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USE OF VISUAL AND TACTUAL CUES IN LEARNING OF SIMULTANEOUS SHAPE DISCRIMINATIONS BY ALBINO AND PIGMENTED RATS *(RATTUS NORVEGICUS)*

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ABSTRACT: Albino Wistar, pigmented DA and crossbred (F_1) rats were compared in learning of 4 versions of a simultaneous circle-triangle discrimination. On tasks with 3 dimensional shapes, either with both visual and tactual cues available, or without the tactual cues, albino rats performed as well as the pigmented rats. On tasks with reduction of visual cues, (one task with 2 dimensional cues, the other with tactual cues, and reduced 3 dimensional visual cues), the albino group's performance was significantly inferior to that of the pigmented rats. The two types of pigmented rats did not differ in learning on any task.

In the present study we have examined the differing propensities of albino and pigmented rats to use strong or weak visual cues and tactual cues in the learning of four versions of a simultaneous shape discrimination task.

Albino rats have been used extensively in studies involving visual discrimination (e.g. Bennett & Anton, 1972; Bennett & Ellis, 1968; Gibson & Walk, 1956; Kerpelman, 1965; Oswalt, 1972) in spite of defects in the albino visual system. Albino rats have poorer visual acuity compared to pigmented rats as measured by their thresholds for detection of striations (Lashley, 1930; Montero, 1973). The pigmented (gray) rat's optic nerve has larger axons with thicker myelin (Fukuda, Sugimoto & Shirokawa, 1982; Sugimoto, Fukuda & Wakakuwa, 1984). The albino rat does not show optokinetic nystagmus or vestibular nucleus activity to optokinetic stimuli as is seen in the pigmented (DA) rat (Precht & Cazin, 1979). In the albino there are aberrant retinal projections to the lateral geniculate nucleus (Guillery, 1974), and more of the visual field is represented by uncrossed optic fibres with deficient projections in the visual cortex (Lund, Lund & Wise, 1975). Such visual system differences appear to be

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correlated with lack of pigment in the pigment epithelium of the retina (Lavail, Nixon & Sidman, 1978; Wise & Lund, 1976).

In view of these differences it would not be surprising to find that pigmented rats perform better than albinos on visual discrimination. This is, however, not always the case. In earlier studies we have found that, after undergoing a pre-training exposure condition, albino rats were inferior to pigmented rats in the rate of learning of a three dimensional shape (circle versus triangle) discrimination, with both visual and tactual cues available. However, for control animals given no prior exposure to the cues, albino and pigmented rats did not differ significantly in the learning of the discrimination task (Bell & Livesey, 1981).

This finding that, in spite of an inferior visual system, the albinos performed at a level comparable with that of the pigmented rats in the control condition became our focus of interest in the current experiment.

In other studies involving pre-exposure to discrimination cues, investigators have found that albino rats needed three dimensional cues (tactual and visual) to solve shape discriminations. Albinos were not able to learn a two dimensional shape discrimination unless given lengthy prior and simultaneous exposure to three dimensional (3D) shapes (Gibson & Walk, 1956). If such exposure was to two dimensional (2D) shapes, rats did not learn the discrimination (Walk, Gibson, Pick & Tighe, 1959). Bennett and Ellis (1968) demonstrated that exposure in which albinos were able to manipulate the 3D forms, led to significantly better learning of the 2D task, compared with visual only exposure to the 3D forms. They argued that this was probably the result of tactual/kinesthetic feedback. In exposure experiments with pigmented rats, however, visual-only 3D cues were found to be effective in enhancing discrimination learning, with opportunity to manipulate the shapes providing no extra gain (Bennett, Rickert & McAllister, 1970).

In view of the above findings it seemed likely that, in our control condition (Bell & Livesey, 1981), the albinos made use of both the visual and tactual cues, possibly relying more strongly on the tactual information, while the pigmented animals made more use of the visual information. In the present experiment we set out to resolve whether albino rats do use a different strategy than do pigmented rats in solving this discrimination task, and in comparison, how they performed on the shape task without tactual cues.

