Prepulse Inhibition of the *Tritonia* Escape Swim

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Presenting a weak stimulus just before a strong, startle stimulus reduces the amplitude of the ensuing startle response in humans and other vertebrates. This phenomenon, termed “prepulse inhibition” (PPI), appears to function to reduce distraction while processing sensory input. To date, no detailed neural mechanism has been described for PPI. Here we demonstrate PPI in the marine mollusk *Tritonia diomedea*, which has a nervous system highly suitable for cellular analyses. We found that a 100 msec vibrotactile prepulse prevented the animal’s escape swim response to a closely following 1 sec tail shock. This inhibition was highly transient, with a significant effect lasting just 2.5 sec. These findings indicate that the *Tritonia* escape swim response undergoes a form of PPI phenomono-

logically similar to that observed in vertebrates. Further tests showed that the vibrotactile stimulus had no inhibitory effect if applied after tail shock, while the animal was preparing to swim, but it acted to terminate swims once they were actively under way. As a first step toward a cellular analysis of PPI, we recorded from neurons of the swim circuit in a semi-intact preparation and found that the vibrotactile stimulus used in the behavioral experiments also prevented the tail shock-elicited swim motor program. These results represent the first explicit demonstration of PPI in an invertebrate and establish *Tritonia* as a model system for analyzing its physiological basis.

Key words: prepulse inhibition; startle; mollusc; *Tritonia*; sensorimotor gating; schizophrenia

“Prepulse inhibition” (PPI) refers to the ability of a weak stimulus, which itself may elicit little or no behavioral response, to transiently inhibit the normal response to a closely following startle stimulus. In the most common experimental paradigm, the vertebrate acoustic startle response can be inhibited by a variety of prepulse modalities, including auditory, visual, and tactile stimuli (Ison and Hammond, 1971; Graham, 1975; Pinckney, 1976; Schwartz et al., 1976; Hoffman and Ison, 1980; Blumenthal and Gescheider, 1987; Swerdlow et al., 1993). As pointed out by others (Graham et al., 1975; Hoffman and Ison, 1980), because the prepulse inhibits the startle response the very first time it is presented, PPI is not a learning-related phenomenon—either associative or nonassociative. Instead, in vertebrates it is believed to play an important role in pre-attentive sensory processing, acting to reduce distraction while processing sensory input (Graham, 1992; Hoffman and Ison, 1992; Cadenhead and Braff, 1995). Because of this sensory gating role, and because deficits in PPI may underlie certain cognitive disturbances associated with schizophrenia (Braff et al., 1978; Grillon et al., 1992; Perry and Braff, 1994), the cellular basis of PPI is of considerable interest.

To evaluate the generality of PPI, as well as to facilitate studies of its mechanism, here we investigated whether it could be demonstrated in *Tritonia diomedea*, a marine mollusk with a nervous system highly suited for cellular analysis. When an aversive stimulus is applied to the animal’s skin, *Tritonia* undergoes a vigorous escape response consisting of a series of alternating ventral and dorsal whole-body flexions. The neural circuit underlying this response has been described in some detail (Willows et al., 1973;

Getting, 1983; Frost and Katz, 1996). Here we tested whether a single, closely preceding tactile stimulus had the ability to block the escape swim. We found that it could, and, furthermore, that this inhibition displayed the key characteristics of vertebrate PPI. We also demonstrated PPI in a reduced preparation, while recording from neurons of the swim neural circuit.

Portions of this work have appeared previously in abstract form (Mongeluzi et al., 1997).

MATERIALS AND METHODS

Animals. *T. diomedea* were collected from the waters of Puget Sound, Washington. Experiments were conducted in natural seawater facilities (11–12°C) at the University of Washington’s Friday Harbor Laboratories (Friday Harbor, WA) and in artificial seawater aquaria (Instant Ocean, 10–11°C) in Texas. Animals were kept at the local ambient light/dark cycle at Friday Harbor and on a fixed 12 h light/dark cycle in Texas. All animals were rested a minimum of 2 d after arrival in the laboratory and isolated at least 3 hr before each experiment.

