RESEARCH ARTICLE

An Experiment on Precognition with Planarian Worms

Fernando Alvarez

Calle del Molino 4, Tomares (Sevilla), Spain
alvar_gonzalez@hotmail.com

Abstract—The ability to predict a random noxious stimulus (a startle sound) was explored in the black planarian *Girardia dorotocephala*. During the experiment, planarians were put individually and only once into a testing chamber and after 3 minutes either an audio startle stimuli or a control moment of silence was randomly presented (corresponding, respectively, to the 43 experimental and the 37 control subjects, all of them having the same time courses of observation). All worms were filmed during the experiment, and the frequency of their Head Movements (this behavior being indicative of distress and/or ambient exploration) was registered in the two 10-second segments immediately before and one minute before stimulus presentation for the experimental subjects and immediately before and one minute before the time point 3 minutes from start for the controls, which received no stimulus. Nonparametric comparisons of the frequencies of Head Movements showed that the values obtained during the two observation periods for the experimental planarians were significantly higher than those during the corresponding observation periods for the control planarians. Additionally, in both the experimental and control subjects no significant difference was observed between the values for the two observation periods within the same session. These results suggest that planarians are able to anticipate future events at least one minute before they occur.

Keywords: behavior—planarians—precognition

Introduction

The ability to perceive an event prior to its occurrence without any apparent clues has been demonstrated in humans by observational (Vassy 1978) and experimental studies dealing with changes in physiological variables such as heart rate, fingertip blood volume, electroencephalogram changes,

magnetic resonance imaging, electrodermal activity, and pupil dilation preceding the random presentation of emotional pictures (Radin 1997a,b, 2004, Bierman & Radin 1997, 1999, Bierman & Scholte 2002, McCraty, Atkinson, & Bradley 2004a,b, Sartori, Massaccesi, Martinelli, & Tressoldi 2004, Tressoldi, Martinelli, Massaccesi, & Sartori 2005), or audio startle stimuli (Spottiswoode & May 2003, May, Paulinyi, & Vassy 2005, Tressoldi, Martinelli, & Semenzato 2011, 2013).

The use of human physiology to predict the occurrence of future random events has been supported by a meta-analysis carried out by Mossbridge, Tressoldi, and Utts (2012). Since the phenomenon is based on unconscious physiological activity, the term Predictive Anticipatory Activity (PAA) is defined by Mossbridge, Tressoldi, Utts, Ives, Radin, and Jonas (2014) as "statistically reliable differences between physiological measures recorded seconds before an unpredictable emotional event occurs vs. seconds before an unpredictable neutral event occurs," while the term precognition would apply more to a perception or a behavior (not a physiological measure).

Although research on non-humans would no doubt widen the opportunity for understanding the biological mechanisms involved in anomalous anticipatory activity, very few studies have been undertaken with them on this topic. The results obtained with birds (Alvarez 2010a,b) and mammals (Duval & Montredon 1968, Sheldrake & Smart 1998, 2000, Radin 2002) prove that the phenomenon also occurs in animals endowed with a highly developed nervous system. On the other hand, the nearly significant result obtained in an experiment performed with earthworms (Wildey 2001) suggests that it may also occur in animals endowed with a less complex nervous system.

When looking for a subject species furnished with a primitive nervous system and where PAA or precognition has been observed, we encounter the free-living freshwater planarians.

Within the phylum Platyhelminthes, the planarians are among the simplest living animals presenting bilateral symmetry and cephalization, the sense organs of vision (the ocelli or eyespots) and smell (the auricles) being located in the head. Consequently, planarians show quite active and directional locomotion.

Planarians are among the most primitive animals with a central nervous system (CNS), neurons representing up to 20% of the total number of cells in their body (Baguñá & Romero 1984). Their CNS consists of a mass of bi-lobed cephalic ganglions in the head region, from which emerge the pair of laterally located nerve cords extending the length of the body and

connected by many transversal commissures. Their cerebral ganglion is the most primitive type of brain in animal evolution, although resembling that of the early developmental stages of the CNS of vertebrates, presenting a cortex of nerve cells and a core of nerve fibers, the neurons and synaptic organization resembling those of the vertebrate brain more than those of advanced invertebrates (Agata, Soejima, Kato, Kobayashi, Umezono, & Watanabe 1998). Accordingly, the planarian cerebral ganglion is not only the most primitive real brain, but may actually be the ancestor of the vertebrate brain (Sarnat & Netsky 1985, 2002).

