The Dynamic of Crying and its Interactive Role: Phasic versus Tonic Components

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***Abstract* - The investigation of crying is an important topic of both infant care research and research on the development of human vocal communication. Most former studies on these topics concentrated on the characteristics of single cries. However, as crying is usually performed bout-wise, there was a clear need for inquiries into its serial and temporal dynamics. Here, we summarize an approach designed to elucidate the interactive role of this property. Our study simulated situations of 'baby-sitting' wherein subjects were exposed to playbacks of either unmodified or modified crying recordings, and then asked to immediately indicate when exactly the perceived crying would signal a need for support. Analyses of response data allowed to identify two effects which, in terms of their temporal relationships to the presented stimuli, were distinguished as either phasic or tonic responses. The results confirmed predictions of our dual-component model and documented a significant interactive role of crying dynamics.**

I. INTRODUCTION

Crying is an important alarm display and call for support usually addressed to an infant's mother or her substitute. Alternatively, crying can signal protest and, e.g. in nonhuman primates, may serve even to signify an inadequate caregiver [1]. In contrast to many other vocalizations, crying is inappropriate for a mutual exchange of acoustic signals, but instead well-adapted to induce specific non acoustic responses. Interactional conflicts arising on either side of the party may be obscured by some obvious relationships between crying and consecutive care giving responses [2].

The understanding of variables that affect infant care by influencing adult subjects is a major objective of classical cry research. Since the pioneering studies of Wasz-Hoeckert and his colleagues (1962) a growing number of investigators has focused on the identification of acoustic parameters as either reliable cues about an infant’s state or as salient stimuli affecting caregivers [3, 4]. Significant signal features were: intensity measured by loudness and acoustic density, shrillness measured by atonal structures and lifted frequency ranges, e.g. a raised fundamental frequency [5, 6]. Although the majority of studies focused on the signal properties of single cries or short strains of cries only, it became clear that the extended crying of a normal infant can be remarkably variable, and thus should not be regarded as a stereotyped process [7].

In addition it has been shown that a variation of cry parameters can occur at different hierarchical levels: within and between cries. Within a cry, the most subtle phenomenon is a jitter of the fundamental frequency which can indicate neural deficiencies [8]. Across cries, there are trends of parameter variation which can include instances of 'extreme parameter increases`: EPIs and `synchronous parameter peakings’: SPPs [9]. Due to the experimental setting applied so far, it remained unclear, however, whether and how crying parameters that affect the attention, concurrently also can influence the distinct time and quality of a care giving act.

Referring to established models of stimulus-response relationships the decisions underlying the performance of care giving behaviors in response to crying should be mediated by a system of different intrinsic components [7, 8]. A model of such data processing is illustrated in Figure 1. It hypothesizes: With respect to their temporal properties, one component promotes decisions with a tonic characteristic, the other one influence decisions with a phasic characteristic.

Per definition *tonic* influences last for some time and vary only gradually, whereas *phasic* influences are short in duration and clearly defined in terms of their onset/offset [8]. Because of these properties, the latter ones can be analyzed more precisely and more elegantly than the first ones which normally are difficult to quantify.

Variables such as culture, convention, genetic predisposition, parental status and individual experience which above have been classed to long term factors provide a `tonic background` on which short term factors can operate concurrently. Also, short term factors such as psychophysical state, cognitive processes, context and especially the infant's cry signals can influence the probability of care giving behaviors in a tonic manner. Whereas these tonic influences have been documented by numerous investigators [4, 9], there remained a deficiency of evidence about phasic influences. Phasic influences from crying were often neglected because of the experimental design preferred in the past (application of single cries or short strains of cries).

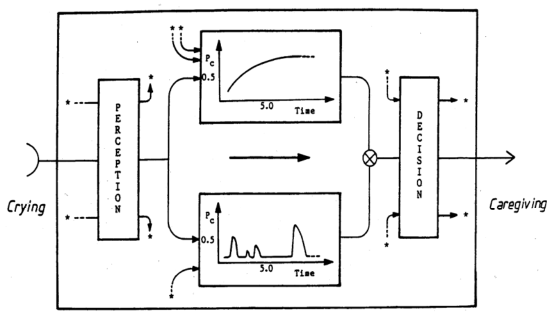

Fig. 1. Model illustrating operational relationships among four subsystems (boxes) which mediate between sensory stimuli (here: crying) and behavioral patterns (here: care giving). Arrows indicate direction of influences (* = to or from other subsystems) Pc = potential contributing to the probability of a particular care giving behavior (arbitrary units) with a particular time depending characteristic. - The model predicts that an increase of crying intensity which is both large and rapid provides a temporal trigger for a care giving act via the phasic component (given below). In addition, the occurrence of such an act depends on the tonic component (given above). This is influenced by a number of variables e.g. long term or short term factors, among which perceived crying parameters can play a specific role. However, before succeeding to induce a particular care giving act, the influences from both components have to pass a `decision gate`.

