Moving in the Beat of Seconds

Analysis of the Time Structure of Human Action

Irmgard Feldhütter, Margret Schleidt, and Irenäus Eibl-Eibesfeldt

Forschungsstelle Humanethologie in der Max-Planck-Gesellschaft, Andechs, Federal Republic of Germany

An intercultural comparison in three nonindustrialized cultures (Yanomami. Himba, and Trobriander) investigated the duration of small units of movement patterns in working processes and movements of the hand to the body. Analysis of 1542 of such action units showed that 93% have a duration of 2 to 3 seconds. No difference was to be seen in this respect between the three cultures nor between the two kinds of actions. A significant difference showed up, however, between rhythmically repeated movement patterns and not repeated ones. The first are longer, near to three seconds, and thus make maximal use of the "window of the present" postulated by Pöppel.

KEY WORDS: Time structure; Temporal segmentation; Intercultural comparison; Working behavior; Hand-body contact

INTRODUCTION

Our sensitiveness to the course of time is evident in the context of relatively large time spans, e.g., circadian rhythms, where we are aware of the influence of time on our condition and behavior. But within us there are also temporal structures of much shorter periods of which we are generally unaware, and yet which also greatly influence our behavior.

Pöppel (1978, 1985) discussed the significance of a time span of approximately three seconds for human beings. On the basis of findings in the physiology of perception he postulated mechanisms in the central nervous system responsible for the integration of successive events into a subjectively experienced time unit. This integration is, according to him, only possible up to a duration of around three seconds and is a prerequisite for that conscious moment which in man represents what we consider as

Received November 3, 1989; revised March 21, 1990.

Address reprint requests to: Dr. Margret Schleidt, Forschungsstelle für Humanethologie in der Max-Planck-Gesellschaft 8138 Andechs, Federal Republic of Germany.

Ethology and Sociobiology 11: 511–520 (1990)

0162-3095/90/$3.50

"present" or "nowness". Other authors (e.g., Ditzinger and Haken 1989) also discuss temporal structures of a few seconds which cause the spontaneous reversions in ambiguous patterns like the Necker cube.

To what extent is, besides perception, also human action governed by temporal segmentation? Turner and Pöppel (1983) showed that, in reciting poems, people from all over the world (14 different languages) speak in a rhythm lasting about three seconds. This time structure evidently matches the listener's expectation. Whether, and to what extent, rhythmic behavior patterns other than speech, also obey a certain time structure was first investigated by Schleidt et al. (1987) and Schleidt (1988). In this work rhythmically repeated behavior patterns like "waving goodbye," "jumping up and down," "shaking hands," and "throwing a ball" were studied, and it was found that people prefer action units of approximately three seconds. This study was done in four different cultures, industrialized and nonindustrialized, and a universal time constant for rhythmically repeated behavior patterns was postulated. Feldhütter (1989) in a study with three different nonindustrialized cultures (including one not studied by Schleidt) examined the time structure of nonrepetitive normal everyday behavior in two behavior categories which differed both in complexity and in consciousness: working procedures and movements with hand body contact. The results have already been reported in a short communication (Schleidt and Feldhütter 1989) and they will be referred to here more extensively.

MATERIAL AND METHODS

Films of everyday behavior in people from three cultures were analysed:

1. Himba, pastoralists from Namibia
2. Trobrianders, polynesian fishermen/horticulturalists living on coral islands of Papua New Guinea
3. Yanomami, hunters/horticulturalists living in the jungles of Venezuela.

These cultures are very suitable for intercultural comparison because they live in quite different parts of the world under different economic, ecological and socio-cultural conditions.

The film material had been obtained by Eibl-Eibesfeldt during his documentation of unstaged human social behavior.

The two behavior categories studied were defined as follows:

a) *working behavior* consists of actions where, by means of different movement patterns, an obvious goal is reached. Only adults were taken into account and not the playful "working" of children. Such work imitations of children, if they consisted of series of repetitive movements, have already been considered in the former analysis by Schleidt.

b) *hand-body contact* are movements of the hand toward the body in the course of which skin, hair, or clothing are touched. If hand-body contact represented a state rather than an action, e.g., the hands on the hips, then such body positions were not included. Ritualized behavior was also not included, because of the influence of fixed sequences of actions, e.g. in dances. If instruments were used as in shaving or decorating the face with paint, the action was regarded as part of working behavior. All age groups were included with the exception of children under one year because of their immature motor development.