In accordance with the complexity of its CNS, planarians rely on the sensory input of specialized receptors for detecting light, chemicals, vibrations, and water currents, and various types of pressures are integrated to provide motor responses of the entire body (Sarnat & Netsky 1985), planarians being also capable of learning and related skills (Thompson & McConnell 1955, McConnell, Jacobson, & Kimble 1959, Hicks, Sorocco, & Levin 2006).

Methods

A colony of black planarians *Girardia dorotocephala* was maintained in $14 \times 22 \times 7$ cm polypropylene plastic containers filled up to 3 cm height with dechlorinated tap water at 21–23 °C, and fed raw beef liver once a week, followed by a water change. They were exposed to diffuse natural light during the day and kept dark at night.

The experiments were carried out between June 25 and August 3, 2015. The subjects were among the larger in the colony (10.5–15 mm long) and were used only one time for this experiment, being fed 3–6 days before the start of all trials (larger black planarians acclimated to 22 ºC showed higher motility, remaining high and constant after 3–5 fasting days [Claussen, Grisak, & Brown 2003]). All trials were performed between 8:00 and 11:00 UT, since black planarians trained to perform a task in the morning appeared to learn the correct response significantly more often than those trained at night (Cohen 1965). To transfer the worms, 3 ml disposable plastic pipettes were used.

The concern for behavioral bias in relation to habituation and sensitization in planarians (McConnell 1966) and the fact that single-trial training can induce persistent sensitization in invertebrates (Hawkins, Kandel, & Bailey 2006, Acheampong, Kelly, Shields-Johnson, Hajovsky, Wainwright, & Mozzachiodi 2012) advise the use of single-trials in this experiment.
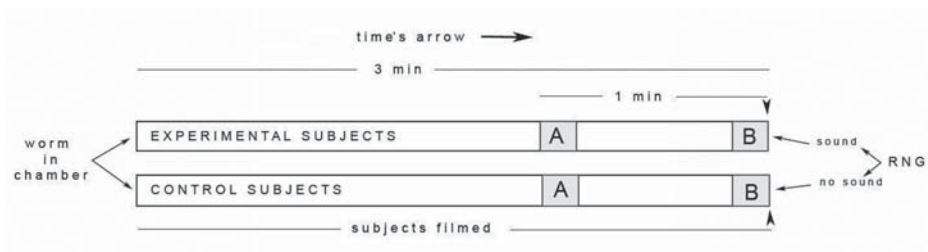
Figure 1. Order of events of the experimental sessions. Video-clips extracted for behavior analysis are represented in gray.

During each trial, one planarian was taken from its colony and placed in the experimental chamber. The latter was a 25 × 45 × 13 mm plastic trough, filled up to 2–3 mm with water from the maintenance container of the trial subject, and kept at 21–23 ºC during the trial. In order to provide sound stimuli to the subject, the chamber was placed on top of a plastic sheet, which was attached to a loudspeaker driver and the loudspeaker was connected to a computer.

During each experimental session and three minutes after the planarian was put into the chamber, a true random number generator (RNG) by Orion Electronics would determine whether a sound stimulus (gunshot.wav of 44100 Hz and 0.03 sec duration, downloaded from the Internet) was or was not presented. The first and second situations corresponded, respectively, to the experimental and control subjects (Figure 1). All subjects responded to the stimulus with a strong longitudinal contraction.

Beginning at the start of each trial, each subject was filmed with a 25 frames per sec video camera located 17 cm directly above the experimental chamber (a Sony DCR-SR72E provided with a polarizing filter in order to suppress glare from the water surface). In consonance with the species, minimum evoked ocellar potential in the red (mainly at 600 nm and above [Brown, Ito, & Ogden 1968]), diffuse illumination was provided by a led lamp emitting red 620–630 nm light.

