

Research report

# Rats' responsiveness to tactile changes encountered in the dark, and the role of mystacial vibrissae

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## Abstract

This study aimed to assess male and female rats' ability to utilize egocentric cues for detecting a change in tactile stimulation encountered in the dark (and possible sex differences). It also investigated the role of mystacial vibrissae in tactile discrimination in this particular setting. Hooded rats of both sexes were accordingly exposed, in the dark, to Y-maze arms with either two rough (sandpaper) or two smooth floors (Perspex), or one rough and one smooth floor. One of the floors was then changed to the opposite type of surface and the rats' ability to locate and explore this changed (or novel) arm in the dark was measured. Both sexes were able to complete this task successfully thereby suggesting that they had used egocentric body cues, rather than visual or olfactory cues for locating the position of the novel arm. Because rats with all their mystacial vibrissae removed were not seriously disadvantaged in locating and exploring the tactually novel arm, it appeared that their ability to discriminate between the tactile properties of the maze arms was not crucially reliant on their whiskers and allied trigeminal system, and may have also involved tactile receptors in their paws. It was concluded that rats of both sexes were able to utilize egocentric cues in detecting a tactile change, and did not rely exclusively on mystacial vibrissae for discriminating between the tactile properties of the maze-arm floors.

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## 1. Introduction

Half a century ago, two important papers were published describing experiments that aimed to resolve two then conflicting interpretations of the motivation of exploratory behavior in animals. In the first paper by Kiviy et al. [35], laboratory rats were able to see into but not enter two black (or white) arms of a T maze by means of transparent barriers placed across each arm entrance. After 1, 5 or 15 min, the rat was removed while an insert comprising a floor, two side walls and an end wall was swapped for one of the opposite brightness, and the transparent barriers were withdrawn. The rat was then re-introduced into the maze for a choice trial. These authors reasoned that, during the earlier exposure trial, the rat would have become "satiated" for the brightness of the arms and would have consequently avoided the same brightness thereby choosing the different brightness. Such a prediction was based on a "boredom" explanation for explo-

ration whereby familiar stimuli were said to initiate exploratory acts that were reduced in strength and accordingly reinforced when novel stimuli were encountered [19]. As Kiviy et al.'s rats entered the changed arm after a prior exposure trial of 15 or 30 min, the results were interpreted as confirmation of the satiation explanation.

In a subsequent paper, Dember [10] reversed the brightness conditions of the exposure and choice trials, thereby confronting his rats with two arms of the same brightness for all their choices. The rats continued to enter the arm that had changed from what it had been during exposure trials even though they should have been satiated for both black and white and thus show no preference for either [10]. It was accordingly concluded that the rats had been attracted to explore the novelty of the brightness change thus supporting the opposing "curiosity" explanation which maintained that exploration was initiated (and also reinforced) by novel stimuli [19]. This finding was subsequently confirmed in several studies involving rats [18,41,48], ferrets [24] and opossums [42]. Although on their own, Dember's results were not able to conclusively resolve the conflict between the two interpretations, his experiment provided an intriguing procedure that

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was adopted by a number of later authors as a measure of short-term recognition memory, chiefly in investigations of drug and lesion effects [4,20,39,40,44].

More recently, the procedure has been modified to include longer-term measures of responsiveness to change in a Y maze so as to provide ordinal scales of measurement (as well as the nominal scale of a changed arm entry or not that had characterized all prior research), and repeated-measures designs [25]. The resulting measurement, economic and animal welfare improvements have proved useful in the investigation of effects of memory-enhancing agents on rats [26–28,32]. It now appears that the ability to detect which of the two arms has changed depends on sex-related responsiveness to place-related (or allocentric) visual cues within and outside of the apparatus [31] in a similar fashion to what characterizes tests of spatial learning and memory [15,34]. However, it also seemed possible that females were better than males at utilizing response-related egocentric cues based on relationships between body position characteristics (involving vestibular and kinesthetic cues), and the maze arm that was subsequently changed [31].