Swim stimulus. Escape responses were elicited via electric shock applied to the tail (10 msec DC pulses, 10 Hz, 1 sec), using a pair of implanted 0.005-inch-diameter Teflon-coated silver wires (A-M Systems, Inc., Everett, WA). After removing ~3 mm of insulation from one end, the wires were implanted by threading the exposed end through a 22½ gauge hypodermic needle, bending the end of the wire back into a barb, and then inserting the needle into the animal’s skin, after which it was withdrawn, leaving the barbed end of the wire embedded in the skin. After implanting two wires ~1 cm apart, the animal was rested for several minutes.

The next step was to adjust, for each animal, the intensity of the shock used to elicit the swim response. Aversive stimuli produce a lowering (sensitization) of threshold in rested animals (Frost et al., 1998). To avoid such changes in threshold while setting shock intensity, all animals first received a single sensitizing (swim-eliciting) salt stimulus (0.15 ml of 4 M NaCl applied to the skin). Five minutes later, an escalating series of monophasic tail shocks were delivered (5 min interstimulus interval), starting at 10 V and doubling in intensity each time thereafter, until a swim of at least four cycles was obtained (shock range, 10–150 V). The last voltage was then multiplied by 1.5 (maximum voltage = 150 V), and that value was used throughout the training session, which began 5 min later. On average, each animal received three or four shocks while setting threshold. All shocks were delivered using a Grass S48 stimulator with an

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in-series $10^3 \Omega$ resistor. The resistor was used to keep the current below the 100 mA overload level of the stimulator.

Prepulse Stimulus. The vibrotactile “prepulse” stimulus was delivered by pressing the tip of a 33-cm-long, 0.8-cm-diameter hollow glass rod taped against the long axis of an electric razor (model SS, Wahl Clipper Corp.), and activating the razor via a Grass S48 stimulator, which closed a relay inserted into the power cord of the razor. When the razor was on, it produced a 60 Hz vibration of the rod tip with a lateral deflection of ~ 0.5 cm. The glass probe was removed from the animal’s skin immediately after the end of the prepulse. The prepulse stimulator also triggered the tail shock stimulator with a controllable delay. All stimulus parameters were monitored and adjusted using a Nicolet digital oscilloscope. Although the prepulse itself elicited rhinophore withdrawal, it was never, at any intensity, observed to elicit the swim itself.

Electrophysiological methods. Animals were anesthetized by injecting ~ 60 ml of a solution composed of half 350 mM MgCl_2 and half artificial seawater (Instant Ocean, Aquarium Systems). A recording chamber was used in which the animal could be positioned dorsal side up, with the brain exposed and stabilized on the Sylgard surface of a 1-cm-diameter post rising from the chamber floor. A thin cylindrical sleeve, containing slits to allow the nerves passage, was raised around the brain, the slits were closed with Vaseline, and the brain and body chambers were perfused separately with saline. Saline composition was (in mM): 420 NaCl, 10 KCl, 10 CaCl_2 , 50 MgCl_2 , 10 HEPES, pH 7.6, and 11 D-glucose. The brain chamber was initially perfused at 2°C , during which the thin sheath enclosing the ganglia was removed to expose the neurons for intracellular recording. Once the neurons were exposed, both brain and body chambers were perfused at 11°C . Swim neurons (dorsal swim interneurons, ventral flexion neurons, and dorsal flexion neurons) were identified based on their location, size, color, synaptic connections with other identified neurons, and their activity during the swim motor program (Gettings et al., 1980; Hume et al., 1982).

Data analysis. Data were analyzed with three types of statistical tests (Zar, 1984). For experiments involving dichotomous nominal scale variables (e.g., whether animals swam), the Cochran Q test was used to test for overall differences, followed by Marasculio and McSweeney *post hoc* tests for individual pairwise comparisons. For all experiments involving a single paired comparison between means, paired *t* tests were used. For those involving more than one such comparison, a repeated measures ANOVA was used, followed by Newman–Keuls *post hoc* tests.

RESULTS

Prepulse inhibition of the *Tritonia* escape response

Vertebrate PPI is most commonly studied by testing the ability of a weak prepulse to inhibit startle responses. The resulting inhibition is rapid in onset and highly transient in duration, typically lasting a few hundred milliseconds to no more than a few seconds (Graham, 1975; Pinckney, 1976; Hoffman and Ison, 1980; Braff et al., 1992; Gewirtz and Davis, 1995).