Video analysis concentrated on quantifying the frequency of Head Movements during slow-motion film analysis (accuracy of 0.04 sec) in two 10-sec observation periods immediately before (−10 sec to 0 sec) and one min before (−60 sec to −50 sec), the presentation of the startle sound stimulus for the experimental subjects, and the corresponding two observation periods (−10 sec to 0 sec and −60 sec to −50 sec) for the control
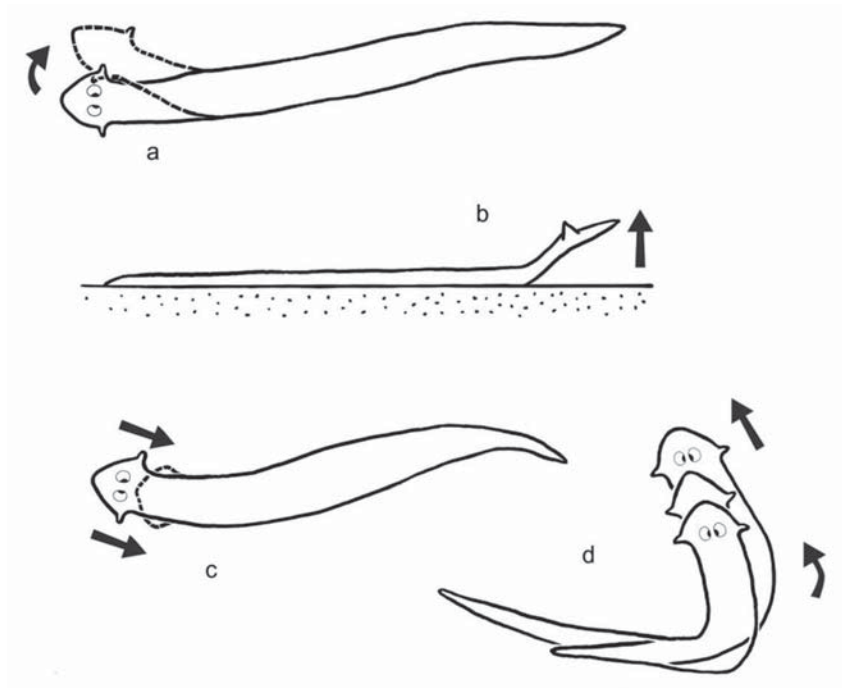
Figure 2. Forms of Head Movement behavior: a) lateral head turning, b) head lifting (seen from the side), c) head contraction, d) lateral head turning followed by change in direction of locomotion.

subjects, using VLC Media Player and Prism computer program by NCH Software.

I chose to quantify this behavior since it is the most common deviation shown by the worms during the usual smooth gliding motion, this behavior being also indicative of distress and/or ambient exploration (Pearl 1903, Brown, Dustman, & Beck 1966, Raffa & Dessai 2005). The sudden Head Movements shown by planarians during the normal straight gliding motion may consist of brief lifting of the head or lateral head turning (at least 45° with respect to the body axis, not to be mistaken with the smooth, slight swaying from side to side during locomotion), as well as longitudinal head contraction. Lateral head turning often results in a change in the direction of locomotion (Figure 2).

TABLE 1
Frequency of Head Movements Behavior for Each of the 10-sec Blocks
(A) 1 min before and (B) immediately before, Stimulation for
Experimental Subjects and Corresponding Periods for Control Subjects

	Mean ± SE	N
Experimental A	0.86 ± 0.13	43
Experimental B	1.14 ± 0.17	43
Control A	0.38 ± 0.11	37
Control B	0.41 ± 0.10	37

In order to prevent experimenter subjective bias, after extracting from the film records the 10 sec blocks both immediately and one min before the presentation of the experimental and control stimuli (by the use of the VideoPad application by NCH Software), a third person provided them to the author (who analyzed the video clips), not indicating whether each preceded a sound stimulus or a control and then revealing it when the information for each subject was completed.

Statistical Analysis

Since the populations of behavior frequency values are not normally distributed (Experimental: N = 43, P < 0.05; Control: N = 37, P < 0.01, Kolmogorov-Smirnov test), a non-parametric technique was applied. The non-parametric Wilcoxon matched-pairs signed-ranks test was used to compare behavior frequencies of the two pre-stimulation observation periods for the experimental planarians and the corresponding observation periods for the control planarians. To compare behavior frequencies between experimental and control groups, the non-parametric Mann-Whitney U test for independent samples was used (Siegel & Castellan 1988). Data analysis was done using the STATISTICA 6.0 computer program. All reported p are two-tailed.

TABLE 2

Results of Comparison between Frequencies of Head Movement Behavior during 10-sec Blocks (A) 1 min Before and (B) Immediately Before Stimulation for 43 Experimental Subjects and Corresponding Periods for 37 Control Subjects

	Experimental		Control	
	A	B	A	B
Experimental A		$T = 286.5$, $p = 0.223$*	$U = 549$, $p = 0.017$**	$U = 559.5$, $p = 0.022$**
Experimental B			$U = 464.5$, $p = 0.001$**	$U = 487$, $p = 0.003$**
Control A				$T = 49$, $p = 0.826$*
Control B				

* Wilcoxon matched-pairs signed-ranks
** Mann-Whitney U test

Results

Frequencies of Head Movements behavior during the two observation periods (one min before and immediately before stimulation) for the experimental planarians more than doubled that of values during the corresponding observation periods for the control subjects (Table 1).

Comparison between the two pre-stimulus observation periods (immediately before and one min before stimulation) for the experimental planarians showed the value distributions of the two periods to be statistically equivalent, and the same situation was found in the case of the control planarians (Table 2).