Like so many laboratory tests of rat behavior, the responsiveness-to-brightness change procedure relies on a sensory modality that is of minimal significance for this nocturnal species for which, in natural settings, olfactory, tactile and vestibular/kinesthetic cues are obviously of greater importance when navigating their mainly dark environment. In a recent investigation, it was accordingly shown that rats' ability to locate a changed Y-maze arm is not confined to brightness, but will also occur with a tactile change from two rough (or smooth) floors to one rough and one smooth, or vice-versa [30]. Since all subjects in this study were tested in dim fluorescent lighting, it was likely that their ability to locate the tactually changed arm depended on visual cues within or outside of the apparatus, as typified at least male rats in the most recent responsiveness-to-brightness change study [31]. It was also not possible to determine if the rats had sampled the tactile characteristics of the maze-arm floors mainly by means of their vibrissae [22] and allied trigeminal system, or through receptors in their paws [5,21].

The aims of the present study were therefore (1) to see if rats are able to detect a tactile change when tested in the dark (thereby requiring the use of egocentric in the absence of visual cues), (2) to investigate possible sex differences in ability to utilize egocentric cues alone, and (3) to determine the role of mystacial vibrissae in perception of the tactile properties of the maze-arm floors.

## 2. Experiment 1

As the sense of touch is the first to develop in the mammalian fetus [1,7,23], it is reasonable to expect tactile stimuli to play an important part in postnatal behavior of the rat. For example, tactile stimulation resulting from maternal interactions with [12] and human handling of pre-weanling rats has long been known to contribute to the development of lower levels of emotional reactivity and associated corticosterone responsiveness [38]. This in turn leads to increased curiosity [11,13] and better avoidance learning [36,37]. As rats are able to relatively easily

discriminate between surfaces of varying tactile properties (e.g. [8,11,14,17,30,46]), it is conceivable that they are able to use such information for navigating a dark environment in addition to or instead of directional allocentric cues based on other non-visual modalities. However, if non-visual or other allocentric cues were insufficiently salient, it is likely that egocentric cues would need to be utilized instead. The present experiment was accordingly designed to assess rats' ability to locate a change in tactile stimulation without the aid of visual or other identifiable allocentric cues.

### 2.1. Materials and methods

#### 2.1.1. Animals

The subjects were 24 male and 24 female 8-months old Long-Evans hooded rats that had been bred in the Animal Facility of the Department of Psychology, University of Canterbury. They were housed in groups of three or four same-sexed animals with *ad libitum* food and water in 12-h light:12-h dark with an ambient temperature of  $20 \pm 1$  °C. To avoid any disrupting effects of being suddenly removed from the dark colony room into illuminated areas of the building, all testing was carried out during the light phase of the light:dark cycle.

#### 2.1.2. Apparatus

All subjects were tested in a clear-varnished wooden Y maze with 45-cm long arms and a 30-cm stem. The maze was 14 cm high and 10 cm wide, and each arm contained a black-painted aluminum liner comprising an end wall, two side walls and a wooden floor insert onto which had been glued coarse sand paper (grade 40 grit) that was either left uncovered ("rough") or covered with thin, clear Perspex ("smooth"). The thickness of both types of floor was 6 mm. The apparatus was covered by hinged clear Perspex lids apart from the south end of the stem over which was a 15 cm × 12 cm wooden lid that enabled rats to be introduced into the maze. The apparatus sat on a 76 cm high table behind dark curtains.

