Title

Effects of Absolute Proximity Between Landmark and Platform in a Virtual Morris Pool Task with Humans

Journal
International Journal of Comparative Psychology, 18(3)

ISSN
2168-3344

Authors
Artigas, A. A.
Aznar-Casanova, J. A.
Chamizo, V. D.

Publication Date
2005-12-31

Peer reviewed

International Journal of Comparative Psychology, 2005, **18**, 225-239.

Effects of Absolute Proximity Between Landmark and Platform in a Virtual Morris Pool Task with Humans

A. A. Artigas, J. A. Aznar-Casanova, and V. D. Chamizo
Universitat de Barcelona, Spain

In two experiments in a virtual pool the participants were trained to find a hidden platform placed in a specific position in relation to one (Experiment 1) or two (Experiment 2) objects; then, all the participants received a test trial, without the platform, and the time spent in the segment where the platform should have been was measured. In Experiment 1, groups differed in the distance between the landmark and the hidden platform. Test results showed that the control acquired by the landmark was different depending on its relative distance from the platform: Closer landmarks acquired a better control than distant ones. In Experiment 2, two objects, B and F, were simultaneously present during acquisition. Object B was just above the hidden platform (i.e., a beacon for the platform) while object F was above the edge of the pool (i.e., a frame of reference). On the test, the spatial location of B in relation to F was manipulated in the different groups and a generalization gradient was found: Participants spent more time in the segment where B was when B was in front of F (training position), and this time decreased symmetrically with distance of B from F. The two experiments provide convergent evidence of spatial learning effects in a virtual task with humans.

The aim of the present study was to contribute to the spatial learning literature by expanding the study of conditioning phenomena in the spatial domain to humans (for recent reviews see Chamizo, 2002, 2003; Rodrigo & Prados, 2003). Conditioning phenomena in spatial learning are consistent with associative theory but not with O'Keefe and Nadel's (1978) theory. O'Keefe and Nadel claimed that true spatial learning occurs nonassociatively. One way to explore this issue is to look for parallels between spatial learning and other forms of learning. Do spatial and nonspatial stimuli behave differently? Two effects are addressed in this study: absolute proximity (Experiment 1) and generalization gradient (Experiment 2).

It is well known that proximity to a goal can be an important determinant of landmark control (Bennett, 1993; Cheng, 1989; Cheng et al, 1987; Collett, Cartwright, & Smith, 1986; Spetch & Wilkie, 1994; Tinbergen, 1951; Vallortigara, Zanforlin, & Pasti, 1990; for a review of landmark use, see Cheng & Spetch, 1998). Spatial contiguity can favour landmarks at the goal or near the goal as the best predictors of its location (for demonstrations of spatial contiguity with very different procedures, see Rescorla & Cunningham 1979; Testa, 1975). In the study by Spetch and Wilkie (1994) pigeons received food for pecking a hidden goal location when using a touch-screen procedure. Three "natural" landmarks (a tree, flowers, and a log) were located near the goal on a field of grass. For some birds the goal was closer to the tree, whereas for others it was closer to the flowers and log. Subsequent test trials demonstrated that pecking was not controlled by the configuration of the landmarks. Instead, this response highly depended on prox-

The software for this study was designed by J. A. Aznar-Casanova. This research was supported by grants from the Spanish 'Ministerio de Ciencia y Tecnología' (Refs. nº BSO2001-3264 and BSO2001-3639). The authors are grateful to M. R. Papini for helping to improve the English version of this manuscript. Requests for reprints should be sent to V.D. Chamizo, Universitat de Barcelona, Facultat de Psicologia, Departament de Psicologia Bàsica, Passeig de la Vall d'Hebron, 171, 08035-Barcelona, Spain (victoria.diez.chamizo@ub.edu).

imity to the goal of the individual landmarks. The clear implication is that the animals were solving the spatial tasks elementally, by learning about individual landmarks, rather than by learning configurations of landmarks (for demonstrations of configural learning, see O'Keefe & Conway, 1978; Prados & Trobalon, 1998; Rodrigo et al., 1997; Suzuki, Augerinos, & Black, 1980).

In a recent study with rats trained in a Morris pool (Morris, 1981), Chamizo and Rodrigo (2004) asked how important could be the relative distance of a single landmark from a goal, without the presence of other landmarks or other sources of information. Their results revealed that a beacon on top of a hidden platform as well as the same object at a certain distance from the platform (50 cm away or 110 cm away) were sufficient to locate the platform and, most importantly, in all cases a graded effect was found during acquisition (rather than an all-or-none effect). Subsequent test trials without the platform demonstrated that rats trained with a beacon on top of the hidden platform showed the best performance, followed by that of rats with the landmark 50 cm away from the platform, and finally animals with the landmark 110 cm away from the platform. Thus, increasing the distance between a goal and a landmark impaired spatial performance. These results showed a clear parallelism in comparison with the effect of absolute temporal proximity of the conditioned stimulus (CS) and the unconditioned stimulus (US) in classical conditioning. Normally, conditioning improves as the interval between CS and US decreases, although at very short intervals conditioning may be impaired (Ost & Lauer, 1965; Schneiderman & Gormezano, 1964). One aim of the present research was to try to expand the generality of this effect to humans, using similar designs but a virtual navigation task (Experiment 1). Humans can locate a hidden goal using virtual landmarks in much the same way that rats do it in a Morris pool (Astur, Ortiz, & Sutherland, 1998).

A second effect studied in the present study refers to generalization decrement (Pavlov, 1927; Gutman & Kalish, 1956). While working with dogs and tones of different auditory frequency, Pavlov (1927) observed that when a salivary response had been established to one particular tone (a CS), subjects also salivated to similar tones and that the effectiveness of the new stimuli to elicit such a response declined in proportion to their distance from the trained stimulus. This result is called a stimulus generalization gradient (Mackintosh, 1974). Subsequent research confirmed this phenomenon in a variety of stimulus dimensions and with different species, both in classical and instrumental conditioning. In the classical study by Guttman and Kalish (1956), pigeons were trained to peck at a key which was illuminated by a light of a specific wavelength (580 nm). After training, the animals were tested with a variety of other wavelengths presented on the key (520-640 nm). The results showed a gradient of responding as a function of how similar each test stimulus was to the original stimulus: The highest rates of pecking occurred in response to the training stimulus, 580 nm, and as the colour of the test stimuli became increasingly different from the colour of the training stimulus, progressively fewer responses were observed.