For this purpose we utilized four versions of the circle-triangle discrimination which differed in availability of visual and tactual cues. A simultaneous discrimination paradigm was employed in a within experiment comparison of albino and pigmented rats. The tasks employed were (i) the previously used three dimensional, visual/tactual discrimination (VT), (ii) the three dimensional discrimination without access to the tactual cues (3DV), (iii) the 3D task with the tactual cues but with markedly reduced visual cues (TRV), (iv) a task with two dimensional visual cues only (2DV).

In our previous experiments, the albino rats used were from a Wistar strain and the pigmented rats a DA strain. These were not inbred groups and, in addition to differing in terms of the albino gene, the two stocks were known to differ in coat colour genes; the DA rats being homozygous for the agouti allele (AA), while the Wistars were homozygous for non-agouti (aa); and they also differed at the white spotting or hooding locus (HH versus hh) and the brown locus (BB versus bb) (Robinson, 1979). These coat differences were established in the two stocks we were using by a crossbreeding programme, examining F_2 and backcross progeny. Strain differences other than those associated with the albinos' visual anomalies might conceivably be important in a learning context. For example differences in reactivity could have differential effects on discrimination learning (e.g. Cowan, 1977; Harrington, 1971). Because of this and to gain further information on differences between different types of rat, we included a sample of crossbred (F_1) rats, the offspring from Wistar-DA matings. The learning patterns of these heterozygotes could thus be compared with those of the parent strains. While the F_1 rats were pigmented and therefore had the same pigmentation of the eye as the DAs, they did not have the particular phenotype of either strain. It is reported too, that animals heterozygous for albinism do share some of the visual neural deficits of albinos though not to the same extent, e.g., hooded rats show some reduction in optic nerve axons and myelin (Fukuda, et al. 1982).

Thus, in this experiment, separate groups of Albino Wistar (W), Pigmented DA (DA), and F_1 rats were given the four versions of the circle-triangle discrimination. In view of our earlier finding (Bell and Livesey, 1981) it was anticipated that albino rats would perform as well as pigmented animals on the VT task. Evidence from other studies indicated that the DA rats would be superior to W rats learning the 2DV task. If the albinos rely more on tactual than on visual cues to solve the VT task then we would expect them to perform at least as well as the DA animals on the TRV task but not on the 3DV task. We expected that the DA rats would do equally as well on the 3DV as on the VT task. If the differences in learning between the DA and W rats were due to differences in visual capability and not significantly affected by other strain differences, then the F_1 rats would not differ significantly from DA rats in learning of these tasks.

METHOD

The design of the experiment was a three by four factorial: with three types of rat (W, DA & F_1) and four tasks: (VT, 3DV, 2DV, and TRV).

Animals

(a). Thirty-two albino rats from Wistar stock (W1MWA) of the Animal Resources Centre (ARC), Murdoch, Western Australia. A closed breeding colony had been maintained for 20 years at the University of Western Australia prior to transfer to the ARC in 1981. It is believed that the stock originally came from Adelaide, South Australia. (b). Thirty-two rats from DA stock of the Psychology Department, University of Western Australia. This colony was established in 1973, with stock from the Walter and Eliza Hall Institute of Medical Research, Victoria, Australia. (c). Thirty-two F_1 (crossbred) rats, offspring of reciprocal matings between Wistar and DA rats. These F_1 rats were of similar appearance to the DA's i.e., pigmented agouties, but were distinguishable by patches of white fur on the legs and belly, due to the heterozygous form of the white spotting gene.

The rats were all male and aged between 60 and 70 days at the beginning of the experiment. Animals from each rat type were allocated randomly to each of the four tasks, with eight rats per type per task.

