Can spontaneous movements be modulated by visual and acoustic stimulation in 3-month-old infants?

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Abstract

Background: The assessment of the quality of general movements (GMs) in infants proves to be a reliable and valid diagnostic tool for detecting brain dysfunction early in life. Of special interest, particularly for the prediction of cerebral palsy, is the fidgety kind of GMs, the so-called fidgety movements (FMs) observable in 3- to 5-month-old infants. GMs are part of an infant’s spontaneous motor repertoire and as such endogenously generated by the nervous system itself. Aim: The question was raised as to what extent the temporal organisation of FMs can be modulated by visual and acoustic stimulation. Study design: Spontaneous motility in supine position with and without stimulation was recorded on video and the data were semiquantitatively analysed. We studied the effect of visual stimulation (red ring, red puppet), unanimated acoustic stimulation (68, 77, 88 dB) and of the mother, approaching her infant in a talkative manner after an absence of a quarter of an hour. Subjects: Twenty-nine healthy infants at the age of 12 weeks who all showed normal FMs. Results: Visual stimulation demonstrated that only the presentation of a red puppet elicited a significant level of focussed attention and led to a decrease of FMs. A red ring, unanimated acoustic stimulation as well as the interaction with the mother had no influence on the temporal organisation of FMs. Conclusion: This study demonstrated that in 3-month-old infants, FMs is a predominant motor pattern and that it is possible to assess FMs during (playful) social interaction. © 2002 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: General movements; Fidgety movements; Focussed attention; Infant neurology; Mother–infant interaction

Abbreviations: FMs, fidgety movements; GMs, general movements; PMA, postmenstrual age; PTA, postterm age.

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1. Introduction

Spontaneous movements in the human fetus emerge as early as 7 1/2- to 8-week post menstrual age (PMA) and they appear patterned and highly coordinated right from the beginning [1,2]. One of these early movement patterns is the so-called general movements (GMs). GMs are gross movements involving the entire body. They are complex and wax and wane in intensity, force and speed, and the movements are characterised by a smooth onset and end [3]. Because of the complexity, frequent occurrence and long duration of GMs, the quality of these movements can be readily assessed. It has been shown repeatedly that the quality of GMs changes if the developing nervous system is impaired (for a review, see Ref. [4]). Hence, the qualitative assessment of GMs is a suitable diagnostic tool for assessing the condition of the young nervous system.

GMs are continuously present from early fetal life onwards (9th to 10th week PMA [2]) until about 20-week postterm age (PTA) [5]. From term age onwards, GMs are called writhing movements because of the superimposed elliptical arm movements typical for that age [6,7]. At 6- to 9-week PTA, GMs with a writhing character gradually disappear while fidgety GMs gradually emerge [5,8]. Fidgety movements (FMs) are circular movements of small amplitude, moderate speed and variable acceleration of neck, trunk and limbs, in all directions [8]. They may occur together with other gross movements such as kicking, wiggling, oscillating and swiping with the arms [7]. FMs are present up to 15 to maximum 20 weeks of age at which time manipulation and antigravity movements occur and start to dominate [7,8].

As already stated, the quality of GMs changes if the nervous system is impaired. From this follows that the quality of FMs also changes since FMs are GMs at a specific age. Abnormal FMs are exaggerated in amplitude, speed and jerkiness and often predict later neurological deficits [8]. An even more powerful predictor of later spastic cerebral palsy is the absence of FMs [8]. In a collaborative study involving five centres, Prechtl et al. [8] collected data on the normal and abnormal quality of FMs in 130 infants. These data were related to the assessment of the neurological development of these children at 2 years of age. A total of 67 (96%) out of 70 infants with normal FMs had a normal neurological outcome. In the remaining 60 infants, abnormal quality or total absence of FMs was followed by neurological abnormalities in 57 (95%) infants. Specificity and sensitivity of the assessment of FMs were higher (96% and 95%, respectively) than that of ultrasound imaging of the infants’ brains (83% and 80%, respectively). These findings were later confirmed by studies on preterm [9], small-for-gestational age infants [10] and preterm infants with chronic lung disease [11].