In each film scene analysed notes were taken of: the age and sex of the analysed person; the kind of action; the social context (interacting with another person or not); and the direction of the individual's attention (direction of looking). The duration of the movement patterns was measured in a frame-by-frame analysis which, as all the films were shot at the rate of 25 frames per seconds, permits an accuracy of time measurement of 40 msecs. An action unit lasts from the beginning of a movement pattern up to: its end, the beginning of a different movement pattern, or the beginning of the same movement pattern in another place.

Sometimes short movement patterns are repeated in series as, for example, when people are scratching or hammering. These repeated movement patterns that are morphologically identical succeed one another without any interruption. When at least three such movement patterns occur one after the other, we defined them as an action unit of repetitive behavior. If only two morphologically identical movement patterns build up a series, we defined them as an action unit of nonrepetitive behavior. This grouping together of three or more repetitive behavior patterns was introduced by us intuitively. However, it has also been used by Thelen (1981) who defined "rhythmic stereotypies" as "movements of parts of the body or the whole body repeated in the same form at least three times at regular intervals of about a second or less." We also found that it is correct to consider repetitive behavior of at least three movements in a row as something different from two repetitions as the latter—concerning the length of their action units—are more similar to single nonrepeated movements.

The same criteria that we used to define the length of an action unit in nonrepetitive movements can in most cases be applied to repetitive ones. In some cases, however, they have to be applied in a very subtle way. If there are movement patterns repeated over a long time (which occurred in 12% of our material), short pauses, slight changes of place, and slight variation in the form of one single movement pattern in a sequence of similar patterns, showed that the individuals even in these cases structured the chain of their successive movements with slight interruptions.

To achieve a random sample, all scenes in a film that matched our criteria for the behavior categories were analysed until a total of 30 scenes of working behavior and 50 scenes of hand body contact were obtained for each culture. Fewer scenes with working behavior were chosen, because these sequences usually last for much longer, so that they comprise more action units. Thus in very long sequences of working behavior only the first

30 action units were analyzed, to avoid gathering a large sample with too little variation. To cover the rich diversity of working behavior of people shown in the films, not more than three scenes of a certain working activity were analysed, and this had to be done by three different persons. In contrast, frequently encountered hand body contact varied little (see Tables 2 and 3). It therefore seemed unnecessary to set a limit with respect to content.

To avoid individual pecularities, no person was analyzed in more than three scenes.

RESULTS

We analyzed a total of 104 scenes with 1091 action units of working behavior and 172 scenes with 451 action units of hand body contact with more-or-less equal distribution across the three cultures. Although there are more scenes of hand body contact, the number of action units was only half as many as in scenes of working behavior. The movement patterns that occurred are listed in Tables 1 and 2.

Table 1. Behavior Patterns in Working

Himba, Trobriander, and Yanomami	Number of Occurrences
Chopping/felling	13
Pealing	12
Transfering	10
Wiping/rubbing	9
Cutting/cleaving	6
Stiring/poking	5
Knocking	5
Sewing/plaiting	5
Roof thatching	3
Stacking	3
Making jewelry	3
Smoothing leaves	3
Gathering	2
Pulling	2
Rowing/punting	2
Scratching	2
Shaving	2
Shoveling	2
Hammering branches	2
Painting the body	2
Buttering	1
Throwing	1
Wrapping	1
Wood Planing	1
Spinning	1
Lighting the fire	1
Cutting up wood	1
Melking the cow	1
Fishing insects out of a pot	1
Grinding	1
Slaughtering cattle	1

Table 2. Behavior Patterns with Hand Body Contact

Himba, Trobiander, and Yanomani	Number of Occurrences
Scratching	62
Touching	50
Wiping/stroking	31
Finger in the ear or nose	6
Clapping hands	5
Finger in the mouth	3
Rubbing	3
Rubbing the hands	3
Hitting/knocking	2
Pintching	1
Pulling hairs	1
Other	5

Table 3 shows an imbalance in favor of female subjects and children. This is most probably because the filmmaker often directed attention toward children and mothers. As the results do not differ between the sexes and children and adults we decided this imbalance could be disregarded.

