard sequence, misses were false responses to four letter sequences which had been presented within the standard sequence, false alarms were false responses to four letter sequences which had not been presented within the standard sequence, and correct rejections were correct identifications of four letter sequences which had not been presented within the standard sequence. *A'* values of .50 indicated random responding at chance level.

For the sequence production task, we counted the number of generated chunks of three elements which were part of the standard sequence in both inclusion and exclusion condition (see also Destrebecqz & Cleeremans, 2001). Then, we subtracted the number of correct chunks of the exclusion condition from the number of correct chunks of the inclusion condition as measure of performance in this task.

Results

Although participants of the surprise face condition said more often than participants of the no-surprise face condition that they had noticed a certain sequence during the experiment, $t(39) = 2.22$, $p < .05$, this could not be confirmed by performance in the explicit tests. In the recognition memory test, participants showed overall *A'* values above chance level, $M = 0.58$, $SD = 0.14$, $t(40) = 3.67$, $p = .001$. In the sequence production task, overall $M = 1.88$ ($SD = 2.17$) more triplets were identified correctly in the inclusion than the exclusion condition. Face condition groups did not differ significantly, neither in the recognition memory test, $t(39) = 1.61$, $p > .12$, nor in the sequence production test, $t < 1$, $p > .51$. Both tests did not correlate significantly with each other, $r = .20$, $p = .22$. Thus, we separated participants into groups according to the performance in the recognition memory test (criterion: individual *A'* at least .09 above or below chance level) and the sequence production task (criterion: more correctly identified triplets in the inclusion than the exclusion condition, e.g., Fu, Fu, & Dienes, 2008). According to this severe criteria, there were $n = 24$ recognition memory high performer and $n = 31$ sequence production high performer. We entered these group variables as additional factors to the analyses of the implicit learning task.

Additionally, we analyzed the five questions at the end of the experiment regarding concentration and discomfort caused by the face preparation. Here, only one question revealed significant differences between face condition groups, which pointed out that participants of the surprise face condition said more often than participants of the no-surprise face condition that they experienced the fixation of the adhesive tapes as physically unpleasant, $t(39) = 4.47$, $p = .001$.

For the implicit learning task, mean RTs of each block for each face condition group are shown in Figure 2; mean RTs of the standard and the deviation sequences

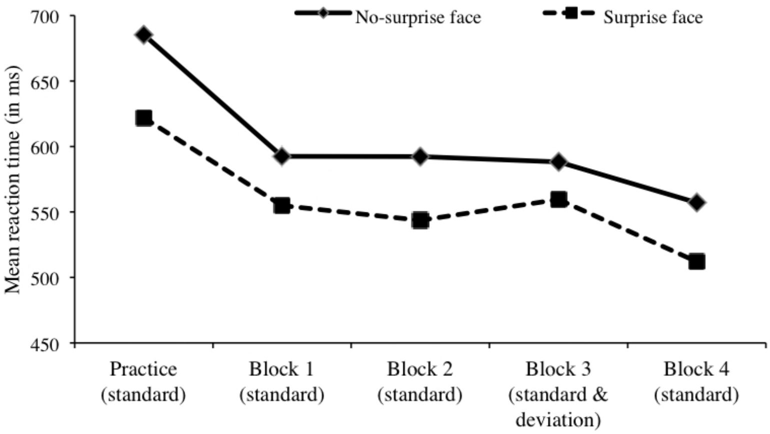

Figure 2. Mean RTs of each block separately depicted for the surprise face condition and the no-surprise face condition. The practice block contained 6 standard sequences, blocks 1, 2, and 4 contained 24 standard sequences each, block 3 contained 12 standard sequences and 12 deviation sequences, presented in random order.

