Visual discrimination in horses

The effect of stimulus height on visual discrimination in horses[1]

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ABSTRACT

This study investigated the effect of stimulus height on the ability of horses to learn a simple visual discrimination task. Eight horses were trained to perform a two-choice black/white discrimination with stimuli presented at one of two heights: at ground level or at a height of 70cm from the ground. The height at which the stimuli were presented was alternated from one session to the next. All trials within a single session were presented at the same height. The criterion for learning was four consecutive sessions of 70% correct responses. Performance was found to be significantly better when stimuli were presented at ground level with respect to number of trials taken to reach the criterion, percentage of correct first choices and repeated errors made. Thus training horses to carry out tasks of visual discrimination could be enhanced by placing the stimuli on the ground. In addition, the results of the present study suggest that the visual appearance of ground surfaces is an important factor in both horse management and training.

Key words: Horse, Learning, Position effect, Discrimination, Vision, Visual stimuli.

Introduction

Stimulus position has been found to affect the ability of the horse to perform tasks involving visual discriminations. In a study by Gardner (1937a), horses were trained to select a feed box covered with a black cloth from two other plain feed boxes. The effect of re-positioning the black cloth either above or below the box containing the food reward was then investigated (Gardner, 1937b). The latter study found that more errors were made with the black cloth in the high rather than the low position. However, more errors were made in both of the new positions compared to the original position which was over the food box (i.e. in the same location as the reward). In a more recent study using a visual discrimination task to assess intelligence and learning in horses the reward was presented in the same location as the stimulus, but both at nose height (Sappington and Goldman, 1994). The results of an early study into equine colour vision where stimuli were presented at ground level (Grzimek, 1952) differ from findings of subsequent studies involving higher level stimulus presentations (Pick et al., 1994; Macuda and Timney, 1999; Smith and Goldman, 1999). Although there were inevitably other differences in methodology between these studies in addition to that of stimulus position, there is a need for further controlled investigation into the role of stimulus height in optimizing horse performance in visual tasks.

To assess the effect of stimulus position on performance, horses in this study were trained to perform a simple two-choice, black/white discrimination with stimuli either at ground level or nose height. The aim was to test the prediction that stimuli presented at ground level would be easier for the horse to discriminate and result in an improved learning rate, relative to stimuli presented in an identical way but at a higher level.

Materials and Methods

Subjects

Eleven experimentally naive horses from the equestrian centre at the Brackenhurst College campus of the Nottingham Trent University began the pre-test training. Three of these horses did not learn to open the stimulus box in two training sessions and so were excluded from the study. Eight subjects learnt to push open the stimulus box to obtain a reward within the first training session. The three mares and five geldings were of varying types, ridden for two hours a day, six days a week. Their heights ranged from 152 to 165cm, with a mean height of 157.87cm. Ages ranged from 6 to 16 years, with a mean age of 10 years. All horses were stabled during the study and turned out on their day off. They were all accustomed to eating forage and concentrate rations at various levels, from the ground to above nose height and all had been fed carrots at some time.

Test area and apparatus

The test area was located in an enclosed barn with a concrete floor. Skylights in the roof provided daylight. The half of the building used for testing was fenced off along the long side using galvanised wire mesh barriers (120cm in height) and screened from view by sheeting to a height of 300cm. A gap of 10cm in this screening allowed the experimenter to view the subject performing the trials while remaining outside the test area. The test area was 5m wide, 10m long; a "starting" line of masking tape was placed on the floor 6.5m from the end wall where the stimuli were displayed. Two identical wooden boxes were placed against the wall, each being 125cm from the side wall with a gap between the two boxes of 150cm. The stimulus box was either located on the floor for ground-level presentations or on a table for high-level presentations 70cm above ground level. Each table had a top measuring 120 x 60 cm. A rubber mat was placed under the stimulus box when placed on the table, to prevent it moving when the horse tried to open it. See figure 1 for a plan of the test location.

The stimulus boxes were built from 2cm plywood. Each measured 50 x 60 cm and was 52 cm high. The top flap of the box sloped forwards at an angle of 60 degrees from the vertical and was hinged at the top to open inwards. The flap door could be locked by placing a wooden block within the box which could not be seen from outside. A hole at the bottom of the flap allowed it to be opened upwards manually. This hole was taped loosely on the inside to prevent visual access to the inside of the box. Small flaps of rubber prevented the unlocked box from opening until it was pushed down by the horse's nose. Perspex sheets were mounted on the opening flaps of each box, behind which the stimulus cards could be slotted. See Figure 2 for a plan of the stimulus box.