Figure 1 shows the length of action units in working behavior and hand body contact in the three different cultures. The similarity of the time structure in the two different behavior types in all the three cultures is striking. No statistically significant difference could be found between them (Kolmogorov-Smirnov-test, two tailed, $p = 0.2$). The medians are all around two seconds.

In Figure 2 the data of the three cultures are combined, but divided according to nonrepetitive and repetitive behavior. In around 20% of all action units—equally distributed in the three cultures—repetitive behavior could be found (working behavior 19%, hand body contact 22%). The most frequent lengths of the single movement pattern components of action units of repetitive behavior are 0.5–0.6 seconds (range 0.4–0.9 secs). These results are very similar to those previously reported by Schleidt (1988).

Action units in repetitive behavior, whether working behavior or hand body contact, tend to be longer than those in nonrepetitive behavior (Kol-

Table 3. Number of Observed Persons

	Himba	Trobriander	Yanomani
Working behavior			
Female	17	20	21
Male	11	10	10
Hand-body contact			
Female	24	24	31
Male	22	16	14
Hand-body contact			
Children	35	30	27
Adults	11	10	18

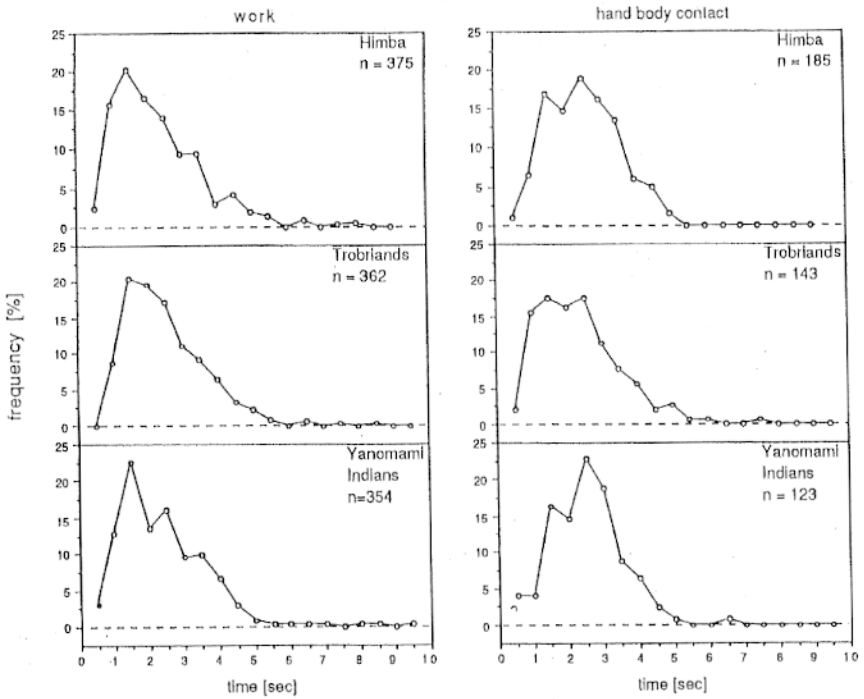
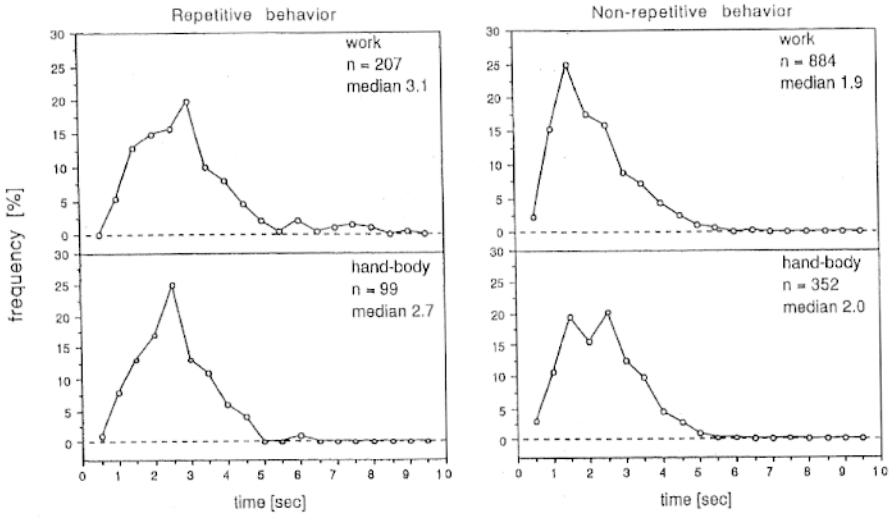