To test for PPI in *Tritonia*, we used a 60 Hz vibrotactile stimulus as the prepulse and electric tail shock as the swim-eliciting stimulus (Fig. 1; see Materials and Methods). After determining that swims could be reliably elicited with tail shock, and also that our vibrotactile stimulus did not itself elicit the swim response, we tried the stimuli in combination. Animals were given three consecutive tail shock trials, separated by 5 min. The first and last were shock-alone trials. On the middle trial animals received a 100 msec vibrotactile stimulus (prepulse) beginning 120 msec before tail shock onset. We found that the prepulse prevented swim initiation in 10 of 10 animals (Fig. 2; $\chi^2_{(2)} = 14.00$; $p < 0.001$). Marasculio and McSweeney *post hoc* tests indicated that this inhibition was significant with respect to the shock-alone trials administered both before and after, in which all animals swam ($p < 0.05$). The swim response to the third trial indicated that the swim failures on the middle trial were attributable to the presence of the prepulse, rather than habituation to the tail shock. This inhibition of the swim response to tail shock by a tactile prepulse satisfied one key feature of vertebrate PPI:

Figure 1. PPI stimulus protocol. *A*, The prepulse stimulus was a 100 msec, 60 Hz vibrotactile stimulus applied to the animal’s dorsal skin. The startle stimulus was a 1 sec tail shock (10 msec DC pulses, 10 Hz) that normally elicits the escape swim response. *B*, PPI was tested for by administering the prepulse, followed at a specified interstimulus interval (ISI) by the tail shock.

Figure 2. PPI of the escape swim. Ten animals each received three tail shock trials, separated by 5 min. On the first and third, which were tail shock alone trials (white bars), all animals swam. On the second trial (black bar), animals received a tail shock beginning 120 msec after the onset of a 100 msec tactile prepulse. The prepulse prevented the swim in all animals. Asterisks on this and subsequent figures indicate significant differences (see Results).

the ability of a weak prepulse to produce rapid-onset inhibition of a startle response.

The second key characteristic of vertebrate PPI is its brevity. To assess the duration of the tactile-induced inhibition, we next systematically varied the interstimulus interval between the prepulse and the tail shock. Ten animals had stimulating wires implanted in their tails. Each animal was given seven tail shock trials, with a 5 min intertrial interval. The first and last were

Figure 3. Duration of PPI. Ten animals received seven tail shock trials each, separated by 5 min. On the first and last trials, which were tail shock-alone trials, all animals swam. On trials 2–6, in randomized order, animals received a tail shock 2.5, 5, 10, and 20 sec after and 2.5 sec before (–2.5 sec), a 100 msec vibrotactile stimulus. Only the shortest forward pairing interval produced significant inhibition of swim initiation (black bar).

shock-alone trials. On trials 2–6, tail shock was delivered, in random order, at 2.5, 5, 10, and 20 sec after, and 2.5 sec before (–2.5 sec), the onset of a 100 msec vibrotactile stimulus applied to the dorsal midbody region. For each trial, we recorded whether the animal swam to the tail shock.

The results of this experiment are shown in Figure 3. The 100 msec vibrotactile prepulse was found to produce a powerful but transient inhibitory effect on swim initiation ($\chi^2_{(6)} = 34.58$; $p < 0.001$). *Post hoc* tests indicated that significant inhibition occurred at the 2.5 sec interval ($p < 0.05$) but not at longer intervals. Taken together (Figs. 2, 3), these results demonstrate PPI in *Tritonia*. Trials on which swims did occur showed no difference in cycle number ($p > 0.05$), indicating that the inhibitory effect of the prepulse was on swim initiation rather than swim duration.

While tactile stimulation delivered 2.5 sec before the tail shock was highly inhibitory, the same stimulus delivered 2.5 sec after tail shock failed to produce any discernible inhibition (Fig. 3, –2.5 sec). In this reverse-order trial, the vibrotactile stimulus was delivered while the animal was actively flattening and extending its body in preparation for swimming but before the swim had yet begun. The swims elicited on this trial were of the same duration as those elicited by the shock-alone trials at the beginning and end of the experiment (mean swim cycle number of tail shock alone trials, 5.7 ± 0.4 cycles; –2.5 sec trial, 5.6 ± 0.5 cycles; $t_9 = 0.35$; $p > 0.05$).

