LOOMING: AN INFORMATION SOURCE FOR AVOIDING AND MAKING CONTACT

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Introduction

In 1959, Purdy signalled the potential effect of ' looming ' for judgement about when an approaching object will make contact with her or him. Experimental work by Schiff, in the early sixties, showed that expanding shadow projections evoked avoidance behaviour in rhesus monkeys (Schiff, Caviness & Gibson, 1962), adult fiddler crabs and two week old chickens (Schiff, 1965). In the mid seventies, it was David Lee (1976), who demonstrated that the pattern of optical expansion, brought about by the relative approach between the actor and the environmental structure of interest, contained predictive temporal information about making contact. The purpose of this paper is to provide evidence for the value of the predictive visual information source called ' looming '. This in respect with avoiding and making contact with the source which causes the looming.

Avoidance behaviour

A number of studies on impending collision investigated the development of avoidance or defensive behaviours in response to approaching objects (Ball & Tronick, 1971; Bower, Broughton, & Moore, 1970; Schiff, 1965; White, 1971; Yonas, Bechtold, Frankel, Gordon, McRoberts, Norcia, & Sternfels, 1977). One concern of the researchers on this topic was to determine if impending collision stimuli elicite avoidance response from animals reared in darkness or newborn infants (i. e., if avoidance to " looming " was innate or learned). A further issue was to determine the onset age of avoidance response in human infants. Using dark-reared nonhuman species. Schiff found that several animals responded avoidantly to optical expansion patterns (Schiff, 1965). However, in some species, the younger subjects (e. g., kittens of 26 days of age) failed to respond relialy, suggesting that for some higher mammals, the avoidance response may have to be learned. Testing on human infants, ranging from 8 days to 11 weeks, two earlier studies reported that avoidance responses were observed in both real and virtual situations (e. g., styrofoam object vs expanding shadow on screen) (Ball &

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Tronick, 1971; Bower, Broughton, & Moore, 1970). These positive findings, however, were confronted with studies by Yonas *et al.* (1977), who reported that avoidance response was absent in their youngest subjects of 1- to 2-month-old infants. In addition, they examined various concurrent behaviours, such as head rotation, head withdrawal, and visual tracking. They pointed out that the positive findings by Ball & Tronick (1971) and Bower *et al.* (1970) ere the result of designating the infants' tracking response as avoidance response. They concluded that the negative results of their own testing of 1- to 2-month-olds were in agreement with the earlier data on the development of the blink reflex obtained by researchers such as Gesell in 1975, Kasahara and Inamatsu, in 1931 and White, in 1971 (see Yonas *et al.* 1977).

While these previous studies used infant subjects ranging from 8 days to 9 months old, no study of children beyond this age seems to have been attempted yet. Furthermore, although several speeds of the approaching objects were tested in these studies, with one exception (i. e., White, 1971), no study tested the effect of more familiar objects such as an approaching baseball, a vehicle coming towards the viewer, or a falling piece of toy or furniture etc. At the present the authors are conducting a study in order to investigate the development of avoidance response of children from 3 to 11 years of age to impending collision, using video clips depicting scences of different degrees of familiaity as well as speeds. Our pilot observation suggested the importance of identification of event in avoidance response to impendng collision situation, because the absence of avoidant eyeblinking in some subjects was attributed by the sbjects to "not knowing what was going on" (Chen & Savelsbergh, 1993).

The expanding optical projections in the aforementioned studies thus specified imminent collision and, therefore, evoked avoidance behaviour. However, the inverse of the relative rate of dilation, denoted 'tau' (Lee, 1976, 1980) is not only useful in avoidance behaviour but also in circumstances require to make contact.