Housing consisted of racked small cages (36 x 26 x 20 cm) with wire mesh front and back and solid metal sides. Rats were housed two from the same group to a cage. The air-conditioned housing room was with a 12 light and 12 dark cycle.

Apparatus

The discrimination apparatus was one used previously for experiments on prior exposure and shape discrimination learning (Bell & Livesey, 1981). It comprised a small mesh cage (36 x 26 x 20 cm) joined along one of the longer sides to a wooden compartment (25 x 26 x 20 cm), which was painted flat grey. The compartments could be separated by a metal slide. A clear Plexiglass lid was hinged over each section. In the end of the wooden compartment opposite the cage section were two openings 9 x 9 cm, 4.5 cm apart. There were small food wells, one behind each opening. Backing onto each opening and hung from a metal rod was an aluminium panel (16 x 10 cm) on which each discriminative stimulus was displayed. The panels were held closed against the back of the openings by magnetic tape. A grey wooden shutter could be lowered in front of the cue panels.

All tasks involved a discrimination between an equilateral triangle (6.8 cm/side) and a circle of equal area (diameter 5 cm). For the VT task each shape was three dimensional, being 1 cm thick, and each was painted white on a black panel. For the 3DV tasks the stimuli were the same, but each shape was covered by a clear plastic plate (7.5 x 7 cm), so that the three dimensional shapes were clearly visible but could not be touched. The plastic plates were attached to the stimuli by white, doublesided tape, which covered the surface of the shapes. For the TRV task shapes were the same as for VT and 3DV tasks but were white on white panels and the room lights were dimmed. For the three visual tasks the luminance reading in the discrimination area was 15.1 lux; but for this task it was reduced to 0.95 lux. For the 2DV task each cue was the same size as the 3D shapes, but was only two dimensional, being painted white on a black panel.

Procedure

The rats were placed on a restricted diet with water available ad libitum and were handled daily for six days before testing commenced. The rats were fed a set amount of food daily to maintain an appropriate level of motivation (at about 90% of ad lib. feeding body weight). As the albino and F_1 rats were heavier and ate more food ad lib. than did the DA rats, these two groups required slightly more food during the experiment to maintain a similar level of deprivation.

Pretraining. Each rat was placed in the discrimination apparatus and allowed to explore and eat from the food wells for fifteen minutes on each of two days. The reinforcement was minced, concentrated dog food (Loyal), shaped into small pellets. On the third day, each rat was taught to push the pretraining panels open (these were plain black) and to receive the food pellet from behind the panel. Each rat was required to complete 10 trials of panel push responses. If an animal adopted a position strategy (3 trials to one side) it was not rewarded for the next trial until it shifted its response to the other side.

Training. All rats were given 10 trials per day on their particular task with the position of the positive stimulus being varied according to Fellows' (1967) revision of the Gellerman sequence. A noncorrection procedure was used. If the rat responded incorrectly the shield was lowered immediately in front of the discriminative cue panels and the rat returned to the starting compartment ending the trial. An incorrect response was defined as a push on the panel with the negative cue. For a correct response, the rat pushed open the panel with the positive cue, and received a food pellet that was introduced from behind the panel on the end of a rod. To emphasise the negative cue in the initial learning trials, a wooden block was placed behind the negative panel for the first 30 trials. The block was positioned so that the panel would be blocked after opening only sufficiently to activate the negative response warning light. On later trials, when the animal pushed the negative panel, it swung open and then the experimenter closed it and the shield. This procedure was to prevent the rats from attempting to use the blocking of the panel as a pressure cue. If a rat scored 7/10 or better before completing 30 trials, the wood block was removed at that stage. Training was continued until a criterion of 90% correct responses over three consecutive days (27/30) was reached. Training was stopped at 300 trials if criterion was not attained. Two experimenters (the authors) trained the rats. For each task, half the rats were trained with the circle as the positive cue, the other half with triangle positive.

