3. Visual Vigilance

In this experiment, a dolphin was tested on its ability to detect and report accurately the presence of a "critical" visual stimulus and to withhold response to any other "non critical" stimuli.

3.1. Materials and Methods

The SRD was used in these experiments. Stimuli were 2-dimensional pictures presented on the television monitor to the dolphin's visual sense. In the final experimental configuration test sessions consisted of 10 trials with 60 stimuli used in each trial. The following parameters were manipulated:

- Exposure time: the time from the onset of each stimulus on the television screen to the time it was no longer visible.
- Inter-Stimulus-Interval (ISI): the time between removal of a stimulus from view and presentation of the subsequent stimulus
- Total number of stimuli per trial
- Number of "critical" stimuli per trial (i.e., probability of the occurrence of a critical stimulus as for any given position)

A computer program (Visual Random Generator, see Appendix B) was designed in MAX 3.5 to construct schedules of trials for each session. A computer rendering of the programming interface is shown in Figure 6. The software allowed for the creation of 10 trials in which the total number of stimuli and the number of critical stimuli per trial could be manipulated. A second computer program (Visual Player, see Appendix B) was also designed in MAX to control the sequence of events for each trial, manipulate the ISI and presentation time and record the dolphin's responses to all stimuli. A computer rendering of the programming interface is shown in Figure 7. In both interfaces, the data flow is represented by lines connecting objects. The objects represent software functions such as mathematical calculations, data storage or other actions. Thus, the complete program can be seen as a very detailed flow diagram.

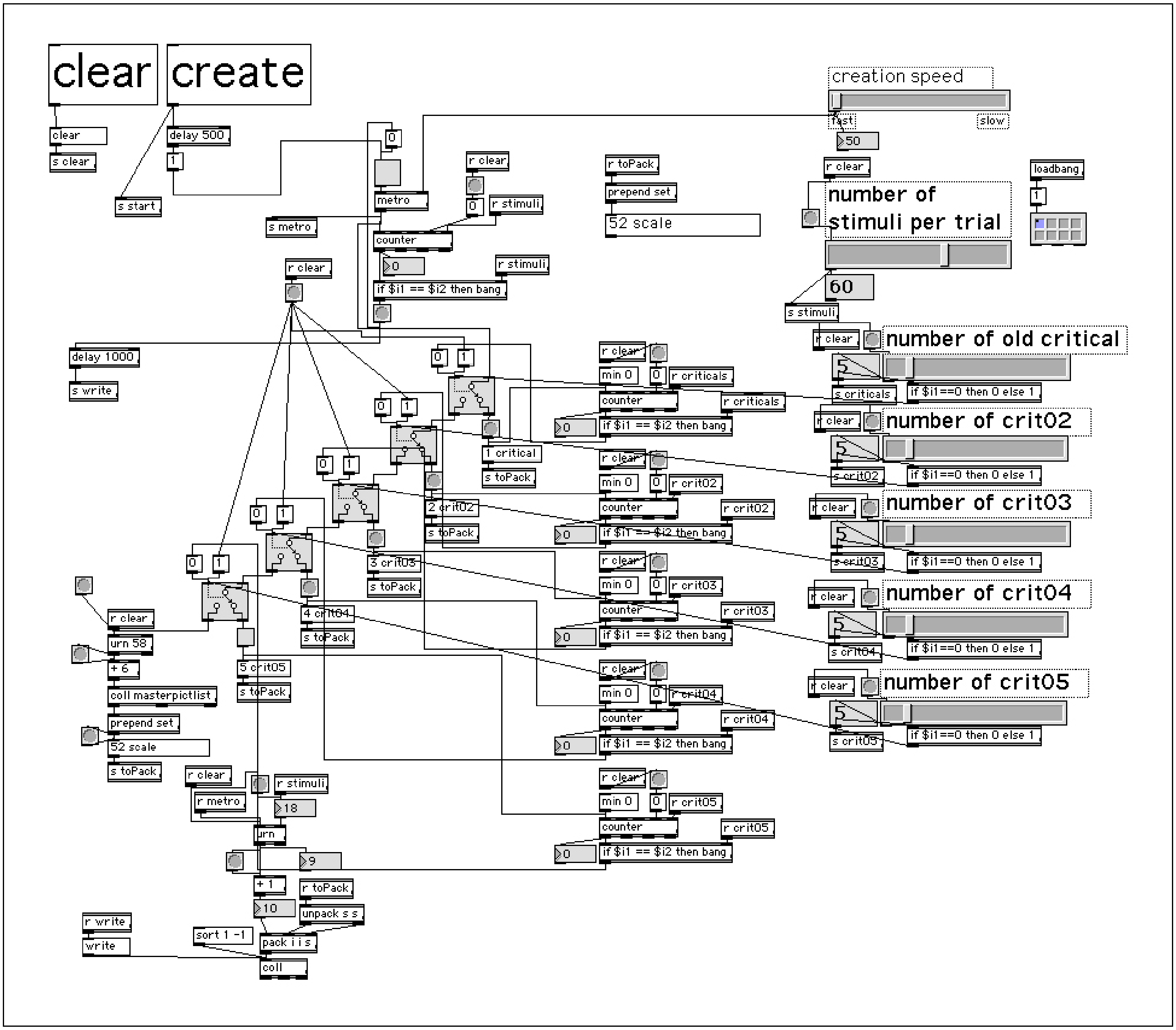


Figure 6: Computer display of the program that was used to create test trials with varying stimuli and parameters

Feedback on correct or incorrect responses was given through a yellow progress bar at the bottom of the screen that increased by a step when the dolphin correctly detected the presence of a critical stimulus but did not change when the animal missed a critical. In contrast, upon a false alarm the length of the bar decreased by one step. Additional feedback in the visual vigilance experiments was provided through the underwater speaker that was connected to the Mackie mixer/amplifier (see Figure 5), A short click sounded when the dolphin sufficiently deflected the response paddle.

Test schedules were pre-planed to allow for the control of all parameters. The positions of the critical stimuli were determined pseudo-randomly by the computer while adhering to the following restrictions: not more than four critical or non-critical stimuli in a row and no regular detectable pattern (i.e., A-B-A-B or A-B-B-A, etc.).

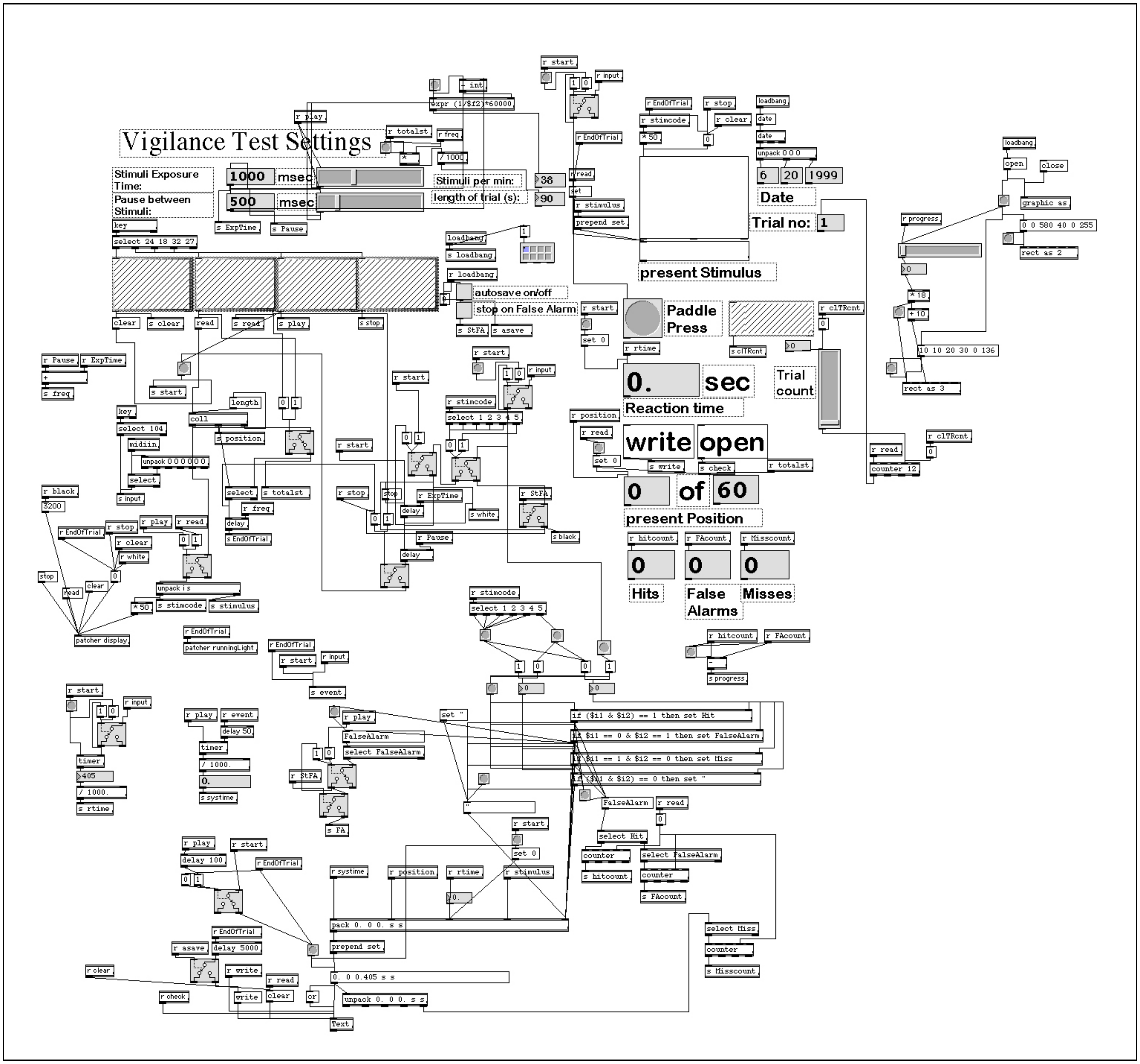


Figure 7: Computer display of the program that was used to control the test trials and the display of the stimuli.

3.2. Stimuli

The stimuli used in all visual experiments consisted of black-and-white computer-generated renderings of objects that filled a 640-x-480-pixel computer screen or television display. All stimuli were chosen to be distinctly different from each other as judged by the experimenter. They were selected for high contrast to ensure that the dolphin would not have difficulties in perceiving the images through the underwater window. Table 2 shows all stimuli used throughout the various parts of the experiment.