Further behavioral features of tactile inhibition

Having demonstrated PPI, our next experiment examined two additional issues, both with potential relevance to the cellular mechanisms underlying PPI. The first concerned whether the inhibitory effectiveness of the prepulse is different when the prepulse and tail shock stimuli are delivered to the same, versus different, body sites. Previous work described a single population of afferent neurons, named S-cells, that are excited by both tactile and aversive skin stimuli (Gettings, 1976; Slawsky, 1979). The limited receptive fields described for these neurons made it likely that our different-site PPI paradigm activated separate S-cell populations. A failure to obtain PPI when using same-site stimulation would therefore be consistent with a requirement for heterosynaptic circuit interactions in its mediation.

The second issue was whether the 100 msec vibrotactile stimulus used to produce PPI could also inhibit swims already in progress. Such a result would suggest a locus of inhibition downstream from the sensory neurons, which fire relatively little once the swim motor program has begun (W. Frost, unpublished observations).

After setting tail shock intensity in 17 animals, each received five suprathreshold tail shocks at a 5 min intertrial interval. The first and last of these were shock-alone trials. Trials 2–4, presented in random order for each animal, were (1) tail shock 120 msec after a tactile stimulus applied to the dorsal midbody, (2) tail shock 120 msec after a tactile stimulus applied to the tail shock site, and (3) tactile stimulus to dorsal midbody, just after the second dorsal flexion of the tail shock-elicited swim. In all cases, the tactile stimulus was our standard 100 msec vibrotactile stimulus and the tail shock was a 1 sec, 10 Hz train of 10 msec DC voltage pulses. The data corresponding to each of the two issues listed above were analyzed separately.

Effect of prepulse location

In this experiment, all 17 animals swam to both tail shock-alone trials, 9 of 17 swam when the prepulse was delivered to the tail shock site, and just 1 of 17 swam when the prepulse was delivered away from the tail shock site (Fig. 4A). A Cochran's Q test performed on these four groups indicated a significant overall effect of treatment ($\chi^2_{(3)} = 37.71$; $p < 0.001$). Marsculio and McSweeney *post hoc* tests revealed that the different-site PPI protocol yielded significant inhibition ($p < 0.05$), whereas the same-site protocol did not ($p > 0.05$). Thus, a separate-site paradigm was found to be more effective at producing PPI than a same-site paradigm.

Effect of tactile stimulation during an ongoing swim

Our earlier experiment (Fig. 3) showed that tactile stimulation had no inhibitory effect when applied 2.5 sec after the tail shock, during the “swim preparation” time (also see Fig. 6). Here, in contrast, we found that it acted to abruptly halt the swim when applied later, once the swim was actively under way (Fig. 4B). Cycle number data were obtained for 11 of the 17 animals in this experiment. A repeated measures ANOVA yielded a significant overall effect of delivering a tactile stimulus during the active phase of the swim, with respect to swim cycle number ($F_{(2,20)} = 16.61$; $p < 0.001$). Newman–Keuls *post hoc* tests indicated that the swims receiving a tactile stimulus were significantly shorter than either of the shock-alone swims that bracketed the tactile stimulus trial ($p < 0.05$ for each comparison). Because two full cycles had already occurred when the tactile stimulus was applied, the mean of 2.8 ± 0.4 cycles for this trial indicates that the tactile stimulus acted to terminate the swim.

In Figure 4B the second shock-alone trial, which was the last of the five total shock trials, produced a smaller swim response than did the first trial (4.2 ± 0.4 vs. 5.6 ± 0.6 cycles; $p < 0.05$). This trial was used to assess the degree of habituation that developed over the course of the five shock trials. Although habituation occurred, the fact that the swim response on the during-swim tactile trial (Fig. 4Bb) was significantly shorter than that on the final shock-alone trial (Fig. 4Bc) indicates that the lower response of the swim receiving tactile stimulation was attributable to inhibition rather than habituation.

A Cellular Analog of PPI in a Reduced Preparation

Tritonia, with its experimentally tractable nervous system, is an especially suitable preparation for exploring the cellular basis of

Figure 4. Further behavioral features of tactile inhibition. *A*, The prepulse had a stronger inhibitory effect when applied to a different (*b*) rather than the same site (*c*) used to elicit the escape swim. Shock-alone trials, which elicited swims in all animals ($n = 17$), were administered at the beginning and end of the experiment (*a*, *d*). *B*, When applied after the second dorsal flexion of an ongoing swim, the vibrotactile stimulus abruptly halted the swim, resulting in a lower cycle number (*b*) compared with the cycle number of the two shock-alone trials (*a* and *c*).