RESULTS

The main measure used was total number of errors (either to criterion or to 300 trials). This was preferred to the measure of number of trials to criterion because a number of albino rats failed to reach criterion. Progress in learning for each group is shown in Figure 1 in terms of mean percentage of correct responses for each successive block of 10 trials.

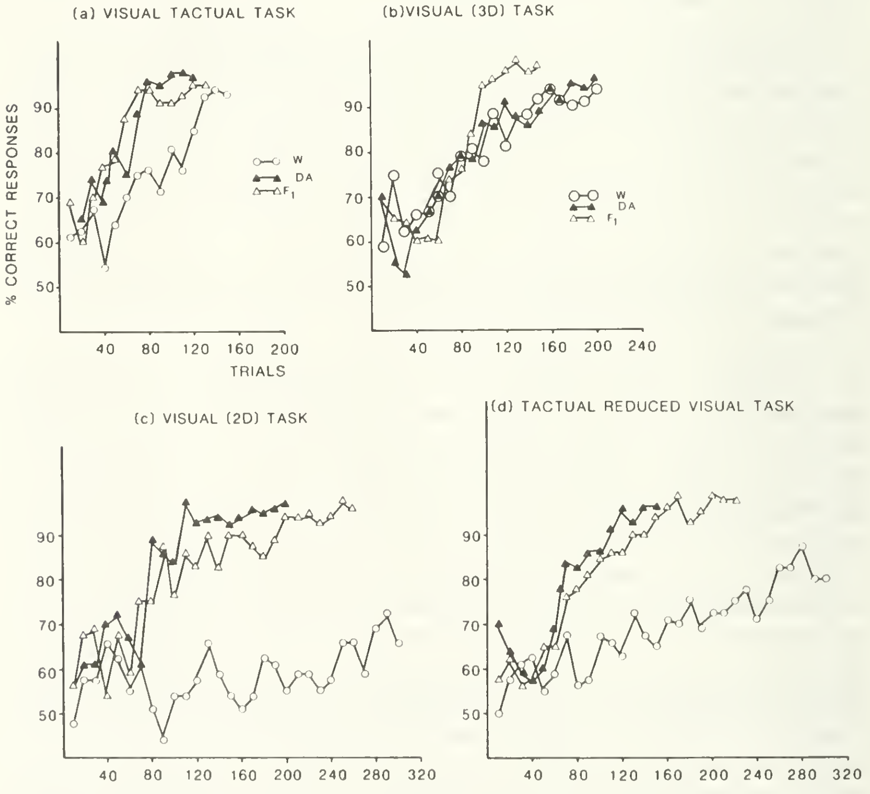

FIGURE 1. Mean percent correct responses for blocks of 10 discrimination trials for Albino Wistar (W), Pigmented DA (DA) and F1 rats on the four tasks; a 3D Visual Tactual (VT). b.3D Visual (3DV). c.2D Visual (2DV). d. Tactual, Reduced Visual (TRV).

It is evident from the figure that there was little difference between W, DA and F_1 rats on the VT and 3DV tasks. However, on the 2DV and TRV tasks, the albino rats showed only slight improvement over the 300 trials whereas the pigmented animals learnt these tasks readily.

The analysis of errors confirmed these differences and also highlighted some more subtle differences. Figure 2 shows mean total errors for each rat type over the four tasks.

Analysis of variance revealed a significant rat factor, F(2,84) = 47.18, $p < .01$; a significant task factor, F(3,84) = 21.62, $p < .01$ and a significant interaction, F(6,84) = 11.5, $p < .01$. One way analyses were conducted within each factor to establish the basis for the interaction. For the rat analysis the significance level was set at .05/3 groups, i.e., .016 (Kirk, 1968). It was found that the rat stocks did not differ significantly in errors on the VT and 3DV tasks but there were significant differences on the 2DV task, F(2,84) = 55.5, $p < .01$; and on the TRV task, F(2,84) = 23.3, $p < .01$. As is evident in Figures 1 and 2, it was the W groups that performed poorly on these two tasks; with only one W rat reaching criterion on the 2 DV task and three reaching criterion on the TRV task. All the pigmented rats reached criterion on these tasks. For the task analysis (significance level of .05/4 tasks, i.e., .0125), only for the albino rats was there a significant difference in errors between tasks, F(3,84) = 40.8, $p < .01$. On the TRV task the albino rats made significantly more errors than on the VT and 3DV tasks while, on the 2DV task, significantly more errors occurred than on the other three tasks.