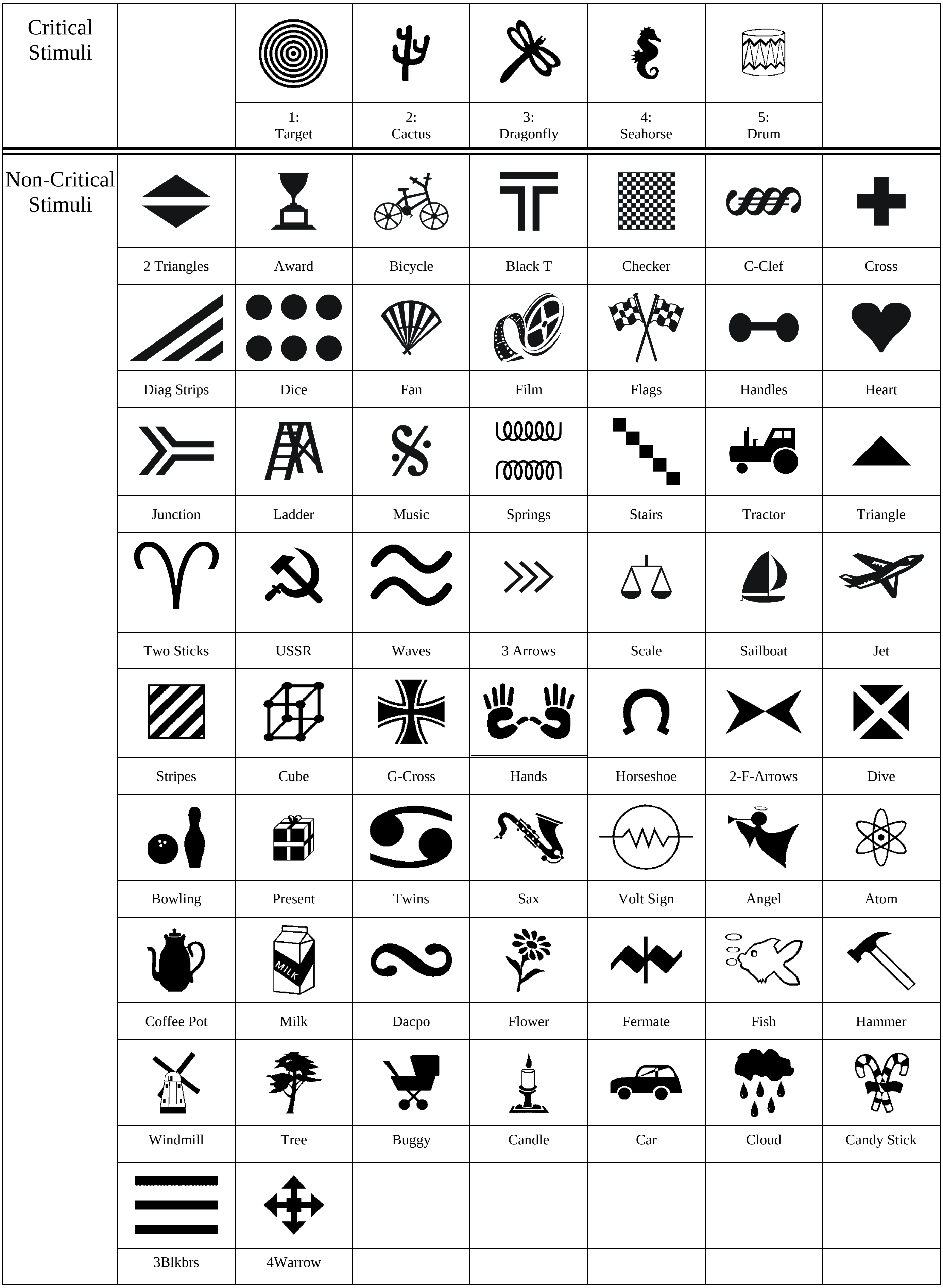
3.3. Subject

The subject of the visual vigilance study was a 14-year-old female bottlenosed dolphin (*Tursiops truncatus*) named Elele. Elele was housed together with three other bottlenosed dolphins in two interconnected seawater tanks (1.8m deep and 15.2m diameter) at the Kewalo Basin Marine Mammal Laboratory in Honolulu, Hawaii. Elele received a daily diet of approximately 8.2 kg of Herring, Sardines and Capelin, a portion of which was fed during test sessions. Elele had extensive experience in visual discrimination tasks including visual matching-to-sample, visual same/different, and visual-echoic cross-modal matching, and visual discrimination of human gestures (Herman et al., 2000; Pack and Herman 1995, Herman & Pack 1992, Herman et al 1998, Shaw 1990, Uyeyama 1999).

3.4. Training

Over a three-month period, Elele was habituated to the stationing device and learned to press the response paddle to indicate a detection of a critical stimulus. This training was conducted in several phases.

Table 2: Critical and non-critical stimuli as used in the visual experiment. Images are to scale relatively to the size of the screen. All stimuli used as critical stimuli are shown in the first row.

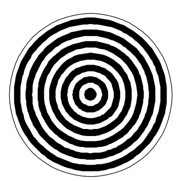
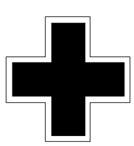
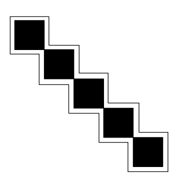
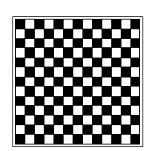


Critical Stimuli		1: Target	2: Cactus	3: Dragonfly	4: Seahorse	5: Drum	
Non-Critical Stimuli	2 Triangles	Award	Bicycle	Black T	Checker	C-Clef	Cross
	Diag Strips	Dice	Fan	Film	Flags	Handles	Heart
	Junction	Ladder	Music	Springs	Stairs	Tractor	Triangle
	Two Sticks	USSR	Waves	3 Arrows	Scale	Sailboat	Jet
	Stripes	Cube	G-Cross	Hands	Horseshoe	2-F-Arrows	Dive
	Bowling	Present	Twins	Sax	Volt Sign	Angel	Atom
	Coffee Pot	Milk	Dacpo	Flower	Fermate	Fish	Hammer
	Windmill	Tree	Buggy	Candle	Car	Cloud	Candy Stick
	3Blkbrs	4Warrow					

3.4.1. Phase I

Elele was trained initially from tankside to press a paddle when a critical stimulus was exposed (critical 1: target, see Table 3) and to withhold response to any of four non-critical stimuli (cross, stairs, checkerboard and triangle, see Table 3). A prototype of the final response paddle was built and attached to the tank wall in front of the trainer. This paddle consisted of a PVC-frame that was placed over the tank wall with one side facing the dolphin. A Plexiglas lever that served as a response paddle was attached to the frame. The stimuli used were black and white pictures pasted on to $^{1}/_{8}$-inch thick plywood sheets (38 x 38 cm). The size of these stimuli was the same as those that would be eventually presented on television. Images of the critical and non-critical stimuli are presented in see Table 3. On each trial, the dolphin stationed in front of the response paddle with its head out of the water. On a signal by an experimenter located in an observation tower adjacent to the dolphin pool, the trainer raised the critical stimulus from behind the wall in air to the dolphin and pointed simultaneously to the paddle, indicating to the dolphin to press it (for a review of the dolphin's understanding of the indicative gesture see Herman et al; 1999). Through this procedure, the dolphin learned to associate a presentation of the

Table 3: Stimuli used in the training phase of the experiment

	 critical stimulus		
 cross	 stairs	 checkerboard	 triangle

critical stimulus with a deflection of the paddle. Upon a presentation of a non-critical stimulus (see Table 3, second row) Elele was signaled through a familiar gesture ("wait") to withhold responding (correct rejection). Correct responses (either deflection of the paddle for a presentation of the critical stimulus or no deflection upon a presentation of a non-critical stimulus) were rewarded with a whistle, fish and social praise. These were omitted following an incorrect response. Once Elele had learned (performing better that 80% correct within one session) this association, the number of presentations per trial was increased from one to three. Thus, trials could consist of any combination of the stimuli shown in Table 3, containing between zero and three presentations of the critical stimulus. Over the course of 23 sessions Elele demonstrated (better than 80% correct on three consecutive sessions) that she had acquired the procedure and the training advanced to Phase II.

3.4.2. Phase II

In Phase II, the final apparatus configuration was placed inside the tank in front of the underwater window. The same stimuli used in Phase I were also presented to the dolphin through the underwater window. On each trial, Elele was sent down to the underwater window by her tankside-trainer where she stationed in front of the apparatus. The experimenter, located behind the window, then presented the stimuli and Elele was required to indicate her responses by pressing the lever that was now attached to the PVC-frame underwater in front of the window. Thus, in contrast to Phase I where Elele viewed objects in air, in Phase II, she viewed them underwater. Trials consisted of three successive presentations of stimuli, as they had at the end of Phase I. Once Elele was performing above 80% correct responses in three consecutive sessions, training advanced to Phase III.

3.4.3. Phase III

A 35-inch Mitsubishi TV-monitor was now placed in front of the underwater window. Instructions and the stimuli were presented to Elele via a camera in the remote room that was connected to the TV-monitor in the underwater window. Trials consisted of presentations of three stimuli. On each trial, Elele was signaled to approach the underwater window by her tankside trainer. She stationed in front of the apparatus and the TV-monitor. A “video trainer” instructed her to “pay attention” by giving her a familiar gestural signal. Next, one of the four stimuli used in Phase II was raised by the video trainer into the field of view of the camera. If a critical stimulus was presented, Elele was required to press the paddle. If a non-critical stimulus was presented, she was required to refrain from pressing for three seconds. After a delay of two seconds the next stimulus was presented. On an incorrect rejection (Miss) or an incorrect detection (False Alarm), the experimenter in the remote room instructed the tankside trainer to call Elele back to station and omit fish reward. Once Elele had performed better than 80% correct with three stimuli the number of presentations per trial was increased to six. Upon correct completion of a set, Elele's trainer rewarded her with a whistle, social praise and a fish. A short inter-trial-interval (15 - 20s) ensued before she was sent to the window for the next trial. Once Elele was performing at or above 80% correct in three successive sessions, training advanced to Phase IV.

3.4.4. Phase IV

In the next training step the transition from presenting stimuli manually to the presentation of stimuli by the computer was achieved. The experimenter that presented the stimuli on TV was gradually removed from the dolphin's view by having him stand behind a white cloth screen with both arms exposed through two vertical slits. Thus the dolphin would only see the gestures by the two arms and the presented stimuli and not the video trainer himself. The stimuli were raised by hand up into the viewing area of the camera. Once Elele had learned this part of the procedure and was performing with an accuracy of better than 80% correct over three consecutive sessions, stimuli were no longer presented by hand. The image that the dolphin could see was switched between the camera image and a computer display of the stimuli using a Panasonic digital AV-mixer. Thus, the only difference in the presentation was that the stimuli, that previously had been raised by hand into the viewing field of the camera, appeared now instantaneously on the screen. After a short habituation period (four sessions), Elele had learned to respond to the computer screen in the same way as she had to handheld stimuli. At the end of this phase, the video trainer was only visible at the beginning of a trial. At the end of a sequence of stimuli, a yellow light pattern running across the screen was shown, signaling Elele the end of a trial. After Elele had demonstrated performance accuracy of 80% or better over a period of *five* consecutive sessions in this final configuration of the training, test sessions for Experiment 1 began.

3.5. Experiment 1: Varying Rate of Stimulus Presentation (Event Rate)

This experiment was designed to investigate the effects of rate of stimulus presentation on the dolphin's performance accuracy and reaction time. In experiments with human subjects (Davies & Parasuraman, 1982; Lanzetta et al., 1986), researchers have shown that with increasing stimulus presentation rate and decreasing ISI, performance accuracy decreased. In their review of vigilance performance, Parasuraman and Davis (1977) classified event rates of lower that 24 events per minute as low and event rates of 24 and above as high. This differentiation was based on findings that an event rate of 24/min or higher significantly reduced sensitivity. Parasuraman (1979) showed that only high event rates in *successive* discrimination tasks caused a decrement in sensitivity. In order to create similar conditions for the dolphin, the experiment was designed the following way: the stimulus exposure time (SET) and the inter-stimulus-interval (ISI) were systematically decreased over sessions until the dolphin's performance dropped below 85%. Simultaneously, the number of stimuli presented during a trial was increased.

3.5.1. Procedure

At the beginning of this experiment a trial consisted of 12 images, each presented for 3 sec (SET) followed by a 1-sec pause (ISI). The change in parameters over the course of the test sessions is shown in Table 4.

Table 4: Sessions as tested in Experiment 1. Changes in parameters are indicated in gray.