Because the assessment of FMs is of the utmost importance to infant neurology, it seems equally important to come to a better understanding of the character of these movements. Prechtl et al. [8] reported that FMs are present continuously in the awake infant except when the infant’s attention is focussed. It is self-evident that FMs can hardly be seen when the infant is crying or fussing since all movements then become jerky, even rigid, and speeded up. Therefore, the quality of GMs cannot be assessed during fussing and crying, at whatever age [6]. However, it remained an open question as to what extent focussed attention interferes with FMs. The purpose of this study was
to explore whether visual and acoustic stimuli of different levels of interest would elicit focussed attention and if this would interfere with FMs.

We addressed the following specific questions:

- Do infants show different levels of attention to two different visual stimuli and if so, does more or less focussed attention influence FMs?
- Does an increase in the level of sound pressure influence FMs?
- Do FMs change if the mother approaches her infant after an absence of 15 min and how does the infant react socially?

2. Subjects and methods

2.1. Subjects

From November 1998 to January 1999, thirty-three 12-week-old infants (16 girls and 17 boys) were studied at our Department. The families were recruited from the Department of Obstetrics and Gynaecology of Graz Hospital a few days after the birth of the infant. If the infants were born at term without any perinatal complications and if their Apgar score was at least 9 at 1 min and 10 at 5 min, they were selected. The families belonged to the middle or upper social classes, lived in or close to Graz, and gave their informed consent to participate at this study according to the standards of the local research ethics committee. In order to be included in the study, all infants had to show normal FMs at the time of the neurological examination at 3 months [12]. Two infants failed this criterion and had to be excluded. Two other infants had to be excluded because of extensive crying during the observations. Thus, we analysed the recordings of 29 infants (13 girls and 16 boys). Despite the fact that all the infants studied were born at term (38- to 42-week PMA), their age was corrected to their PMA at birth. Thus, the median age at the time of observation of the FMs was 11-week PTA (IQR: 10–12 weeks; range: 9–14 weeks). Some infants cried during the different trials and so every experimental trial had a slightly different number of subjects (with a minimum of 21 infants). The interval between the various experimental trials was 30 s, but had to be adapted in some infants according to its behavioural state.

2.2. Video recording and analysis of fidgety movements

All infants were recorded during active wakefulness while lying supine in a cot in the observation room. A single chip camera was installed high above the cot to avoid attracting the infant’s attention and to provide an optimal (midsagittal) view of the infant. The infant was observed continuously on a monitor outside the recording room by one of the examiners, and the infant’s mother. The infants wore a small nappy and a short-sleeved bodysuit and they had been fed for the last time about 1 h before the observation. Before starting the visual stimulation experiments, the infants were recorded without any external stimulation for approximately 2 min. This served as a baseline for the temporal organisation
and the quality of FMs. All the recordings were analysed off-line by the two authors. Interscorer agreement was 98%.

The temporal organisation of FMs was scored as follows.

Continual FMs (score: ++): FMs occur frequently but are interspersed among short pauses. As FMs are by definition GMs, the movements involve the whole body, particularly the neck, trunk, shoulders, wrists, hips and ankles. Depending on the actual body posture, in particular, the position of the head, FMs may be expressed differently in the different body parts.

Intermittent FMs (score: +): Although FMs occur regularly in all body parts, the temporal organisation differs from FMs++. In fact, the pauses between FMs are prolonged, giving the impression that FMs are present for only half of the observation time.

Sporadic FMs (score: ±): Sporadic FMs are like FMs+ but interspersed with even longer pauses. Thus, FMs can be seen in all body parts but intermittently and localised.

In all three examples of the different temporal organisations of FMs, gross movements may occur together with FMs, i.e. FMs are superimposed on gross movements or gross movements may occur during the pauses between FMs, or both.

Absent FMs (score: –): FMs cannot be observed, although some gross movements may occur.

The quality of FMs was assessed according to Prechtl’s method of qualitative assessment of GMs based on visual Gestalt perception (for a review, see Ref. [6]). In addition, any other gross movements concurrent with FMs were noted.

2.3. Visual stimulation

2.3.1. Visual stimulation with a red ring

All 29 infants participated at this trial. The experimenter (J.D.) stood beside the infant’s cot and presented a red ring without engaging in any social contact with the infant. The red ring, with an inner diameter of 9.6 cm and an outer diameter of 10.5 cm, dangled in front of the infant at a distance of about 30 cm. The median duration of stimulus presentation was 27 s (IQR: 21–31 s; range: 13–31 s). FMs were assessed 10 s before, during and 10 s after stimulation. We scored focussed attention during stimulation as continuous, interrupted by short periods of looking away, or absent.

