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# Strategy selection during exploratory behavior: sex differences

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**Abstract**

This study was designed to assess sex-related differences in the selection of an appropriate strategy when facing novelty. A simple visuo-spatial task was used to investigate exploratory behavior as a specific response to novelty. The exploration task was followed by a visual discrimination task, and the responses were analyzed using signal detection theory.

During exploration women selected a local searching strategy in which the metric distance between what is already known and what is unknown was reduced, whereas men adopted a global strategy based on an approximately uniform distribution of choices. Women's exploratory behavior gives rise to a notion of a secure base warranting a sense of safety while men's behavior does not appear to be influenced by risk. This sex-related difference was interpreted as a difference in beliefs concerning the likelihood of uncertain events influencing risk evaluation.

Keywords: exploration, spontaneous strategies, sex differences, decision-making.

## 1 Introduction

Males and females seem to differ in spatial abilities and styles (e.g., Jahoda, 1980; Mann, et al., 1990). Generally, studies involving navigational problems showed that female cognitive style relies more on detailed information, while male style relies more on global information (e.g., Meyer-Levy, 1989; Moffat et al., 1998; Silverman et al., 2000). Evolutionary mechanisms could potentially account for sex differences in spatial behavior. For example, these behavioral differences may be due to mating patterns that induced a selection of large-range navigation in males (Gaulin & Fitzgerald, 1986, 1989). Mating patterns or mating strategies are linked to the dynamics of reproduction and sexual selection (Darwin, 1871), and sexual selection is restricted to characteristics that influence mate choice and competition for mates. Typically, males have to compete through extensive ranging for access to mates while females have to choose mating partners according to reproductive success (for reviews: Andersson, 1994; Trivers, 1972; Geary, 2000).

Another proposition, but exclusively directed at humans, suggested that the division of labor (game hunting and plant gathering) would have put greater selection pressure on females' spatial memory because females sustained gathering duties (Silverman & Eals, 1992).

However, as argued by Ecuyer-Dab and Robert (2004a), "the selection of male characteristics depends on females' choice for mates. In females, however, spatial cognition would have been primarily shaped by the natural selection of a strong concern for survival (both of self and of offspring). This concern would have compelled them to favor low-risk strategies, like concentrating on proximal spatial cues, when coping with space-related problems. Such focusing would have enabled secure navigation based on detailed landmark encoding, as well as, in certain species, regular feeding based on remembering the exact locations of potential resources" (p. 222). Thus, the hypothesis of labor division would be a by-product of sexual selection and not the cause of sex differences in spatial behavior.

Taken together, the literature seems to indicate that the key to understanding the evolution of behavioral sex differences relies on the relative costs and benefits of producing offspring (see Trivers, 1972, but also Geary, 2000). In that context spatial skills play a crucial role since they increase reproductive success and the accessibility to food resource but, at the same time, multiply the risks of getting lost, being killed or consumed by other animals (predation). Hence, the survival of mobile species depends on their ability to balance costs and benefits induced by locomotion and this balancing should differ according to sex.

Experimental investigations of sex differences in spatial abilities yield apparently disparate results (e.g., Jones et al., 2003; Ecuyer-Dab & Robert, 2004a). This might be partly due to the complexity of contemporary experimen-

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tal designs, but also to a lack of investigations concerning decision-making processes involved in the selection of strategies.

The current study investigates sex differences in basic behaviors like exploration, detection and discrimination involving the selection of strategies when coping with uncertainty. Following the above quotation from Ecuyer-Dab and Robert's, the hypothesis is that women, compared to men, should favor low-risk strategies when coping with space-related problems. To test this, I used a simple spontaneous two-dimensional exploratory task. This choice relies on the fact that exploration is a natural behavior and that it is fundamental in acquiring spatial knowledge. It seems to be based on driving factors such as curiosity, comfort or mastery over one's environment. Moreover, it is commonly defined as serving to reduce uncertainty and thus allow coping with fear (for a review about exploration, see Hughes, 1997).

