Decomposition of Temporal Sequences

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Abstract

This paper deals with the decomposition of temporal sequences and the emergence of events. The problematic nature of various definitions of events is first reviewed and an hypothesis - the cut hypothesis - is proposed. The cut hypothesis states that a sequence of stimuli is cut out to become a cognitive entity if it is repeatedly experienced in different contexts. The hypothesis can thus explain the emergence of events on the basis of former experience. Two experiments were conducted to compare the predictions of the cut hypothesis to the predictions of two other explanations, explanation by association and explanation by changes along the sequence of stimuli. The first experiment showed that subjects better recognized a certain sequence after seeing it repeated as a whole than after seeing it as a part of another repeating sequence. The second experiment demonstrated that after experiencing a certain repeating sequence subjects would hardly consider dividing in its midst even though that point was a point of maximal change, as evidenced by divisions made by control subjects who did not experience the repeating sequence.

This paper deals with the decomposition of temporal sequences of stimuli into parts, into entities. We look for the basis of decomposition, and ask whether it is objective, independent of the person who performs the decompositon or subjective, depending on that person's former experience.

The question can be phrased much more simply as: "What is an event?" Events are generally treated as basic, even atomic, entities of which all occurances are composed. The error is evident, however, when considering the hierarchical nature of events (J. J. Gibson, 1979). In an earlier work (Avrahami & Kareev, 1990), we studied how easy it was to describe the components of an occurance and then immediately divide the components into sub-components. Even children (6th and 8th graders) easily divided and subdivided the sequences, which shows that the components are not 'atoms'.

We do not claim that atomic units of perception do not exist: it is, of course, these atomic units which make up the whole perceived sequence (Treisman & Gormican, 1988). The question is how sequences of atomic units turn into entities which are considered as events.

Some say that an event includes both transformation and invariance (E. J. Gibson & Spelke, 1983; J. J. Gibson, 1979). But this does not clarify how the begining and the end of an event are determined.

Quine (1985) proposes that events should be reified by their spatial and temporal characteristics, leaving the determination of their boundaries to "what concerns us". Yet, for something to concern us it has to be known as a 'something' first.

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Davidson (1969), dealing with the individuation of events, says that events are often related to changes in a substance and are often thought to be uniquely determined by their time and place. Yet, he claims, neither substance nor time and place can uniquely determine an event because one can think of different events which occur in the same place, at the same time and on the same substance. Davidson proposes to individuate events by their causes and their effects. However, since we cannot point at the boundaries between the causes and the events (causes and effects being events too) this definition does not answer the question of how temporal sequences are decomposed into events.

Some, indeed, tie events to objects and define an event as an action which is connected to some object. E. Gibson (1969), for instance, suggests that a ball rolling over the floor is an example of an event and that everything connected to this rolling is one event. Still, it is easy so see that the question of decomposition into objects is not solved either: If a ball is an object, is a pinball machine one object or several? and if two balls are shot in the machine together are they participating in one event or two? and so forth.

Following J. J. Gibson, who said that in every event there is invariance, we may be able to define an event by that which does not change in it: e.g. the agent, the object, the location. The boundaries of an event would then be the points where maximal changes occur. Of the same approach is the explanation of events as the products of the perception of dynamic geometric patterns (McCabe, 1986) with the beginings and ends determined by seams in the perceived patterns of energy (Michaels & Carello, 1981).

However, even a cursory inspection of the components mentioned by subjects in various studies shows that such changes may occur both within and between events. To take two examples: in the birthday party mentioned by Nelson, Fivush, Hudson & Lucariello (1983), in which "You cook a cake and eat it", it is clear that there is no less change within the "cooking" of the cake (materials, utensils, the baking oven) than there is between cooking and eating. In the restaurant script, mentioned by Schank and Abelson (1977), which is composed of entering, being seated, ordering, eating and paying, it is obvious that eating itself may include several courses, hence change of plates and their contents, change of cutlery, etc. It is therefore possible that though maximal changes may serve as breakpoints in sequences of stimuli not experienced before, experience may dictate other organizations which ignore those changes.