In a recent study by Cheng, Spetch, and Johnston (1997), also with pigeons, spatial location was used as a stimulus dimension (a dimension already used by Pavlov, 1927). In Experiment 1 of the study reported by Cheng et al. (1997), birds were trained on a fixed-interval schedule to peck at a computer screen following presentations of a small square in a fixed screen location. Then, unrewarded test trials at a range of locations were intermixed with the previous trials. The results showed a gradient of responding as a function of the relative proximity of the test locations to the location of the original stimulus: Pigeons showed higher responding to the training location that decreased symmetrically with distance from it. Spatial generalization gradients have also been found, using different testing methods, with human subjects (Cheng & Spetch, 2002) and with honeybees (Cheng, 1999, 2000, 2002), thus showing a clear cross-species generality. These results have been replicated with rats and a Morris pool (Rodrigo, Sansa, Baradad, & Chamizo, 2005). In the study by Rodrigo et al., it was asked whether spatial generalization gradients could be found when varying the location of two stimuli in a navigation task. During acquisition, B, a target object, was just above a hidden platform (i.e., a beacon for the goal), and a second object, F, was in front of B, directly above the wall of the pool (i.e., a frame of reference). After acquisition, test trials without the platform presented B at a range of places in relation to F. On these test trials, a gradient of responding as a function of the relative proximity of B in relation to F was found: Time swimming peaked in the segment where B was when B was placed in front of F (its original position), and it decreased symmetrically with distance from F. The implication of these experiments is that when spatial location is analysed in a manner similar to that used in other stimulus dimensions (e.g., wavelength and auditory frequency), the control exerted by the location of stimuli appears to be similar. The second aim of the present manuscript was to extend the generality of this effect to humans, using similar designs but a virtual navigation task (Experiment 2). In the two experiments reported here, the landmark/s rotated virtually from trial to trial along with the position of the platform, thus preserving a constant relationship between the platform and the landmark/s.

Experiment 1

Chamizo and Rodrigo (2004) have shown that the position of a single landmark is a crucial factor for rats' navigation toward an invisible platform. Specifically, that the control acquired by a landmark is better the closer it is to the platform. This result shows a clear parallelism with the effect of absolute temporal proximity of the CS and US in classical conditioning (Ost & Lauer, 1965; Schneiderman & Gormezano, 1964). The aim of Experiment 1 was to provide convergent evidence of this effect with human participants.

Method

Subjects. The subjects were 60 psychology students at the University of Barcelona with ages approximately between 22-24 years. They were assigned at random to one of 6 groups (n = 10). Groups differed in the distance (i.e., “units”) between an object, a sphere, and a hidden platform. For all the groups, this single object defined the location of the platform and was at one and the same distance from the “water”. For Group 0, it was exactly above the hidden platform (i.e., a beacon for the hidden goal); for the remaining groups this object, a landmark, was in the midline directly above the wall of the pool and the distance between this landmark and the hidden platform was systematically manipulated as a consequence of an angular displacement: 40 units (Group 40), 72 units (Group 72), 116 units (Group 116), 148 units (Group 148), and 160 units (Group 160), as shown in Figure 1. The participants were naive about the hypothesis of the experiment in which they participated as volunteers and received course credit for their participation.

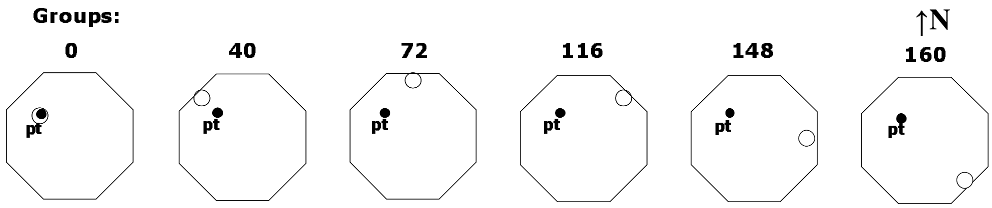

Figure 1. A schematic representation of the design of Experiment 1 showing the pool and the six different positions of an object (open circle) in relation to the hidden platform (filled circle) for the different groups. The object could be exactly above the platform (Group 0), relatively near from it (Groups 40, 72, and 116), or further away from the platform (Groups 148 and 160).

Apparatus. The experiment was conducted in a room with four individual soundproof small compartments. Each compartment was equipped with a PC computer (Pentium III 450 MHz) and a color monitor placed on a shelf, a set of headphones, and a chair from which the participants could comfortably reach the keyboard of the computer**.** Each monitor was 15 inches diagonal and was equipped with a WinFast 3D S600 Graphic card (4 MB), which allows graphics acceleration and high resolution configurations. The programme language used to run the experiments was C++/Open GL (a software interface for 3D graphics, with hardware developed by Silicon Graphics, California, U.S.A.). Each computer was programmed to control the presentation of the virtual environment (which was in first person perspective), the auditory information (the background sound and the positive and negative feedback), and to register the time taken to reach the platform. The auditory positive feedback consisted of a brief song ("That's all folks") that lasted 3 s. The auditory negative feedback consisted of an unpleasant melody (the sound of mournful bells, three times) that also lasted 3 s. The auditory background sound was slightly unpleasant in order to generate some distress in the participants and thus to reproduce the conditions of an escape task. All the auditory information was presented through the headphones and the visual information was presented through the color monitor. In order to navigate, the participants had to use three of the keyboard arrow keys. The "up" arrow key controlled forward movement; the "right" arrow key turning right; and the "left" arrow key controlled turning left.

The virtual space was an octagonal swimming pool (radius = 100 units) modeled after that used by Chamizo et al. (2003). This length, 100 units, implies that one student could cross the diameter of the pool in a minimum time of approximately 4 s, and perform a complete turn (360º), without any displacement, in approximately 2.5 s. These speeds (speed = space/time) to move ahead and to turn around are equivalent to those used by Chamizo, Aznar-Casanova, and Artigas (2003). The pool was situated in the middle of the virtual space (centered in coordinates: 0,0), had a red wall that could not be crossed, and was filled with a blue surface (i.e., the "water"). The pool was surrounded by a pale blue surface. One object was placed hanging from an invisible ceiling. This single object defined the location of the platform (coordinates 23,55). A circular platform (radius = 8 units) could be placed in the pool, slightly below the surface of the "water" (i.e., an invisible platform). The landmark used in this experiment was a three-dimensional object, a circular sphere, pink color (approximate size diameter = 20 units), as shown in Figure 1.