Session number	Non criticals	Image/ trial	Pause (sec)	Exp time (sec)	% total correct	% critical correct	% non-critical correct	Average Reaction time
1	6	12	1	3	95.83	91.67	100.00	1.421
2	6	12	1	3	94.44	90.28	98.61	1.537
3	6	12	1	3	97.22	94.44	100.00	1.481
4	6	12	1	3	96.53	93.06	100.00	1.432
5	6	12	1	3	99.31	98.61	100.00	1.258
6	6	12	1	3	97.22	94.44	100.00	1.149
7	6	12	1	3	96.53	93.06	100.00	1.213
8	6	12	1	3	92.36	84.72	100.00	1.465
9	6	12	1	3	93.06	86.11	100.00	1.557
10	6	12	1	3	97.22	94.44	100.00	1.200

Session number	Non criticals	Image/ trial	Pause (sec)	Exp time (sec)	% total correct	% critical correct	% non-critical correct	Average Reaction time
11	8	12	1	3	95.14	90.28	100.00	1.495
12	8	12	1	3	95.83	91.67	100.00	1.257
13	10	12	1	3	90.28	80.56	100.00	1.332
14	10	12	1	3	95.83	93.94	96.97	1.502
15	12	12	1	3	96.53	95.83	97.22	1.346
16	12	12	1	3	93.75	87.50	100.00	1.506
17	12	12	0.75	2.75	97.92	95.83	100.00	1.405
18	12	12	0.75	2.75	97.92	97.22	98.61	1.169
19	12	12	0.5	2.5	98.61	97.22	100.00	1.278
20	12	12	0.5	2.5	93.06	90.28	95.83	1.286
21	12	18	0.5	2.5	94.91	89.81	100.00	1.149
22	12	18	0.5	2.5	98.61	97.22	100.00	1.106
23	12	18	0.5	2.5	99.07	98.15	100.00	1.094
24	12	18	0.5	2.5	98.61	97.22	100.00	1.080
25	12	18	0.5	2.25	97.69	95.37	100.00	1.085
26	12	18	0.5	2.25	98.61	97.22	100.00	1.043
27	12	18	0.5	2	93.06	86.11	100.00	1.136
28	12	18	0.5	2	99.54	99.07	100.00	0.938
29	12	24	0.5	2	96.88	93.75	100.00	0.997
30	12	24	0.5	2	96.88	93.75	100.00	1.150
31	12	24	0.5	2	96.18	92.36	100.00	1.208
32	12	24	0.5	2	92.71	85.42	100.00	1.128
33	12	24	0.5	2	95.14	90.28	100.00	1.084
34	12	24	0.5	2	95.83	91.67	100.00	1.074
35	12	24	0.5	1.75	93.06	86.11	100.00	1.013
36	12	24	0.5	1.75	94.44	88.89	100.00	1.009
37	12	24	0.5	1.75	95.83	91.67	100.00	0.899
38	12	24	0.5	1.75	91.67	83.33	100.00	1.027
39	14	24	0.5	1.75	90.28	87.50	93.06	0.977
40	14	24	0.5	1.75	93.40	92.36	94.44	1.013
41	15	24	0.5	1.75	98.26	96.53	100.00	0.953
42	15	24	0.5	1.75	97.92	95.83	100.00	0.973
43	15	24	0.5	1.5	96.88	94.44	99.31	0.930
44	15	24	0.5	1.5	98.27	96.53	100.00	0.961
45	15	30	0.5	1.5	97.22	94.44	100.00	0.860
46	15	30	0.5	1.5	99.17	98.33	100.00	0.779
47	17	30	0.5	1.5	97.50	95.56	99.44	0.796
48	17	30	0.5	1.5	95.00	90.00	100.00	0.890
49	19	30	0.5	1.5	96.11	92.78	99.44	0.819
50	19	30	0.5	1.5	99.17	98.33	100.00	0.810
51	19	30	0.5	1.25	96.11	92.22	100.00	0.814
52	19	30	0.5	1.25	99.72	100.00	99.44	0.755
53	19	36	0.5	1.25	96.30	92.59	100.00	0.721
54	19	36	0.5	1.25	96.06	92.13	100.00	0.726
55	21	36	0.5	1.25	97.45	95.83	99.07	0.757
56	21	36	0.5	1.25	94.21	88.43	100.00	0.801
57	21	36	0.5	1	92.13	84.26	100.00	0.760
58	21	36	0.5	1	93.29	87.96	98.61	0.710
59	21	42	0.5	1	91.07	82.94	99.21	0.698
60	21	42	0.5	1	92.26	86.90	97.62	0.692

Session number	Non criticals	Image/ trial	Pause (sec)	Exp time (sec)	% total correct	% critical correct	% non-critical correct	Average Reaction time
61	23	42	0.5	1	92.26	84.92	99.60	0.594
62	23	42	0.5	1	93.45	88.49	98.41	0.662
63	25	42	0.5	1	91.07	82.14	100.00	0.689
64	25	42	0.5	1	96.63	93.25	100.00	0.636
65	25	42	0.75	1	96.43	93.25	99.60	0.663
66	25	42	0.75	1	96.63	93.25	100.00	0.713
67	25	48	0.75	1	95.49	92.71	98.26	0.655
68	25	48	0.75	1	95.66	91.32	100.00	0.681
69	27	48	0.75	1	93.58	87.50	99.65	0.682
70	27	48	0.75	1	93.40	94.43	92.33	0.614
71	27	54	0.75	1	87.96	93.21	82.72	0.543
72	27	54	0.75	1	92.28	95.68	88.89	0.601
73	29	54	0.75	1	89.04	91.67	86.42	0.585
74	29	54	0.75	1	88.33	87.04	89.63	0.620
75	31	54	0.75	1	88.33	80.74	95.93	0.659
76	31	54	0.75	1	80.56	65.19	95.93	
77	31	36	0.75	1.5	85.56	91.11	89.63	
78	31	36	0.75	1.5	88.89	89.44	88.33	0.852
79	31	36	0.75	1.5	78.33	93.89	62.78	0.715
80	31	36	0.75	1.5	94.17	96.67	91.67	0.707
81	31	36	0.75	1.5	98.89	98.89	98.89	0.664
82	31	36	0.75	1.5	97.78	95.56	100.00	0.722
83	31	42	0.75	1.5	97.62	95.71	99.52	0.741
84	31	42	0.75	1.5	99.29	98.57	100.00	0.728
85	31	48	0.75	1	96.88	93.75	100.00	0.733
86	31	54	0.75	1	99.44	99.26	99.63	0.697
87	31	60	0.75	1	98.67	97.33	100.00	0.706
88	31	60	0.75	1	99.67	99.33	100.00	0.645

To decrease the total length of a trial, the pause time was decreased from 1.0 sec to 0.75 after 16 sessions and then to 0.5 sec. The exposure time was decreased from 3.0 sec to 2.5 sec. Then the number of stimuli per trial was increased from 12 stimuli to 18. Elele was required to be correct on more then 85% of all stimuli to move on to the next step. While the pause time remained at 0.5 sec, the exposure time was decreased successively. By the end of this experiment a session consisted of 10 trials of 60 stimuli each with an exposure time of 1.0 sec and a pause time of 0.75 sec. The pool of non-critical stimuli had been increased to 30. The probability of the appearance of a critical stimulus was set at 50% throughout the entire test phase.

3.5.2. Results and Discussion

During Sessions 1 - 75 Elele's performance on both critical and non-critical stimuli was 80 % correct or greater.

Figure 8 shows that Elele's reaction time decreased as the exposure time and ISI was decreased. No special training was required. In Session 57 (see Figure 9) the exposure time was set to 1.0 sec and the pause time was set to 0.5 sec. Over the next 8 sessions Elele's performance accuracy dropped below 85% and she showed a very specific pattern of misses: If critical stimuli were presented in sequence, she tended to miss every second critical stimulus, if there was a third critical stimulus in that sequence she would respond to it. If non-critical stimuli were presented between criticals she did not miss. An analysis of the recorded videotapes showed that on some occasions Elele tried to respond to every second stimulus. The reason for this pattern seemed to be that she was able to detect each of the occurring critical stimuli but she was not able to indicate her detection (by responding to the paddle) and return to her original position in time before the next stimulus was presented. Her movement time and the time it took the response paddle to return to its original position were longer than the frequency of the presentation. To avoid this confound, in the following sessions the pause time was increased to 0.75 sec. At this frequency the effect disappeared.

In Session 70 Elele suddenly switched her response criterion. Previously her errors consisted primarily of misses and only a small proportion were false alarms. In session 70 she switched strategies: performance on critical stimuli was better than performance on non-critical stimuli. During the previous sessions feedback about false alarms had only been given through a yellow progress bar (see material and methods). This had been the only feedback given. To avoid a large increase in false alarms the procedure was now altered so that if Elele made a false alarm the computer screen was switched to black and she was called back to station by her trainer. After a short pause she was sent down to the window and the trial continued. After experiencing this change in procedure *twice* Elele adjusted her criterion again and her performance on non-critical stimuli increased.

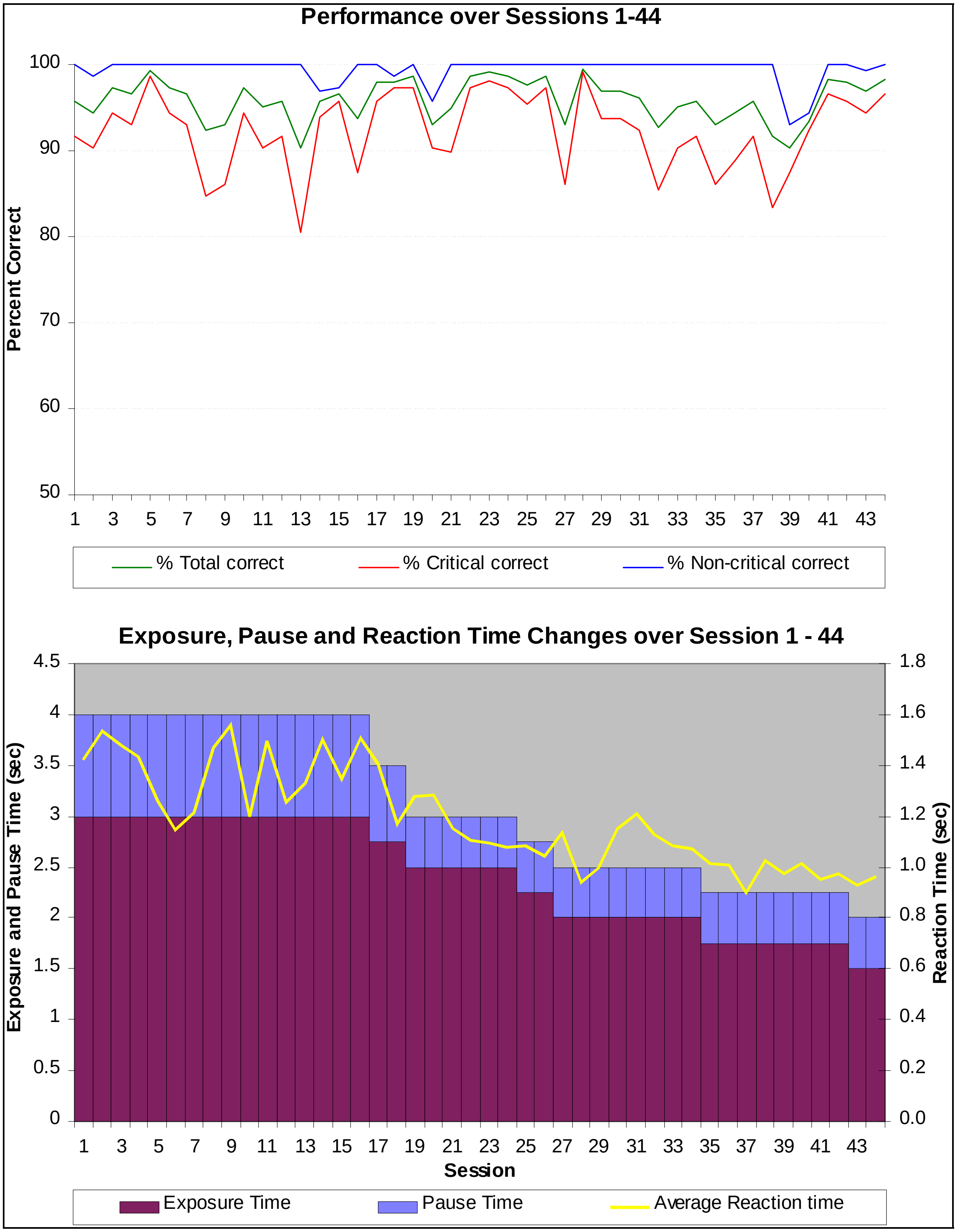


Figure 8: Graph of performance and reaction time in relation to the changes made in exposure and pause time for sessions 1 through 44.