#### 2.1.3. Procedure

For all rats, each testing session consisted of a 6-min acquisition trial and then, 90 s later, a 1-min retention trial. Both trials were conducted entirely in the dark. In the course of four testing sessions, 12 rats of each sex experienced a total of four acquisition followed by four retention trials (one pair/session) that were defined as "cued" because each arm contained a floor of differing tactile properties, namely, one rough and the other smooth. For two of the retention trials, the change was from both floors rough, and for the other two it was from both floors smooth. The remaining 12 males and 12 females experienced a total of four acquisition and then four "non-cued" retention trials which were more demanding on memory [30] because they involved the reverse sequence of textured floors to the cued condition namely, a change from one rough and one smooth floor to both floors rough for two trials, and both floors smooth for the other two. For all subjects, the novel arm was on the left for half the retention trials in each condition, and on the right for the other half. The position of the novel arm and whether it was cued or not was randomly determined for each subject on each of its testing sessions. As the incentive to perform in responsiveness-to-change tasks is relatively weak, each rat's testing sessions were separated by at least 24 h so as to maximize interest in exploring a novel arm. After this period, rats are unable to locate an arm that has changed in brightness without the assistance of a memory-enhancing agent [32].

Each testing session for an individual rat involved placing it in the stem of the apparatus with either both arms containing rough or smooth floors, or one arm containing a rough and the other containing a smooth floor. After 6 min, it was returned to a holding cage outside of the curtained area for 90 s while, under conditions of very low illumination, both arm liners were replaced with clean liners containing a rough and a smooth floor, or by inserts that both contained either rough or smooth floors. Replacing both floors plus washing the whole apparatus (including the internal surfaces of the Perspex lids) with a 2% solution of the disinfectant, Powerquat Blue, minimized the possibility of olfactory cues influencing the rats' arm choices during retention trials. The low-level

illumination was then extinguished and the rat was returned to the stem of the apparatus entirely in the dark for its retention trial after which the apparatus was washed again.

All data was recorded on video tape by means of an infrared camera suspended above the apparatus and a video recorder and monitor in an adjacent room. Following the rat's first complete entry of an arm, its behavior was recorded for exactly 1 min, which is the optimum period for assessing responsiveness to change before habituation leads to indifference to both arms [25]. Nobody was present in the experimental room during either acquisition or retention trials, and the light level in the apparatus for both was 0 lx. Subsequent analyses of the video tapes enabled determination of whether or not the changed arm had been entered first, the number of entries of and time spent in both arms, and the percent entries of and time spent in the changed (or novel arm).

2.2. Results

For each rat, choices/day of the novel arm were calculated as percent first entries of, percent repeated entries of and percent time spent in it. Total entries of and total time spent in both arms/day were also calculated. For the rats in each novelty type group (cued and non-cued), individual scores on each of these measures comprised averages of the two retention trials experienced with the novel floor rough, and the two trials with the novel floor smooth. All data were then subjected to separate 2 (sex) × 2 (novel floor texture) × 2 (novelty type) ANOVAs with repeated measures on novel floor texture (see Table 1 for main effects). One-sample *t*-tests were also applied to the three measures of novel arm choice for each sex, novelty type and novel floor texture to determine whether or not they differed from chance expectancies of 50%.

2.2.1. Percent first entries of the novel arm

Although main effects were not significant for sex, novelty type (cued or non-cued), or novel floor texture (rough or smooth), there was a significant interaction between sex and novelty type ( $F(1, 44) = 5.65, p < 0.025$ , see Fig. 1).