Making contact

Lee (1976, 1980) demonstrated that the pattern of optical expansion, brought about by the relative approach between an object in the environment and an actor, provides predictive temporal information-the (remaining) time-to-contact being directly specified by the inverse of the relative rate of dilation of the closed optical contour of an approaching object, as it is generated in the optic array (the optical variable Lee called *tau*). Even in situations where a discrepancy exists between *tau* and the real time-to-contact i. e., in situations where the approaching object is accelerating (e. g. a falling ball that has to be punched away) subjects still gear their actions to the optical variable tau and not to the real time to contact (Lee, Young, Reddish, Lough & Clayton, 1983).

The use of optical time-to-contact information in control of action has been explored in a variety of contexts over the years-e. g., automobile driving (Lee, 1976; McLeod & Ross, 1983; Cavello & Laurent, 1988), striking the take-off board in long jumping (Lee, Lishman & Thompson, 1982), the folding of the wings by diving gannets (Lee & Reddish, 1981), the visual control of the step length during running over irregular terrain (Warren, Young & Lee, 1986) and the regulation of the landing of house flies (Wagner, 1982). More recently, Bootsma and Van Wieringen (1990) have invoked a similar explanation in the control of a directed strike of a table-tennis ball and for the regulation of gait in the jumping of obstacles by horses, Laurent, Dinh Phung and Ripoll (1989) have demonstrated that it is the retinal expansion pattern of the obstacle that is used by the riders.

With respect to muscular activity by means of EMG measurements evidence is found for the use of the expansion pattern in order to control the action (Dietz & North, 1978; Sidaway, McNitt-Gray & Davis, 1989). For example, Sidaway *et al.* (1989) have demonstrated that preparatory muscle activation prior to impact landing from different heights is triggered by a specific *tau*-value, e. g., a constant time before contact, like Savelsbergh and co-workers showed for the muscular activity in one handed catching (Savelsbergh, Whiting, Burden & Bartlett, 1992).

Fascinating as all these experiments have been, they only demonstrate that the various actions are consistent with the use by subjects of *tau* information and not that subjects, necessarily, make use of such information. It remained for Savelsbergh (1990; Savelsbergh, Whiting and Bootsma, 1991; Savelsbergh, Whiting, Pijpers & van Santvoord, in press) to carry out a direct manipulation of the optical expansion or looming pattern and, thereby, to provide firmer evidence for the use of *tau* information by subjects in the context of ball catching actions. In their experiments, balls of constant size as well as a ball the diameter of which could be changed during flight (deflating ball) were used. In contrast to the balls of constant size, the deflating ball provides the subject with optical expansion information which is non-verdidcal-in the sense that the time-to-contact it specifies as it approaches is different from that which would be specified by a ball of constant size. The findings of these experiments demonstrated that the closing of the fingers was later for the deflating ball than for the balls of constant size thus confirming that subjects must have been making use of retinal expansion information for making time-to-contact judgements in catching. All in all, the series of experiments, briefly discussed above, provide a catalogue of evidence in support of the explanatory power of 'direct' perception (Gibson, 1979) and of a *visual* control of timing in a variety of ecologically appropriate skills.

Conclusion and discussion

A conclusion that can be derived from previous studies on impending collision is that although the exact onset time of avoidance response depends on how one interprets the backward movement of the young infant's head (i. e., either as eye tracking or as avoiding backing), the appearance of avoidance response after 6 months is considered established.

A wealth of empirical evidence has provided evidence that subjects can use two dimensional time-to-contact information, The effect on performance of directly manipulating the optical expansion pattern has been, empirically, addressed by Savelsbergh *et al.* (1990, 1991, 1992). These experiments strongly indicate that such coupling is based on time-to-contact information specified directly by the relative optical expansion pattern. Stoffregen and Riccio (1990) showed that peripheral as well as focal vision can be used in order to judge time-to-contact based on the expansion pattern.