Procedure. The experiment lasted one session and the participants were tested mainly in groups of three or four, one student per individual compartment. At the beginning of the experiment, the participants had to read specific instructions, presented to them on a sheet of paper while they were seated, to become familiar with the task. Any question was then answered by an experimenter. The information they received in Experiment 1 reads as follows:

This experiment will last about 20 min and it will consist of several trials. Imagine that you have been swimming for a long time in a circular pool from which you are not able to get out of and that you are very tired. You will only be able to rest if you find a floating platform. Your task consists of reaching it. On the first trial you will see the platform. Only on this trial. In the following trials you will not be able to see it, but you can be sure that it will always be in the same position in relation to one object.

Following this information the participants had a drawing similar to one of the schematic pools in Figure 1 (specifically, Group 40), with the exception that no platform was indicated (only the shape of the pool and one sign indicating an object). To the right of this drawing, inside a rectangular frame, whose title was "Being at the helm", information to navigate was presented to the participants. It was indicated, with symbols, that the vertical arrow meant "advance"; the arrow facing right, "turn to the right"; and the arrow facing left, "turn to the left". Then, a new paragraph with the following information followed:

To move, please use the navigation keys (see above “Being at the helm”). When you find the platform you will hear the song “That’s all folks”, and then a new trial will begin. If you do not find the platform in the permitted time for each trial, mournful bells will sound and then a new trial will begin. At the beginning of each trial you will always find yourself in the pool (either North, South, East, or West). Please try to find the platform as quickly as you can. When you think you have understood the instructions, click on OK to begin a trial. If you haven’t understood, ask the experimenter. Good luck!

To start the experiment, after the participants had indicated verbally that they had understood the instructions, they had to click one OK button on the keyboard. Following this, a new screen was presented telling them that they had to click on OK, again, and then they found themselves in the pool (either North, South, East, or West—see Figure 1). Trial 1, with a visible platform and no landmark present, was an escape-from-the-water preliminary trial, to familiarize the participants with the task. The student was given 60 s. to reach the platform. Reaching the platform was rewarded by playing the song “That’s all folks” and also ended the trial. Then, there were two types of trial: first, escape trials (with the hidden platform and one landmark present), and secondly, one final test trial (without the platform, but with the landmark present).

Acquisition (escape trials) was identical for all the participants with the exception that the location of the landmark (a pink sphere), and therefore its distance from the hidden platform, varied in the different groups (from 0 to 160 units, as shown in Figure 1). Escape trials consisted of placing the subjects in the pool with the landmark and the platform present, as shown in Figure 1. The subjects received twenty four consecutive trials, with an average intertrial interval (ITI) of approximately 10 s. Each student was given 60 s to find the platform. As in the first trial, reaching the platform was rewarded by playing the song “That’s all folks” and also ended the trial. Then, a new screen with a rectangular frame on it appeared. This frame had the written instruction “click on OK to continue”. When that happened, a few seconds afterwards another screen appeared, whose composition was a square frame (containing a small symbol and the address of the University of Barcelona), and the rectangular frame “Being at the helm”, both at the top of the screen, and below this the following phase: Your attention please, when you click on OK the next trial will begin. Therefore, the participants had to click twice on OK to begin a new trial. If a student did not find the platform within 60 s, the trial ended and the mournful sound was presented. Then, the instructions appeared on the screen and he/she had to click on OK twice to begin a new trial. The platform was invisible for all the participants. Subjects in all groups were placed in the pool equally often in all four cardinal positions (North, South, East, and West) at the beginning of a trial. (The cardinal positions were in relation to the center of the pool, i.e., coordinates 0,0.)

Following acquisition all the participants had a test trial. This trial consisted of placing the subject in the pool, with the landmark present but without the platform, and leaving it there for 60 s. As in the previous trials, subjects in all groups were placed in the pool equally often in all four cardinal positions (North, South, East, and West) at the beginning of this trial. For purposes of recording the participant's behavior, on the test trial the pool was divided into four quadrants of 90º (where the platform should have been, right to it, left to it, and opposite to it), and the amount of time the participants spent in the correct quadrant (where the platform should have been) was recorded. A significant level of $p < 0.05$ was adopted for the statistical tests reported in this article. Only significant results are presented.

Results and Discussion

Figure 2 shows the mean escape latencies of the six groups during acquisition in blocks of two trials. An analysis of variance, with Groups (0, 40, 72, 116, 148, 160), and Blocks of Trials (1-12) as factors, revealed that the main effect of groups was significant, $F(5, 54) = 11.67$ (subsequent Newman-Keuls comparisons indicated that Group 0 and Group 40, which did not differ, differed from all the other groups, Group 72, Group 116, Group 148, and Group 160, which in turn, did not differ from each other); the effect of blocks of trials was also significant, *F*(11, 594) = 12.89 (all participants improved their performance as the experiment progressed), as well as the interaction groups x blocks of trials, *F*(55, 594) = 1.52. A closer look at Figure 2 suggests that the interaction groups x blocks of trials could be due to the speed of Group 0 in the second block of trials. In order to check this possibility two further analyses were conducted. The first analysis took into account blocks of trials 1 and 2 only, and revealed that the variable groups was significant, *F*(1, 54) = 13.54, as well as the interaction groups x blocks of trials, *F*(5, 54) = 2.39, but the variable blocks of trials was not significant (*F* < 1); the analysis of the groups x blocks of trials interaction revealed that only Group 0 showed a better performance on the second block of trials in comparison with the first block, *t*(9) = 5.19. The second analysis took into account blocks of trials 3-12, and revealed that the main effect of groups was significant, *F*(5, 54) = 9.56, as well as blocks of trials, *F*(9, 486) = 7.76; but the interaction groups x blocks of trials did not reach the level of significance (*F* < 1.5). Although all groups improved their performance as the experiment progressed, the last two analyses confirm that the interaction groups x blocks of trials was due to the better performance of Group 0 at the beginning of the acquisition phase.