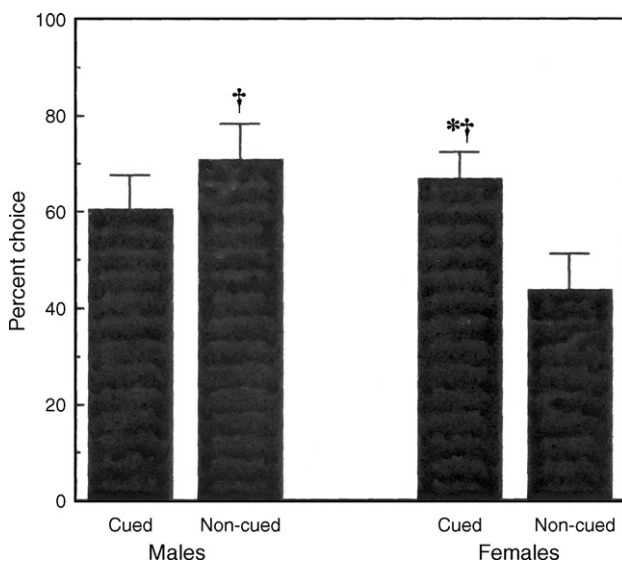


Fig. 1. Mean (+S.E.M.) percent first entries of the novel arm for male and female rats faced with cued and non-cued novel floors. Difference between the two novelty types significant for each sex (\* $P < 0.025$ ). Significantly greater than a chance expectancy of 50% (one-sample *t*-test, † $P < 0.05$ ).

Table 1  
Mean (±S.E.M.) percent per day first entries and repeated entries of and time spent in the novel arm, repeated entries of and time spent per day in both arms for males and females, the two novelty types, the two novel floor textures, and results of ANOVAs and one-sample *t*-tests (d.f. = 22)

	Sex		Novelty type		Novel floor texture		F(1, 44)
	Females		Cued		Smooth		
	Males	Females	Cued	Non-cued	Smooth	Rough	
Percent first entries of novel arm <sup>a</sup>	65.63 (±7.31)	55.21 (±6.62)	63.55 (±6.41)	57.29 (±7.53)	64.58 (±4.70)†	56.25 (±5.08)	1.75
Percent repeated entries of novel arm	57.59 (±2.04)†	54.64 (±2.07)†	58.15 (±2.18)†	54.07 (±1.88)†	55.90 (±1.58)†	56.31 (±2.10)†	1.45
Percent time spent in novel arm	58.23 (±2.41)†	56.44 (±1.95)†	60.43 (±2.55)†	54.24 (±1.54)†	57.07 (±2.22)†	57.60 (±2.44)†	<1
Total entries of both arms	3.06 (±0.21)	3.03 (±0.17)	2.67 (±0.19)	3.43 (±0.16)	2.94 (±0.16)	3.16 (±0.15)	2.01
Total time spent in both arms (s)	26.74 (±1.25)	28.15 (±1.32)	25.67 (±1.45)	29.22 (±0.99)	24.91 (±1.13)	29.98 (±1.09)	14.08**

<sup>a</sup> Sex × novelty type interaction significant (see text).

\*  $P < 0.05$  for effects of novelty type.

\*\*  $P < 0.01$  for effects of novelty type and novel floor texture.

† Significantly greater ( $P < 0.05$ ) than a chance expectancy of 50%.

This was due to significantly fewer first entries of the novel arm when confronted with non-cued than with cued novelty for females [ $t(22) = 2.42, P < 0.025$ ], but not for males [ $t(22) = 1.01$ ], and a significant sex difference favoring males in the former condition [ $t(22) = 2.55, P < 0.02$ ]. First choices of the novel arm significantly exceeded chance expectations of 50% for males faced with non-cued novelty, for females faced with cued novelty, and for all rats when the novel arm had a smooth floor.

#### 2.2.2. Percent (repeated) entries of the novel arm

The effects of sex, novelty type and novel floor texture on this measure all failed to reach significance, and no interactions were significant. However, repeated entries of the novel arm were significantly greater than 50% in each condition.

#### 2.2.3. Percent time spent in the novel arm

While there were no significant effects of either sex or novel floor texture, significantly less time was spent in the novel arm when the rats encountered non-cued rather than cued novelty. Nevertheless, the rats in both these groups spent significantly more than 50% of their time in the novel arm, as also typified each sex and all rats' choices of the novel arm when it was either rough or smooth. No interactions were significant.

#### 2.2.4. Total entries of both arms

This measure was affected by neither sex nor novel floor texture, but rats that were faced with non-cued novelty entered both arms significantly more often than those faced with cued novelty. No interactions were significant.