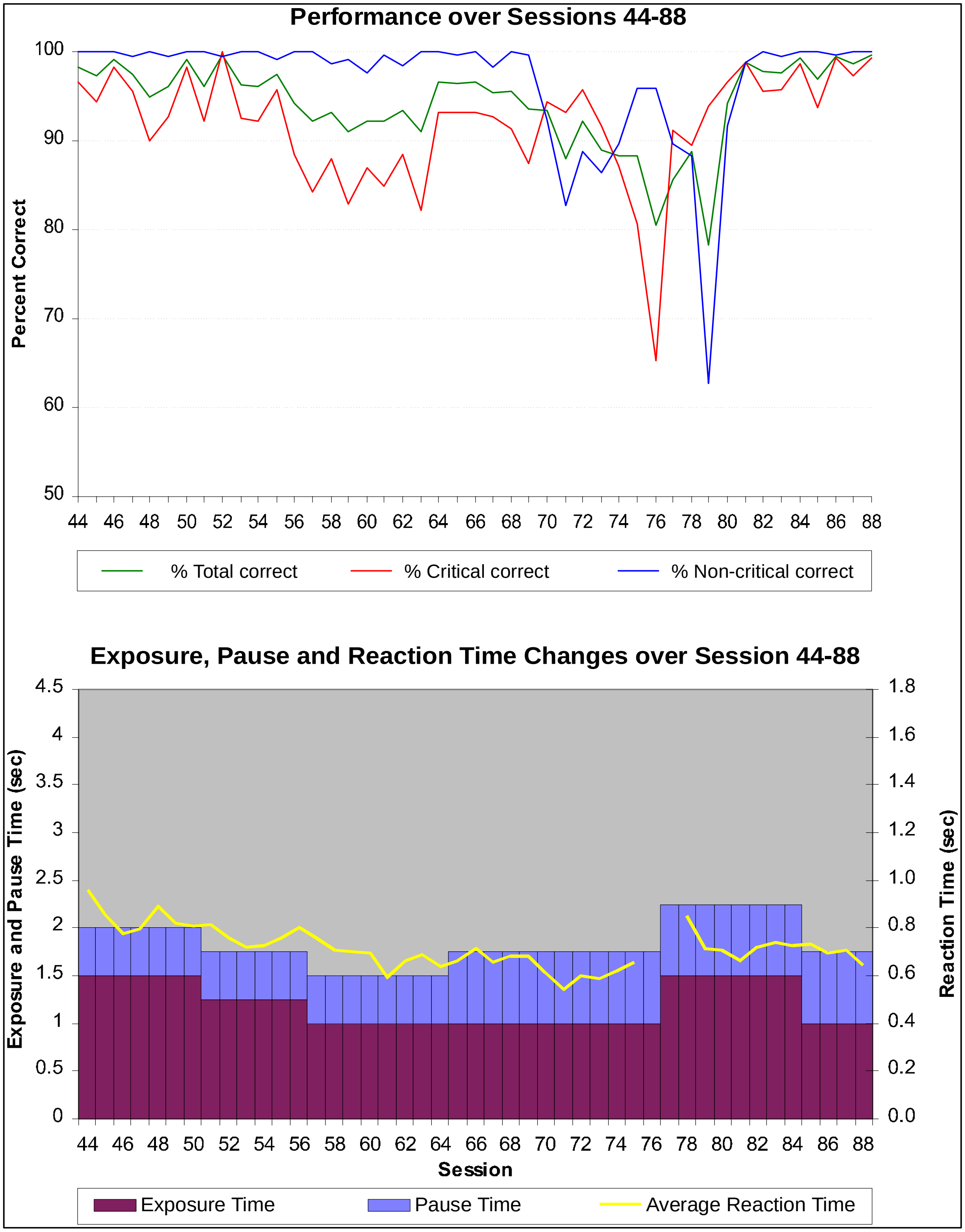


Figure 9: Graph of performance and reaction time in relation to the changes made in exposure and pause time for Sessions 44 through 88. Due to a computer error no reaction times were obtained during sessions 76 and 77.

In Session 74 Elele's performance on critical stimuli suddenly decreased to 80 % (see Figure 9). An analysis of her video-taped response behavior showed that for most of her misses she did detect the target stimulus but she did not press the paddle hard enough to trigger the switch. Thus the computer did not record a correct detection. To give her feedback a short click sound was played by the midi-board when the paddle was deflected sufficiently to trigger a signal. After a three sessions of habituation to the change in procedure Elele's performance increased again to previous levels.

3.5.3. Discussion

Overall Elele performed well throughout all parts of the test. Elele's problems with an exposure time of 1.0 second and a pause time of 0.5 seconds were probably caused by her movement time. She was clearly able to detect all stimuli, but the time it took to move to the paddle, press it, return to the original viewing position and for the pipette bulb under paddle to expand again was longer than the combined exposure and pause time of a stimulus. Performance clearly remained above 80 % throughout sessions. No correlation of vigilance decrement with the manipulation of the parameters (SET, ISI and number of stimuli per trial) was apparent except in sessions where the pause time was too short for Elele to indicate detection. Rather, performance seemed to change with Elele's knowledge of the task and the rules applied. Overall, she adjusted her reaction time to the increased speed of presentation. Within trials, no significant change in reaction time or performance accuracy was detected. Errors (Misses and False Alarms) were distributed randomly across trials. Across positions no significant change in performance accuracy or reaction time was detected.

3.6. Experiment 2: Probability Variation

This experiment investigated the effects of changes in the probability of occurrence of a critical stimulus in any given position of a trial on the performance accuracy and reaction time. Warm and Jerison (1984) showed that performance accuracy of human subjects in a vigilance task is directly related to signal density or probability. In experiments with human subjects, signal probability is normally varied between 0.01 and 0.25. In these studies researchers found that it is more difficult for a subject to predict when a signal might occur in the train of non-signals if the probability is low than at a higher probability where signals occur on a more regular basis. To test whether this would also apply to dolphins, an experiment was designed in which the signal density or probability of occurrence was varied between sessions.

3.6.1. Methods

In Experiment 1 50% of the stimuli per trial were critical stimuli. That is, the probability of occurrence of a critical stimulus in any given position in a trial was set to 50 %. Elele performed near ceiling levels in this condition. To investigate the effect of changes in probability of the occurrence of a critical stimulus both above and below a particular baseline probability, a new baseline of 30 % probability was established over the course of four sessions. The same apparatus and general setup as in the previous experiment was used here. Sessions consisted of 10 trials with 60 stimuli each. The Stimulus Exposure Time (SET) was set at 1.0 sec and the Inter-Stimulus-Interval (ISI) was set at 0.75 sec. After the establishment of a new baseline (30%), the following five probability values of the appearance of the critical stimulus were chosen for testing: 50%, 40%, 20% and 10%. To avoid any influence on current performance from previously run test sessions, two sessions of 30% probability were embedded between tests with different probabilities. The complete experimental design is shown in Table 5. Other than the first four baseline sessions each probability value was tested for two consecutive sessions to ensure that any recency effect from previous sessions would be minimized.

Table 5: Order in which different probabilities were tested. Baseline sessions are shaded gray.

Session	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Probability	30	30	30	30	10	10	30	30	50	50	30	30	20	20	30	30	40	40	30	30

3.6.2. Results and Discussion

Over all 20 test sessions Elele's performance remained at or near ceiling levels. Figure 10 A shows the percent correct detections of the critical stimulus at each probability as well as the percent correct rejections of non-critical stimuli. No significant difference in performance was detected. Figure 10 B shows Elele's average reaction times summed over the tested probabilities decreasing from 50 % to 10 %. Her accuracy of response never dropped below 92.5 % on critical and 97.4% on non-critical stimuli, 71.0 % of the errors she made were missed critical stimuli. The remaining errors (29.0 %) were false alarms.

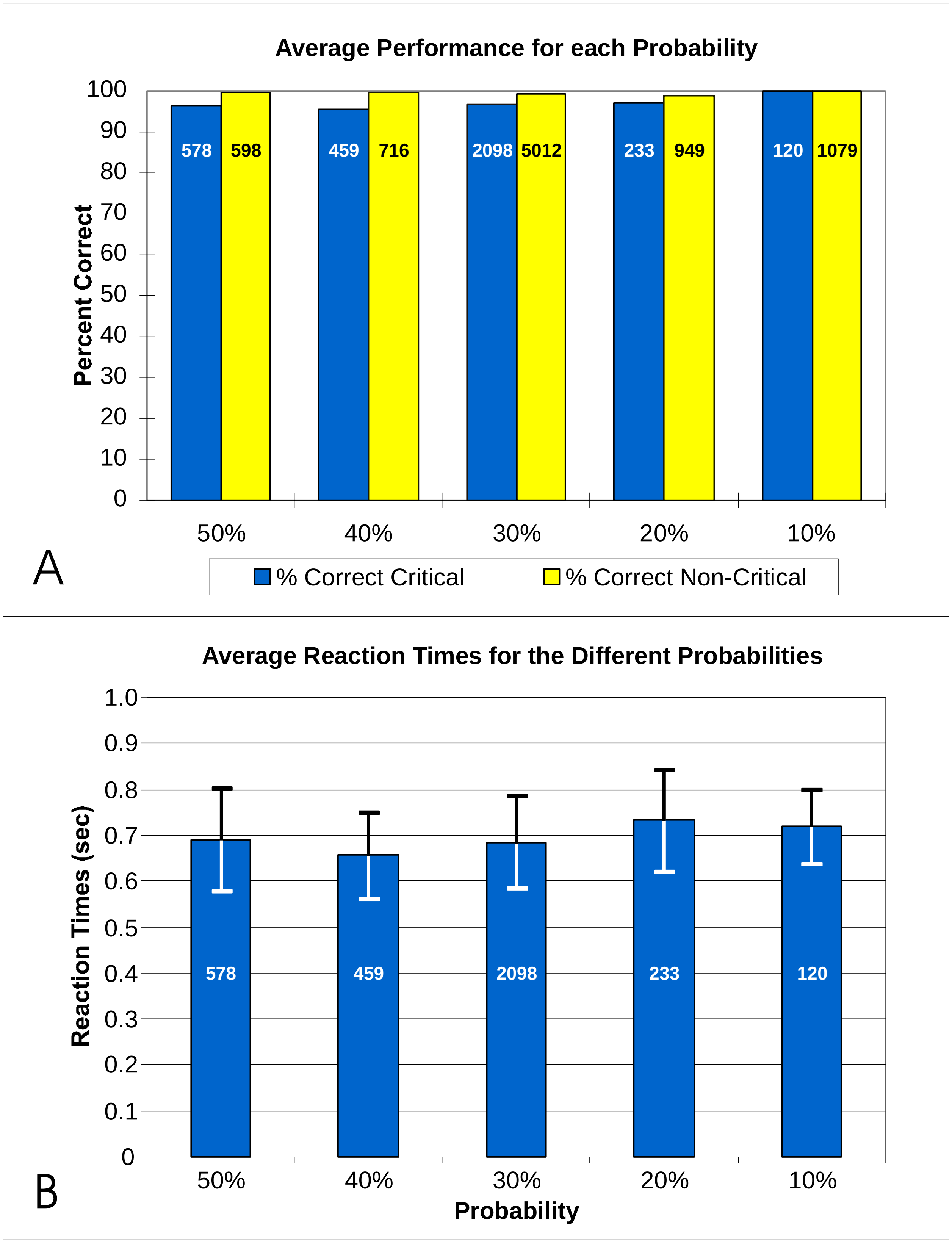


Figure 10: A: shows the average performance on critical and non-critical stimuli over the tested probability values. B: shows the corresponding average reaction times on correct detection of criticals and their standard deviation. The numbers in each bar represent the sample size of each average value.

Elele’s average reaction time varied between 0.66 sec at 40 % probability and 0.73 sec at 20 % probability. An analysis of variance revealed a significant difference ($F=25, p=0.0001$) for the *average reaction times* at each probability. A Scheffé-test showed that there was no significant difference between average reaction time at 10 % and 20 % probability and between average reaction time at 50 % and 30 % probability. Probabilities that showed no significant difference were combined into groups. A significant difference was found between group 1 (10 and 20%), group 2 (50 and 30%) and group 3 (40%) with decreasing reaction times respectively ($\alpha=0.05$, critical $F=2.37448$). Although there was no strict linear correlation between probability and reaction times, these findings show similarity to human data where the reaction time increases if the stimulus density decreases (Parasuraman 1998). As mentioned above, decrement in performance accuracy of sustained attention tasks can be detected through changes in two types of results: first, *performance accuracy* is one measurement of decrement and one would expect to find lower performance accuracy with increasing duration of the task. This was not the case in the current experiment. One possible explanation for these results is that the length of a trial was not long enough to show a drop in performance accuracy with the time tested. Longer trials were not possible, as the dolphin would have lost interest in the task (between experiments 2 and 3 longer trials with up to 90 stimuli per trial were tested, but Elele lost motivation to participate. Thus the trial length was kept at 60 stimuli) and would have to come to the surface to take a breath. The second and subtler indicator of decrement is that before a subject starts making more misses the *reaction time* for detected stimuli increases until the threshold for the correct detection of a critical stimulus is reached and a miss occurs. Thus, changes in reaction time are *earlier* indicators of changes in the performance of a subject than accuracy itself and can reveal effects that are not directly visible for a given length of a test. To test whether this hypothesis is also true for dolphins the obtained reaction time data were analyzed.