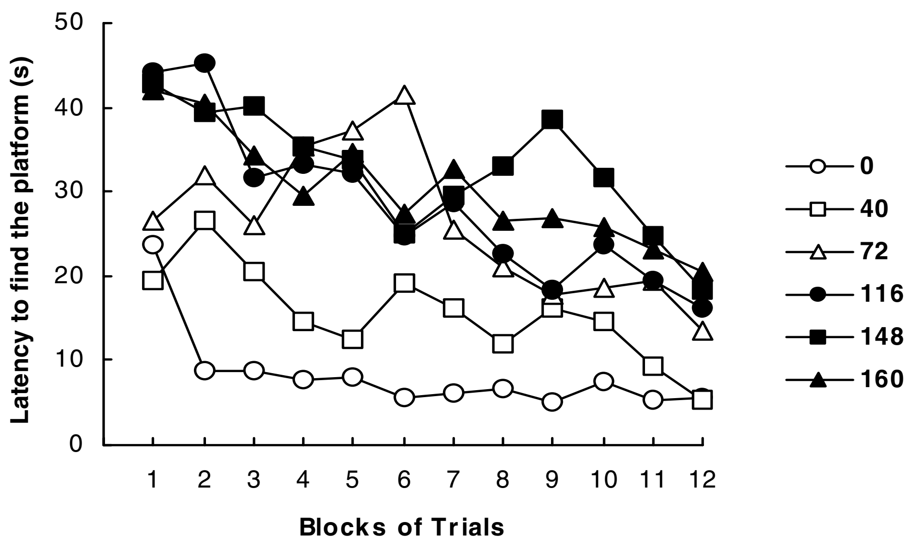

Figure 2. Mean escape latencies for the six groups of Experiment 1 during the training phase.

Figure 3 shows the time in the platform quadrant for each of the 6 groups during the test trial; an asterisk above each test indicates whether the group differed significantly from chance. *T*-tests were used to compare participants' performance in the test trial of the different groups with chance (i.e., 15 s searching in the quadrant where the platform should have been) in order to evaluate whether the test results reflected significant spatial learning. Four groups differed from chance: Group 0, *t*(9) = 13.36; Group 40, *t*(9) = 6.15; Group 72, *t*(9) = 5.34; and Group 116, *t*(9) = 2.93. Thus, only the performance of 4 groups reflected significant spatial learning on the test trial. An analysis of variance revealed that the groups differed, *F*(5, 54) = 9.47. Additional comparisons (Newman-Keuls) showed that

Group 0 differed from Groups 116, 148, and 160, which did not differ from each other. Groups 0, 40, and 72 did not differ from each other. These two groups (Groups 40 and 72) significantly differed from Groups 148 and 160, which did not differ from each other. Finally, Group 116 did not differ from any of these groups (Group 40, Group 72, Group 148, and Group 160). These results indicate that the general performance of the different groups deteriorates as the distance between the landmark and the hidden platform increases. As expected, these results with humans, as well as those previously obtained with rats (Chamizo & Rodrigo, 2004), show a clear parallelism with the effect of absolute temporal proximity of the CS to the US in classical conditioning.

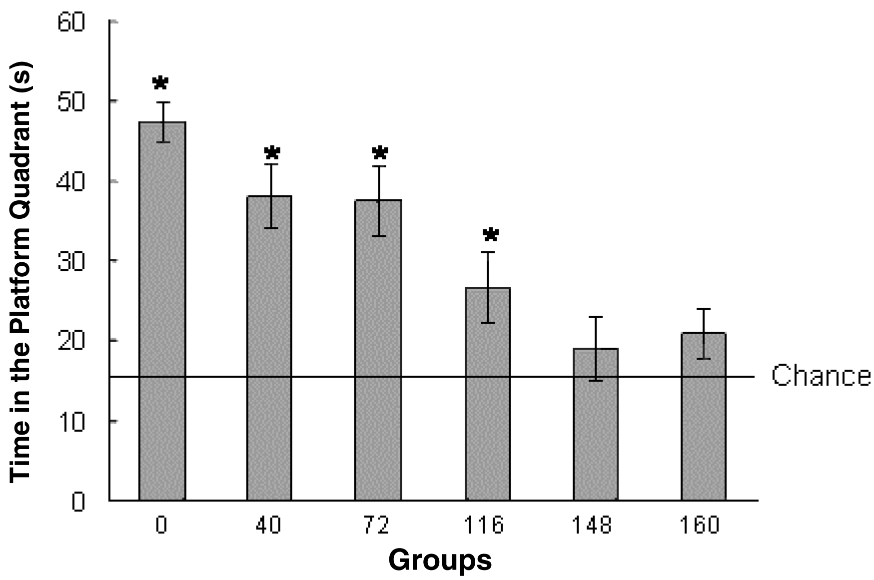

Figure 3. Mean time spent in the platform quadrant by the six groups of Experiment 1 during the test trial. Error bars denote standard error of the mean.

Experiment 2

A recent study by Rodrigo, Sansa, Baradad, and Chamizo (2005) with rats in a Morris pool has shown spatial generalization gradients when varying the location of two stimuli. In the two experiments of this study rats were trained to find a hidden platform which was located in a specific position in relation to two objects, B and F, which were presented together, one in front of the other. Although this study was not designed as an overshadowing one, competition between these objects was inevitable. Therefore, a manipulation was always needed to reduce competition of B (the critical landmark) by F so that object F could behave as expected, as a frame of reference. In Pavlovian experiments, it has been shown that the presence of another potential stimulus can overshadow or reduce learning involving a target stimulus, and that the degree of overshadowing depends on the relative salience of both the overshadowing and the overshadowed stimuli (Mackintosh, 1976; for examples of overshadowing in the spatial domain, see Chamizo, Sterio, & Mackintosh, 1985; Chamizo, Aznar-Casanova, & Artigas, 2003; Sánchez-Moreno et al., 1999; Spetch, 1995; for a related study showing the role of proximity to the goal among landmarks see Chamizo et al., 2005). In the study by Rodrigo et al. (2005), object B was just above the platform (a beacon for the platform, the critical object) while the second object, F, was above the edge of the pool (supposedly, the frame of reference). In Experiment 2 (2A and 2B) and during acquisition, F- trials (i.e., trials without the platform, in the presence of F only), were intermixed with BF+ trials (i.e., trials with the platform, in the presence of B and F); there were a total of 25 BF+, and 15 F- trials in Experiment 2A, and a total of 24 BF+ and 24 F- trials in Experiment 2B. In addition, in Experiment 2B a brief extinction phase to F was introduced at the end of the acquisition phase. Finally, rats received test trials, without the platform, in which B was presented in different positions in relation to F (i.e., 0º, 45º, 90º, and 135º; see Figure 4 in the present paper for a similar design). As expected, the results showed one gradient of responding in the B segments: Rats spent more time swimming in the segment where B was when B was placed facing F (B's training position), which decreased symmetrically with distance from F. Moreover, the time swimming in the F segment was also recorded. This time did not differ from chance in tests 90º and 135º; when it differed from chance, as happened in test 45º in Experiment 2A, Experiment 2B showed that it could be an artefact (i.e., due to its close vicinity to the position where B was). These results, as well as those by Cheng et al. (1997), show a clear parallelism in comparison with the effect of stimulus generalization (Pavlov, 1927; Gutman & Kalish, 1956). The aim of Experiment 2 was to provide convergent evidence of this effect with human participants using a procedure similar to that of Rodrigo et al. (2005, Experiment 2).