The stimuli were black and white cards (39cm high x 38cm wide). One box displayed the black card and the other box displayed the white card. The flap of the box displaying the positive stimulus was left unlocked, while the flap of the box displaying the negative stimulus was locked. A correct choice was rewarded by access to the food within the box. This consisted of a small piece of carrot, approximately 3 x 1 cm, placed in both of the stimulus boxes so that olfactory cues could not guide stimulus selection. During training and testing, both boxes were treated identically with respect to changing the stimulus cards, opening and shutting the flaps and removing or inserting the locking block, so auditory cues could not guide stimulus selection.

Training

Each horse was introduced to the stimulus box. Once they could open this by pushing down the flap with their nose to obtain the reward, either black or white was designated as their correct stimulus (4 horses in each of the 2 conditions: black correct or white correct) and pre-test training commenced. Training sessions were held twice a week and consisted of ten separate trials. The training sessions took 20 – 40 minutes according to individual performance. For each separate trial the horse was released at the starting line and during the first session the handler walked by its side towards the stimulus boxes. The horse was then shaped to push the flap of the box with its nose (by tapping the box). During the first training session if a wrong choice had been made the horse was allowed to change its selection and obtain a reward for the correct choice. The horse was then led behind the screens, the stimulus boxes were re-loaded with carrot and the position of the cards was altered. After the first three trials of the second session, the horse was taken back to the starting line following a wrong choice and had to return to make another selection. This procedure was repeated without altering the presentation of the stimuli until the horse made the correct choice, these repeat corrections being counted as one trial. The latter protocol was adopted during the experimental trials. During the training sessions (only), after three repeated errors within one trial the horse would be guided to the correct box. In the testing phase, there were no such forced corrections.

Throughout the training and experimental testing the left/right position of the positive stimulus was varied randomly, up to a maximum of three consecutive choices on one side to avoid spatial cues becoming more important than visual cues. The horses were released by the handler from either side to control for directional influences. During the first session the initial height of the stimulus for four of the subjects was on the ground and on the table for the other four, to control for any effects of order of presentation (two high, two low in the black designated correct group; two high, two low in the white designated correct group). The height of presentation in the subsequent sessions was alternated, high for one whole session and low for the next session.

Pre-test training was complete once the horse could freely approach the stimulus boxes from a distance of 6 metres at both the high and low presentation heights, then select one of the boxes to obtain reinforcement. This was accomplished during the first two sessions for all of the horses.

Experimental testing

Test sessions were carried out twice a week and each session consisted of ten trials. The height at which the stimuli were presented was alternated from one session to the next, and it was the same for all ten trials within a single session. Two consecutive training sessions within one week constituted one training set, the first sessions at high and low height presentations forming the first training set. The position of the stimuli (left / right) was varied as in the training sessions and equal numbers of left and right presentations of the correct stimulus were included in each experimental session.

At the start of each session, the horse was led into the barn, the doors were closed and the horse was positioned behind the starting line, directly facing the stimulus boxes. It was released and allowed to approach the boxes to make its selection. A correct choice was rewarded by access to the carrot via the unlocked flap before the subject was caught and led behind the screens. The number of trials that the horse made a correct selection at the first attempt was calculated as a percentage of the total number of trials and resulted in an accuracy score. An incorrect choice resulted in the horse being caught by the handler before it could try the correct box and being led back to the starting line to try again. If an incorrect choice was made, the same presentation was repeated until the horse made the correct choice. The initial choice would be scored incorrect and repeated errors with the same stimulus presentation were counted up within any one trial. The number of error runs (on first or subsequent attempts) was calculated as a percentage of the total number of runs (whether correct or incorrect) in that session. Thus the error scores were not simply the obverse of accuracy scores and reflected perseverence in making an incorrect choice.

At the end of each trial the horse was led behind the screens while the experimenter re-positioned the stimuli according to the pre-arranged semi-random order. When no change of stimulus position was required the cards were removed and replaced in the same box to control for possible auditory cues. After a period of 30 seconds, the horse was led back to the starting line to commence the next trial. Both accuracy and error rates were calculated as percentages for the session.