Three different trend analyses (linear regression) were applied to the complete set of data. In the first analysis, the change of reaction time from Position 1 to Position 60 in a trial was examined. For that purpose, the average values for all reaction times in a given position in all trials of sessions of the same probability were calculated. Subsequently, a linear regression for these values was tested for significance. Of the five groups tested, three (50%, 40% and 30%, see Figure 11), showed a significant trend towards faster reaction time at the end of a trial ($F = 39.9$, $F = 61.4$ and $F = 58.2$ at $p = 0.01$, respectively). No significant trend was observed for the 20% and the 10% group ($F = 2.3$ at $p=0.01$ and $F=2.6$ at $p=0.01$). These results are in contrast to human data where reaction times increase with the progress of the task. A possible explanation for

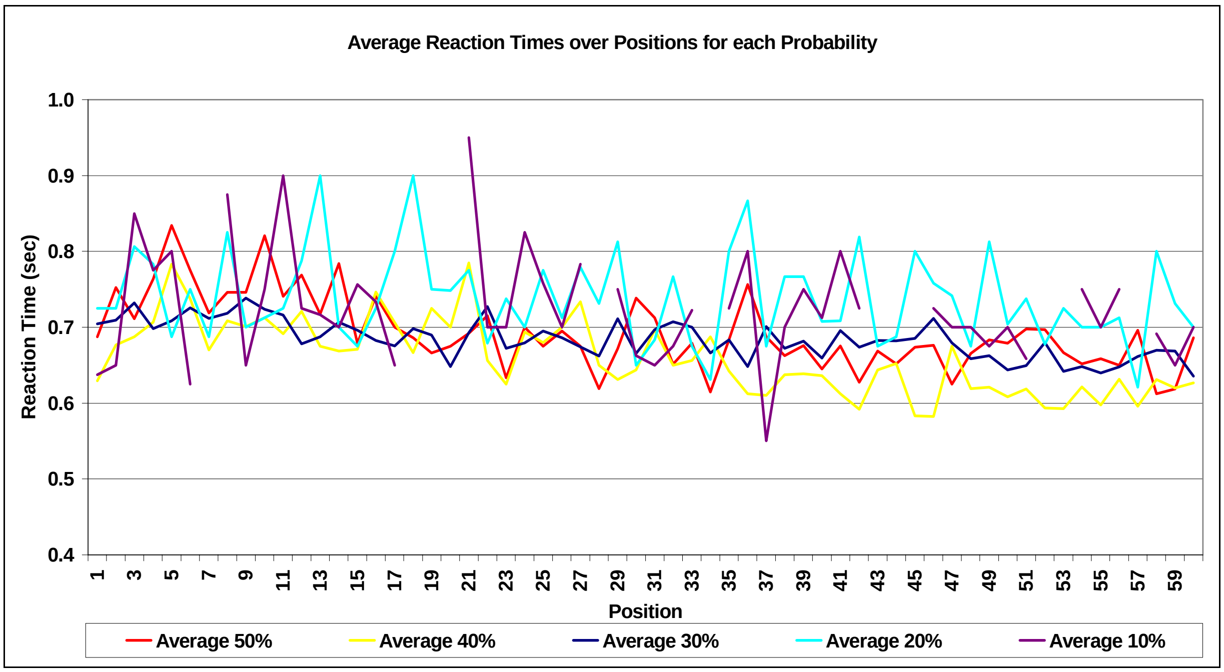


Figure 11: Average reaction times for each probability in a trial form position 1 – 60. Interrupted lines represent positions that did not have any reaction time values (low N-values for 10 % probability)

these results could be that Elele had a "warm-up phase at the beginning of each trial, which could be the reason for both a larger number of errors at the beginning of a trial as well as a decreased average reaction time after the presentation of the initial stimuli. Any comparable increase in reaction time or decline in performance accuracy as observed with humans would then occur much later in time and therefore would not be within the current time constraints of the experiment.

Due to the very low number of errors (114 misses and 46 false alarms in 12000 total stimuli presentations) misses and false alarms were pooled over all test sessions. The proportion of errors in a given position averaged over all trials and sessions decreased significantly (F=22.5, p=0.01). Figure 12 shows the proportion of errors (Misses and false alarms) averaged over blocks of 5 consecutive positions to minimize local fluctuations. Thus, contrary to findings with human subjects in which performance

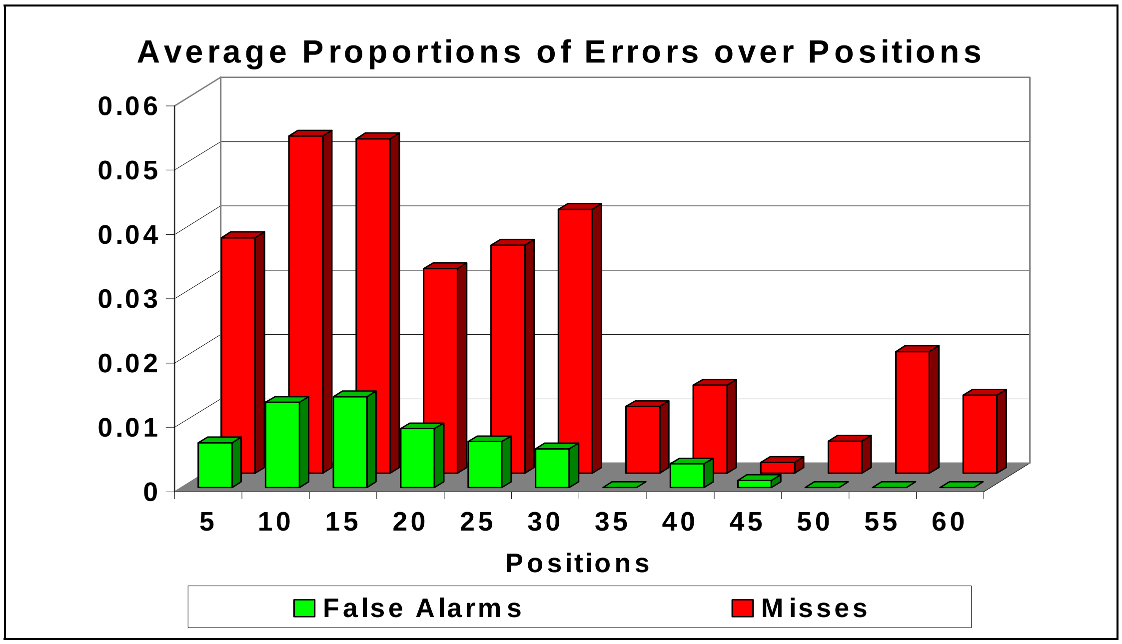


Figure 12: Average proportions of errors (False Alarms and Misses) made in all 20 test sessions. Each column represents the average of 5 positions.

accuracy decreases within a trial Elele's performance accuracy increased over the time of a trial. One possible explanation for this difference is that Elele may have required time at the beginning of a trial to focus her attention on the task. As attention was focused the reaction time decreased and the performance accuracy increased. That is, less accurate performance at the beginning of a trial may indicate that the dolphin's attention was less focused during these initial stimulus presentations and as a trial progressed more attention was allocated to the task. Possibly, a decrement in performance would occur with trials of longer duration. In this experiment the trials were 1.5 min long. In contrast, human subjects are generally tested for 40-50 min. However, with the experimental design used it was not possible to explore longer trial durations because the dolphin typically surfaced to breathe after 60 presentations. Furthermore, with increased trial durations the award given at the end of a trial would not have been sufficient to maintain Elele's interest in the experiment and she would have simply refused to participate.

Elele's performance over consecutive trials was investigated in a second analysis. First, the change of reaction times *over consecutive trials* regardless of the position was investigated. For that purpose the average of all reaction times in a given trial was calculated. Reaction time values from sessions with the same probability were again pooled together. Only one group, (reaction times from 40% sessions) showed a significant decrease in reaction times averaged per trial ($F=5.6$, $p=0.05$), all the other groups showed no significant change of reaction times. Thus, overall there was no correlation between the total length of a test session and the average reaction times. Secondly, average performance for each trial was examined. Misses and false alarms were again pooled over all sessions. To adjust for the difference in probabilities, proportions of misses and false alarms (number of misses or false alarms divided by the number of presentations of critical or non-critical stimuli per trial respectively) were calculated.

Over all sessions there was a significant increase in misses (slope: 0.003439, F= 14.68231 and p= 0.01) from trial 1 to trial 10 (see Figure 13) but no significant change in the proportions of false alarms made (slope: 0.000467, F=1.87638). These results show that there is decrement in performance over time, which is similar to findings in human data (Parasuraman 1998, Parasuraman and Davis 1977). The fact that this decrement is based on misses but not on false alarms indicates that Elele's decision criterion was biased and her interpretation of the rules was to rather make more misses than false alarms. These results could be explained with the fact that at one time during the training phase Elele was called back to her tankside station and reinforcement (fish reward and social praise) was withheld when she made a *false alarm* (see Experiment 1, session 70). Differential reinforcement for *misses* (less fish and social praise) was only given at the *end* of a trial and therefore not as salient to Elele as the callback for false alarms. Even though this procedure was only used over the course of several sessions to correct her bias on misses (she would indicate detection of critical stimuli on everything), Elele continued to show response characteristics as if as this feedback was still present.

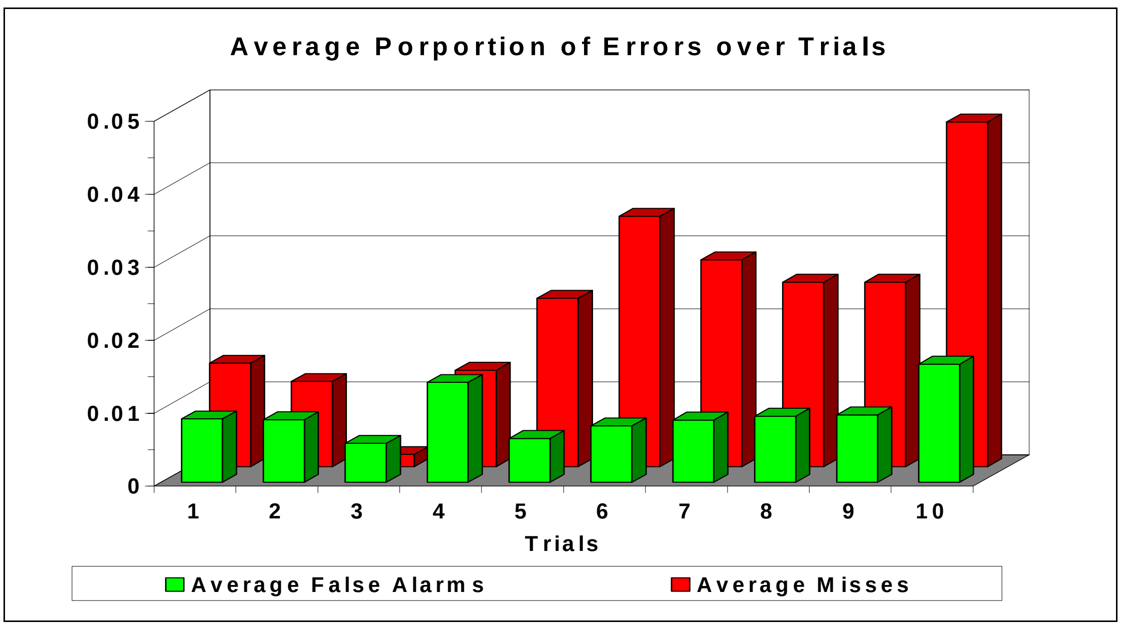


Figure 13: Average proportion of errors (Misses and False alarms) over trials. All probabilities are pooled together.

A third regression analysis was performed on all presentations as they occurred in a session. In this case consecutive trials were linked together. Data from sessions with the same probability were pooled. Only two groups (50 and 40%) showed a significant decrease in reaction times over all 600 positions (slope: -0.0001, F=14.63 p=0.01 and slope=0.00006, F=5.76 p=0.05 respectively). The three other groups did not show any significant change in reaction times over all presentations.

Figure 14 shows the distribution of reaction times averaged over all sessions. Proportional values were used to adjust for the change in probabilities over sessions. The bell-shaped distribution indicates that Elele had one decision criterion that she applied to any stimulus presented to her.