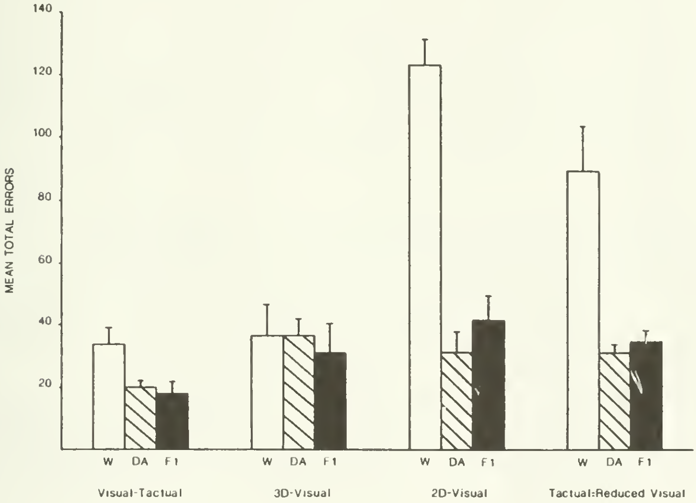

FIGURE 2. Mean total errors and standard errors for Albino Wistar (W), Pigmented DA (DA) and F1 rats on the four tasks. a. 3D Visual Tactual (VT). b. 3D Visual (3DV). c. 2D Visual (2DV). d. Tactual, Reduced Visual (TRV).

Thus, for pigmented rats, all four tasks were of a similar level of difficulty, all being learnt readily. For the albino rats, performance on the VT and 3DV tasks was comparable with that of the pigmented animals but much more difficulty was experienced with the other two. The TRV task was significantly more difficult for the W rats, with the majority failing to reach criterion, while the 2DV task proved the most difficult.

Further information on the use of visual and tactual cues was gained from observation of rats during training on the VT and TRV tasks, where both cues were available. One experimenter recorded instances of unambiguous use of either visual or tactual cues on trials where a correct choice was made. A rat was recorded as using visual cues if the choice of stimulus was made well before it could make physical contact with the stimulus. Use of tactual cues was defined as contact with both shapes, usually by vibrissae, snout or mouth, before making a correct choice. A total of 8 W, 10 DA and 8 F_1 rats, over both tasks, were recorded as demonstrating unambiguous cue use. The other rats appeared to be using a mixture of cues on a particular trial, or it was not possible to ascertain what they were doing. For example, rats often made physical contact with one shape, then appeared to visually inspect the other before making a choice, responding to the first stimulus.

Table 1 shows proportions of rat groups using (a) visual cues only, (b) tactual cues only, (c) visual cues on some trials and tactual cues on others and (d) undetermined or ambiguous cue use.

Over both tasks, more of the albino rats used tactual cues, either alone or interspersed with visual cues, whereas the pigmented rats, particularly, the DAs, favoured the visual cues even on the TRV task. The F_1 rats' cue use fell between that of the two strains. The three W rats

TABLE 1
Proportions of Rat Groups Using Different Cues While Learning the VT and TRV Tasks

	W		*DA*		*F_1*	
RAT TASK	*VT*	*TRV*	*VT*	*TRV*	*VT*	*TRV*
Cue use:						
a) Visual only	.125	0	.5	.25	.25	.125
b) Tactual only	0	.375	0	.125	0	.125
c) Visual and Tactual	.5	0	.25	.125	.375	.125
d) Ambiguous	.375	.625	.25	.5	.375	.625

which used tactual cues alone did not reach criterion. Thus the use of tactual cues alone did not appear to be a successful learning strategy although it appeared that many rats were successful with some combination of visual and tactual cues (see proportions of groups in categories c and d).