The overall learning criterion for the discrimination learning task was reached once 70% accuracy was attained on four consecutive sessions. Because sessions alternated this criterion included two sessions at high presentation and two at low presentation (i.e. two training sets). The total number of trials required for each horse to reach the individual criteria at at each of the high and low positions (two scores of 70% or over, attained consecutively at a single height and independently of the scores at the alternate height) provided an additional measure of the effect of stimulus height on learning.

Data Analysis

To assess the effect of stimulus height on performance of the visual discrimination, the number of trials taken to reach the criterion of 70% correct on two consecutive sessions was calculated for each presentation height separately (accuracy scores of 70% or above for two consecutive sessions at a single presentation height, regardless of interim scores at the other height). Mean accuracy and error rate scores for the two heights of presentation were calculated. Two-way mixed analyses of variance were conducted with the within subjects factor of height (of stimulus) and the between subjects factor of stimulus (black or white designated correct). The dependent variables were trials to criterion, accuracy and error rates. The interaction between height and stimulus designated correct was also investigated.

Learning rate was examined using training sets scores (the combined means of all eight subjects for accuracy and error rate at the different heights of stimulus presentation for each individual session). Because the horses took different numbers of trials to reach the training criterion (see above), learning rate over the training sessions could only be assessed for the first ten sessions of training (for which there was complete data). These data were analysed as five training sets (at both high and low presentations) in a repeated measures design, with the factors of height and training set, again the between subjects factor was stimulus. Planned comparisons were made by paired samples t-tests (one-tailed) in order to assess the predicted effect of height of stimulus on performance as training progressed.

Results

All the horses which completed the pre-test training went on to learn the discriminations. Performance was assessed by three dependent variables: trials to criterion, accuracy and error scores.

Trials to criterion

The number of trials taken to reach the overall learning criterion ranged from 76 to 282, with a mean of 183 trials (s.e. = 27.51). Separate scores for each height of stimulus presentation ranged from 25 to 204 trials for the low presentations (mean = 97.63, s.e. = 21.48); 66 to 269 for the high presentations (mean = 162.88, s.e. = 24.53). The number of trials taken to reach the criterion of 70% accuracy for two consecutive sessions at a single presentation height was less when the stimuli were presented in the low position. There was a significant main effect of height of stimulus [$F(1,6) = 11.76$, $p = 0.014$]. The trials to criterion was not affected by which stimulus was designated correct and there was no significant interaction between height and black/white colour of stimulus.

Performance accuracy

Overall accuracy scores ranged from 61.54 to 77.29% (mean = 67.93%, s.e. = 1.96). Mean accuracy scores for the different presentation heights were 74% at the low presentation (s.e. = 2.85), 61.86% at the high presentation (s.e. = 2.41). Accuracy was found to be significantly better when the stimulus was presented at ground level. There was a highly significant main effect of height: [$F(1,6) = 19.98$, $p = 0.004$]. No significant difference in accuracy was found in relation to the stimulus designated correct. A marginal interaction [$F(1,6) = 5.90$, $p = 0.051$] between the stimulus designated correct and its height was found in the accuracy scores, showing a tendency for the positional effect to be greater when the positive stimulus was black.

To compare learning rates at the two heights of presentation, mean accuracy scores for all of the first ten sessions (five high, five low) are shown in Figure 3. Statistically, there was again a main effect of height [$F(1,24) = 6.42$, $p = 0.044$], but the interaction between training set and height was only marginal [in the linear trend, $F(1,6) = 5.04$, $p = 0.066$]. Thus, although accuracy of performance at the outset was similar regardless of the height of the stimulus, it was consistently better with the low level presentations on subsequent training sets, significantly so for training sets three [$t(7) = 2.47$, $p = 0.022$], four [$t(7) = 2.01$, $p = 0.043$] and five [$t(7) = 3.62$, $p = 0.005$].

Repeated errors

Overall error rates ranged from 21.84 – 34.25% (mean = 28.55%, s.e. = 1.57). Mean error rates for the different presentation heights were 23.25% at the low presentation (s.e. = 2.76), 33.85% at the high presentation (s.e. = 1.31). The error rate was significantly lower when the stimulus was presented at ground level. There was a highly significant main effect of height [F(1,6) = 15.05, p = 0.008]. No significant difference in error rate was found in relation to the stimulus designated correct and there was no interaction between height and stimulus designated correct.