When the comparisons were done among the frequencies of the two observation periods for the experimental subjects with those of the two observation periods for the control planarians, they appeared to be significantly different in all cases (Table 2 and Figure 3).
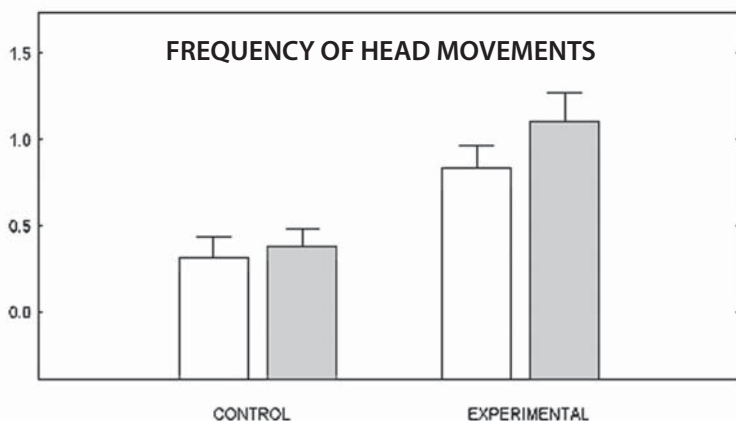
**Figure 3. Mean and SEM frequency of Head Movements behavior of experi-
mental planarians during the 10-sec observation periods one min
before (empty bar) and immediately before (gray bar) stimulation.**

In Figure 3, empty and gray bars for the control subjects refer to the corresponding observation periods (respectively, one min before and immediately before the silent time point of sham stimulation). In Figure 1, the end of the graph shows the trial time for the experimental and control subjects, and the small vertical arrows point to the moment when the RNG selected the stimulus (either a sound or a moment of silence).

Discussion

The significantly higher frequency of Head Movements before stimulation, as compared with that during the controls, supports the idea that planarians are able to anticipate future events, and that the effect is not limited to the few seconds before stimulation, but extends to at least one minute before.

Apart from head contraction and head turning being common responses to stress, the latter behavior also offers opportunities for ambient exploration, since the auricles (organs for olfaction) and eyespots (visual organs), both located on the head of planarians. Head turning often results in a change in the direction of locomotion, which would be the most obvious way to flee from impending danger.

For the present study, the pre-stimulus activity consisted of movements

indicative of distress and/or ambient exploration (Pearl 1903, Brown, Dustman, & Beck 1966, Raffa & Desai 2005), while the immediate post-stimulus activity is always a strong longitudinal contraction, sometimes followed by immobility (subsequent behavior was not recorded). Therefore, my results cannot be directly interpreted in consonance with those of Mossbridge, Tressoldi, and Utts' (2012) meta-analysis, where the aim was to test the hypothesis that the direction of pre-stimulus activity would predict the direction of post-stimulus activity.

On the other hand, these results are in accord with most studies dealing with prediction of random future events (and made clearer in Mossbridge, Tressoldi, & Utts' 2012 meta-analysis) in that the effect is small but highly statistically significant, the mechanism remaining unclear.

The phenomenon is anomalous in the sense of lacking an explanation in today's scientific paradigms. Nevertheless, as noted by Mossbridge, Tressoldi, Utts, Ives, Radin, and Jonas (2014), recent findings in quantum physics (weak measurements, delayed-choice entanglement, and quantum effects shown in biological systems) lend support to the existence of retrocausal quantum effects such as precognition or PAA in biological systems.

It appears of interest that in the case of planarians, the phenomenon extends at least one minute before stimulation (in that respect it differs from previous work on humans). Although the difference in the values obtained immediately before and one minute before stimulation (Figure 3) did not reach the level of statistical significance, the amount of the difference between the means for both populations represents one fourth of the frequency value for the time period immediately before stimulation, suggesting that nearness in time with respect to the moment of stimulation may offer a higher opportunity for prediction.

The proposed relationship of the planarian nervous system with that of vertebrates (Sarnat & Netsky 1985, 2002) may account for the occurrence of precognition in this primitive animal and in the human autonomous nervous system (McCraty, Atkinson, & Bradley 2004a,b, Sartori, Massa-ccesi, Martinelli, & Tressoldi 2004, Tressoldi, Martinelli, Massaccesi, & Sartori 2005, Tressoldi, Martinelli & Semenzato 2011, 2013), with the central nervous system (Bierman & Scholte 2002, Radin & Lobach 2007) apparently playing a role in the process. In any case, the finding that birds, mammals, planarians, and perhaps also earthworms can physiologically or behaviorally predict the future, point to this ability perhaps being an attribute of all or most animals.

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