#### 2.2.5. Total time spent in both arms

Although sex had no significant effect on this response, rats that encountered non-cued novelty spent more time in both arms than those for which the novelty was cued. The subjects also spent significantly more time in the arms when the novel floor was rough than when it was smooth. As this result suggested a preference for a rough rather than smooth floor, differences in the non-cued condition between time spent in the arms when both were either rough (mean  $\pm$  S.E.M. =  $31.20 \pm 1.39$  s) or smooth ( $27.71 \pm 1.42$  s), were compared by means of a  $t$ -test. The difference was not significant [ $t(23) = 1.92$ ]. No interactions were significant.

### 2.3. Discussion

The most striking outcome of this experiment was the clear indication that the rats efficiently located and continued visiting the tactually novel arm in the absence of visual or other obvious allocentric cues. This was more evident in their longer-term choices than in their initial entry of an arm. Apart from this latter response for females, whether the novelty was cued or non-cued did not appear to prevent the animals from successfully locating the changed arm (even though all rats spent less but still significantly more than 50% of their time in it when it was non-cued). Similarly, differences in texture of the novel floor did not detract from their longer-term preferences for the novel arm.

Although novelty type and novel arm floor texture only had minor effects on the novelty choice measures, there was more evidence of their influence on repeated entries of and time spent in both arms, namely, increases in each when the rats encountered a non-cued novel arm, and longer time spent in both arms when the novel arm floor was rough rather than smooth. It is possible that, because non-cued novelty involved being faced with two arms of the same floor texture, it was more difficult to locate the novel arm thereby requiring more tactile sampling of both. As suggested by the total time spent in both arms, it is also possible that the smooth novel floor was slightly less preferred than the rough, but this was not supported by either the lack of floor texture effects on preferences for the novel arm, or the non-significant difference between rough and smooth floors in the time spent in the two arms for rats in the non-cued group (when both comprised the same texture).

The results of this experiment strongly suggest that, in the absence of salient allocentric cues, rats are able to make use of egocentric information for locating the position of a maze arm that has changed from what it had been during a prior acquisition trial. The nature of the test environment made it very unlikely that their choices were based on visual or other cues either within or outside of the apparatus. Instead, it is possible that each rat's behavior was guided by associations between kinesthetic cues arising from the orientation of its body in relation to the position of the novel maze-arm before and then after it had changed in its tactile properties. When locating a brightness change, female rats appeared to utilize visual landmarks to a lesser extent than males and were probably better at making use of kinesthetically based egocentric cues [31], as is evident in other memory tasks [34]. However, the lack of sex-related differences in the present experiment (apart from first entries of the novel arm for rats faced with non-cued novelty) suggests that, when visual cues are not available, males are no less effective than females in utilizing egocentric cues for locating a changed maze arm. While this was also possible for the earlier report of responsiveness to a tactile change in which sex differences were similarly unimportant [30], because all rats were tested in the light, their use of visual information in addition to or instead of egocentric cues (especially by males) could not be ruled out. And in addition, even though considerable effort was put into removing any influence of odor cues in both the present and earlier experiments, there remained the possibility that the sandpaper on the wooden floor inserts had provided olfactory cues generated by glue used in its manufacture and/or to attach the sandpaper to the inserts. If so, such cues may have been masked by the clear Perspex covers over the sandpaper on the smooth inserts thereby producing a distinguishable olfactory difference between the rough and smooth floors.

### 3. Experiment 2

This second experiment was designed to determine whether or not any possible glue-derived differences between the two types of floor had played a part in determining the results of Experiment 1. Although there do not seem to be any recorded studies of rats' olfactory responsiveness to sandpaper glues,

Table 2

Mean ( $\pm$ S.E.M.) percent per day first entries and repeated entries of and time spent in the novel arm, repeated entries of and time spent per day in both arms for males and females and the two novel floor textures, and results of ANOVAs