Although all the experiments reported here have been in the visual mode, note should be taken of Fitch, Tuller and Turvey's (1982, p. 277) point 'that the information needed to tune muscle systems is not tied to a particular sense modality'. It is, perhaps, that time-to-contact information is not limited to the visual mode that led Lee (1989) to argue for the generality of the *tau* principle. For a variety of information sources (e. g. sound, heat etc.), he speculates, time-to-contact judgements are based on the general principle of *rate of intensity* change, Rosenblum, Carello and Pastore (1987) as well Schiff and Oldak (1990) demonstrated that subjects can make reliable judgements about the timing of a moving sound source.

An experiment on vision substitution devices for the blind conducted by White, and his co-workers showed that a matrix of vibrations acts as a 'tactile' array (White,Saunders, Scadden, Bach-Y-Rita & Collins, 1970). In this experiment one vision substition system transmitted a pattern of intensity differences from a portable television camera to a bank of mechanical vibrators on the subject's back. This matrix of vibrators acts like a 'tactile' array, which can be made to change by the optical array as presented by a camera. While testing this device, the experimenter accidentally moved the zoom lens. This resulted in a rapidly expanding tactile array on the back of the subject which was followed by an avoidance reaction on his part. The expanding tactile array, like an expanding optic array, specified that an object is about to make contact.

The series of experiments of Savelsbergh (1993) provide empirical support for haptic time-to-contact judgements based on pressure changes caused by an approaching air flow. The task was to avoid contact with this approaching airflow (hair-dryer) by adducting the hand just before contact. The findings indicated that subject did not adducted their hand at some absolute pressure level but supported the idea that the judgements of the time of arrival of the object were based on the rate of pressure changes. In a second experiment, subjects were required to make judgements based on cold or warm airflow or on the bases of auditory information. The results showed that all three sources were useful in order to make time-to-contact judgements and support David Lee's (1989) notion of the existence of a 'general' tau.

References

Ball, W. & Tronick, E. (1971). Infants responses to impending collision: optical and real. *Science*, **171**, 812-820.

Bootsma, R. J. (1988). *The timing of rapid interceptive actions*. Ph. D. thesis, Amsterdam: Free University Press.

Bootsma, R. J., & Van Wieringen, P. W. C. (1990). Timing an attacking forehand drive in table tennis. *Journal of Experimental Psychology: Human Perception and Performance*, **16**, 21-19.

Bower, T. G. R. (1972). Object perception in infants. *Perception*, **1**, 15-30.

Bower, T. G. R. (1974). *Development in infancy*. San Francisco: Freeman.

Bower, T. G. R., Broughton, J. M. & Moore, M. K. (1970a) Demonstration of intention in the reaching behaviour of neonate humans. *Nature*, **228**, 679-681.

Bower, T. G. R., Broughton, J. M., & Moore, M. K. (1970b). The coordination of visual and tactual input in infants. *Perception and Psychophysics*, **8**, 51-53.

Cavello, V., & Laurent, M. (1988). Visual information and skill-level in time-to-collison estimation, **17**, 623-632.

Chen, S. J., & Savelsbergh, G. J. P. (1993). Absence of avoidance response to impending collision in children. *Annual Report 1991-1992, Research and Clinical Center for Child Development*, Hokkaido University.

Dietz, V., & North, J. (1978). Pre-innervation and stretch reponses of triccps brachii in man falling with and wihout visual control. *Brain Research*, **142**, 576-579.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston : Houghton-Mifflin.

Laurent, M., Dinh Phung, R., & Ripoll, H. (1986). What visual information is used by riders in jumping. *Human Movement Science*, **8**, 481-501.

Lee, D. N. (1976). A theory of visual control of braking based on information about time-to-collision. *Perception*, **5**, 437-459.

Lee, D. N. (1989). Ways of coupling action to the environment. Paper presented at The Fifth International Conference on Event Perception and Action. Miami University, Oxford, Ohio, USA.

Lee, D. N. (1980). Visuo-motor coordination in space-time. In G. E. Stelmach and J. Requin (Eds.), *Tutorials in motor behavior*. Amsterdam : North Holland.