within block 3 for each face condition group are presented in Figure 3. Mean RTs of block 3 were subjected to a 2 (face condition: surprise *vs*. no-surprise) x 2 (recognition performance: high *vs*. low) x 2 (sequence production performance: high *vs*. low) x 2 (sequence: standard *vs*. deviation) mixed ANOVA. There was a significant main effect of sequence production performance, $F(1, 33) = 4.23$, $MSE = 15478$, $p = .048$, $\eta_p^2 = .11$, indicating faster responses of high performer compared to low performer. Additionally, a significant interaction of sequence and sequence production performance results, $F(1, 33) = 6.53$, $MSE = 283$, $p = .015$, $\eta_p^2 = .17$. High sequence production performer showed faster reactions in standard than deviation sequences, $t(30) = 3.22$, $p = .003$, whereas low sequence production performer showed equally fast reactions in standard and deviation sequences, $t < 1$, $p > .55$. Most important, there was a significant interaction of face condition and sequence, $F(1, 33) = 5.32$, $MSE = 283$, $p = .027$, $\eta_p^2 = .14$. As expected, participants of the surprise face condition showed larger increases in reaction times to deviation sequences compared to standard sequences than participants of the no-surprise face condition who did not show differences between deviation and standard sequences, $M_{surprise} = 14$ ms, $SD = 24.93$, $t(20) = 2.64$, $p = .016$, $M_{no\text{-}surprise} = 1$ ms, $SD = 25.79$, $t(19) = 0.17$, $p = .87$ (see also Figure 3). No other main or interaction effect reached significance (all *ps* >.07).

The same analyses with mean error rates revealed a main effect of sequence with overall more errors in deviation sequences compared to standard sequences, $F(1, 33) = 10.61$, $MSE = 0.04$, $p = .003$, $\eta_p^2 = .24$. No other main or interaction effect reached significance (all *ps* >.09).

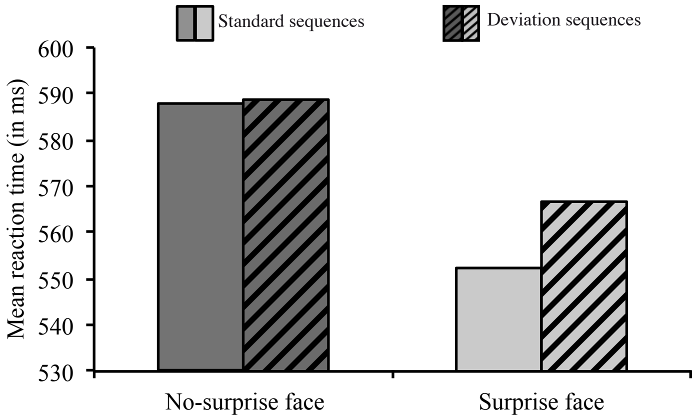

Figure 3. Mean RTs of standard and deviation sequences within block 3 for each face condition group.

DISCUSSION

We could present results which can be interpreted as evidence for the facial feedback hypothesis regarding surprise. We analyzed whether facial feedback of surprise versus no-surprise can modulate reactions following deviations in an implicit sequence learning task. We fixed adhesive tapes at several positions in participants' face forcing them to show either a surprised face or preventing them from showing a surprised face. After several blocks in which a standard sequence consisting of a predefined order of 12 elements was repeated, in block 3 standard sequences and sequences in which one element differed from the standard sequence were intermixed. The results confirmed our hypothesis: Participants of the surprise face condition showed –compared to typical implicit learning task (e.g., Fu *et al*., 2008)– normal responding with decreasing RTs over standard blocks, an increase in RTs in block 3 and again a decrease in RTs in the final standard block. Most importantly, participants of the surprise face condition showed longer RTs to deviation sequences than to standard sequences in block 3. In contrast, participants of the no-surprise face condition showed no increase of RTs in block 3, and they did not show any difference between deviation sequences and standard sequences within block 3. Besides, we found significant effects of performance in the sequence production task on reactions to deviation sequences compared to standard sequences. We want to discuss these results, first, with respect to implicit sequence learning, second, related to emotion and facial feedback research, and third, regarding possible limitations of the study.

The question whether learning generally can be implicit has been discussed continuously (e.g., Destrebecqz & Cleeremans, 2001). Evidence with different research paradigms including neuroscientific methods support the claim that consciousness is not (always) necessary for learning to occur (e.g., Destrebecqz & Cleeremans, 2001; Henke, Mondadori, Treyer, Nitsch, Buck, & Hock, 2003; Wong, Bernat, Bunce, & Shevrin, 1997). However, was learning in the present experiment really implicit? Results from both explicit tests showed that a serious part of participants acquired some kind of knowledge over pure implicit and procedural knowledge during the task. The recognition memory task likely reflects some kind of explicit knowledge. However, as could be shown, performance in this task had no influence on performance in the implicit learning task, that is, implicit as well as explicit learners according to this direct test showed the same pattern of learning in the implicit sequence task as measured with reaction times.