Variables that effect intrinsic decisions in a phasic manner can have many different origins. The context as well as an organized schedule, or just a spontaneous idea. In terms of crying, theoretically any cry which is distinguished from a background noise could be responded within a distinct latency. Practically, however, it is quite unlikely that all cries in a sequence of cries are appropriate candidates in providing effective temporal triggers. As previously shown [10], temporal triggering requires that a signal designed to operate as such, clearly differs from other signals preceding it. On can expect that cries produced either at the beginning of a crying process or at a sequential position where they are preceded by acoustically different cries would fit to induce a phasic response [11].

Our novel study was designed to investigate this issue and especially to also clarify `when` exactly a crying is responded to by an adult addressee. The study was guided by the concept illustrated in Figure 1. We expected that an adult's decision for soothing the infant may be confounded by a conflict among different behavioral tendencies. Therefore, the infant should be interested in influencing such a decision. An optimal strategy would be a combination of (i) a continued signaling, whereby the infant raise probability of a caregiver's responses in a 'tonic' manner, i.e. along with an increasing duration of his crying, and (ii) a structured signaling which provides specific cues that temporally trigger a facilitated care giving act and thereby contributing to its release within a defined latency, i.e. in a 'phasic' manner [12].

To test for consequences of such data processing, we conducted experiments with adult participants acting as virtual 'baby-sitters'. These subjects were presented with playbacks of either unmodified or modified crying sequences, and – already during these exposures – had to immediately indicate when (1) the perceived crying would reflect a need for support or (2) they themselves would decide to look after the 'virtual baby'.

II. METHODS

The study included two experiments, one with unmodified and another one with sequentially modified crying sequences. In either case, students of biology (non parents, 20-30 years of age) with a symmetrical gender distribution, served as participants.

In the first experiment, participants (n=110) were exposed to playbacks of original crying sequences (duration: 2-3 min. each). Sequences stemmed from healthy infants (age: below 3 months; state: before feeding; time: morning; context: normal environment). Subjects were asked to press a button during the ongoing playback and immediately whenever (1) a cry (rated as being emphasized by the infant) raised a subject's attention and (2) a subject got the idea that (in a real `baby sitting` situation) he/she would look after the infant. Additional self-report data were collected by questionnaires which the subjects filled in after termination of each playback (7-point Lickert scales).

The second experiment was conducted with another group of participants (n= 57). We used the same experimental setting as described for the first experiment. Here, however, participants were presented with cry sequences that were modified in their sequential organization. For control, participants were exposed also to the original sequence. The modified sequences were produced by first parsing the original into segments of 20 s duration and then arranging the segments in a new sequential succession. Test sequences used in the main experiment contained either a 'randomized succession of segments' or a sequence with a 'partly stereotyped segment succession'. For illustration see below:

Original sequence: A, B, C, D, E, F, G, H, I, J.

Randomized sequence: J, C, F, I, D, H, B, G, A, E.

Stereotyped sequence: A, B, C, D, D, D, D, D, D, D.

Data evaluation and testing for statistical significance followed well-established methods published elsewhere [9].

III. RESULTS AND CONCLUSIONS

Comparison of self-report data and analyses of relationships between these data and the crying sequences revealed the following results:

(1) Ratings from questionnaires on properties of the crying signals were positively correlated to measures of one-line responses collected during the last 20s of a crying process. Since such a correlation was not evident for response measures found earlier in the same process, we concluded that the post-hoc ratings reflected a kind of `recency effect`.

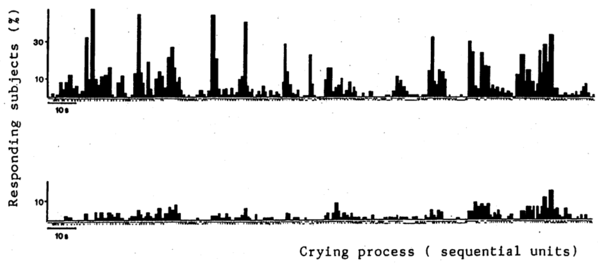

Fig. 2. Distribution of discrete responses of adult subjects along with a crying process to which they were exposed to. The percentage of subjects (n = 110) responding within the same sequential unit (ordinate) is plotted against the succession of these units (expiratory cries; abscissa). Structured lines below abscissa symbolize the crying process (duration: 200s). TOP: Distribution of responses immediately given when a cry (rated as emphasized by the infant) attracted the subject's attention. BOTTOM: Distribution of responses immediately given when subjects rated that they would have looked after the infant in case of a real `baby-sitting` context.