PPI. As a first step in that direction, we tested whether we could produce PPI in a reduced preparation, consisting only of the animal's nervous system and body wall (see Materials and Methods). The swim motor program was monitored with intracellular electrodes inserted into identified neurons of the swim circuit. We first found that shocking the tail with implanted wire electrodes (1 sec train of 10 Hz, 5 msec DC voltage pulses) would reliably elicit a swim motor program in this preparation, just as it did in the intact animal. We next found that applying a 100 msec vibrotactile stimulus to the dorsal midbody, 120 msec before the onset of the tail shock, blocked the ability of the tail shock to initiate the swim motor program ($n = 4$ preparations; Fig. 5). In each case, this was obtained using an A-B-A design, in which shock-alone trials before and after the PPI trial elicited the motor program.

DISCUSSION

Tactile inhibition of the *Tritonia* escape swim as an example of prepulse inhibition

The various effects of tactile stimulation on the *Tritonia* swim response are summarized in Figure 6. We found that a 100 ms

Figure 5. Neural analog of PPI. *A*, A tail shock stimulus (1 sec train of 10 Hz, 5 msec DC pulses) elicited a three-cycle swim motor program, as monitored by an intracellular recording from central pattern generator neuron dorsal swim interneuron. *B*, The swim motor program was prevented when a 100 msec vibrotactile prepulse was administered to the dorsal midbody 120 msec before tail shock onset. *C*, A subsequent tail shock again elicited a three-cycle swim motor program.

Figure 6. Summary of effects of tactile stimulation on the *Tritonia* swim response. In the absence of tactile stimulation, an aversive stimulus (Swim Stim.) elicits the escape swim response, which consists of a preparatory phase, involving gill and rhinophore withdrawal and body extension, followed by the active swim itself. A 100 msec vibrotactile stimulus applied in the moments before the swim stimulus (*a*) produced PPI, resulting in no swim. The same stimulus applied during the preparatory phase, 2.5 sec after the swim stimulus (*b*), had no inhibitory effect. However, the vibrotactile stimulus acted to terminate ongoing swims when applied at the end of the second dorsal flexion (*c*).

vibrotactile stimulus applied to the dorsal midbody blocked *Tritonia*'s escape swim response to a closely following 1 sec tail shock. This inhibition exhibits the key parametric features of vertebrate PPI. To our knowledge, this is the first explicit demonstration of PPI in an invertebrate. Recently we have also described PPI in a second marine mollusk, *Aplysia californica* (Mongeluzi et al., 1998).

As in vertebrate PPI, prepulse inhibition in *Tritonia* was most profound when the prepulse occurred just before (120 msec–2.5 sec) the onset of the startle-eliciting stimulus. Given that some animals also failed to swim at the 5 and 10 sec time points, further work may establish that PPI in *Tritonia* lasts a few additional seconds. This time course is longer than most, but not all, examples of vertebrate PPI, which typically lasts <1 sec. Tactile-elicited PPI of the human knee-jerk reflex lasts up to 2 sec

(Bowditch and Warren, 1890), and skin shock-elicited PPI of acoustic startle lasts up to 20 sec (Pinckney, 1976).

PPI is generally studied with regard to the inhibition of *startle* responses. Although research on PPI has previously focused on vertebrate startle, startle responses are also a common feature of invertebrate behavior. Although slow in onset and duration compared with vertebrate startle, the *Tritonia* escape response has the key features described by Bullock (1984) in his consideration of invertebrate startle: a whole-body response that is rapid on the time scale of the predator eliciting the response. In *Tritonia*'s case, one known predator is the seastar *Pycnopodia helianthoides*, which crawls at 1–2 cm/sec when hunting (Mauzey et al., 1968; Frost et al., 1998). Although the *Tritonia* escape response represents an example of invertebrate startle, its rhythmic nature and long duration (up to 2 min) distinguish it from the brief, unitary reflex and startle responses typically used in studies of vertebrate PPI.