In contrast, results of the other direct test –the sequence production test– had some influences on reaction times in the implicit learning task. However, it is argueable whether this kind of knowledge really represents strong cases of explicit knowledge. Most likely, performance in the sequence production task was at least partly subtended by implicit sequence knowledge (see also e.g., Destrebecqz & Cleeremans, 2001; Fu *et al*., 2008; Jimenez *et al*., 2009). Participants had to perform their task with the same effectors and with the same equipment as in the implicit learning task. According to this point, implicitly learned motor sequences should be produced easier than other sequences especially in the inclusion condition. This would lead to better performance in the inclusion than the exclusion condition which, in turn, could not be interpreted as strong claim for better explicit knowledge. Thus, performance in the sequence production task most likely reflects a mixture of explicit and implicit knowledge. However, performance in the sequence production tasks had influences on performance in the implicit learning task. First, participants who generated more correct triplets under inclusion than exclusion conditions showed overall faster responses in the implicit learning task (block 3) than participants who did not generated more correct triplets under inclusion than exclusion conditions. Second, high sequence production performers showed faster reactions in standard than deviation sequences, whereas low sequence production performers showed equally fast reactions in standard and deviation sequences.

Interestingly, there are several reports in which faster reaction times come along with some kind of explicit knowledge or good performance in generation tasks. For example, Ferdinand (2008) investigated differences in implicit sequence learning with explicit instructions versus incidental, thus implicit, occurrence. Here, participants of the explicit learning group were overall faster than participants of the implicit learning group. In studies on differences between older and younger subjects, older subjects showed overall longer reaction times in the implicit learning task, and at the same time, older subjects showed no differences between inclusion and exclusion conditions in direct generation tasks whereas younger subjects showed better performance in inclusion than exclusion conditions (e.g., Dennis *et al*., 2006). A further example for this pattern represents the study of Destrebecqz and Cleeremans (2001) in which faster reactions of participants in a condition with a response-stimulus-interval (RSI) of 250 ms –compared to slower reactions of participants in a condition with an RSI of 0 ms– also come along with better performance in a generation task. Overall, these results could be interpreted as evidence that faster reactions both cause and result from (explicit) knowledge represented by the generation task. One speculation might be that the initial experience of fluency leads to faster reactions and, in turn, over training these faster reactions lead to more familiarity with the sequence. Another possible explanation might be that after some training one element of the sequence acts as prime or cue for the following element(s). As known, for example from affective priming studies, priming occurs more likely and stronger when the intervals between primes and to-be-primed targets are not too long (e.g., Hermans, De Houwer, & Eelen, 2001; Klauer, Roßnagel, & Musch, 1997). Thus, it might be that faster reactions determine that the occurrence of priming in implicit sequence learning becomes possible –thus, priming might be one process contributing to implicit sequence learning (of course priming would be only one process of several processes). Moreover, the triggering of the next response by priming mechanisms, in turn, might be also responsible for better performance in sequence generation tasks.

In general, the implicit sequence learning paradigm can be interpreted as measure of the detection or the response to events deviating from previously learned sequences. Most interesting, the present data reveal that surprise reactions seem crucial for implicit responding to deviations within implicit sequence learning. That is, either the facial expression *per se*, for example widely opened eyes, lead to faster or more accurate detections of deviations. In turn, participants reliably showed RT differences between standard and deviation sequences. Or –and even more likely– the facial expression acts via associations with several behavioral and cognitive processes. For example, facial expression of surprise might be associated with a higher degree of conflict monitoring, a specific distribution of attention, orienting behavior, and slowing down or disrupting ongoing behavior. With preactivation of such processes (especially when external cues as deviating elements additionally confirm these preactivations as adequate), first, it would be easier to classify deviations as deviations and to have the feeling that the fluency was interrupted, and second, it might be more probable and possible to show reactions typically occurring in situations deviating from expectation. The no-surprise face condition hindered participants to show surprise. It might be that these participants did not have the feeling that fluency was interrupted. In turn, this suggests that in implicit sequence learning experiments without manipulating participants' face, surprise is shown incidentally by participants. To confirm this hypothesis, further research could use the *facial acting coding system* (FACS; Ekman, Friesen & Hager, 2002) or electromyography (EMG) of relevant facial muscles.