Method

Subjects and Apparatus. The experiment was run in two replications, with 83 participants in the first replication and 73 in the second. The experiment was conducted in the same room and with the same equipment used in Experiment 1, with one main exception. Two identical objects, two circular spheres, were used in this experiment instead of only one, as in Experiment 1. One of the spheres was pink, object B (the same as in Experiment 1), and the other was green, object F. Within each replication, the participants were assigned at random to one of four groups (Group 0, with 16 participants in the first replication, and 15 in the second one; Group 45, with 23 participants in the first replication, and 17 in the second one; Group 90, with 22 participants in the first replication, and 20 in the second one; and Group 135, with 22 participants in the first replication, and 21 in the second one). Groups differed only in the final test trial, as shown in Figure 4. All the participants were psychology students at the University of Barcelona with ages approximately between 22-24 years. They were naive about the hypothesis of the experiment in which they participated as volunteers and received course credit for their participation.

Procedure. Experiment 2 lasted one session and the participants were tested in groups of three or four, one student per individual compartment. The instructions and general procedure were similar to those in Experiment 1. To start the experiment, after the participants had indicated verbally that they had understood the instructions, they had to click one OK button on the keyboard. Following this, a new screen was presented telling them that they had to click on OK, again, and then they found themselves in the pool, in a different position each time (North, South, East, and West). Trial 1, with a visible platform only, was an escape from the water preliminary trial, and it was identical to Experiment 1. Then, there were three types of trial: escape trials (with 8 trials in total, both in the first and in the second replication), extinction trials (with 4 trials in the first replication and 8 in the second one), and a final test trial (i.e., a single trial both in the first and in the second replication). All trials lasted 60 s. On acquisition, escape trials (i.e., trials with platform, in the presence of B and F, BF+ trials), were intermixed with extinction trials (i.e., trials without the platform, in the presence of F only, F- trials). The participants in the first replication received 12 trials in total, 8 escape trials intermixed with 4 extinction trials (i.e., 8 BF+ trials and 4 F- trials); while those in the second replication received a total of 16 trials, 8 escape trials intermixed with 8 extinction trials (i.e., 8 BF+ trials and 8 F- trials). At the end of acquisition, all the participants received one test trial in the presence of B and F, without the platform. The four groups only differed in the angular separation of B from F on this test trial: 0 degrees amplitude of separation of B from F in Group 0, 45 degrees in Group 45, 90 degrees in Group 90, and 135 degrees in Group 135. In both replications, for approximately half of the participants in three groups (Groups 45, 90, and 135), B was separated from F to the right, and for the other half to the left (as shown in Figure 4). For purposes of recording the student's behaviour on the test trial the pool was divided into eight segments (i.e., octants) of 45º each (instead of four segments of 90º each, as in Experiment 1), and the participants were, as far as possible, placed in the pool in the four cardinal points, North, South, East, and West. On this trial, the amount of time a student spent in the segment where object B was, as well as the amount of time spent in the segment where object F faced were recorded.

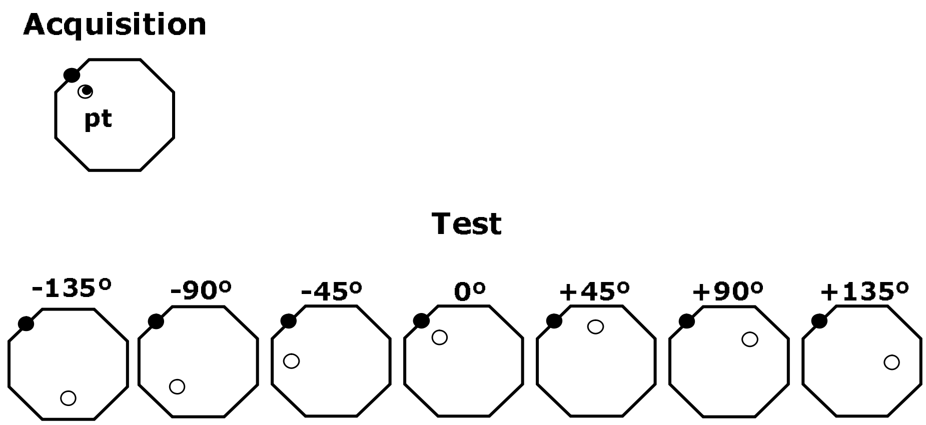

Figure 4. *Top* - A schematic representation of the pool and the position of the two objects, B (open circle) and F (filled circle), as well as the platform (small filled circle) during acquisition. Object B was exactly above the platform (i.e., a beacon for the goal, the hidden platform) while object F was above the edge of the pool (i.e., a frame of reference). *Bottom* - A schematic representation of the different test trials in the four groups (Groups 0, 45, 90, and 135): -135º, -90º, -45º, 0º, +45º, +90º, and +135º (i.e., when manipulating the spatial location of object B, in relation to its original position, in front of object F).

Results and Discussion

Figure 5 shows the mean escape latencies of the four groups during acquisition. As expected, an analysis of variance, with Groups (0, 45, 90, and 135), Replications, and Trials (1-8) as factors, revealed that the only significant effect was trials, $F(7, 1029) = 39.80$. No other main effect or interaction was significant (Fs < 2.00). All groups improved their performance as trials went by.

The top gradient of Figure 6 (i.e., the B gradient) shows the mean time in the sector where B was located during the test trial. T-tests were used to compare participants' performance with chance (i.e., 60/8= 7.5 s searching in the segment where B was located) in order to evaluate whether the test results reflected significant spatial learning. The participants' performance differed from chance on all test trials: Test -135, $t(23) = 10.62$; -90, $t(19) = 8.35$; -45, $t(20) = 9.05$; 0, $t(30) = 13.55$; +45, $t(18) = 13.17$; +90, $t(21) = 9.40$; and + 135, $t(18) = 5.68$. Thus the performance of the participants reflected significant spatial learning on all test trials. An analysis of variance taking into account the variables groups and replications showed that the variable groups was the only significant result, $F(3, 148) = 7.70$. No other main effect or interaction was significant (Fs < 1). Posthoc comparisons (Newman-Keuls) showed that both Group 0 and Group 135 (which differed from each other) differed from Group 45, and from Group 90 (which did not differ from each other). Additional analysis of variance, taking into account the variable laterality (right versus left), showed the on the B gradient, this factor was not statistically significant in either of the tests: 45, 90, and 135 (*F*s < 4.00). In conclusion, as expected these results show a clear gradient of responding as a function of how close each test location was to the original location: The participants spent more time in the acquisition location (when B and F were facing each other), and the amount of time in the sector where B used to be decreased symmetrically with distance from F (although Group 45 and Group 90 did not differ from each other).