2.3.2. Visual stimulation with a red puppet

Twenty-six infants (11 girls, 16 boys) took part at this trial. After the red ring had been removed, the experimenter presented a red puppet in the same way as described above. It was a red Santa Claus of 24 cm long and 17 cm wide. The median duration of stimulation was 31 s (IQR: 29–31 s; range 20–31 s). FMs and focussed attention were analysed as described. Two infants started to cry immediately following the end of stimulation so the data on their FMs were unavailable.

2.4. Acoustical stimulation by means of different sound pressure levels

Twenty-five infants (10 girls, 15 boys) participated in this part of the study. In three cases, the analysis of FMs could not be carried out during either the one or the other...
acoustical stimulation trial because of fussing or crying. The stimuli consisted of a tape-recorded series of three sounds of different sound pressure levels. The recorded sounds were that of a rattle, a bell and a recorder. The sound pressure levels were 68, 77 and 88 dB. The sounds were presented in increasing order. Each sound lasted for 5 s with an interval of 10 s. FMs were assessed as described before.

2.5. Approach by the mother

Twenty-one infants (9 girls, 12 boys) took part in this trial. The infants were separated from their mothers for a median duration of 16 min (IQR: 13–15 min; range 11–27 min). The mother could watch her infant on a monitor outside the observation room during the baseline recordings, the visual and acoustical stimulation, as well as during another experimental trial that will be reported on elsewhere. After the separation, the mother was asked to enter the room, greet her infant and to keep up a running conversation with her infant while standing beside the cot. The mother had been asked not to touch her infant. The infant’s FMs were scored in the manner described above. In addition, the time interval (in seconds) from the mother’s appearance at the side of the cot to the infant’s first looking towards her and its first smile was assessed. Looking towards the mother was scored as continuous, incidental, or absent.

2.6. Statistics

As the Wilcoxon Test could not be applied one-tailed, and hence, did not fulfill the requirement to distinguish between ‘no change’ in the temporal organisation of FMs and ‘decrease of FMs’, the Chi-square and Yates corrected chi-square tests were applied. For some computations, the decrease of FMs and the stop of FMs were pooled as both phenomena were considered as a ‘decrease’. A \( p \)-value < 0.05 was considered as statistically significant.

3. Results

During the 2-min baseline recording, the majority of infants (\( n=18; 62\% \)) had continual FMs. Eleven infants (38%) had intermittent FMs only. For 17 infants, the temporal organisation of FMs in the baseline recording and in the sequence before the different experiments was the same. For the remaining 12 infants, the frequency of FMs varied between that of the baseline recording and the sequences before the different experiments. The quality of FMs did not change during any of the experiments.

Besides FMs, other movement patterns we observed were: kicking [13], swipes [7], wiggling–oscillating [7], saccadic arm movements [7], hand–hand contact, hand–mouth contact, hand–hand–mouth contact, manipulation of clothes, trunk rotation, hand–knee contact and foot–foot contact. Spontaneous asymmetric tonic neck responses were also noted but these were easily overcome by flexion of the jaw arm by all infants.
3.1. Visual stimulation

3.1.1. Visual stimulation with a red ring

Immediately after and during the whole sequence of stimulation, the red ring did not elicit continuous attention nor did it influence the temporal organisation of FMs significantly (Table 1). The temporal organisation of FMs after removing the red ring did not change in 18 infants (62%). In the 11 remaining infants, the temporal organisation of FMs either decreased (7 infants, 24%) or even increased (4 infants, 14%).

Table 1
The influence of two different visual stimuli, a red ring and a red puppet, on the temporal organisation of fidgety movements and on the level of the infant’s attention

<table>
<thead>
<tr>
<th></th>
<th>Red ring (29 infants)</th>
<th>Red puppet (26 infants)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The temporal organisation of FMs did not change</td>
<td>11 (38%)</td>
<td>4 (15%)</td>
</tr>
<tr>
<td>FMs and concurrent movements stopped at or during stimulation for 3–31 s</td>
<td>13 (45%)</td>
<td>13 (50%)</td>
</tr>
<tr>
<td>The temporal organisation of FMs decreased</td>
<td>4 (14%)</td>
<td>9 (35%)</td>
</tr>
<tr>
<td>The temporal organisation of FMs increased</td>
<td>1 (3%)</td>
<td>–</td>
</tr>
<tr>
<td>Continuous attention to the object</td>
<td>18 (62%)</td>
<td>20 (77%)</td>
</tr>
<tr>
<td>Short periods of looking away</td>
<td>10 (35%)</td>
<td>6 (23%)</td>
</tr>
<tr>
<td>No attention at all</td>
<td>1 (3%)</td>
<td>–</td>
</tr>
</tbody>
</table>

FMs, fidgety movements.