	Sex		<i>F</i> (1, 22)	Novel floor texture		<i>F</i> (1, 22)
	Males	Females		Smooth	Rough	
Percent first entries of novel arm	56.25 ( $\pm$ 9.30)	60.20 ( $\pm$ 8.95)	<1	60.42 ( $\pm$ 8.50)	56.25 ( $\pm$ 8.68)	<1
Percent repeated entries of novel arm	50.49 ( $\pm$ 6.73)	50.02 ( $\pm$ 4.44)	<1	48.55 ( $\pm$ 5.31)	51.96 ( $\pm$ 4.84)	0.27
Percent time spent in novel arm	50.73 ( $\pm$ 6.88)	46.74 ( $\pm$ 4.68)	0.23	44.94 ( $\pm$ 5.95)	52.53 ( $\pm$ 4.93)	1.06
Repeated entries of both arms	1.44 ( $\pm$ 0.28)	2.44 ( $\pm$ 0.11)	10.97*	1.83 ( $\pm$ 0.20)	2.04 ( $\pm$ 0.21)	1.10
Time spent in both arms (s)	17.90 ( $\pm$ 2.90)	29.43 ( $\pm$ 1.87)	11.17*	24.85 ( $\pm$ 2.51)	22.47 ( $\pm$ 2.14)	1.22

\*  $P < 0.005$  for sex difference.

awareness of such a possibility in studies of rats' haptic perception has been considered by at least one research team [9].

### 3.1. Materials and methods

A further 12 male and 12 female rats experienced identical sequences of 6-min acquisition and 1-min retention trials as those experienced in Experiment 1. However, for each pair of trials, all floor inserts were covered with fine zinc mesh that prevented any physical contact with their rough or smooth surfaces but did not prevent detection of any olfactory cues arising from glue. The rats were of the same strain and age and kept in the same conditions as rats tested in Experiment 1, and were all tested in the dark. Each animal experienced two retention trials involving a change from both arms rough to one rough and the other smooth, and two involving a change from two smooth to one of each texture. The same measures were recorded as in Experiment 1 and all testing sessions were separated by at least 24 h.

### 3.2. Results and discussion

Effects of sex and type of change (rough to smooth and vice versa) on each behavioral measure, and results of separate 2 (sex)  $\times$  2 (type of change) repeated measures ANOVAs are outlined in Table 2.

There were no significant effects of type of change on any measure, and as shown by one-sample *t*-tests, none of the indices of responsiveness to the novel arm exceeded chance expectancies. However, unlike the outcome for Experiment 1, female rats made more entries of both arms (irrespective of their novelty value) and spent more time in them than males. It would therefore seem that any odor differences arising from glue on the floor inserts were not the reason why rats in Experiment 1 preferred to enter and spend time in the novel rather than familiar maze arm. Instead, it is clear that their choices had been based entirely on the changes in tactile stimulation they experienced. The sex differences in entries of and thus time spent in both arms reflect the commonly observed higher levels of locomotor activity in female rats [2].

The final experiment addressed what receptors may have been responsible for the sampling of tactile stimuli encountered in each arm, and thus the detection of change.

## 4. Experiment 3

It has been long known that rats are very sensitive to tactile stimulation in the snout region [45] and that the mystacial vibrissae between the nose and mouth play an important part

in tactile exploration [49]. Through use of these vibrissae, rats are able to discriminate between surfaces varying in roughness [8,22,33,47] thus suggesting that they may have been involved in perception of the tactile properties of the two maze-arm floors in Experiment 1. However, it is also clear that, in the absence of vibrissae, rats are capable of discriminating different tactile textures by means of receptors in their paws [21]. Through their removal, this experiment aimed to determine if vibrissae are essential for rats' ability to detect a change in tactile stimulation when all acquisition and retention trials are conducted in the dark. The mystacial vibrissae in the rat are of two sizes, namely large (macro) and small (micro) [16]. Although macrovibrissae are probably the more important for discriminating texture [6,43], special care was taken to remove both types in case microvibrissae might share this function to some extent.