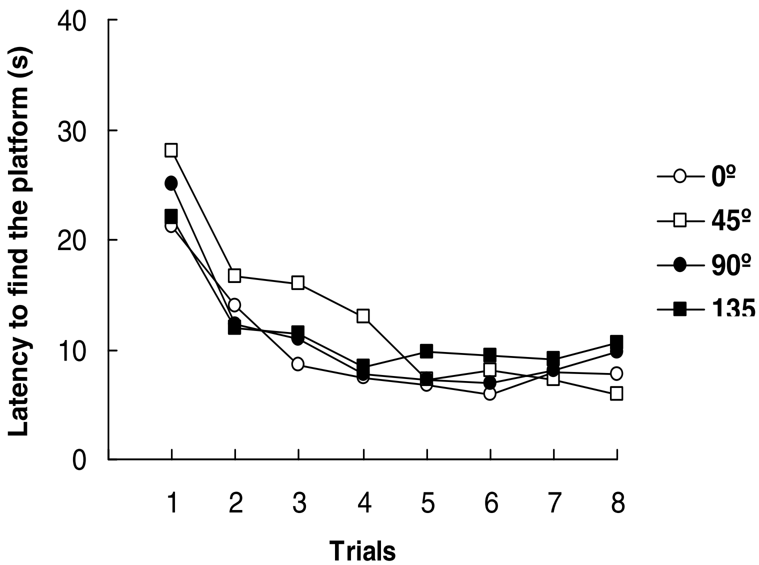

Figure 5. Mean escape latencies for the four groups of Experiment 2 during the training phase.

The bottom gradient of Figure 6 (i.e., the F gradient) shows the meantime in the segment where F was of the participants during the test trial. T-tests were used to compare the participants' performance with chance (i.e., 7.5 s searching in the segment where F was) in order to evaluate whether the test results reflected significant spatial learning. The participants' performance differed from chance on all test trials: Test -135, $t(23) = 3.76$; -90, $t(19) = 3.60$; -45, $t(20) = 3.89$; 0, $t(30) = 13.55$; +45, $t(18) = 5.56$; +90, $t(21) = 4.69$; and +135, $t(18) = 4.12$. Thus the performance of the participants reflected significant spatial learning on all test trials. An analysis of variance taking into account the variables Groups and Replications showed that the variable groups was the only significant result, $F(3, 148) = 52.51$. No other main effect or interaction was significant (*F*s < 1). Posthoc comparisons (Newman-Keuls) showed that Group 0 differed from all the other groups (45, 90, and 135), which did not differ from each other. An additional analysis of variance, taking into account the variable laterality (right versus left), showed that on the F gradient, this factor was not statistically significant in any of the tests: 45, 90, and 135 (*F*s < 3.00). Although all the tests (45, 90, and 135), differed from chance, these results do not show a gradient of responding.

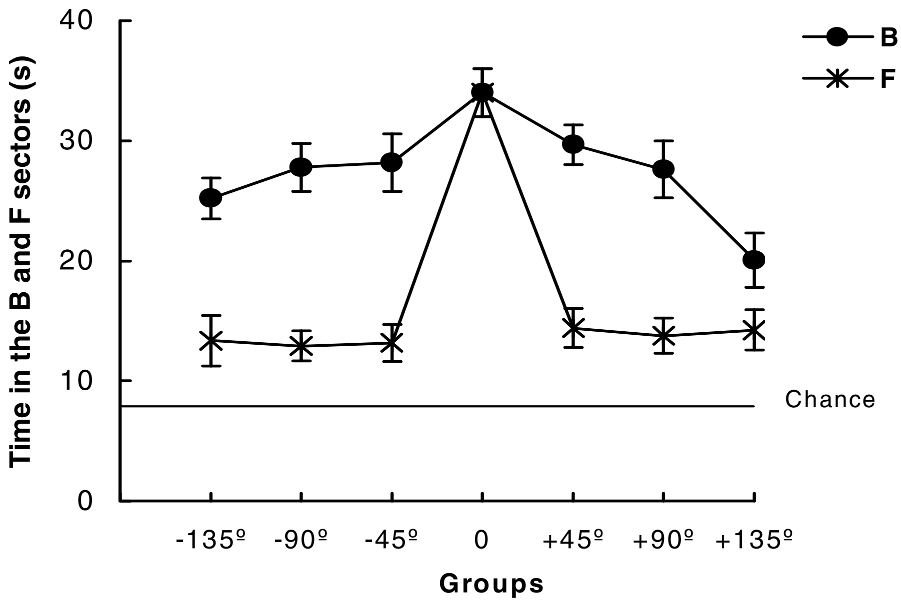

Figure 6. *Top gradient* (filled circles) - Mean time spent in the B segment by participants of Experiment 2 during the test trial. *Bottom gradient* - Mean time spent in the F segment by the same participants during the test trial.