Fig. 1. Case 26: Temporal organisation of FMs (y₁-axis) and level of attention (y₂-axis) during stimulation with the red puppet. The behavioural course is given before and at stimulation, then in 3-s epochs until a maximum of 31 s during stimulation, and after stimulation.
3.1.2. Visual stimulation with a red puppet

In the sequence preceding stimulation, 14 infants (54%) had continual FMs and 12 infants (46%) had intermittent FMs. In contrast to the red ring, the red puppet did elicit a significant amount of continuous attention ($p < 0.01$) as well as a significant change in the temporal organisation of FMs ($p < 0.01$). The relation between the reduction of the temporal organisation of FMs and continuous attention was significant ($p < 0.05$; Table 1). Fig. 1 illustrates that at the onset of stimulation, the temporal organisation of FMs decreased, whereas the attention towards the object increased. During the whole stimulation, no FMs were observed, whereas the infant was continuously attracted by the red puppet. After the red puppet was removed, FMs reappeared with the same temporal organisation as before stimulation. Fig. 2 illustrates similar results in another infant.

The median duration of decrease or even stop of the temporal organisation of FMs lasted for 23 s (IQR: 13–30 s; range: 0–31 s), which is 8 s shorter than the median stimulus presentation. The median latency to decrease or stop was 0.5 s (IQR: 0.5–4; dB, decibel; FMs, fidgety movements.

**Table 2**

| Influence of three different sound pressure levels on the temporal organisation of fidgety movements |
|---------------------------------|---------------------------------|---------------------------------|
| 68 dB (24 infants) | 77 dB (24 infants) | 88 dB (22 infants) |
| The temporal organisation of FMs did not change | 13 (54%) | 15 (63%) | 7 (32%) |
| FMs and concurrent movements stopped | 8 (33%) | 5 (21%) | 10 (45%) |
| The temporal organisation of FMs decreased | 3 (13%) | 4 (16%) | 5 (23%) |

Fig. 2. Case 7: Temporal organisation of FMs ($y_1$-axis) and level of attention ($y_2$-axis) during stimulation with the red puppet. The behavioural course is given before and at stimulation, then in 3-s epochs until a maximum of 31 s during stimulation, and after stimulation.
The median duration of attention lasted 30 s (IQR: 27–31; range: 18–31) with a median latency of 0.5 s (IQR: 0.5–1; range: 0.5–31).

After withdrawing the red puppet, the temporal organisation of FMs did not change in 12 infants (50%), whereas in 6 infants (25%), FMs decreased and in another 6 infants (25%), the temporal organisation of FMs increased. However, these changes were not significant.

### 3.2. Acoustic stimulation at different sound pressure levels

None of the sounds influenced the temporal organisation of FMs significantly (Table 2). A tendency to decrease or even stop of FMs was observed after the 88-dB sound. No other behavioural responses to the sounds were observed. A few seconds after the stimulation period, the temporal organisation of FMs was the same as before.

### 3.3. Approach by the infant’s mother

In contrast to what was previously assumed [6], in 16 out of 21 infants (76%), the mother’s appearance did not influence the temporal organisation of FMs. Only in five infants (24%) FMs decreased or stopped. Fourteen infants (67%) looked towards their approaching mothers immediately ($p < 0.05$) and continued having eye contact, whereas only four infants (19%) looked towards their mother incidentally. Three infants (14%) did not look towards their mother at all. The lack of relationship between the temporal

<table>
<thead>
<tr>
<th>The temporal organisation of FMs did not change</th>
<th>The temporal organisation of FMs decreased</th>
<th>FMs stopped entirely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Looking towards the mother continuously</td>
<td>12 infants (57%)</td>
<td>1 infant (5%)</td>
</tr>
<tr>
<td>Incidentally looking towards the mother</td>
<td>2 infants (9%)</td>
<td>1 infant (5%)</td>
</tr>
<tr>
<td>Not looking towards the mother</td>
<td>2 infants (9%)</td>
<td>1 infant (5%)</td>
</tr>
</tbody>
</table>

FMs, fidgety movements.