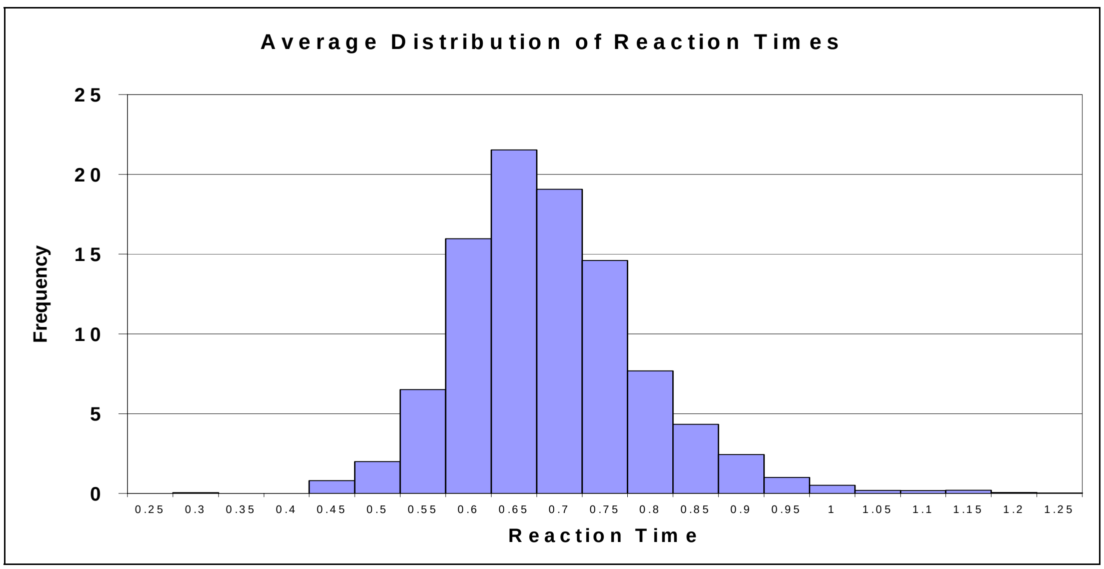


Figure 14: Distribution of reaction times averaged over all sessions.

In summary, all the data taken over the course of the 20 sessions show clearly that Elele maintained high performance accuracy independent of the changes in probabilities of critical stimuli occurring in any given trial. In none of the cases where probabilities changed from one session to the next was any residual or recency effect observed. Thus, Elele showed that she was able to readily adjust her responses to the changed settings. Although her performance accuracy did not change over different probabilities it did change over trials (on average): she made more *misses* at the end of a session then at the beginning. This is concurrent with data obtained from human research where performance decreases with time spent on the task (Parasuraman 1998). On average though, in a trial Elele made more *errors* (misses and false alarms) at the beginning of a trial rather than the end. This could be explained as a "warm up phase" in which Elele takes some time to focus her attention on the task. Decrement of performance or reaction time could not be shown within the limits of this experiment. As human data suggests, a decrease in performance would appear much later in a trial, typically after 15 to 25 minutes. However, in the current experimental setting longer trials were not possible because the dolphin would have to hold its breath for an extended period of time and Elele would have eventually left the stationing apparatus to take a breath and thus end the trial prematurely.

3.7. *Experiment 3 Multiple Criticals*

This experiment was designed to test Elele’s ability to monitor for several critical stimuli simultaneously. In the previous experiments Elele showed no decrement in performance over time. In experiments with human subjects decrement normally occurs at about 15-20 minutes into the task. Nuechterlein et al. (1983) were able to show that if stimuli are presented degraded and at a high rate, processing demand increases and decrement of vigilance can occur as early as 5 minutes into the task. To increase the difficulty of the task for Elele the pool of *critical* stimuli was increased successively up to five. Thus, an experimental setup was created in which decrement of vigilance was more likely to occur and appear at an early stage throughout the task. With the new setup vigilance decrement should be visible much earlier because the dolphin would have to compare each presented stimuli not just with one critical stimulus that she kept in memory but with five. This increase in difficulty should be detectable either through a drop in performance accuracy or through an increase in reaction time if more than one critical stimulus was present. This hypothesis was tested over the course of 35 sessions and the training for the task ensued the following way: Four new stimuli were trained over the course of 65 sessions. Each of the new stimuli was trained separately in a session to insure that the dolphin had no prior experience with a combination of stimuli in a test trial.

3.7.1. Training

Training of each new stimulus followed the same procedure as used in Phase III of Experiment 1. Each new critical stimulus did not resemble any of the previously used stimuli (critical or non-critical) as judged by the experimenter. For training purposes each new critical stimuli was printed in back on white paper, cut out and glued on a 61 x 61cm cardboard background. For a training trial Elele was sent down to the underwater window by her trainer where she stationed in front of the window. A trainer in a remote room gestured Elele to pay attention. Upon correct positioning in front of the window the new critical stimulus was manually raised into the viewing field of the camera. Simultaneously the trainer in the remote room gestured Elele to press the paddle.

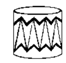
When Elele had pressed the paddle sufficiently, she was rewarded with a whistle, social praise and fish. On some trials non-critical stimuli were presented to insure that Elele would learn to press the paddle only upon presentation of a critical stimulus. Once Elele had learned to associate the new stimulus with a press of the response paddle the number of stimuli presented per trial was increased. When her accuracy was better than 80 % correct the stimuli were then presented by the computer and the trainer in the remote room was not longer visible on the screen after a trial began. Over the course of 16sessions the length of trials increased up to 30 presentations of stimuli. Then the next new critical was trained using the same technique. Once each of the four new critical stimuli was trained, the number of stimuli per trial was increased for all criticals simultaneously. Each session used only one critical but successive sessions used different criticals. This procedure continued until Elele showed good performance (better than 85% correct) in two consecutive sessions with 10 trials and 60 stimuli per trial.

3.7.2. Testing

Following completion of training, testing commenced using the same procedure as in the previous experiment. Each session consisted of 10 trials with 60 stimuli each. A total of 50% of the presented stimuli in each trial were critical stimuli and 50% were randomly selected non-critical stimuli from a set of 80. In any given trial each non-critical stimulus was presented only once, whereas the particular critical stimulus used in this session could be occur several times in successive positions. The inter-trial-interval was kept constant at 95 sec ± 10 seconds. With this setup it was possible to compare the successive trials in regard to its position in a session. For example if trial 5 would have been followed by a long pause the dolphin would have had enough time to recover its ability to perform the task and trial 6 would have to be treated similar to trial 1 as the beginning of a new block.

The experiment was designed in five different steps (Table 6). Each step increased the number of unique critical stimuli used by one. Thus on successive steps the difficulty of the task increased as the dolphin had to monitor for a greater number of different critical stimuli.

Table 6: Number of critical stimuli used per session throughout Experiment 3

Session	 Critical 1	 Critical 2	 Critical 3	 Critical 4	 Critical 5	Total number of criticals per session
Mc-1-01	300					300
Mc-1-02		300				300
Mc-1-03			300			300
Mc-1-04				300		300
Mc-1-05					300	300
Mc-2-01	150	150				300
Mc-2-02			150	150		300
Mc-2-03	150				150	300
Mc-2-04		150	150			300
Mc-2-05				150	150	300
Mc-2-06	150		150			300
Mc-2-07		150		150		300
Mc-2-08			150		150	300
Mc-2-09	150			150		300
Mc-2-10		150			150	300
Mc-3-01			100	100	100	300
Mc-3-02	100	100	100			300
Mc-3-03		100		100	100	300
Mc-3-04	100		100	100		300
Mc-3-05	100	100			100	300
Mc-3-06		100	100	100		300
Mc-3-07	100		100		100	300
Mc-3-08	100	100		100		300
Mc-3-09		100	100		100	300
Mc-3-10	100			100	100	300
Mc-4-01	75	75	75	75		300
Mc-4-02		75	75	75	75	300
Mc-4-03	75	75		75	75	300
Mc-4-04	75		75	75	75	300
Mc-4-05	75	75	75		75	300
Mc-5-01	60	60	60	60	60	300
Mc-5-02	60	60	60	60	60	300
Mc-5-03	60	60	60	60	60	300
Mc-5-04	60	60	60	60	60	300
Mc-5-05	60	60	60	60	60	300

3.7.2.1. Step 1

In Step 1 each of the different criticals was used exclusively in one session and appeared 300 times over the course of the 10 trials of this session. This was done to obtain a baseline performance of correct detection and the corresponding reaction times for each of the five stimuli.

3.7.2.2. Step 2

In Step 2 each possible combination of two out of the five previously trained critical stimuli (e.g.: critical 1 and critical 4 or critical 2 and critical 3) were used to fill the 30 available positions for critical stimuli in each trial. Thus each critical of a pair appeared 15 times per trial but the total number of presentations of critical stimuli (30) was kept consistent throughout a trial. Over all, each stimulus appeared 150 times within a session of Step 2. The order of these appearances was pseudo-random with the following limitations: a) Not more than four stimuli of either class (critical or non-critical) in a row. b) not more than two identical criticals in a row. Ten sessions were run to cover all possible combinations of two criticals (Mc-2-01 to Mc-2-10).

3.7.2.3. Step 3

In Step 3, three of the five critical stimuli were combined in equal parts in each of the ten trials (e.g.: critical 1, 3 & 5, or critical 4, 2 & 3). Thus each critical used in a session appeared 10 times per trial and over all, each stimulus appeared 100 times within any session of Step 3. The order of stimuli was again pseudo-random and the same limitations as in Step 2 applied. Ten sessions (Mc-3-01 to Mc-3-10) were conducted to test the same number of all possible combinations.

3.7.2.4. Step 4

In Step 4 the number of combined criticals was raised to four and each of the critical stimuli appeared either 7 or 8 times per trial. This was balanced over the 10 trials conducted in a session and therefore each of the four criticals used, appeared a total of 75 times per session.

3.7.2.5. Step 5

Finally, in Step 5, all critical stimuli were used evenly for a total amount of five consecutive sessions. Here each stimulus appeared 6 times per trial and a total of 60 times per session. This step differed in comparison with the previous steps in that the five test sessions used the same combination of stimuli (all five), whereas in the previous steps combinations always differed from one session to the next.

3.7.3. Results and Discussion

3.7.3.1. Step 1

Figure 15 presents the dolphin's performance accuracy for each critical over all combinations. Throughout the test Elele performed at or near ceiling levels except for critical 3. In Step 1 Elele performed correctly at 99.0 % for Critical 1, 99.0 % for Critical 2, 96.0 % for Critical 3, 99.3 % for Critical 4 and 98.3 % on Critical 5. Performance on non-critical stimuli (correct rejections) was at 100%, 99.7 %, 97.7 %, 99.3 % and 99.7 %, respectively.

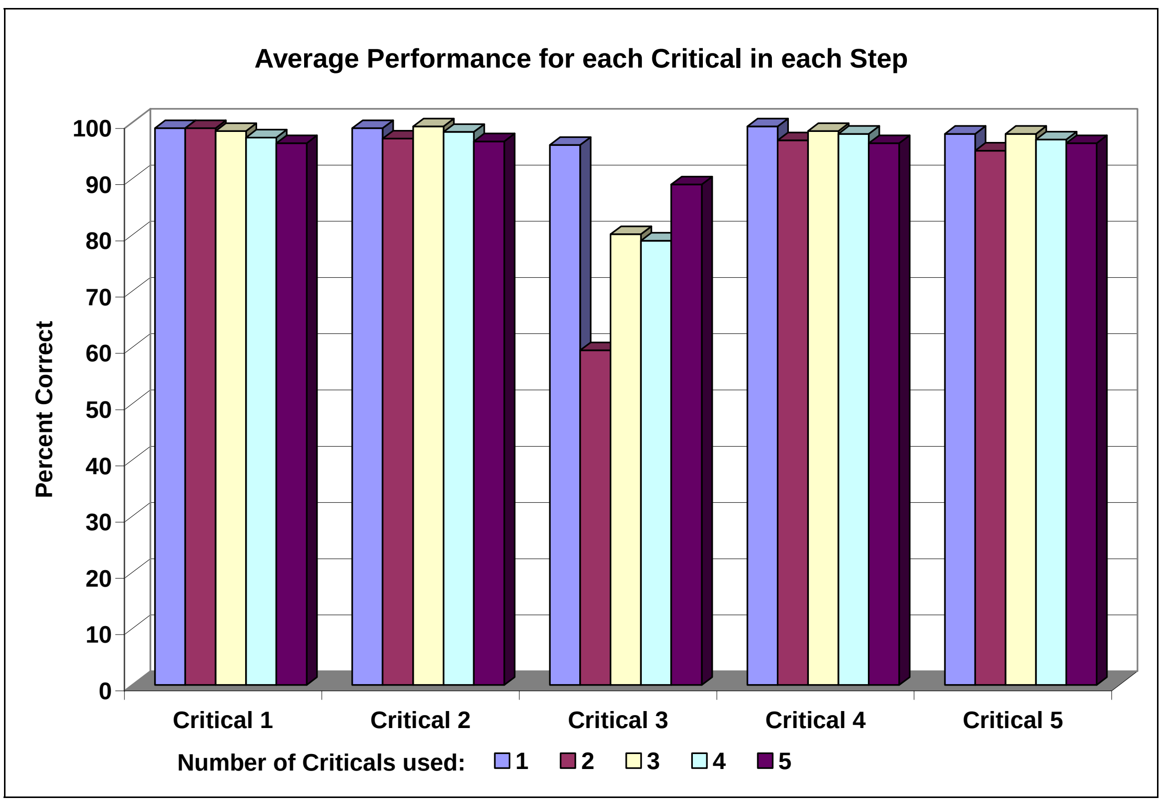


Figure 15: Elele's performance for the five critical stimuli used. Each group of bars represents a particular critical and each color represents the number of criticals used.