General Discussion

In the two experiments presented here, participants were trained in a virtual pool to find a hidden platform placed in a specific position in relation to one (Experiment 1) or two (Experiment 2) objects or landmarks. Then, all the participants received a test trial without the platform and the time spent in the segment where the platform should have been was measured. In Experiment 1 the distance between the landmark and the platform was varied in different groups (Groups 0, 40, 72, 116, 148, and 160). The question of interest was whether a landmark would establish better control the closer it was to the platform. Alternatively, if the position of the single landmark did not affect this elemental learning, no differences between the groups should appear. The results showed that, both during acquisition and on the test trial, the control acquired by the landmark in the different groups was different depending on its relative distance from the platform: Closer landmarks acquired a better control than distant ones. Moreover, the performance of Groups 148 and 160 did not differ from chance on the test trial. This result clearly indicates an absence of significant spatial learning in these two groups. Then, what did they learn during acquisition? Because the platform was always located at a fixed distance from the wall of the pool, it could be the case that the participants in these two groups, Groups 148 and 160, learned to swim in circles at a certain distance from the wall (Alvarado & Rudy, 1995). For these participants swimming in circles at a certain distance from the wall of the pool is causally related to finding the platform. In favour of this explanation, this "response strategy" makes the prediction that no differences between any of the two groups and the level of chance should appear, as was the case. Alternatively, an important factor affecting the results of Experiment 1 could be search error, which is expected to increase in the different groups, as the landmark was more distant to the goal. Such an alternative explanation is very difficult to rule out completely. But a closer look at Figure 3 suggests a tendency, both in Group 148 and also in Group 160, to differ from chance. It could be the case that the number of participants (10 in each group) was insufficient due to the difficulty of the task in these two groups. In order to study further this possibility the test results of both groups, which did not differ between them, were combined to increase the statistical power of our analysis. A *T*-test was used to compare participants' performance with chance (i.e., 15 s searching in the quadrant where the platform should have been) in order to evaluate whether these test results (the results of 20 participants now) reflected significant spatial learning. The participants' performance differed from chance, $t(19) = 2.10$. Consequently, it can be concluded that the performance of these two groups combined, Group 148 and of Group 160, does reflect significant spatial learning on the test trial, thus rejecting the explanation based on the "response strategy". Experiment 1 has replicated the results by Chamizo & Rodrigo (2004) with non-human participants. Taken together, these experiments show a clear parallelism in comparison with the effect of absolute temporal proximity of the CS to the US in classical conditioning (Ost & Lauer, 1965; Schneiderman & Gormezano, 1964).

In Experiment 2, two objects, B and F, were simultaneously present during acquisition. Object B was just above the hidden platform (i.e., a beacon for the platform) while object F was above the edge of the pool (i.e., a frame of reference). Competition or overshadowing between these two objects was inevitable, and was prevented as much as possible. In this experiment, B was closer to the platform than landmark F (see Spetch, 1995, for an overshadowing effect by relative spatial proximity; for a related finding, Chamizo et al., 2005), and the training procedure was designed to ensure that B acquired better control than F: Rats were trained with escape trials in the presence of B and F, BF+ trials, intermixed with extinction trials in the presence of F only, F- trials (see Prados, Manteiga, & Sansa, 2003, for a demonstration that extinction in the spatial domain behaves like extinction in standard conditioning preparations). We believe that this training procedure reduced the total amount of associative strength that F could have gained (for the same result with nonhuman subjects see Rodrigo et al, 2005). This procedure was inspired by the notion of relative validity (Wagner, 1969). According to this notion, a more valid cue, one which better predicts the occurrence of reinforcement, will overshadow a less valid one. In a study by Wagner, Logan, Haberlandt, & Price (1968) two groups of rats, Group Correlated and Group Uncorrelated, were trained on a successive go/no-go discrimination. For both groups, a light was followed by reinforcement on 50% of the trials. The two groups differed in their experience with two different tones. For Group Correlated, one tone always predicted reinforcement while the second tone predicted nonreinforcement; but for Group Uncorrelated, the two tones were equal predictors of the occurence of reinforcement as the light was. The results showed that in the presence of a more valid predictor (i.e., in Group Correlated), the light was completely overshadowed. The light acquired good associative strenght only when the auditory stimuli were uncorrelated with reinforcement.

According to the notion of relative validity, in Experiment 2, B, the target beacon, would gain a higher control than F over the subjects' performance because B always predicted the location of the hidden platform, while F did not. On the test, the spatial location of B in relation to F was manipulated in the different groups. The expected results were to find a gradient of responding in the B segments only: More time swimming in the segment where B would be when B is placed in front of F (B's original position), which would decrease symmetrically with distance from F. In addition, a rather flat gradient of responding in the sector where F faces was also predicted (obviously with the exception of the configuration when B and F are one in front of the other, the training position). As expected, a generalization gradient was found: Participants spent more time in the segment where B was when B was in the training position (i.e., facing F), and this time decreased symmetrically with increasing distance of B from F. Object F also acquired some control over the participants' performance, although these results do not show a generalization gradient. Thus, the extinction trials to F did not prevent object F gaining some control of the participants' performance, as can be seen in Figure 6. It is worth mentioning that either 4 or 8 extinction trials (first and second replication, respectively) affected equally the present results. Experiment 2 has replicated the results by Rodrigo et al. (2005) with nonhuman subjects (see also Cheng et al., 1997; for related findings, Cheng, 1999, 2000, 2002; Cheng & Spetch, 2002). The implication is that when spatial location is analysed in a manner similar to other stimulus dimensions (such as wavelength and auditory frequency), the control exerted by the location of stimuli appears to be similar to that exerted by other properties or dimensions of the stimuli.

In conclusion, the results of the present study are those expected by any standard associative learning theory. Acquisition of spatial information seems to be governed by the same general associative principles that apply to both classical and instrumental conditioning. The present study gives very little support to the claim that spatial learning and other forms of learning are different, as O´Keefe and Nadel (1978) have stated.

References

Alvarado, M. C., & Rudy, J. W. (1995). Rats with damage to the hippocampal formation are impaired on the transverse patterning problem but not on elemental discriminations. *Behavioral Neuroscience*, **109**, 204-211.

Astur, R. S., Ortiz, M., & Sutherland, R. J. (1998). A characterization of performance by men and women in a virtual Morris water task. *Behavioral Brain Research*, **93**, 185-190.

Bennett, A. T. D. (1993). Spatial memory in a food storing corvid. *Journal of Comparative Physiology*, **173A**, 193-207.

Chamizo, V. D. (2002). Spatial learning: Conditions and basic effects. *Psicológica*, **23**, 33-57.

Chamizo, V. D. (2003). Acquisition of knowledge about spatial location: Assessing the generality of the mechanism of learning. *Quarterly Journal of Experimental Psychology*, **56B**, 107-119.

Chamizo, V. D., Aznar-Casanova, J. A., & Artigas, A. A. (2003). Human overshadowing in a virtual pool: Simple guidance is a good competitor against locale learning. *Learning and Motivation*, **34**, 262-281.

Chamizo, V. D., Manteiga, R.D., Rodrigo, T., Baradad, P., & Mackintosh, N.J. (2005). *Competition between landmarks in spatial learning: the role of proximity to the goal*. Manuscript submitted for publication.

Chamizo, V. D., & Rodrigo, T. (2004). Effect of absolute spatial proximity between a landmark and a goal. *Learning and Motivation*, **35**, 102-114.