DISCUSSION

The results for two of the tasks were as predicted, with the Wistar rats learning the 3D Visual-Tactual task readily, but proving much less capable on the 2D Visual task. The results for the other two tasks were not expected, particularly with regard to the difficulty the Wistar rats experienced with the Tactual-Reduced-Visual task, for which it was thought that they would use the tactual cues to effect learning quite readily. The success of the Wistar rats on the 3D Visual task was also surprising in view of the reported superiority of the pigmented rats in visual acuity.

A study has demonstrated that there are a considerable number of binocular cells in the albino rat visual cortex, particularly around the border between areas 17 and 18a (Diao, Wang & Pu, 1983). The proportion of binocular cells was lower than in pigmented mice and hamsters; however, the proportion in the albino rat was higher than in other albino animals such as the Siamese cat. In the rat much of the binocular input appears to be from callosal fibres, which contribute input from the ipsi-lateral eye. Blakemore (1969) has suggested that such callosal input may be important for stereoscopic vision. Our finding that albino rats were able to make significantly better use of the 3D than the 2D visual cues is congruent with the proposition that they have some stereoscopic vision. Other cues not necessarily related to binocularity may also have increased the salience of the 3D cues (e.g. shadows).

Another outcome that was not anticipated was the relatively poor performance of the Wistar rats on the Tactual-Reduced Visual task. It was expected that the albinos would show greater reliance on tactual cues than pigmented rats and would thus be able to perform adequately on this task. Proportionately more of the Wistar rats did appear to try to use tactual cues but were not successful with this strategy. The response required in the task, i.e. a press on the panel bearing the cue, may well have adversely affected the performance of the tactual discrimination. From the observations recorded during training it appeared that when the rat contacted the panel to test the cue tactually it had difficulty inhibiting the press response when the incorrect panel was tested. With visual cues the inhibition of response to the cue could be spatially separated from the operant press response that followed contact with the panel. An equivalent separation of cue testing from operant response would therefore seem necessary if a direct comparison is to be made of the efficacy of visual versus tactual cues.

A second problem, evident with the albinos particularly, was in the attention paid to an irrelevant cue, namely the pressure required to push open the stimulus panels. Rats appeared to attempt to assess which panel would open more easily, but of course such a strategy did not correlate in any way with the positive stimulus as there was no difference in the way the panels were held and in any case the correct panel varied from side to side at random. This appeared to interfere particularly with W rats' learning of the TRV and 2DV tasks. On these tasks, although the majority of the W rats did not reach criterion, some did show good performance on some days. On the 2DV task, besides the rat that reached criterion; three scored 9/10 at least once, three scored 8/10 at least once, and the other rat did not get beyond 7/10. On the TRV task, apart from the three rats that reached criterion, four scored 9/10 at least once, and the other, 8/10. The pattern on both tasks towards the end of training, for those rats which did not reach criterion, was for a good score on one or two days followed by one or more days with low scores. Thus the rats apparently were able to attend to and use the relevant cues on some days but had great difficulty in sustaining performance over a long enough period to reach criterion. They seemed to revert to using irrelevant cues, particularly the pressure required to open the panels. Therefore, as we had initially assumed, quite a number of W rats tried to use tactual cues but this was not a particularly effective strategy in this apparatus.

In this study the anticipated difference between albino and pigmented rats in the ability to use weak visual cues was evident; but there was no difference with stronger visual cues. This difference with the weak cues does not appear to be due to any strain differences other than those related to abnormalities of the albino visual system, as the F_1 pigmented rats performed similarly to the DA rats on initial task learning.

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