Whilst the overall effect of height was very clear, there was no evidence for an effect on learning rate with respect to repeated errors over the first ten sessions at the two different heights of presentation. Mean errors scores at the different presentation heights (five high and five low training sets) are shown in Figure 4. For the error scores in the early stages of training, the effect of height was marginal [F (1,24) = 4.48, p = 0.078], and there was no evidence for any interaction between training set and height. However, the planned comparisons confirmed that performance was again significantly worse (reflected in more repeated errors) at the higher position in training sets three [t (7) = 2.56, p = 0.019], four [t (7) =2.05, p = 0.04] and five [t (7) = 2.71, p = 0.015].

Overall performance

Thus on all three measures of performance there was a clear advantage in presenting the stimuli at ground level. There was no significant difference in any measure of performance in relation to the stimulus designated correct.

Discussion

Animals learn to respond selectively to certain stimuli. Such training has been be used to assess intelligence and perceptual ability in the horse, discrimination only being possible if the subject can perceive a difference between two or more stimuli. The position of visual stimuli can affect the performance of such tasks. In the present study, all three measures of performance (trials to criterion, accuracy and repeated errors) varied according to the height at which the stimuli were presented. The horses performed the simple visual discrimination significantly better when the stimuli were presented at ground level. The training set data show that this advantage was present from the early stages of testing and remained consistent throughout the trials.

The results of the present study are consistent with what is known about the horse's visual abilities and factors that should improve visual discrimination learning. The visual field of the horse is constrained by the anatomy and physiology of the visual system as well as by the position of the head and the level at which the eye is carried. The lateral position of the horses' eyes, the size and curvature of the cornea, size and horizontal shape of the pupil and angular extent of the retina, together provide the horse with extensive monocular vision. The binocular portion of the visual field is limited to between 65 (Crispin et al., 1990) and 80 degrees (Harman et al., 1999) in front of the horse. The latter investigation concluded that this binocular overlap was located down the horse's nose and not directly ahead as was previously thought. Harman et al. (1999) also found that a blind area existed in front of the forehead. In order to get the clearest possible picture of the visual stimuli, the image must be projected onto the area of the retina with the highest ganglion cell density. This area has been found to coincide with the area responsible for binocular vision, the temporal end of the visual streak (Guo and Sugita, 2000; Harman et al., 1999; Hebel, 1976).

Thus the position of the head and consequently the level at which the eye is carried is important in projecting the visual image onto the most sensitive areas of the retina, particularly whilst the horse is in motion (Saslow, 1999), as when approaching the stimulus boxes in the present study. If the visual field of the horse is as Harman et al. (1999) conclude, then the position of the horse's head on approaching the stimulus boxes at different heights will need to vary accordingly. When the horse lowers its head the binocular field is directed towards the ground and this should allow the ground level stimuli to remain visible as the horse approaches them. By contrast if the horse failed to raise its head sufficiently when approaching the high level presentation used here, the independent evidence on the nature of the visual field would suggest that the stimuli should disappear from view, in which case the horse would then make a "blind" choice.

The preference shown for the ground level stimuli in this study is consistent with the observation that horses prefer to eat from the floor or from low level receptacles (Houpt, 1991). In this position the horse has its binocular field directed towards the ground and has the benefit of being able to scan the lateral horizon for potential threats with its monocular fields (Harman et al., 1999).

Although retinal ganglion cell density has been found to be greatest at the temporal end of the visual streak (Guo and Sugita, 2000; Harman et al., 1999; Hebel, 1976), the total numbers and exact density of these cells has been debated. A recent study into the structure of the equine retina has found large gaps between ganglion cells in most parts of the equine retina (Ehrenhofer et al., 2002). The majority of these ganglion cells were found to be very large and to have input from many amacrine cells, indicating the sensitivity of the visual system to subtle changes in illumination levels and stimulus motion (Ehrenhofer et al., 2002). It is only in the area of the visual streak and a small area close to the optic disc, where there is a well-balanced ratio of photoreceptor, bipolar and ganglion cells, that the horse possesses any real visual acuity (Ehrenhofer et al., 2002). Even in this area it is thought that the horse has a limited ability to see detail (Saslow, 2002; Timney and Keil, 1992). Given the limitations of the equine visual system, it is importance to present visual stimuli in a position that optimizes their perception by the horse. The present study provides direct evidence that equine visual learning can be enhanced by ground level presentations and the associated lowering of the head, even in the simple task of discriminating between black and white stimuli. This advantage is likely to be even more important in more complex tasks of visual discrimination.