<table>
<thead>
<tr>
<th>Boys ($n = 12$)</th>
<th>Girls ($n = 9$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smiling immediately upon the mother’s arrival</td>
<td>4 (34%)</td>
</tr>
<tr>
<td>Smiling 1–5 s after the mother’s arrival</td>
<td>3 (25%)</td>
</tr>
<tr>
<td>Smiling 6–10 s after the mother’s arrival</td>
<td>1 (8%)</td>
</tr>
<tr>
<td>Smiling 11–15 s after the mother’s arrival</td>
<td>2 (17%)</td>
</tr>
<tr>
<td>Smiling 6–20 s after the mother’s arrival</td>
<td>1 (8%)</td>
</tr>
<tr>
<td>No response</td>
<td>1 (8%)</td>
</tr>
</tbody>
</table>
organisation of FMs and looking behaviour is shown in Table 3a. Fifteen infants (71%) smiled within the first 20 s following their mothers’ approach while six infants (29%) did not smile at their mothers. Although it seemed that boys smiled at their approaching mothers more and earlier than girls did, this finding was not significant (Table 3b).

4. Discussion

On the basis of earlier studies by Prechtl et al. [8], it has been postulated that in 12-week-old infants, FMs occur continually. However, the present study demonstrates that in more than a third of infants, FMs occur intermittently, even when the infant is alone and not stimulated. Already, Hadders-Algra and Prechtl [14] have reported about some infants in whom FMs have been only occasionally observed at 12 weeks. There seem to be large individual differences in the developmental course and hence, the temporal organisation of FMs, comparable to the individual differences well known for many other developmental milestones [15]. An important finding was that different kinds of manipulation did not change the temporal organisation of FMs to a significant extent. Only the presentation of the red puppet caused a decrease or stop of FMs, which lasted for about 20 s. Obviously, very complex visual stimuli [16–19] may influence the temporal organisation of FMs, in both short-looking (Fig. 2) and long-looking infants (Fig. 1) [20–23]. The practical consequence is that for the assessment of FMs, interference only stemming from highly interesting toys must be avoided. If this is not possible, assessment should be postponed until the infant is accustomed to the object and FMs once again occur in the expected temporal organisation.

Although it has been reported that young infants turned their heads following acoustic stimuli of 64 to 82 dB [24–30], our study could not confirm these findings. Moreover, sounds of 68 and 77 dB did not alter the infants’ spontaneous motor activity at all. The 88-dB sound caused a slight tendency towards a decrease in the infants’ movements, including their FMs. Consequently, for the application of Prechtl’s method of qualitative assessment of GMs, one need not necessarily assess the infants in a quiet room.

Our third experiment was designed to confirm the guidelines for the assessment of GMs, and for FMs in particular. It has been stated that the parent’s presence will attract the infant’s attention and that this might interfere with the infant’s spontaneous activity, particularly with the temporal organisation of FMs [6]. There are numerous studies dealing with the infant’s early recognition and discrimination of its mother’s face and voice (e.g. Refs. [31–36]). The majority of our infants looked towards their mother continuously from the moment she approached. However, this focussed attention did not alter the temporal organisation or the quality of FMs. Although both, the mother and the red puppet, elicited almost continuous visual attention, the influence on the temporal organisation of FMs was quite different. However, this is not surprising as it is well known that in contrast to the mother, nonfamiliar and complex toys are highly attractive to young infants [37,38].

Our findings suggest that for the assessment of FMs, infants may be filmed in the presence of the parent, and even while the parent is talking. Hence, in contrast to what has been stated previously, FMs are not influenced by social interference. A problem that
remains is that the analyser’s visual Gestalt perception may be impaired if the parent or other persons are present during the recording. Only visual stimulation with the red puppet resulted in such a high level of attention that FMs decreased or even stopped for about 20 s.

We conclude that FMs, a particular pattern of the infant’s spontaneous motor repertoire, are predominant in the young nervous system. Besides new insights into the methodology of Prechtl’s assessment of the quality of GMs, our results once again underline that the major function of the young nervous system is to generate spontaneous activity: spontaneous activity that is robust and relatively independent of sensory stimulation.

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