Chamizo, V. D., Sterio, D., & Mackintosh, N. J. (1985). Blocking and overshadowing between intra-maze and extra-maze cues: a test of the independence of locale and guidance learning. *Quarterly Journal of Experimental Psychology*, **37B**, 235-253.

Cheng, K. (1989). The vector sum model of pigeon landmark use. *Journal of Experimental Psychology: Animal Behavior Processes*, **15**, 366-375.

Cheng, K. (1999). Spatial generalization in honeybees confirms Shepard's law. *Behavioural Processes*, **14**, 309-316.

Cheng, K. (2000). Shepard's law supported by honeybees in spatial generalization. *Psychological Science*, **11**, 403-408.

Cheng, K. (2002). Generalization: mechanistic and functional explanations. *Animal Cognition*, **5**, 33-40.

Cheng, K., & Spetch, M. L. (1998). Mechanisms of landmark use in mammals and birds. In S. Healy (Ed.), *Spatial representation in animals* (pp. 1-17). Oxford, UK: Oxford University Press.

Cheng, K., Collett, T. S., Pickhard, A., & Wehner, R. (1987). The use of visual landmark by honeybees: Bees weight landmarks according to their distance from the goal. *Journal of Comparative Physiology*, **161A**, 469-475.

Cheng, K. & Spetch, M. L. (2002). Spatial generalization and peak shift in humans. *Learning and Motivation,* **33**, 358-389.

Cheng, K., Spetch, M. L., & Johnston, M. (1997). Spatial peak shift and generalization in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes*, **23**, 469-481.

Collett, T. S., Cartwright B. A., & Smith, B. A. (1986). Landmark learning and visuospatial memories in gerbils. *Journal of Comparative Physiology*, **158A**, 835-851.

Kamin, L. J. (1969). Predictability, surprise, attention and conditioning. En B. A. Campbell and R. M. Church (Eds.), *Punishment and aversive behaviour* (pp. 279-296). New York: Appleton-Century-Crofts.

Mackintosh, N. J. (1974). *The psychology of animal learning*. London, UK: Academic Press.

Mackintosh, N. J. (1976). Overshadowing and stimulus intensity. *Animal Learning and Behavior*, **4**, 186-192

Morris, R. G. M. (1981). Spatial localization does not require the presence of local cues. *Learning and Motivation*, **12**, 239-260.

O'Keefe, J., & Conway, D. H. (1978). Hippocampus place units in the freely moving rat: Why they fire where they fire. *Experimental Brain Research*, **31**, 573-590.

O'Keefe, J., & Nadel, L. (1978). *The hippocampus as a cognitive map*. Oxford, UK: Oxford University Press.

Ost, J. W. P., & Lauer, D. W. (1965). Some investigations of salivary conditioning in the dog. In W. F. Prokasy (Ed.), *Classical conditioning* (pp. 192-207). New York: Appleton-Century-Crofts.

Pavlov, I. P. (1927). *Conditioned reflexes*. Oxford, UK: Oxford University Press.

Prados, J., Manteiga, R. D., & Sansa, J. (2003). Recovery effects after extinction in the Morris swimming pool navigation task. *Learning and Behavior*, **31**, 299-304.

Prados, J., & Trobalon, J. B. (1998). Locating an invisible goal in a water maze requires at least two landmarks. *Psychobiology*, **26**, 42-48.

Rescorla, R. A., & Cunningham, C. L. (1979). Spatial contiguity facilitates Pavlovian second-order conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, **5**, 152-161.

Rodrigo, T., Chamizo, V. D., McLaren, I. P. L., & Mackintosh, N. J. (1997). Blocking in the spatial domain. *Journal of Experimental Psychology: Animal Behavior Processes*, **23**, 110-118.

Rodrigo, T., & Prados, J. (2003). Aprendizaje asociativo y aprendizaje espacial: historia de una línea de investigación (1981-2001). In J. Vila & J. M. Rosas (Eds.*), Investigación contemporánea en aprendizaje asociativo. La aproximación México-España* (pp. 7-21). Jaen, Spain: Editorial del Lunar.

Rodrigo, T., Sansa, J., Baradad, P., & Chamizo, V. D. (2005). *Generalization gradients in a navigation task with rats.* Manuscript submitted for publication.

Saavedra, M. A. (1975). Pavlovian compound conditioning in the rabbit. *Learning and Motivation*, **6**, 314-326.

Sánchez-Moreno, J., Rodrigo, T., Chamizo, V. D., & Mackintosh, N. J. (1999). Overshadowing in the spatial domain. *Animal Learning and Behavior*, **27**, 391-398.

Schneiderman, N., & Gormezano, I. (1964). Conditioning of the nictitating membrane of the rabbit as a function of CS-US interval. *Journal of Comparative and Physiological Psychology*, **57**, 188-195.

Spetch, M. L. (1995). Overshadowing in landmark learning: Touch-screen studies with pigeons and humans. *Journal of Experimental Psychology: Animal Behavior Processes*, **21**, 166-181.

Spetch, M. L., & Wilkie, D. M. (1994). Pigeons' use of landmarks presented in digitized images. *Learning and Motivation*, **25**, 245-275.

Suzuki, S., Augerinos, G., & Black, A. H. (1980). Stimulus control of spatial behavior on the eight-arm maze in rats. *Learning and Motivation*, **11**, 1-18.

Testa, T. J. (1975). Effects of similarity of location and temporal intensity pattern of conditioned and unconditioned stimuli on the acquisition of conditioned suppression in rats. *Journal of Experimental Psychology: Animal Behavior Processes*, **1**, 114-121.

Tinbergen, N. (1951). *The study of instinct*. Oxford, UK: Claredon Press.

Vallortigara, G. Zanforlin, M., & Pasti, G. (1990). Geometric modules in animals' spatial representations: A test with chicks (*Gallus gallus domesticus*). *Jornal of Comparative Psychology*, **104**, 248-254.

Wagner, A. R. (1969). Stimulus validity and stimulus selection in associative learning. In N. J. Mackintosh & W. K. Honig (Eds.), *Fundamental issues in associative learning* (pp. 90-122). Halifax, Canada: Dalhousie University Press.

Wagner, A. R., Logan, F. A. Haberlandt, K., & Price, T. (1968). Stimulus selection in animal discrimination learning. *Journal of Experimental Psychology*, **76**, 171-180.

Received January 28, 2005.
Revision received July 26, 2005.
Accepted August 5, 2005.