### 4.1. Materials and methods

The subjects were a further 24 male and 24 female hooded rats of the same age and kept in the same conditions as rats in Experiments 1 and 2. The apparatus and general testing procedure was the same as for the previous experiments. However, 24 h before their first test, all macro and micromystacial vibrissae of half of each sex were clipped off to skin level with very fine surgical scissors. This procedure was repeated 24 h before each subsequent test to ensure that any re-growth of the vibrissae was removed. The other half of each sex underwent a similar manipulation 24 h before their testing sessions except that the scissors were merely placed against the rats' snout and moved in such a way that they were exposed to the sound and vibration of the scissors' cutting motion, but without any vibrissae being cut.

Each rat experienced a total of eight acquisition/retention trial pairings—four with a cued and four with a non-cued tactile change. All testing sessions were separated by at least 24 h.

### 4.2. Results

The same responses that were recorded in Experiments 1 and 2 were also recorded in the present experiment and subjected to separate 2 (sex)  $\times$  2 (vibrissae treatment)  $\times$  2 (novelty type) repeated measures ANOVAs. The results are outlined in Table 3.

#### 4.2.1. Percent first entries of the novel arm

There were no significant main effects on this measure of any of the three factors. However, the novel arm was entered first significantly more often than expected by chance by females, control rats that had not had their vibrissae cut, and by all subjects when tested in the presence of both cued and non-cued novelty. No interactions were significant.

Table 3  
Mean ( $\pm$  S.E.M.) percent per day first entries and repeated entries of and time spent in the novel arm, repeated entries of and time spent per day in both arms for males and females, the two novelty types, vibrissae treatment, and results of ANOVAs and one-sample *t*-tests

	Sex		Novelty type		Vibrissae treatment		<i>F</i> (1, 28)
	Females		Non-cued		Cut		
	Males		Cued		Control		
Percent first entries of novel arm	55.47 ( $\pm$ 4.41)	64.84 ( $\pm$ 5.62) <sup>†</sup>	60.94 ( $\pm$ 4.88) <sup>†</sup>	59.38 ( $\pm$ 4.59) <sup>†</sup>	64.06 ( $\pm$ 5.21) <sup>†</sup>	56.25 ( $\pm$ 4.97) <sup>†</sup>	1.30
Percent repeated entries of novel arm	52.03 ( $\pm$ 1.41)	56.20 ( $\pm$ 1.21) <sup>†</sup>	55.34 ( $\pm$ 1.36) <sup>†</sup>	52.88 ( $\pm$ 1.24)	55.64 ( $\pm$ 1.43) <sup>†</sup>	52.59 ( $\pm$ 1.30)	2.84
Percent time spent in novel arm	52.36 ( $\pm$ 1.76)	56.61 ( $\pm$ 1.55) <sup>†</sup>	57.50 ( $\pm$ 1.31) <sup>†</sup>	51.48 ( $\pm$ 1.79)	55.29 ( $\pm$ 1.87) <sup>†</sup>	53.69 ( $\pm$ 1.59) <sup>†</sup>	<1
Total entries of both arms	3.52 ( $\pm$ 0.20)	3.53 ( $\pm$ 0.21)	3.51 ( $\pm$ 0.15)	3.54 ( $\pm$ 0.16)	2.99 ( $\pm$ 0.19)	4.07 ( $\pm$ 0.19)	4.67*
Total time spent in both arms (s)	31.41 ( $\pm$ 1.21)	33.06 ( $\pm$ 0.95)	33.02 ( $\pm$ 1.06)	31.45 ( $\pm$ 0.77)	32.20 ( $\pm$ 1.21)	32.27 ( $\pm$ 1.00)	<1

\*  $P < 0.05$  effects of sex, novelty type.

\*\*  $P < 0.01$  effects of sex vibrissae treatment.

† Significantly greater ( $P < 0.05$ ) than a chance expectancy of 50%.