Exploration is mainly characterized by a succession of progressions and stops (Drai, Benjamini, & Golani, 2000), and the selection of exploration could rely on its capacity to act as a regulator of uncertainty. Indeed, progressions are based on decisions taken during stops, and stops correspond to choice points allowing decisions. Voss (1983) refers to the exploration process as the generation and testing of hypotheses concerning the object's meaning and potential use.

In order to assess risk-taking, a classical visual discrimination task based on the stimuli observed during the exploration task was used. The results were analyzed with signal detection theory.

# 2 Materials and methods

## 2.1 Participants

The participants were 160 volunteers (80 males and 80 females) recruited from the campus of the University of Lausanne (Switzerland). The mean age of the males and females was 22.9 (SD 1.4) and 23.5 (SD 1.2) years, respectively.

## 2.2 Apparatus

A set of one-hundred cards differentiated by homogenous male and female characters was used.

For Experiment 1, a two-dimensional pattern (Figure 1) was created in placing 62 cards (3 x 5 cm) on a large board (130 cm x 75 cm). Two men and two women designed the shape of the pattern to avoid any sex bias. A card was randomly chosen and duplicated to serve as goal. The remaining set of 38 cards was used for Experiment 2.

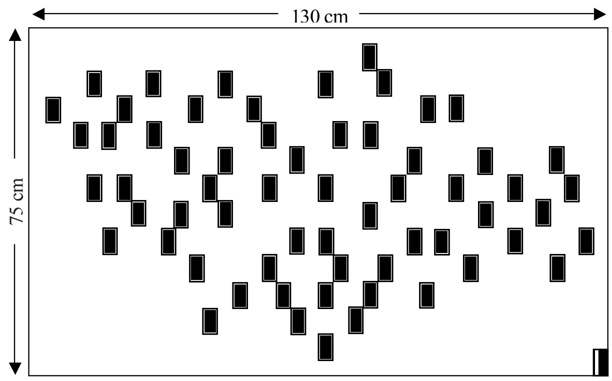


Figure 1: Two-dimensional pattern used for Experiment 1, the card placed at the lower right corner corresponds to the goal.

## 2.3 Procedure of testing

### 2.3.1 Exploration task

The board lay on the floor of the experimental room with the 62 cards turned the wrong side up. The duplicate of the goal turned right side up was put on the lower right corner of the board (Figure 1). Each participant was greeted and placed in front of the board and was asked to find the hidden goal by turning up as few pictures as possible and leaving them exposed. After having found the goal, participants were asked to turn up the remaining pictures in order to look at all characters. Double blind shuffling of cards made different strategies (e.g., systematic or random) equivalent with regard to the probability to get the goal in one draw.

### 2.3.2 Discrimination task

A sample of 32 new pictures of characters was added to the original sample of 62 pictures used during the exploration phase and the hundred pictures (62 already shown in Experiment 1 and 38 new) were randomly presented one by one to the participants. The participant's task was to discriminate between the pictures already shown (signal) and the one never shown during exploration. Subjects' responses were coded as followed: 1/ hit (present, already shown, correct response), 2/ false alarm (present, never shown, incorrect response), 3/ correct rejection (absent, never shown, correct response), 4/ miss (absent, already shown, incorrect response).

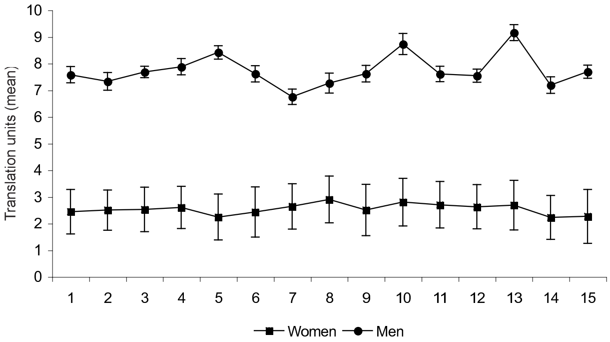


Figure 2: Mean (± sem) axial translations during the first fifteen draws (mean women: 2.56 ± 0.09; mean men: 7.73 ± 0.26)

# 3 Results and discussion

## 3.1 Exploration task

Exploration was assessed through axial translations units between explored locations during the first fifteen draws. As shown in Figure 2, men adopted a global strategy in which pictures were randomly chosen from an approximately uniform distribution over spatial locations. In contrast, women used a local searching strategy in which the probability of selecting a card was a function of its distance from a cluster of visited locations. Difference in searching strategy was confirmed by a one-way ANOVA on mean units translation ($F(1, 158) = 372.95$; $p = .001$) indicating that the mean unit translation was larger in men than in women (Fisher's PLSD men > women, $p = .001$).