FIGURE 1. Length of action units in three cultures.

FIGURE 2. Length of action units in repetitive and non-repetitive behavior.



mogorov-Smirnov-test, two-tailed, $p = 0.001$). The median length is 2.9 seconds per action unit in repetitive behavior, which is very similar to the median of 3.0 seconds previously reported by Schleidt.

Two examples of successive action units are given below that are built up by repetitive behavior (except the first unit of two repetitions which according to our definition is subsumed under nonrepetitive behavior). These examples show that it is very likely that the structure in the behavior flow is not caused by external factors, but by internal ones.

Woodcutting (Trobriander 1984). A young man cleaves a piece of wood with a large chopping knife.

2 × cleaving 2.08 secs
short pause in the movement while the blade of the knife is held horizontally
3 × cleaving 3.24 secs

Scratching (Trobriander 1982). A boy scratches his head.

7 × scratching 2.8 secs
short change in the position of his hand
5 × scratching 2.12 secs
again change in hand position
3 × scratching 1.52 secs

Theoretically it should be equally possible to cleave the piece of wood without any interruption five times in a row. That would not change the result of the working process in any way. The short pause of 0.1 secs perhaps permits the arm to relax, but this would make no sense for the scratching where certainly no relaxing of the hand is necessary. For the scratching one could argue that slight variations in the hand position are the aim of the interruption, but this does not alter the scratching movements themselves very much. There is no convincing reason why the boy should not scratch continuously.

Such clearly recognizable "endogenous structure" is found in working behavior in 13% of all action units and in hand body contact in 9%. In working behavior we see this endogenous structure in all longer series of repetitive movement patterns like hacking, cutting, beating, rolling, etc. In hand body contact this phenomenon is only evident in scratching. The medians of the endogenous structured action units are 2.3 secs in working behavior and 2.6 secs in hand body contact.

As described previously, we took two variables of the situation into account: whether the observed person interacted with somebody else or not and whether he/she pays attention to the activity or not. In working behavior interaction with another person was observed rarely because the actor was usually concentrating on the piece of work in hand. The contrary was found in hand body contact. In most cases the subjects were in interaction with

other people and rarely did they pay attention to the scratching, wiping, etc. In our analysis of these variables, no difference has been found concerning the time structure.

DISCUSSION

The duration of the action units in both categories, working behavior and hand body contact, show a very similar distribution, in most cases lasting between one and three seconds. That fact is remarkable as these behavior patterns are so different. Work is strongly influenced by external factors and its process is mainly dictated by the aim of the action. Mostly it consists of complicated, learned movement patterns which have to be combined in a sensible manner to lead to the aspired goal. The individual has to start with a detailed idea of the working process and the end product. Both determine, to a large degree, the flow of the action as well as the single movement patterns. In comparison with work, hand body contact seems to be a relatively simple response (mostly scratching) to a variable stimulus situation. Only seldom did we find criteria which could support the idea that an external irritation on the skin caused the scratching, wiping, etc. On the other hand, the persons quite often touched their own body when interacting with others, mainly in conversation. The hand movements were then done in a calm way and with little intensity. One gets the impression that these hand body contact movements were predominantly caused by a certain pressure inside the person which made him/her act in that way, and that the only aim of the action was performing the movement and touching the body. Those sort of movements certainly correspond to the so-called displacement activities (Tinbergen 1940), that are activities which do not fit into the main context of the ongoing behavior, and the function of which is seen in tension reduction. Displacement activities like biting the fingernails or scratching the head are to be seen in many cultures (Eibl-Eibesfeldt 1989, p. 483). Ekman and Friesen (1972) have named them "self-adaptors."