#### 4.2.2. Percent entries of the novel arm

Although there were no significant vibrissae treatment or novelty type effects, females repeatedly entered the novel arm significantly more often than males. They also chose the novel arm significantly more often than expected by chance, as did control rats and all rats when faced with both cued and non-cued novelty. No interactions were significant.

#### 4.2.3. Percent time spent in the novel arm

There were no significant main effects due to sex or vibrissae treatment, but all rats spent less time in the novel arm in the presence of non-cued than with cued novelty. Significant choices of the novel arm occurred for female rats, both treatment groups and for all rats when confronted with cued novelty. No interactions were significant.

#### 4.2.4. Total entries of both arms

While neither sex nor novelty type significantly affected repeated entries of both arms, control rats entered the arms significantly less often than those that had had their vibrissae cut. No interactions were significant.

#### 4.2.5. Total time spent in both arms

There were no significant effects of any of the three independent variables on this measure or significant interactions.

### 4.3. Discussion

Although there were no significant differences for all three measures of choice of the novel arm between rats that had had their vibrissae cut off and control subjects, the former group showed significant responsiveness to the novel arm only in terms of first entries into and time spent in it. This suggests that, in spite of the ANOVA results, rats with cut vibrissae were obviously still able to detect the novel arm so that they could spend more time in it, but perhaps not quite as effectively as control animals. Because they also repeatedly entered both arms more often than control rats, it is likely that, without vibrissae, they found it more difficult (but not impossible) to discriminate between the two floor textures thus necessitating more visits of each. It therefore appears that, while they probably played a part in enabling discrimination between the tactile properties of the two maze-arm floors, the vibrissae were not absolutely essential. Not surprisingly, other tactile receptors must have also been involved, such as those present in the paws. The results would accordingly seem to support the often neglected importance of paw receptors in haptic perception of the rat [3,5].

Overall, females seemed to show slightly more consistent preferences than males for initially entering, re-entering and spending time in the novel rather than the unchanged arm. Whether or not the type of change encountered was cued or not, generally seemed to make little difference to the rats' ability to respond to the novel arm.

## 5. Conclusions

The main conclusions to be drawn from the results of this study are that the rats were able to detect and show preferences for the arm of a Y maze containing a floor that had changed in its tactile properties from what it had been during a prior acquisition trial when they were required to perform in the dark, thereby requiring the utilization of ego-centric body orientation cues rather than intra- or extra-maze visual cues. It was also clear that any olfactory properties of the maze-arm floors played no part in the rats' ability to locate the novel arm. Whether the novel changed floor comprised a smooth or a rough texture (Experiment 1), or (apart from time spent in the novel arm) whether the change they encountered involved cued or non-cued novelty (Experiments 1 and 3) seemed to make little difference to the experimental outcomes.

Sex differences that have been described for responsiveness to brightness change [25,31], do not appear to be as typical of responsiveness to tactile change whether the animals are tested in either the light [30] or, as in the present study, in the dark. And the conclusion that females may be better at utilizing ego-centric cues when locating a brightness change in the presence of allocentric visual cues [31], would seem less important in rats' ability to locate a tactile change in the dark without such cues, because males seemed to use egocentric cues almost as effectively.

Perhaps the most interesting finding was the clear evidence that ability to discriminate between the tactile properties of the maze-arm floors was not primarily dependent on the presence of intact mystacial vibrissae, as might have been expected from some earlier research [22,33]. However, in survival terms, one would not expect rats' haptic perception in a task dependent on locomotion to be seriously impaired by the absence of vibrissae, when they also have well-developed tactile receptors in their paws which they can use for discriminating between different textures [21].

Although responsiveness to a brightness change has been suggested as a potentially useful model of memory for investigating the effects of memory-enhancing agents [29], sex differences in the behavior and thus in the effects of such agents could limit its value in some situations. Therefore, responsiveness to tactile changes encountered in the dark (when sex differences are less prominent) might eventually prove to be more useful if it is desirable for there to be less impact of rats' sex on the outcomes of experimental manipulations.

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