This difference in strategy is quite intriguing and might be related to risk perception. Risk can be seen here as a chance of something negative happening. In the present task, finding the goal by turning up as few picture as possible has been put at stake. Thus, the probability of not being successful on the first trial was high and risk evaluation should be high too. Early psychologists (Angell, 1907; Fernberger, 1914; Boring, 1920) argued that uncertainty biases responses because it alters confidence, moods and temperament (insecurity or boldness for example). Analogically, exploration of unfamiliar environmental stimuli by a free moving animal has been described as competing states of both fear and curiosity (Montgomery, 1955). In this case, uncertainty and fear, with respect to the external environment, appears to be reduced when the present environment is compared with previously experienced stimuli (Russell, 1983). Another component made apparent by the study of *risk assessment behavior* (new object reaction) in animals was how significant it is for these animals to keep continual contact with familiar markers (Blanchard et al., 1970; Blanchard & Blanchard, 1989; Misslin & Ropartz, 1981). There is a parallel between these animal behaviors and the searching strategy adopted by women. The known part of the board could be used as a secure base and minimizing the distance between this base and what is unknown could permit to feel safer while exploring the environment. Indeed it allows balanced exploration and seeking the proximity of familiar markers. Under this experimental condition, the behavior of women might be interpreted as a risk-reducing strategy allowing coping with uncertainty. To support this hypothesis, it must be added that usually, but not in this task, nearby environments are likely to be more similar in the probability of what they contain. Similarly, distant environments are less known, more uncertain in the sense of having missing information.

However, an alternative hypothesis must be considered. It has been postulated that spatial skills depend on the amount of spatial information processed according to usual home range (Gaulin and Fitzgerald, 1986, 1989). Thus, women's search pattern could be in relation with this *range size navigation mode* hypothesis (Ecuyer-Dab & Robert, 2004b) since they have a tendency to focus on a smaller-scale space than men. Accordingly, differences observed in searching strategies could depend on differences in the selection of environmental features to guide behavior. Indeed, it has been shown that men rely primarily on cardinal references and geometrical environmental features while women rely more on topological cues such as landmarks and their configurational relations (e.g., Montello et al., 1999; James & Kimura, 1997; Choi & Silverman, 1996).

Taken together, these hypotheses suggest that at least two main cognitive processes control exploration and spatial behavior: 1/ Information processing that extracts, selects and encodes relevant information provided by internal and external worlds; 2/ decision or choice processes allowing selecting a strategy. These two operations are altered, respectively, by attentional mechanisms that change discrimination capacities, and by beliefs concerning the likelihood of uncertain events. Information processing is tuned by the attentional level that acts like a filter on perception, while decision-making processes are weighed by subjective probability of risk. Consequently, strategies selected during exploration should be mainly controlled by these two mechanisms.

In order to investigate sex differences in these two cognitive processes, a classical visual discrimination task based on the stimuli observed during the exploration task was used.

## 3.2 Discrimination task

Analysis of responses showed that men said more "yes" and less "no" responses than women (multivariate anal-