Lee, D. N., & Reddish, D. E. (1981). Plummeting gannets : A paradigm for ecological optics, *Nature*, **293**, 293-294.

Lee, D. N., & Lishman, J. R. (1975). Visual proprioceptive control of stance. *Journal of Human Movement Studies*, **1**, 87-95.

Lee, D. N., Lishman, J. R., & Thomson, J. A. (1982). Regulation of gait in long jumping. *Journal of Experimental psychology : Human Perception and Performance*, **8**, 448-459.

Lee, D. N., Young, D. S., Reddish, D. E., Lough, S., & Clayton, T. M. H. (1983). Visual timing in hitting an accelerating ball. *Quarterly Journal of Experimental Psychology*, **35a**, 333-346.

Lee, D. N., & Young, D. S. (1986). Gearing action to the environment. *Experimental Brain Research Series 15*. Berlin : Springer Verlag.

McLeod, R. W., & Ross, H. E. (1983). Optic-flow and cognitive factors in time-to-collision estimates. *Perception*, **12**, 417-423.

Purdy, W. C. (1958). *The hypothesis of psychophysical correspondence in space perception*. Unpublished doctoral dissertation, Cornell University.

Rosenblaum, L. D., Carello, C., & Pastore, R. E. (1987). Relative effectiveness of three stimulus variables for locating a moving sound source. *Perception*, **16**, 175-186.

Savelsbergh, G. J. P. (1990). *Catching Behaviour*. Meppel : Krips Repro.

Savelsbergh, G. J. P. (1993). *Time-to-contact judgements based on haptic information*. In S. Valenti (Ed.), *The proceedings of the VIIth International Conference on Event Perception and Action*. Hillsdale : Erlbaum (submitted).

Savelsbergh, G. J. P., Whiting, H. T. A., & Bootsma, R. J. (1991). Grasping " Tau ". *Journal of Experimental Psychology : Human Perception and Performance*, **17**, 315-322.

Savelsbergh, G. J. P., Whiting, H. T. A., Burden, R., & Bartlett, R. (1992). The role of predictive visual information in the coordination of muscular activity in catching. *Experimental Brain Research*, **89**, 223-228.

Savelsbergh, G. J. P., Whiting, H. T. A., Pieper, R. J., & van Santvoord, A. M. M. (In press). Visual guidance of catching. *Experimental Brain Research*.

Schiff, W., Caviness, J. A., & Gibson, J. J. (1962). Persitent fear responses in rhesus monkeys to the optical stimulus of ' looming '. *Science*, **136**, 982-983.

Schiff, W., & Detweiler, M. L. (1979). Information used in judging impending collision. *Perception*, **8**, 747-758.

Schiff, W., & Oldak, R. (1990). Accuracy of judging time to arrival : Effects of modality, trajectory, and gender. *Journal of Experimental Psychology : Human Perception and Performance*, **16**, 303-316.

Sidaway, B., McNitt-Gray, J., & Davis, G. (1989). Visual timing of muscle preactivation in preparation for landing. *Ecological Psychology*, **1**, 253-264.

Stoffregen, T. A., & Riccio, G. E. (1990). Responses to optical looming in the center and periphery. *Ecological Psychology*, **2**, 251-274.

Todd, J. T. (1981). Visual information about moving objects. *Journal of Experimental Psychology: Human Perception and Performance*, **7**, 795-810.

Wagner, H. (1982). Flow-field variables trigger landing in flies. *Nature*, **297**, 147-148.

White, B. W., Saunders, F. A., Scadden, L, Bach-Y-Rita, P., & Collins, C. C. (1973). Seeing with the skin. *Perception & Psychophysics*, **7**, 23-27.

Yonas, A., Bechtold, A. G., Frankel, D., Gordon, R. F., McRobert, G., Norcia, A., Sternfels, S. (1977). Development of sensitivity to information for impending collision. *Perception and Psychophysics*, **21**, 97-104.

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