A similarity in the time structure could also be found in our cross-cultural comparison. Members of very different cultures show the same rhythm independently of their age and gender. The subjects structure the flow of their behavior by forming short time parcels that are predominantly between two and three seconds long.

This basic beat is especially obvious when different movements follow one another or when one single short series of repetitive movements appears, as for example in scratching, or in the other rhythmically repeated behavior patterns like waving, stroking, kicking, etc. investigated by Schleidt (1988). This time structure, however, can also be observed in long series of repetitive behavior patterns. In working, hammering, beating, rubbing, etc. as well as in hand body contact scratching sometimes can go on over a long period, and one can only notice very slight changes in the movement patterns or very short interrupting pauses. It seems that in such cases there is no external reason for this structuring and the endogenous nature of the temporal segmentation becomes especially clear.

Thus the results of these studies suggest that a time structure with a span of one to four seconds is a general base of human behavior. After having found no significant difference in the intercultural comparison we postulate that this characteristic of human behavior is a universal trait, an inborn quality of humans.

The only statistically significant difference we found was between repetitive and nonrepetitive behavior. The action unit in repetitive behavior is mainly around three seconds long and thus nearly one-third longer than the action unit in nonrepetitive behavior, which is around two seconds long. It is unlikely that this difference is due to our method of measuring, but rather that there is something particular about repetitive behavior which causes this difference. Writing about the connection between time and human perception McGrath (1986, p. 89) states: ". . . rhythms are fundamental organizational principles within biological systems". Thelen (1981) investigated rhythmically repeated movement patterns in newborns and infants and named this sort of behavior "rhythmic stereotypies." Her definition (previously mentioned) fits with our definition of repetitive behavior very well. These rhythmic stereotypes are very often to be seen in small infants, e.g., as repeated pedalling with both legs. Thelen thinks that these movements are precursers of fully developed behavior because they vanish in this form in the course of ontogeny and are replaced by more complex movements. Rhythmically repeated movements, however, as we already stated above, frequently occur in normal complex behavior patterns (in 20% of the action patterns we investigated in this paper). They obviously remain a constituent of human action for the whole life, and could be considered as a very basic form of activity.

During some pathological states stereotype movement patterns are repeated for a long time, as for instance in some psychotic patients. Their movements are machine-like and give an abnormal and unnatural impression, and "get on one's nerves." We think it is likely that these pathological stereotypes lack the two to three seconds structure and therefore fail to be recognized as normal. However, this remains to be investigated.

In rhythmic repetitions of motor activity in everyday life intrinsic structure mechanisms apparently prevail over external factors. The average duration of action units found in repetitive behavior was close to the upper limit of the integration time of three seconds, which was found by Pöppel, while nonrepetitive behavior was much shorter. This temporal segmentation of repetitive behavior, which lies near three seconds, agrees with the results of Turner and Pöppel (1983, 1988) concerning recited poems. Regardless of the language, a spoken line in poetry lasts about three seconds. The speakers take optimal advantage of the "window-of-the-present," writes Pöppel (1985, p. 79). Perhaps when the pressure of external factors is only slight,

as in the case of rhythmic movements and rhythmic verses, and when huma beings act freely and are guided by their inner needs, they tend to produc a time structure of their actions that obeys the beat of three seconds.

REFERENCES

Ditzinger, T. and H. Haken. Oscillations in the perception of ambiguous patterns. *Biologica Cybernetics* 61: 279–287, 1989.

Eibl-Eibesfeldt, I. Human Ethology. Aldine de Gruyter: New York, 1989. German ed. Piper München, 1984.