This variation in visual ability in relation to head position may account for some differences in the results of studies into equine perception. For example, the earliest published study into equine colour vision (Grzimek, 1952), involved stimuli presented at ground level. The results of this study do not correspond with those of more recent studies, where the stimuli were presented to the horses at nose height (Pick et al., 1994; Macuda and Timney, 1999). Grzimek (1952) found that horses were able to select a green stimulus from various shades of grey, the two more recent studies concluded that they could not. Similarly, with a presentation height of 1.22m from the ground, Smith and Goldman (1999) found individual differences in the colour discrimination ability of horses. Three horses successfully discriminated green and yellow from grey, one horse performed at chance levels for these colours. A study into colour vision in fallow deer

(Birgersson et al., 2001) concluded that this ungulate could discriminate greens from greys, with brightness cues controlled for, when the stimuli were presented at ground level. Food selection by both fallow deer and horses involves mainly green stimuli and is carried out at ground level. Given the positional differences in the performance of visual discriminations demonstrated in the current study, the effect of the height of the stimulus on the ability to discriminate specific colours should be investigated further.

During ridden work the horse must be allowed to alter the position of its head in order to obtain a complete visual picture, particularly whilst in motion (Saslow, 1999). This study provides controlled experimental evidence to suggest that by lowering the head, the horse can better assess ground conditions to improve footing.

The results of this study also highlight the importance of the visual appearance of ground level stimuli to the horse. In designing floor surfaces for use in various locations, e.g. stable flooring, ramps and flooring for trailers, this factor should be considered. Further work is required to assess the visual features of ground surfaces that will optimize horse performance

Implications

The results of the current study show that horse performance in a simple visual discrimination task was significantly improved by presenting the stimuli at ground level. Increasing the speed at which discrimination training occurs is of particular value in psychophysical studies, where the time required to train subjects has limited both the number of subjects used and the amount of data collected. Moreover, the use of different presentation heights provides a likely account of some otherwise discrepant findings in horse visual learning. More systematic behavioural tests of the role of stimulus height will improve our understanding of the functioning of the equine visual system, as well as indicate the optimal presentation method for tests of discriminative ability. The effect of stimulus height would be expected to be even greater with more complex visual discriminations.

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Figure 1. Plan of the testing area, drawn to scale, with the horse in the starting position.

Figure 2. Plan of stimulus box (two identical boxes were used).

Figure 3. Mean accuracy percentages for all subjects for the first five training sets (each set consisting of one session with the stimulus presented in the high position and one session with the stimulus presented in the low position).

Figure 4. Mean error percentages for all subjects for the first five training sets (each set consisting of one session with the stimulus presented in the high position and one session with the stimulus presented in the low position).