The explanation we offer for the decomposition of sequences into events rests on an hypothesis which was forwarded in a previous work, the "cut hypothesis" (Avrahami & Kareev, 1990). According to this hypothesis a sub-sequence of stimuli is cut out of a general sequence to become a cognitive entity for someone, if that person has experienced the sub-sequence many times, with the sub-sequences preceding and following it differing on the various occasions; the boundaries of the emergent entity are the boundaries of the repeating sub-sequence. The cut hypothesis can explain decompositions both of space and of time. The hypothesis resembles James' words: "What is associated now with one thing and now with another tends to become dissociated from either, and grow into an object of abstract contemplation by the mind" (James, 1890, p. 506). In other words, a cognitive entity is individuated from the general sequence by virtue of its having appeared in different contexts. To illustrate negatively: it is known that people often fail to describe or define the eyebrows of even close relatives, whose faces they know very well. This cannot be explained by claiming that they have seen the whole faces more often than they did the eyebrows but it can be explained by the cut hypothesis: Since the eyebrows have always been repeated on the same background (the face) they were not individuated into a separate entity, while the face, which was repeated on different occasions on a different background, has become such an entity.

The cut hypothesis is closely related to the theory of associationism which also explains the emergence of cognitive entities as a result of repeating experience with certain stimuli. But according

to associationism the entities are created not by cutting a sequence into sub-sequences but by lumping basic entities together: repetition will cause lumping irrespective of what precedes and what follows the sub-sequences.

Two experiments were conducted: One to juxtapose the cut hypothesis with the associationistic explanation and the other to juxtapose the cut hypothesis. with the claim that the boundaries of events are determined by changes.

The materials for the experiments were video films. The films were constructed from an inventory of 50 basic units, each lasting three seconds. The basic units were extracted from nine different cartoons. Cartoons were used because they generally consist of short "takes" with abrupt cuts between them. Each basic unit depicted a specific action but care was taken that none would convey a sense of a beginning or an end of an episode (e.g., no one crashed in any). No two basic units were adjacent in the original cartoons. All the cartoons were about the same two characters, and in each basic unit either one of them or both were performing an action (See Appendix for a description of some of the units).

In the first experiment subjects watched a film which contained an arbitrary sequence of basic units that was repeated several times among various other basic units which appeared only once.

Both according to the cut hypothesis and according to the laws of association the repeating sequence was expected to become an entity - an event. But according to the associationistic explanation the event would be created by association of its basic units, hence parts of the event would be remembered no less than the whole; in contrast, according to the cut hypothesis the event is carved out from the whole film by virtue of its having different preceding and following sequences, therefore the whole event would be better remembered than its parts.

In the second experiment, two groups of subjects were asked to suggest points at which a test film, made of randomly ordered basic units, could best be divided into parts. The control group saw just the test film. The experimental group saw first a training film which contained a repeating sequence extracted from the test film; it was chosen in such a way that
the most popular breakpoint (among the control subjects) was at its midst. The experimental group was then asked to divide the same test film as the control group.

Lacking any former experience with the film, control subjects were expected to choose points of maximal change for their divisions. The question was whether the experimental subjects would partition the film at the same points - supporting the claim that decomposition is based on maximal changes or, having experienced those points within a repeationg sequence, they would ignore the point of maximal change - thus supporting the cut hypothesis.

Experiment 1

In Experiment 1 we compared the recognition of a sequence of basic units which appeared either as a whole repeating sequence within one film or as a part of a longer repeating sequence in another film.

Method

Design. Four films were used - films I, II, III and IV - with repeating sequences of length three, seven, four and eight, respectively. The sequence presented at the recognition task was either the whole repeating sequence (for the shorter ones) or the middle part of the repeating sequence (for the longer ones). Thus the length of the test sequence was either three (for films I and II) or four (for films III and IV).

Subjects. 48 college students participated in the experiment as paid volunteers, 12 with each film.

Materials. The Films: Out of the total inventory of basic units seven were randomly chosen for the repeating sequence of film II and another eight for film IV. Other units have been randomly chosen to serve as fillers or noise which surrounded the repeating sequence. The repeating sequences of films I and III were the three and four

middle units of the seven and eight of films II and IV. The repeating sequences occured five times in the whole film. Films I and II were 58 units long and films III and IV were 68 units long. To achieve equal length films I and III had 20 more noise units than films II and IV.

The Tests: The tests consisted of three test sequences, all of the same length: three for films I and II, and four for films III and IV. Subjects were asked whether each test sequence appeared in the film they had seen before. The first question, which was the one of interest, was either about the whole repeating sequence (in films I and III) or about the middle part of the repeating sequence (in films II and IV). Note that the questions were identical for films I and II and for films III and IV.