Ekman, P. and W. Friesen. Hand movements. *The Journal of Communication* 22: 353–374, 1972.

Feldhütter, I. Untersuchung der Zeitstruktur im menschlichen Verhalten. Interkultureller Vergleich von Arbeitsvorgängen und Bewegungen mit Hand-Körper Kontakt. Dissertation Ludwig-Maximilians University Munich, 1989.

McGrath, J.E. and Kelly J.R. Time and Human Interaction. Toward a social psychology of time. The Guilford Press: New York, 1986.

Pöppel, E. Time perception. In *Handbook of Sensory Physiology* Vol. VIII, R. Held, H.W. Leibowitz and H.-L. Teuber (eds.) Springer: Heidelberg, 1978, pp. 713–729.

Pöppel, E. Grenzen des Bewußtseins. dva: Stuttgart, 1985.

Schleidt, M., Eibl-Eibesfeldt I. and E. Pöppel. A universal constant in temporal segmentation of human short-term behavior. *Naturwissenschaften* 74: 289–290, 1987.

Schleidt, M. A universal time constant operating in human short-term behavior repetitions. *Ethology* 77: 67–75, 1988.

Schleidt, M. and I. Feldhütter. Universal time constant in human short-term behavior: further results. *Naturwissenschaften* 76: 127–128, 1989.

Thelen, E. Rhythmical behavior in infancy: An ethological perspective. *Developmental Psychology* 17: 237–257, 1981.

Tinbergen, N. Die Übersprungbewegung. Z. Tierpsychologie 4: 1–40, 1940.

Turner, F. and E. Pöppel. The neural lyre: poetic meter, the brain and time. *Poetry*, 277–309, August 1983.

Turner, F. and E. Pöppel. Metered Poetry, the brain, and time. In: *Beauty and the Brain. Biological Aspects of Aesthetics* I. Rentschler, B. Herzberger, and D. Epstein (Eds.). Birkhäuser: Basel, 71–90, 1988.

Tree Swallows and TIT FOR TAT

Response to Koenig

Michael P. Lombardo

Museum of Zoology, Department of Biology, and Michigan Society of Fellows, The University of Michigan, Ann Arbor, MI 48109-1079

Koenig's (*Ethol. and Sociobiol.* 9:73–84, 1988) review of Lombardo's (*Scie* 227:1363–1365, 1985) experiment testing the TIT FOR TAT model of reciprocity rectly concluded that the experiment did not demonstrate the existence of recipr altruism between parent and conspecific nest intruder tree swallows. However, review contained errors that preclude a fair evaluation of the experiment and in pretation of its results. Here I respond to these criticisms, reexamine tree swal behavioral ecology, and suggest that the lack of aggression between parents and truders can best be modeled as by-product mutualism. I reiterate that the bala between parental aggression and nonaggression toward intruders can be maintai by TIT FOR TAT.

KEY WORDS: Prisoner's Dilemma; Reciprocal altruism; Reciprocity; Restraint; FOR TAT; Tree Swallow.

INTRODUCTION

The task of unambiguously demonstrating reciprocal altruism (F in nonhuman animals presents a daunting challenge to empir biologists. Ligon (1989) discussed two reasons for this. First, th is no consensus on how RA should be defined or recognizec nature (e.g., see Koenig 1988; Rothstein and Pierotti 1988; Seyfarth Cheney 1988; Taylor and McGuire 1988; Ligon 1989). Second, empir work has been unable to keep pace with theoretical advances. Consequen nearly all reported cases of RA have been subsequently criticized or r terpreted (e.g., see Waltz 1981; Connor 1986; Koenig 1988; Rothstein Pierotti 1988; Wilkinson 1988). For example, in his careful review of stu that claimed to provide evidence of RA in birds, Koenig (1988) critici reexamined my experiment (Lombardo 1985) with tree swallows (*Tac*

Received September 22, 1989; revised January 25, 1990.

Address reprint requests to: Michael P. Lombardo, Department of Biology, Museum of Zool The University of Michigan, Ann Arbor, MI 48109-1079.