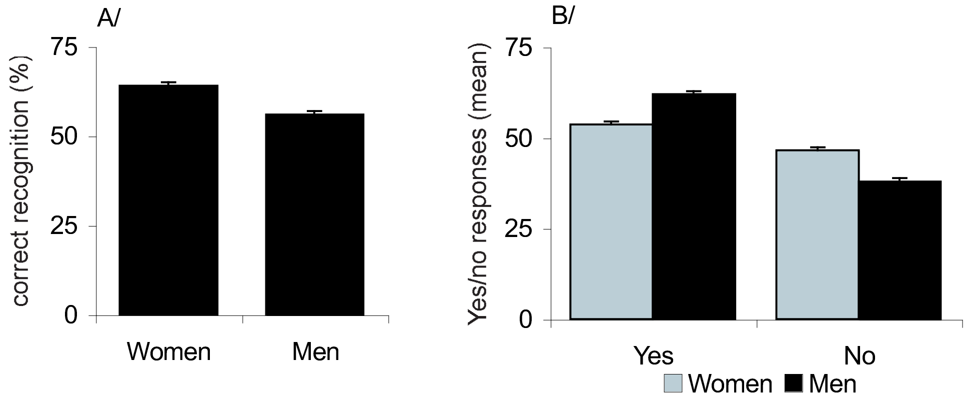


Figure 3: A. Mean (± sem) of "yes" and "no" responses in men and women during the discrimination task. B. Mean (± sem) percentage of correct recognition by men and women during discrimination.

Table 1: Calculation of the probabilities of correct and incorrect detection of a signal (S= signal; N= noise; A= absent; P= present).

| | Responses: | |
|---|---|---|
| Signal: | present | absent |
| Present<br>S | P/S<br>Hit rate | A/S<br>Miss rate |
| Absent<br>N | P/N<br>False alarm rate | A/N<br>Correct rejection rate |

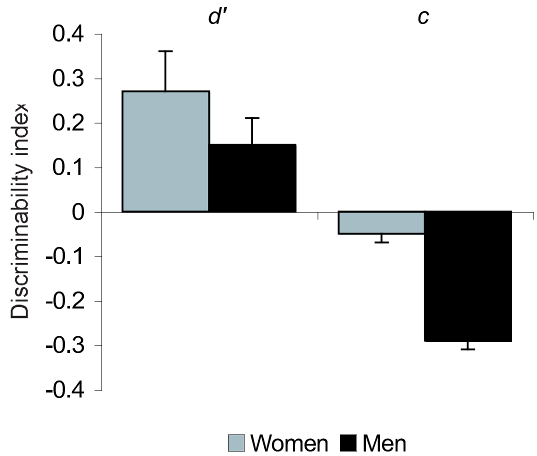


Figure 4: d' and c index values (mean ± sem) measuring sensitivity and temperament in women and men.

ysis sex x yes: $F(1, 158) = 52.16$; $p = .001$, sex x no: $F(1, 158) = 53.3$; $p = .001$), but the percentage of correct recognitions, assessed through a classical coding of answers as correct and incorrect responses, was significantly higher in women than in men (F(1,158)=35.77; p=.001; Fisher's PLSD women > men, p=.001) as shown in Figure 3.

The analysis of the percentage of correct recognition does not allow dissociating between perception and judgment. Signal detection theory (SDT) provides a tool for quantifying perceptual decisions in the presence of uncertainty (Green & Swets, 1966). This theory treats detection of a stimulus as a decision-making process determined by the nature of the stimulus and cognitive factors. The model generally used in SDT assumes that the theoretical distributions of signal and noise are normal and have equal variance. The probability of correct and incorrect signal detection can be calculated from the ratio of the subject's acceptation and rejection responses (Table 1). This probability is then used to determine the probit transformations aimed at estimating *d'* and *c* (Green & Swets, 1966).

The d' index correspond to the distance between means of the distributions. It measures the strength of the stimulus relative to the sensitivity of the subject. The c index corresponds to the likelihood ratio. It reflects the strategy of the subject and can be changed with level of confidence. A low c matches with a rash temperament while a high c matches with a conservative temperament.

The SDT analysis showed that the sensitivity d' did not significantly differ between men and women ($F(1, 158) = 1.33$; ns), but the subjective criterion c was significantly different ($F(1, 158) = 75.74$; $p = .001$). According to the theory, this last result indicates that women's decisions were, on average, more circumspect and were based on conservatism while men's decisions were more risky, in the sense of risking false positives (Figure 4).