The average reaction times for each critical were 0.612s, 0.720s, 0.777s, 0.636s and 0.740s respectively. Thus Elele's response latency increased from critical 1 to criticals 4, 2, 5 and 3 (even though the order in which they were introduced was different, see Table 6). Reaction times did not change significantly (averaged over 10 trials) from position 1 to position 60 except for critical 3 (F=5.1 at p=0.05). Reaction times (averaged over positions 1-60) did not change significantly from trial 1 to trial 10 of each session.

The average proportion of misses did change significantly from position 1 to position 60 (F= 4.5 at p=0.05) but false alarms did not change significantly. There was no significant change in the average proportion of misses or false alarms from trial 1 to trial 10 (see Figure 16).

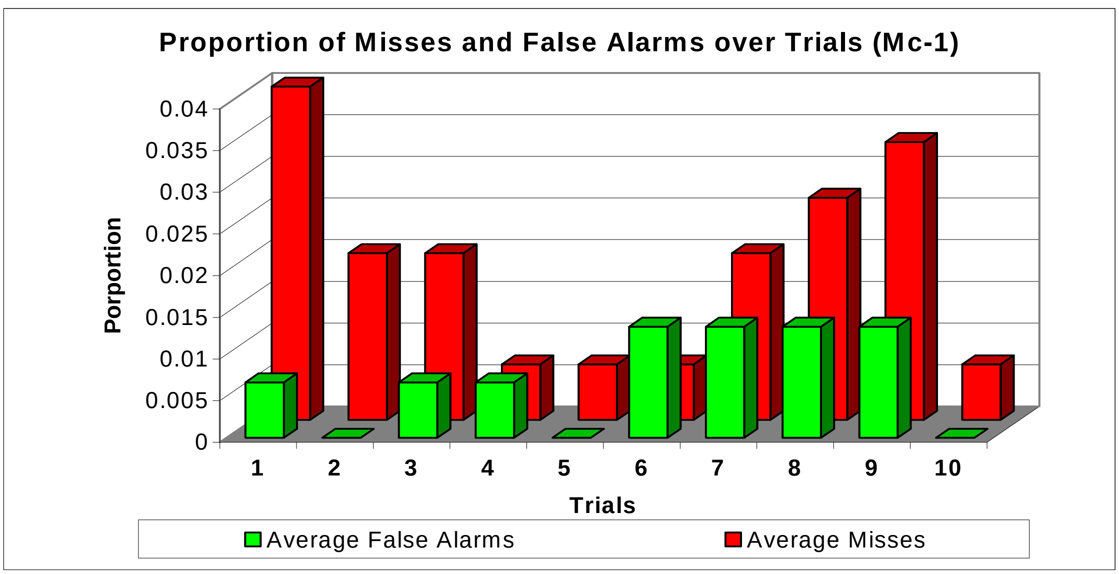


Figure 16: Average proportion of misses and false alarms over trials for sessions with only one critical present.

3.7.3.2. Step 2

In Step 2 combinations of two criticals appeared in each trial. Performance on criticals was combined across the sessions each critical was used (four possible combinations with any of the other criticals). Elele performed near or at ceiling levels for critical 1, 2, 4 and 5 with average detection rates of 99.00 %, 97.17 %, 96.83 % and 95.00 % respectively. On critical 3, however, her performance dropped to an average 59.5 % over the four sessions this particular critical appeared. A more detailed analysis of the sessions revealed that the first session, in which she was presented this stimulus, her performance accuracy dropped to 14.7 % on critical 3 (see Figure 17) while she continued to perform well on the other critical stimuli present. Her reaction times for that stimulus (0.775s) did not differ from the reaction times that were obtained when critical 3 was the only critical stimulus present in the previous step (0.777s). In the following three sessions with this stimulus her performance improved from 50.7% to 84.0 % to 88.7 % while her average reaction times for this critical in those sessions decreased from 0.716s

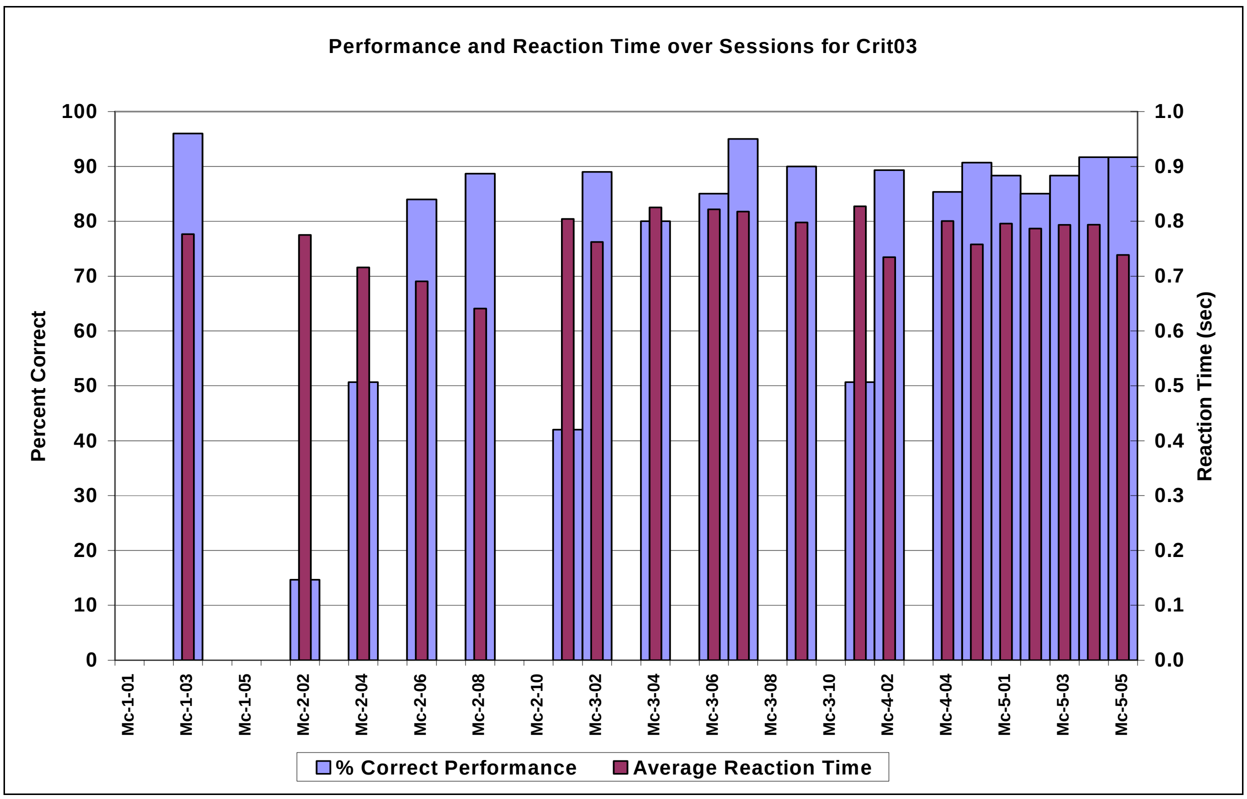


Figure 17: Average performance and average reaction time for Critical 3 in the order of sessions tested. Correct performance (blue) and reaction time data (red) are overlaid to show the inverse correlation between performance accuracy and reaction time.

to 0.690s to 0.641s. The changes in performance and reaction times are linked to that particular critical and were not caused by her first exposure to a combination of two critical stimuli in a session simultaneously (the first sessions with a combination of two critical stimuli contained critical 1 and 2).

In the first four sessions of this step there was no significant change in reaction time (average over all criticals) from position 1 to 60. The remaining six sessions showed a significant (p=0.01) decrease in reaction times form position 1 to 60. Four of six test sessions showed a significant change in reaction time form trial 1 to trial 10 (three at p=0.05, one at p=0.01), three of them showed a decrease and one of the, an increase in reaction time. Performance on non-criticals (correct rejections) was in all sessions above 99.3%. There was no significant change in the average proportion of misses or false alarms from trial 1 to trial 10 (see Figure 18).

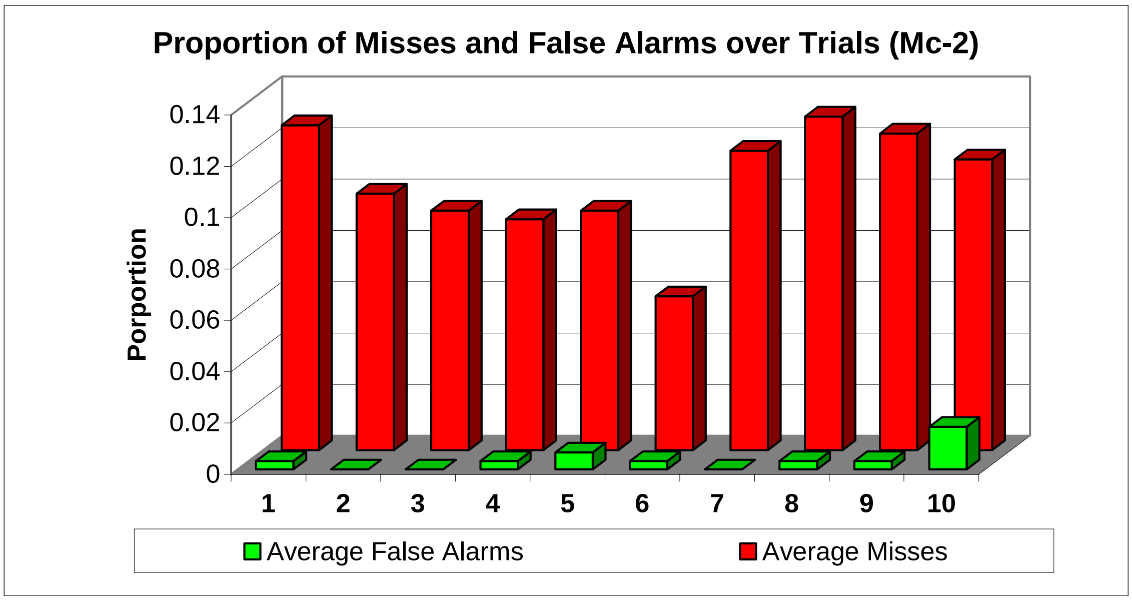


Figure 18: Average proportion of misses and false alarms over trials for sessions with two critical stimuli present.

3.7.3.3. Step 3

In Step 3 performance on each critical was averaged over the six sessions that used this stimulus. Elele was again performing at or near ceiling levels for critical 1,2,4 and 5 with 98.5%, 99.3%, 98.5% and 98.0%, respectively. On critical 3 Elele showed a similar performance as in Step 2: on average she was 80.2% correct but in the first sessions using a combination of three critical stimuli that included critical 3 she performed at 42.0%. Subsequently her detection rate increased to 89.0%, 80.0%, 85.0%, 95.0% and 90.0% for that stimulus.

The average reaction times for each critical in Step 3 indicate that this step was more difficult for Elele: all reaction times increased to approximately 0.8 seconds (critical 1: 0.784s,critical 2: 0.796s,critical 3: 0.805s, critical 4: 0.791s and critical 5: 0.803s). All sessions of step three showed a significant (p=0.01) decrease in average reaction time from position 1 to 60. None of the test sessions showed a significant change in average reaction time from trial 1 to trial 10. No significant change in the proportion of errors (misses and false alarms) over trials was observed (see Figure 19).