Procedure. Subjects first watched the film and then performed the recognition task in which they had to mark down whether or not each test sequence had appeared in the film.

Results and Discussion

The number of subjects (out of 12) answering the critical question correctly was 11, 8, 11 and 7 for films I, II, III and IV, respectively. The proportion of correct answers was, then, .92 for the sequence when it had been experienced as a whole and .63 for the same sequence when experienced as a part. A two-way analysis of variance with Part/Whole and Film as its factors revealed a significant effect only of Part/Whole ($F(1,44) = 6.04$, $p = .018$).

The results show that though watching one of two films of the same length and tested for recognition of the same sequence, which appeared the same number of times in both films, subjects who experienced the sequence as a whole repeating sequence recognized it more easily than subjects who experienced it as a part of a longer repeating sequence. Note that the advantage of the whole repeating sequences is particularly impressive since the sequences of films I and III were embedded in much more noise than the sequences of films II and IV. The results thereby support the claim that a sequence which is repeated in different contexts is cut out to become a whole, a cognitive entity, and is remembered as such. In contrast, when the same sequence always appears as part of a longer sequence, hence always in the same immediate context, it is less likely to become a well recognized entity.

Experiment 2

In Experiment 2 we tested whether a breakpoint within a sequence of stimuli, chosen by subjects who watched the sequence for the first time, would be ignored by other subjects who first experienced repeated presentations of a sub-sequence surrounding this point.

Method

Design. Two groups of subjects, a control and an experimental group, participated in this experiment. The control-group subjects watched one of two test films made of randomly chosen basic units and were asked to suggest where they would divide it. Then two training films were created on the basis of the answers of the control group: the most popular dividing point of each test film was identified and the sub-sequence surrounding it was used as the repeating sequence in the training films. The experimental subjects, having first watched one of the training films, were also asked to divide one of the test films.

Subjects. 34 college students participated in the experiment as paid volunteers: 16 in the control group and 18 in the experimental group.

Materials. The materials were video films made of the same basic units as the films of Experiment 1.

Test film I was of length 15, and the sequence taken out of it was of length three. This sequence repeated five times in a training film of total length of 35. The corresponding numbers for film II were 20, 4, and 45.

Procedure. Subjects in the control group were told that they were going

to see a film made up of short units, and should suggest where the film could best be divided into parts. They watched the film twice: Once, to get familiar with it and a second time to say aloud where they would divide it. The experimenter marked down subjects' answers. Subjects in the experimental group were told they were going to see a film made of short units which they should just watch. Having watched this training film they performed the same task as the control subjects.

Results and Discussion

Though the test films were made of randomly combined unrelated units, it turned out that some division points were more popular than others. The most popular breakpoint in test film I was chosen by six out of the eight control subjects who watched it, and the most popular one in test film II was chosen by seven out of eight control subjects. In both cases the proportion of subjects choosing the point was significantly above chance.

As for the experimental subjects, who first saw the corresponding training film, only two out of nine chose the popular point of film I and two out of nine chose the popular point of film II. A two-way analysis of variance revealed a significant difference between the two groups ($F(1,30) = 16.15$, $p < .001$). As it turned out, the total number of division points provided by the control subjects was higher than that of the experimental subjects. To compensate for that, and employ a more conservative estimate of the difference between the two groups, each subject received a score of 1 divided by her/his total number of division points if they divided the test film at the critical point and 0 otherwise. The difference between the two groups remained significant ($F(1,30) = 10.08$, $p = .003$).

The results show that repeated experiencing of a sequence of basic units embbeded in different others makes them into one entity irrespective of significant changes which occur within that sequence.

Discussion

The experiments demonstrate that the repetition of a sequence of stimuli in various contexts is the basis for the emergence of events. This emergence is best described as cutting the whole repeating sequence out of its context rather than associating its basic units into a whole. The experiments explore the cut hypothesis only in situations of perfect repetition. It is obvious that in reality no sequences of stimuli recur identically. Further research is needed to establish the degree of similarity required for one sequence to be considered a recurrence of another. See Kareev & Avrahami (1990) for a study of a related question.

Appendix

Descriptions of some of the basic units used in the films:

A character throws a dart.

A character adds pepper to a cauldron.

A character hides explosives under a bridge.

A character runs.

A character aims a gun.

The two characters meet.

A character rolls an iron ball off a cliff.

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