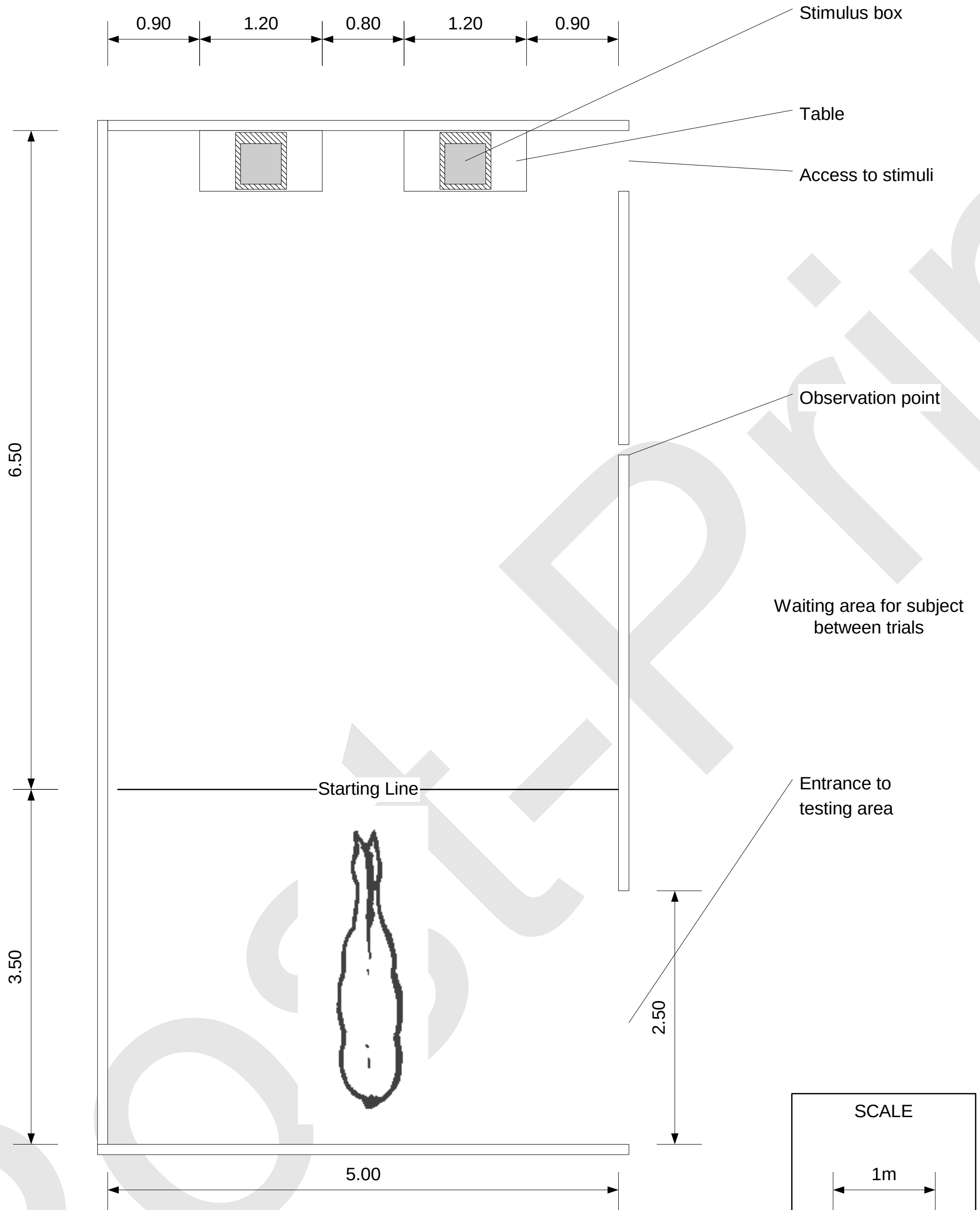
0.90
1.20
0.80
1.20
0.90
Stimulus box
Table
Access to stimuli
6.50
Observation point
Waiting area for subject between trials
Starting Line
Entrance to testing area
3.50
2.50
5.00
SCALE
1m

Figure 1.

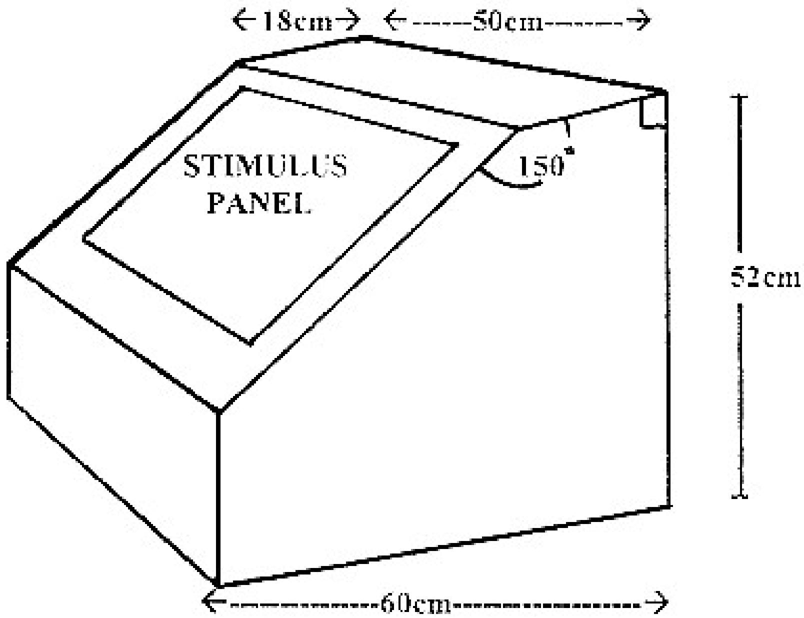

Figure 2.