The issue whether facial activity is only related to positive versus negative affect (i.e., dimensional) or to specific emotions as anger versus sadness (i.e., categorical) has been discussed frequently (e.g., Flack, 2006; McIntosh, 1996). According to the second claim of this question, we have to admit that some facial expressions share physical/facial similarities with each other, for example, disgust and anger. Especially in the case of surprise, surprise is confused with fear, when participants are requested to categorize emotional facial expressions (e.g., Ekamn & Friesen, 1971; Matsumoto & Ekman, 1989; Dailey *et al*., 2010) as well as when participants should show specific facial expressions and report their own feelings (e.g., Flack, Laird, & Cavallero, 1999). In turn, in the present study we cannot exclude completely that the effects found were the result of fear related processes instead of surprise related processes. However, in fear the facial expression typically also shows tensed lower eyelids and lips stretched horizontally to the ears (instead of unstressed opened mouth in surprise) which both is prevented or made rather unlikely by the adhesive tapes as we used it in the present study. Additionally, McIntosh (1996) noted that facial actions and emotions are most likely not related in a one-to-one manner but there may be many influences which modulate these links; one of the possible modulations might be the context and task demands. Thus, it seems unlikely the task used in the present study is able to be associated with fear as participants simply had to classify four letters. Yet, further research on surprise facial expressions could focus on differences between specific emotional facial expressions instead of focusing only on the comparison of one facial expression and a control (non-emotional) expression.

According to the first claim of the question, surprise represents a special case. Surprise is hedonically neutral but not *per se* pleasant or unpleasant, which, in turn, leads to continuous debates whether surprise actually is an emotion or not (e.g., Reisenzein & Meyer, 2009). Reisenzein (2000) offered an interpretation of emotions due to which surprise can be categorized as emotion by suggesting, that the core of an emotion is not to decide whether something is positive or negative, but to decide whether something fits or does not fit with preexisting mental representations. In the case of positive and negative emotions, the comparison is between preexisting desires and newly acquired beliefs. In the case of surprise, the comparison is between preexisting beliefs and newly acquired beliefs. At this point, in principle, we can handle surprise as "normal" emotion. Until now, surprise has been considered very rarely in studies on facial feedback (Reisenzein & Studtmann, 2007). These authors did not find effects of facial surprise expressions on reports of surprise experiences. Perhaps, this is also caused by the finding that in surprise, facial expression, behavioral measures, and self-reports diverged. For example, only 4 to 25% of the participants showed surprise expressions whereas almost all reported surprise feelings (e.g., Reisenzein *et al*., 2006). Conversely, one could speculate that implicit measures which are independent of self-reports on subjective experiences might be more adequate for measuring influences of facial expressions of surprise.

As in emotional research the subjective experience is of central interest, the present study represents an exception. Not subjective feelings but some behavorial responses were measured. Emotions or adjectives related to emotional experiences were not mentioned during the whole course of the experiment. There are only few studies in which influences of bodily states on non-emotional behavior were measured. One of these few studies analyzed different physical postures (i.e., an expansive, upright posture *vs*. a slumped, depressed posture) on the persistence in a frustrating task, namely in solving insolvable puzzles. Consistent with hypothesis, participants of the upright position group persisted longer than participants of the slumped position group (Riskind & Gotay, 1982). That is, non-emotional behavior –as solving puzzles– was influenced by emotion associated postures and in emotion associated direction. The same logic was applied in the present experiment. Instead of asking participants which emotions they had, we measured exclusively the effect of facial expressions associated with emotion on non-emotional behavior. By doing so, we were able to detect differences in responses following deviations between surprise and no-surprise facial expressions. Differences were consistent with hypotheses –facial surprise comes along with responding related to surprise, that is, slowing down of activity after the occurrence of discrepancies between preexisting expectations and the current situation.

McIntosh (1996) distinguished in his review four versions of (contemporary) facial feedback hypothesis. First, facial configuration corresponds to (i.e., covaries with) emotions, which does not imply causality. Second, facial movement can modulate emotions when other emotional stimuli are present. Third, facial action can initiate emotions also in cases in which no other emotional stimuli are present. Fourth, facial action is necessary for the presence of emotions. The present study contributes to some aspects in response to several versions of the facial feedback hypothesis. First, for the present study we have to exchange or attenuate the term emotion to something like “emotion related responding”. Second, in the case of surprise it is rather difficult to distinguish between the second and the third version as the presence of some kind of deviation does –until now– not represent a common emotional stimuli (fully or at least in the narrower sense). Thus, in the case of surprise most likely the formulation of facial feedback hypothesis has to be changed slightly –perhaps with recourse on Reisenzein’s (2000) considerations of surprise as emotion (see above). Additionally, the study seems to confirm at least the second/third version as it could be shown that the facial expression of surprise *vs*. no-surprise modulates whether participants responded with reactions related to surprise or not, respectively, at least in a task in which surprise reactions can be triggered (implicitly). The first and fourth version could be supported in such a way that the prevention of showing a surprised face also prevented surprise related responding as measured by slowed responses in view of deviations. However, in the present state of research and theoretical formulation, it seems not possible to exactly classify the present data as support for or against one version of the facial feedback hypothesis.