(2) With respect to their relation to the cry sequence, response rates were not at all distributed in a random manner, but cumulated at the sequential locations of particular expiratory cries, or groups of cries. Responses indicating the `readiness for a care giving` occurred at the same sequential position as responses interpreting the signaling of the infant, but were less frequent that the latter ones (Fig. 2).

(3) Whereas sequential response profiles of different segments were strikingly different, profiles of the same segments were similar, regardless of their sequential position within the crying process (Fig. 3).

(4) For the same segment different sequential profiles were found in only two cases: If a segment which originally occurred at the beginning of a crying process was presented at a later position or vice versa. Such differences concerned the first section (10s) of a segment only (see Fig. 3, segment 'I & J').

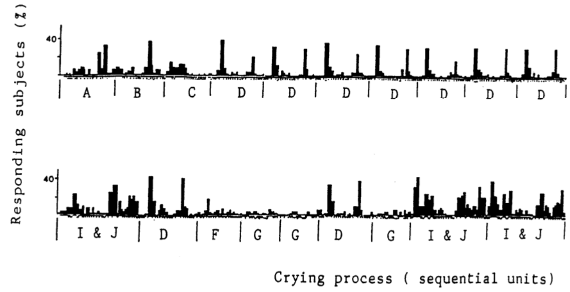

Fig. 3. Distribution of discrete responses of adult subjects along with crying processes which had been modified syntactically before playback. The percentage of subjects responding within the same sequential unit is plotted against the succession of these units (expiratory cries). Structured lines below abscissa symbolize the crying (duration: 200s). Intervals labelled by capitals refer to process segments and their original sequential position. (All segments stem from the same crying process to which the data of Fig. 2 refer, and had the order: A-B-C-D-E-F-G-H-I-J).

(5) The effect described under (3) which was ascertained for relations among randomly mixed segments and their original version, was also significant for segments repeated in a stereotyped manner (Fig. 3).

Since it could be excluded that the sequential coincidence of the recorded responses and specific expiratory cries resulted from contextual variables, our findings verify that a crying process can provide stimuli which temporally trigger behaviors of potential caregivers. They nevertheless invite to tackle further issues: One concerning the temporal dynamic of a crying process and especially the acoustic features of process segments which provide triggering influences. The results of the second experiment suggest that also tonic effects play a role. This can be concluded e.g. from the distributions of responses during exposure to the stereotyped stimulus sequence.

In addition, our results suggest that, if tested on a basis of 20s segments, there is no specific syntax in a crying process, and response releasing effects of particular cries do not depend on the sequential position of such a segment. The finding that this effect does not hold for segments taken either from or to the initiating position of the process, supported the `base line hypothesis` [1]. It says that the response releasing potential of an expiratory cry depends on its acoustic contrast to the cries preceding it. Normally, these provide a `base line` (synonymous: reference value, anchor point) which supports the detection of marked signal variations, such as EPIs or SPPs. The initial effect indicates that subjects, when having no reference value, need to hear signals for about 10s, in order to gain a base line.

IV. GENERAL DISCUSSION

A core sentence of communication theory states that relevant messages should be encoded in a reliable manner, and that reliability requires invariant signals. From a physiological perspective one may argue that the variability in crying is an epiphenomenon of the infant's ontogenetic incompetence to control his sound production and voice [13]. However, from a psychobiological perspective the variability invites to examine its adaptive functions [2].

The classical function postulated for signal variation is that it serves to prevent sensory or perceptional habituation in signal addressees. For crying, however, this is not a convincing hypothesis. In our experiments no habituation effects were found in subjects exposed to a stereotyped crying process (Fig. 3). Rather, crying in its typical, i.e. its variable form may contribute to a sensitization of recipients [1].

The variability in a crying process serves to provide temporal triggers for the attention and behavior of a caregiver. Cries of lower intensity provide a base line, i.e. a reference score, for the perception of more emphasized cries.

A variable cry is a quite economic strategy. Especially if an infant can not be sure that an addressee is close enough to receive his signals, he should cry in a bout wise modulated intensity, instead of continuously investing maximal energy in sound production.

The variation of signal parameters may be a strategy to produce a kind of uncertainty about the 'meaning' of perceived signals and to prolong the process of their decoding. This strategy may help to focus and also hold the attention of an addressee provided he is motivated to understand the signaling.

The advantage of these hypotheses is their evolutionary perspective. In many cases, they have already stimulated and successfully guided comparative approaches on crying behaviors of nonhuman primates [9, 14]. Such approaches have shown that there are surprising correspondences with respect to both structural and dynamical properties of crying in humans and nonhuman primates [1, 4]. In particular, these approaches have contributed to the phasic versus tonic paradigm by documenting that in monkeys dynamic features of crying can have the same functional consequences than in human beings.

V. REFERENCES

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