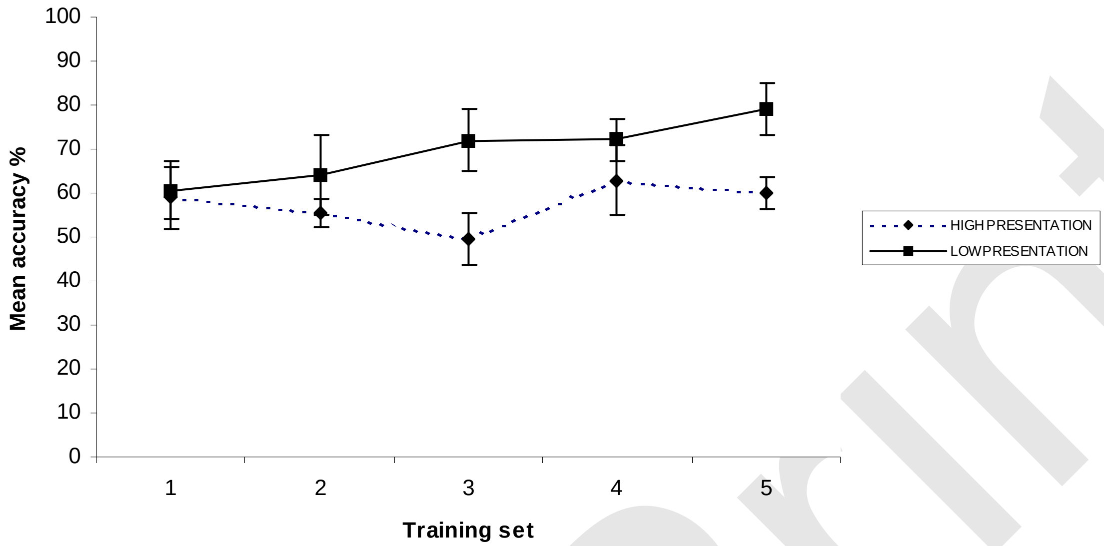

Figure 3.

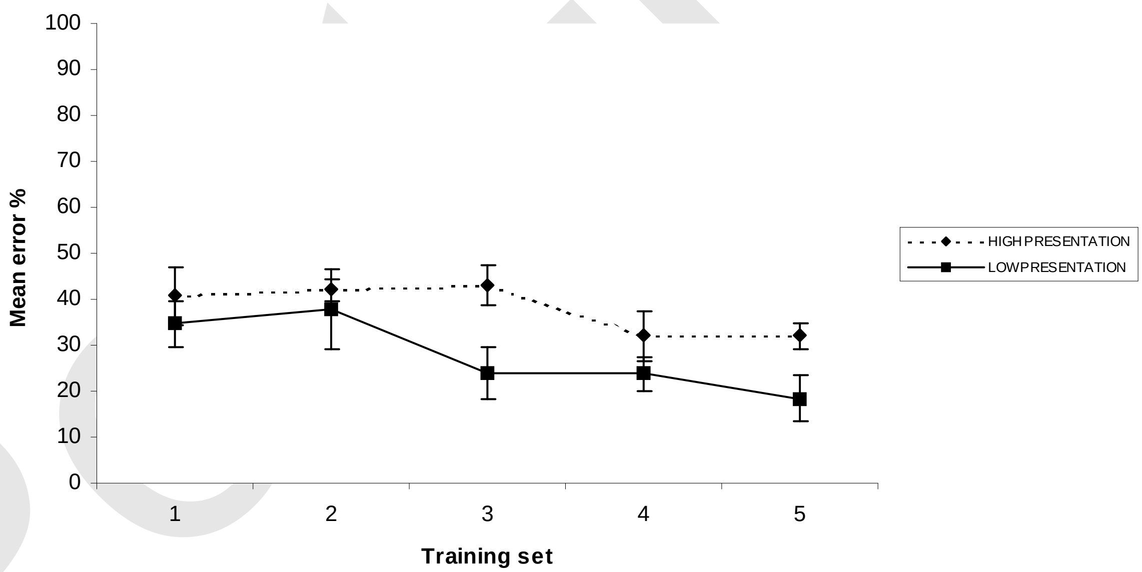

Figure 4.