Surprised facial expressions are most often characterized as short living phenomenon as the facial surprise reaction lasts only a few seconds or even only one second. In some cases, not the facial expression *per se* but rather a sequence of successive facial expressions and further information as duration are crucial for a specific emotion (for example, for embarrassment, e.g., Ekman, 1993). Additionally, there are some reports of facial mimicry studies in which the constant holding of a pen in the mouth (i.e., leading to constant smiling) in fact led to inhibition of mimicry instead of inducing strong positive affect. These findings led to assumptions that (perception of) changes of muscular activity –instead of the expression as result of muscular changes *per se*– are crucial for (perceptions of) an emotion (e.g., Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001; Oberman, Winkielman, & Ramachandran, 2007). In the present study, however, we used static facial expressions and we found influences of facial expression on responses. As there are also a lot of studies in which static expressions of, for example, joy, anger, sadness, or fear were used and influences on responses were found (e.g., Laird, 1972; Larsen *et al*., 1992; Strack *et al*., 1988; Strack & Neumann, 2000), the aspect of changing muscular activity seems overall not as crucial as assumed by some researchers. However, further research could use dynamic versions of surprise expressions, perhaps to boost the results presented here.

In this section, we want to summarize suggestions for future research. First of all, the relationship between subjective experience and unconscious processes of surprise could be questioned. Originally, the facial feedback hypothesis is related to determinants of subjective experience. With the present experiment (see also, e.g., Riskind & Gotay, 1982), we extended the scope of application of the hypothesis. However, as we were not interested in subjective surprise feelings, the link between subjective emotional feeling and reaction times to deviating stimuli is lacking and could be addressed by future research. Second, we used only one method of facial feedback manipulation for surprise. It would be desirable to test other manipulation methods, for example, to look up or down (e.g., Reisenzein & Studtman, 2007), to induce surprise faces and replicate our data pattern by use of other manipulations. By doing so, alternative interpretations (e.g., perhaps the adhesive tapes had induced different moods which led to different data pattern) possibly could be ruled out and the issue of ecological/external validity of facial manipulation possibly could be addressed. However, it is difficult to rule out alternative explanations in terms of different amounts of oxygen which could be inhaled in the no-surprise *vs*. surprise face condition (thus, perhaps leading to faster or slower neural processing) or differences in perceiving stimuli due to wider or more narrow eyes as these aspects are inherently differently between no-surprise and surprise. Third, it could be explicitly shown that exclusively surprise (but not, for example, fear) causes the effect. Thus, other emotional control conditions would be also desirable as well as to measure control variables (e.g., mood or strenuousness). Fourth, as it could be the case that facial expression influences action processes in an unconscious manner, it would be eligible to measure (e.g., with video coding or EMG) facial surprise reactions to deviating stimuli in a control group without any facial feedback manipulation. Fifth, a control group without any facial feedback manipulation would also help to clarify the influences of suppression (possibly acting in the no-surprise face condition) and enhancement (possibly acting in the surprise face condition) effects on the resulting data pattern. Sixth, a systematic manipulation check for the effectiveness of the cover story could be applied.

In summary, we could present data which tentatively can be interpreted as evidence for the facial feedback hypothesis in the case of surprise (however, to rule out all alternative explanations, future research is desirable). Facial feedback of surprise as manipulated with adhesive tapes in the present study led to a slowing-down of ongoing activity as response to (implicitly) perceived deviations from an (implicitly) learned repeating sequence. At least, when prevented from showing facial expressions of surprise (in the no-surprise face condition), no such slowing-down was present, thus, the interruption or slowing-down of ongoing activity was suppressed. The combination of facial feedback, surprise, and implicit measures seems a promising tool which possibly opens the issue of facial feedback on surprise and the influence of facial feedback on implicit measures to future research.

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