Previous electrophysiological studies have worked out the elements of the *Tritonia* swim circuit in reasonable detail (Willows et al., 1973; Getting, 1983; Frost and Katz, 1996). Central afferent neurons excite a single paired cell (the dorsal ramp interneuron), that in turn activates a group of interneurons constituting the swim central pattern generator. The pattern generator neurons directly excite flexion neurons that send axons to the periphery to drive the swim behavior. We recently reported that PPI in *Tritonia* appears to involve presynaptic inhibition of the afferent neurons for the swim (Frost et al. 1997). Given that the afferent neurons fire relatively little once the swim is under way, our present finding that tactile stimulation can halt in-progress swims (see also Brown and Getting, 1989) suggests that the tactile prepulse also produces inhibition onto target neurons “downstream” from the afferents, e.g., pattern generator interneurons. Another possibility is that tactile stimuli inhibit different circuit loci when the animal is swimming versus resting.

Inhibitory effects of prestimuli in invertebrates

“Prepulse inhibition” is most commonly used to describe the ability of a weak stimulus, which itself evokes little or no behavioral response, to transiently inhibit the overt response to a closely following strong stimulus. These features distinguish PPI from other behavioral paradigms, such as those involving inhibition between two competing, explicitly evoked behaviors (Sherington, 1906; Kovac and Davis, 1980; Rankin, 1991). They also distinguish it from other previous descriptions of behavioral inhibition in invertebrates. For example, the crayfish lateral giant tail flip response can be inhibited by previous tactile stimulation associated with physical restraint (Vu et al., 1993). This inhibition, however, emerges several minutes after the tactile stimulus and hence is quite different from the transient inhibition characteristic of PPI. The siphon- and gill-withdrawal reflex of the marine mollusk *A. californica* is reduced for 90 sec to several minutes after tail shock (Mackey et al., 1987; Marcus et al., 1988; Illich et al., 1994). Again, because of the long duration of this inhibition, and also because the tail shock (“prepulse”) itself elicits siphon and gill withdrawal, this does not constitute the type of transient sensory gating mechanism exemplified by PPI. A previous study reported that the *Tritonia* escape swim could be prevented by repeatedly poking the animal throughout a several-second salt application that normally elicits the swim response (Brown and Getting, 1989). PPI was not tested for in that study, however. The nearest approximation to PPI previously described for an invertebrate may be “two-tone suppression” of the cricket

startle response to bat ultrasound (Nolen and Hoy, 1986; Farris and Hoy, 1997). In this paradigm, a high-intensity 5000 Hz sound pulse inhibits the startle response when presented simultaneously and, to a lesser degree, a few milliseconds before a lower intensity ultrasound pulse.

Significance of PPI in nervous system function

What is the functional significance of PPI? As mentioned earlier, PPI has been suggested to expose a preattentive sensory gating mechanism in vertebrates that serves to minimize distraction during the brief period required to process an initial input. Our present finding of PPI in an invertebrate suggests that this gating mechanism may be highly general—a fundamental mechanism used by most or all nervous systems to coherently process sensory input.

Consistent with a widespread role for PPI in nervous system function, prestimuli have been found to inhibit more than just startle responses. For example, brief prepulses have been shown to inhibit the human knee-jerk reflex (Bowditch and Warren, 1890), the human eye blink reflex (Krauter et al., 1973), the rabbit nictitating membrane reflex (Ison and Leonard, 1971), and the frog leg flexion reflex (Yerkes, 1905; Simmons, 1988). Furthermore, tactile prestimuli have also been shown to inhibit conscious awareness of test stimuli, as documented by psychophysical studies of forward masking in humans (Laskin and Spencer, 1979; Lechelt, 1986; Gescheider and Migel, 1995).

A widespread role for PPI is also suggested by the ability of almost any perceptible stimulus to serve as an effective inhibitory prepulse. For example, as cited in the introductory remarks, the acoustic startle response can be inhibited by auditory, visual, and tactile stimuli. The human knee-jerk reflex can also be inhibited by a variety of stimuli, including light flashes, tactile skin stimulation, and even voluntary muscular contractions (Bowditch and Warren, 1890).

Studies of schizophrenia have given rise to the idea that PPI may also play an essential role in normal cognitive function. Sufferers of this disease commonly experience sensory flooding and cognitive fragmentation, symptoms suggested to result from the failure of inhibitory gating mechanisms that normally act to filter sensory input (McGhie and Chapman, 1961; Venables, 1964). Several studies have now established that one such gating mechanism defective in schizophrenia is PPI (Braff et al., 1978, 1992). These findings, derived from studies of the human startle response, have led to a growing interest in PPI and its role in both normal and abnormal brain function. Our present study establishes *Tritonia* as a model system in which to explore the network and cellular mechanisms mediating this fundamental nervous system process.

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