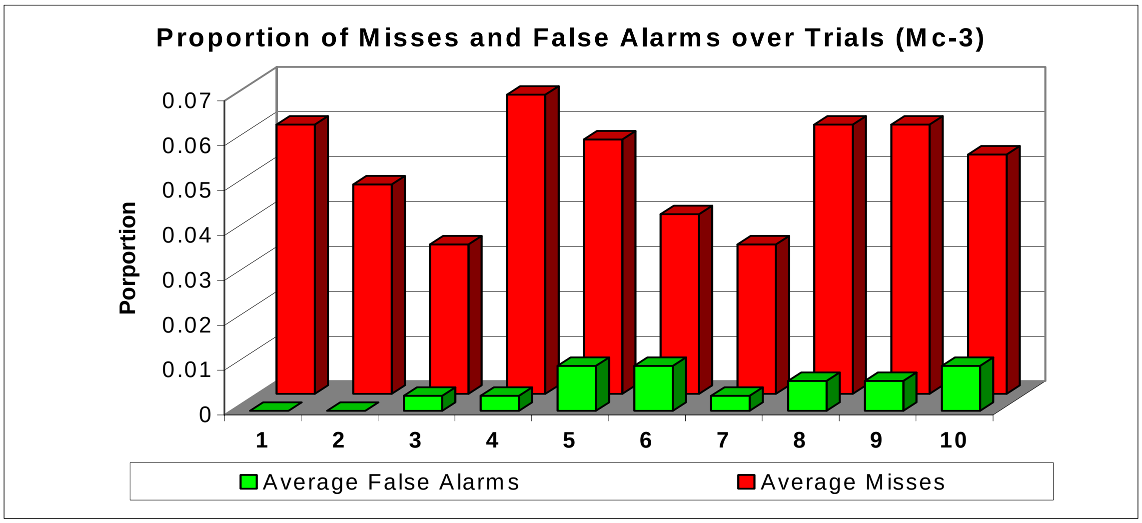


Figure 19: Average proportion of misses and false alarms over trials for sessions with three critical stimuli present.

3.7.3.4. Step 4

Elele performed near ceiling levels for critical 1, 2, 4 and 5 with detection rates of 97.3%, 98.3%, 98.0% and 97.0% respectively. Performance on non-criticals was for all sessions above 99.7%. On critical 3 she had an average performance of 79.0%. Again her performance increased on that stimulus over the course of the four sessions from 50.7% to 89.3% to 85.3% to 90.7%. Reaction times were on average for all criticals 0.762s (0.756s, 0.748s, 0.780s, 0.759s and 0.770s for criticals 1 to 5) and an analysis of variance (Scheffé) showed no significant difference between the reaction times for the five criticals.

In four of five sessions with combinations of four criticals the average reaction time decreased significantly from position 1 to 60. Two of the five test sessions showed a significant decrease in reaction time from trial 1 to trial 10.

In Step 4 the average proportion of misses decreased significantly (p=0.05) while the proportion of false alarms did not change significantly over trials (see Figure 20).

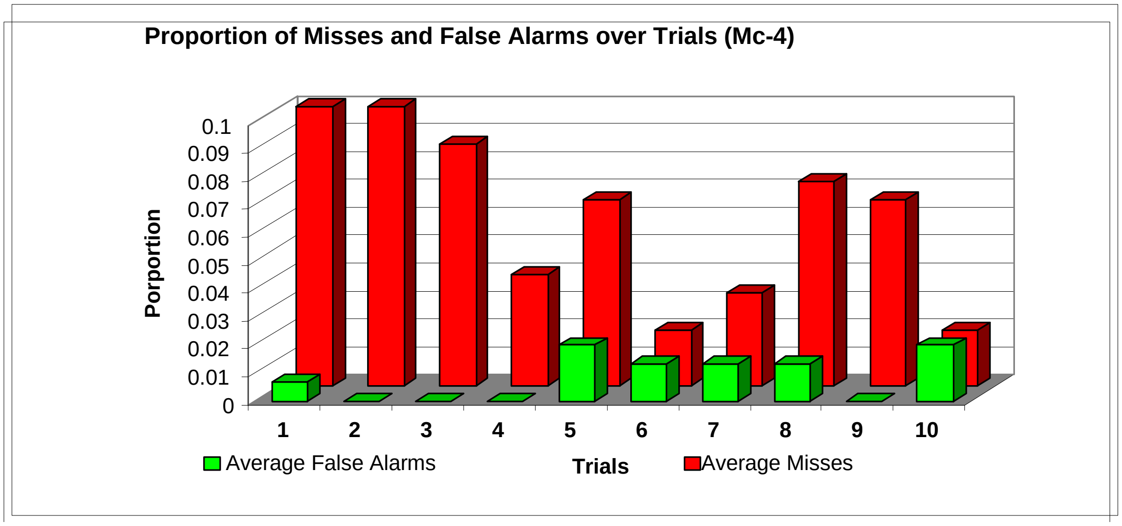


Figure 20 Average proportion of misses and false alarms over trials for sessions with four critical stimuli present.

3.7.3.5. Step 5

In the five sessions, where all criticals were used simultaneous, Elele performed near ceiling levels for criticals 1,2,4 and 5 (96.3%, 96.7%, 96.3% and 96.3% respectively). Performance on critical 3 was higher than in the previous steps (89.0%) but not at the same level as all other criticals. No significant difference in reaction times for the different criticals was detected. (0.799s, 0.798s, 0.782s, 0.80s and 0.813s for criticals 1 to 5 respectively).

Average reaction time also decreased significantly in all five sessions form position 1 to position 60. Two of five sessions showed a significant increase in reaction time form trial 1 to trial 10 and one session showed a significant decrease.

3.7.4. Discussion

Overall, as the difficulty of the task increased by raising the number of criticals presented simultaneously within a trial, Elele's average reaction time also increased (see Figure 21). This is in congruence with the data obtained in human experiments where the average reaction time in a task increases with increasing difficulty of the task. The explanation offered for this phenomenon is that in more complex tasks parallel processing is not longer possible and the task has to be processed sequentially, thus requiring more time. In this specific case a possible explanation might be that Elele represented the critical stimuli in a list that she examined serially against each stimulus appearing on the screen. If the list contained only one item (Step 1), reaction time would be short and mainly determined by the recognition of that particular stimulus. If the list contains two stimuli (step 2) then reaction time should increase. That is, as the number of critical stimuli to hold in memory increases, reaction time to respond to each stimulus

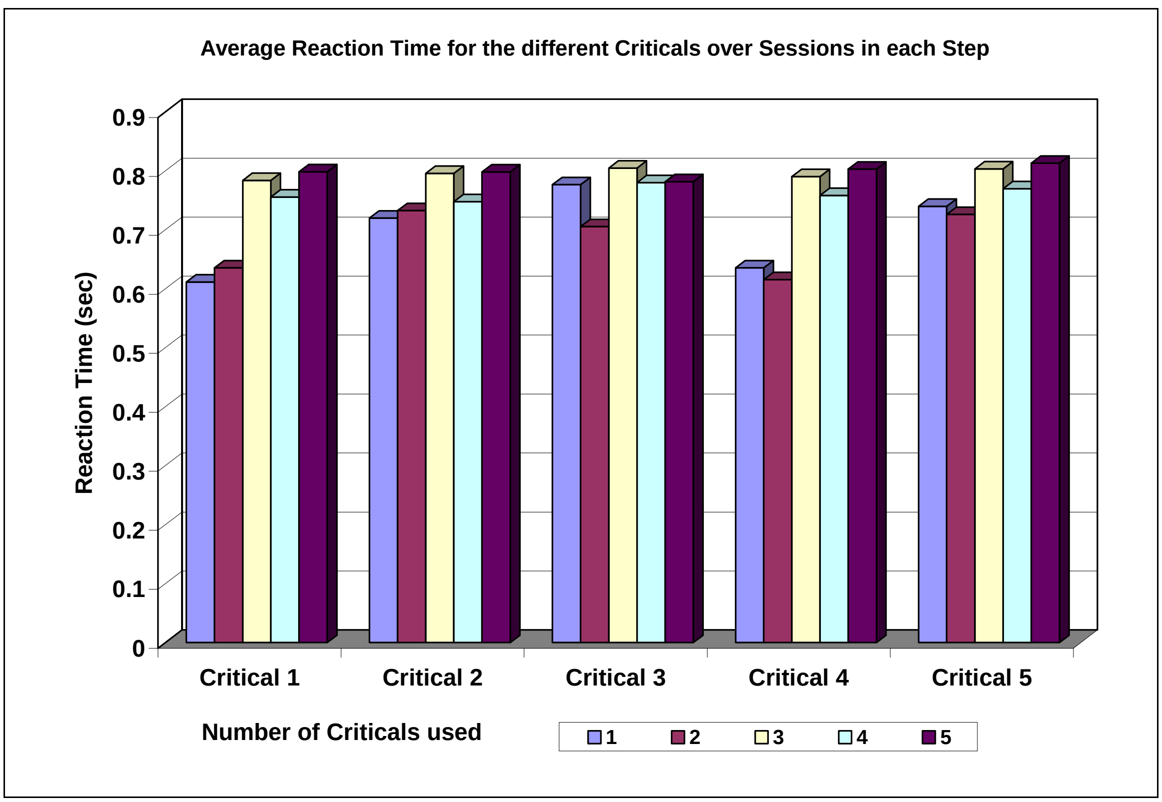


Figure 21: Elele's reaction times on the five critical stimuli used in the five steps. Each bar represents the average reaction time on that particular critical during that step.

presented on television should also increase. Alternatively, if the dolphin represents the crucial stimuli as a list whose items can be compared in parallel, then no change in reaction time should be observed. A parallel processing of the list should yield stable reaction times over increased number of critical stimuli present. At some point though, the maximum capacity for parallel processing should be reached and a change in either performance accuracy or reaction time should occur. The obtained data appear to support the second hypothesis because no linear increase in reaction time was observed and only one significant change in reaction time occurred at the change from 2 to 3 critical stimuli being present simultaneously.

With the exception of Critical 3 performance accuracy did not change with the number of criticals used. This seems to indicate that even though the difficulty of the task was increased in comparison to Experiment 2, the limitations of Elele's processing capacity as well as her ability to sustain performance over a longer period of time under these circumstances was not reached. Thus the hypothesis that a more demanding task would decrease the time after which vigilance decrement can be observed was not proven within the constrains of this experiment. A further increase in difficulty such as a decrease in exposure time, more critical stimuli tested simultaneously or an increase in trial length, might lead to a clearly detectable drop in performance accuracy over time and might thus demonstrate vigilance decrement.

In summary, the dolphin's ability to monitor its continually changing visual environment for the presence of one or more key arbitrary stimuli was excellent. The dolphin was able to represent and monitor for as many as five key stimuli (the greatest number tested) without any appreciable decrement in performance. Performance accuracy and responding remained robust when the dolphin when challenged with changes in probability key signal of occurrence, ISI, etc. Within the limits explored, these changes did not result in any considerable vigilance decrement of the type evidenced in humans (ref). More extensive manipulations of the variables would theoretically produce some of these effects.

3.7.5. Summary

In experiment 1 to 3 a bottlenosed dolphin was tested on its bility to sustain attention over a prolonged period of time while several parameter (SIT, ISI, number of stimuli per trial, Probability, number of critical stimuli presented simultaneously) were varied.

Experiment 1: This experiement tested the dolphin's ability to perform a visual vigilance task and sustain its attention over a prolonged period of time. The animal demonstrated that she could monitor and report a trained critical signal over 10 trials with up to 60 stimuli per trial without decrement of performance accuracy or an increase in reaction time. The variation of the stimulus exposure time, the inter-stimulus interval and the total number of stimuli presented within a trial did not affect either the performance accuracy or the reaction time of the dolphin. Rather she was easily able to adjust her performance to the increased speed and difficulty of the task.

Experiment 2: this experiment examined whether a change in the probability of the occurrence of a critical stimulus would affect Elele's performance accuracy or reaction time. Over all 20 test sessions the animal did not show any decrement in performance independent of the variation in probability between 10 and 50%. In congruence with data obtained in human studies, the reaction time increased with the critical stimulus density (probability).

Experiment 3: Here, Elele's ability to perform the vigilance task with up to five critical stimuli simultaneously was tested. Although her performance dropped with the increased number of critical stimuli used simultaneously, this was not linked to an increase in difficulty rather it was linked to one particular stimulus (dragonfly). Furthermore, an increase in average reaction time for all stimuli was detected when more then two critical stimuli were present.