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DECISION MAKING IN TIC-TAC-TOE: A PSYCHOPHYSIOLOGICAL STUDY

I.O. Aleksandrov
Institute Psychology, USSR Academy of Sciences, Moscow, USSR

One of inherent features of behavior is branching, i.e. possibility of choice of any variant of behavior realization. Obviously, that choice of act, that is decision-making, depends on the structure of subjective experience. Psychophysiological approach to the investigation of behavior has been outlined by the P.K. Anokhin's Functional Systems Theory (Shvyrkov, 1985) considers as an elements of subjective experience the functional systems of integral behavioral acts mutually related due to the timing of their philo-and ontogenetic development. Elements of subjective experience (ESEs) emerge in relation to the goals of a subject, specific of motor activity and environmental conditions. The purpose of this study was to examine in well known tic-tac-toe (1) dependence of decision making (i.e. choice of behavior act to be realized in overt behavior) on characteristics of the structure and dynamics of subjective experience; (2) manifestation of dynamics of subjective experience during the choice of act in slow brain potentials.

Methods

Six trained gamblers (aged between 20 and 36 year) participated in the experiment. In order to win a gambler must obtain an uninterrupted line of 5 signs on 15x15 squares board. The EEG was recorded simultaneously for two gamblers for two gamblers from F3", F4", P3', P4'at standard 10/10 electrodes systems with linked earlobes as a reference. In addition EOG and the marks of the onsets of moves' writings were recorded. The sequence of gamblers' moves, trajectory of the hand moving over the board while choosing the move were recorded on videotape. All the records were digitized at 200 Hz; the EEG was averaged from the onset of the moves' writing by a gambler as by his opponent and from the onset of hand movements.

Result and discussion

Objective description of course of game was based on the quantitative evaluation of the possible consequences of certain game situation. Overt behavior during the game may be regarded as a succession of behavioral acts. Gambler's behavioral act was identified as an interval between two successive moves of the opponent. Acts having identical numerical indices for the starting situation, the gambler's action and resulting situation were referred to the same type. Resulting situation after the return move of opponent was used due to the gambler' s approach to the win or to the loss depends on this event namely. For 6 gamblers about 500 types of behavioral acts have been identified. The repertoire of acts realized by a gambler represent his subjective experience in the tic-tac-toe. It was found that each gambler repeatedly used the sequences of acts joined up to 6 elements. This is the same kind of prognosis which is typical for chessplayers. It can be inferred that if the first member of sequence is actualized, then the rest members are actualized too. These sequences as the single acts may be regarded as the elements of subjective experience. Since it is possible to transit from behavioral act of certain type to several other ones, we can to argue that act to be realized in overt behavior is chosen from the set of simultaneously actualized ESEs (M= 5.2; "M" mean number of ESEs in the set). On the basis of possible simultaneous actualization of ESEs in composition of the same set the relationships between ESEs were inferred. Sinergetical relations between ESEs are reflected in obligatory mutual actualization as components of the same set. If simultaneous actualization of some ESEs is impossible, these ESEs are in strong reciprocal or opponent relationships. Obviously, that strong sinergetic and opponent relations are polar points of wide range of relationships between ESEs. It must be noted that ESE joined in the simultaneously actualized sequences may be related by various magnitude of opponency. In order to evaluate relations between all the ESEs actualized in the same set (including ESEe joined in sequences) index of opponecy was calculated as the ratio of the number of ESEs which are in opponent relation to the total number of ESEs in the set.

In general, the certain act to be realized in overt

behavior is chosen from the set of ESEs which corresponded to all the variants of behavior possible after the current act; it must be pointed out that this set may be restricted due to opponent's move. Analysis of hand movements and hand fixations over certain squares of the board in the course of consecutive tests of alternative moves indicated that tested alternatives belong to the "output" alternatives of previous act. Thus, the choice of act to be realized in overt behavior depends on the decreasing of actualization of competing ESEs. It was found the growth of choice time (i.e. time interval between the onsets of moves' writings of opponent and gambler) when the number of competing ESEs increased($P<.05$). Close relation between choice time and entropy (H) of the ESEs' set ($R= .86$, $p < .001$) indicates that degree actualization of each ESE included in the set is a very important determinant of the choice time. ($H = -\sum$ pi Log pi ("n" – number of alternatives; "pi" probability of transition to an act of "i" type). Important determinants of choice time are the characteristics of ESEs' relationships. For instance, increasing of index of opponency results in the choice time growth. It was found also significant correlation of choice time with number and length of such kind of actualized ESEs as sequences. The move writing is the realization of chosen act in overt behavior. It is possible due to decreasing of number of alternative variants of behavior realization ($M= 1.2$) and leads to the actualization of another set of ESEs which corresponds to all expected opponent's moves in given game situation (in this case the number of actualized ESEs increases: $M = 6.2$). This set serves as a choice material for the next gambler's act. It must be stressed that the sets of actualized ESEs at intervals before and after the move's writing partly overlap mainly due to elements of sequences. Actualization of such ESEs in frame of forming set prevents from the actualization of some ESEs by means of opponent relations. The suggestion is possible that the continuity of compositions of consecutive sets has an influence on decision making on the next steps of the game. Analysis of averaged slow potentials corresponded to the behavioral act in tic-tac-toe revealed negative going shift at the interval between opponent and gambler moves, when the number of actualized ESEs, the entropy of the ESEs' set,the index of opponency were decreased. Components of slow negative shift are connected with test movements of gambler's hand and correspond to consecutive testing and decreasing of actualization of competing alternatives of behavior. At the interval between the moves's writings of gambler and his opponent when abovementioned indices were increased, slow positive wave was observed.

Conclusion

Our results demonstrate that the choice of any behavior act to be realized in overt behavior, that is decision making, is determined by the composition and number of simultaneously actualized ESEs and their relationships. The composition of the ESEs's set at any step of game depends on the compositions of ESEs' sets actualized on previous stages and has an influence on characteristics of decision making at the next stages. The correlation between slow potentials and characteristics of actualized ESEs' sets indicates that slow potentials may serve as an objective index of the structure and dynamics of subjective experience during decision making.

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HUMAN SLOW-WAVE ACTIVITY IN HEART RATE AND CENTRAL NERVOUS SYSTEM RELATED TO DIFFERENT FUNCTIONAL STATES

Z.A. Aleksanyan, N.N Vassilevsky, I.M. Kisselev, N.I. Moiseeva and V.M. Buchko
Institute for Experimental Medicine, Acad. Med. Sci. USSR, Leningrad, USSR

Studying the frequency characteristics of subcortical neuronal activity in man and animals, we saw waves with second, decasecond and minute periods and a peculiarity of oscillatory process related to changes of a general activity or of the brain state. We pointed out, sometimes in CNS there is the formation of dominant rhythm, which modulates neuronal activity. Among second, decasecond and minute fluctuations the decasecond are prevailing. Moreover, the most represented