Finally, correlations as a whole, and within women and men between the exploration measure and the bias

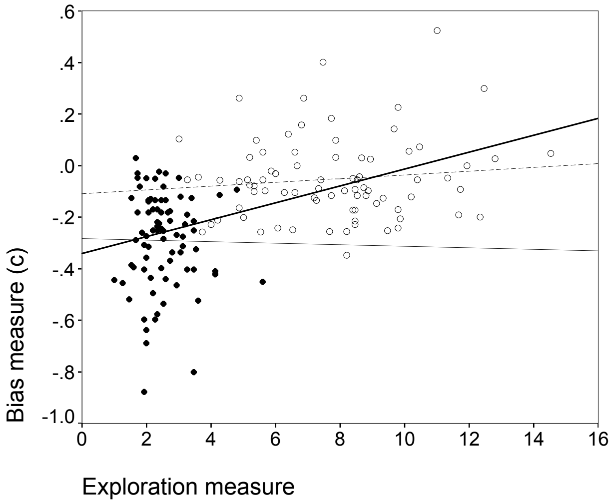


Figure 5: Relation between the exploration measure and the bias measure in women and men. Exploration measure corresponds to the mean translation unit observed during the exploration task, whereas the bias measure corresponds to the c index of the discrimination task.

measure (c) were calculated. As shown in Figure 5, the overall analysis revealed a significant correlation between these two measures ($r(160) = .498$; $p = 0.01$). However, separate analyses conducted within each sex were not significant (women: $r(80) = -.012$; ns; men: $r(80) = .112$; ns).

# 4 General discussion

This study has first shown that the searching strategies used by women and men to solve an exploratory task that may be seek as involving trading off of risk and reward differed according to sex. Women adopted a local searching strategy in which the metric distance between what is already known and what is unknown was reduced. Men adopted a global strategy based on an approximately uniform distribution of choices. These findings appear to be compatible with a female frame of mind expressing careful consideration of all circumstances and possible consequences before making a decision.

The results of the discrimination task through a signal detection analysis showed that women and men sensitivity towards the stimuli (*d'* index) was equivalent while the assessment of confidence in judgment under uncertainty (c index) differed. Indeed, men showed a subjective criterion indicating a more risky temperament than women. The absence of differences in sensitivity contrasted with what is generally expected from results showing that women outperform men when the task requires object identification (Silverman & Eals, 1992; James & Kimura, 1997) or item memory (Galea & Kimura, 1993, Maccoby & Jacklin, 1974, Stumpf & Jackson, 1994). If correlation as a whole supported the hypothesis that strategies selected during exploration rely on temperament, it was not the case for correlations within each group.

It could be argued that these measures were not based on the same cognitive mechanism. Indeed, subjects were facing with the unknown in the exploration task while having to decide if they had already seen or not a picture in the discrimination task. Thus, these two tasks might not be equivalent according to uncertainty but also according to one's confidence in skills. For example, LaGrone (1969) reported that women more often felt disoriented with regard to their "sense of orientation" than men did. Moreover, women expressed a feeling of "worry about becoming lost" that was negatively associated with confidence in the "sense of orientation" (Kozlowski & Bryant, 1977). It has also been shown that the positive representation of an activity in term of payoffs and costs influenced women's favorable judgments concerning consequences (Harris et al., 2006). Interestingly, variations in the relation between exploratory behavior and risk-taking have been also observed in birds (Parus major). In this species, correlation between exploratory behavior and risk-taking behavior depended on the presence and foraging behavior of a mate. Moreover, the presence of a mate resulted in a complex differential effect according to the fact that they were males or females and slow or fast explorers. Slow explorers of both sexes were more audacious in the presence of a mate whereas in fast explorers, females were less audacious in the presence of a mate (van Oers et al., 2005).

The results of this experiment, together with those of an abundant literature, cannot lead to a clear understanding of why and how the mentioned abilities are associated with beliefs concerning the likelihood of information and degrees of confidence consistently with sex differences. One possibility to be examined is that sex-steroid hormones could modulate cognitive mechanisms involved in risk evaluation.

Finally, it is perhaps of some interest to note that the present work was drawn from Ittelson (1960) suggestion that "the problem of exploratory behavior. . . [is] central to the study of environmental perception."

It differs from previous works since it offers a new perspective to assess sex-related differences in spatial behavior through its relation to perception. Perception and sensation should be regarded as particular forms of extended communicative actions and not as alternative end points for the use of environmental information (Green, 2001). All information about the world comes from our sensory systems, and the cognitive process begins with the ability to make some meaning out of this stream of sensory stimuli.

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