Turning behavior in humans: The role of speed of locomotion [1], [2], [3]

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Abstract

We tested the turning behavior of participants under a single-trial procedure that emphasized assessing the initial conditions for learning. In two experiments, male and female university students (Experiment 1), and amateur male soccer players (Experiment 2), were asked to first walk or run along a T-shaped runway (10.8 m long) and then return by either the right or left side of the same runway. Non-significant differences in walking or running were found with respect to turning behavior; however, under the running condition, the soccer players showed the highest proportion of left turns, followed by male students. When the data of the running condition were analyzed in terms of speed (m/s), participants running at slow and medium speed preferred to turn right; in contrast, participants running at high speed preferred to turn left. It is suggested that the ecological approach to learning may provide a conceptual framework for the study of turning behavior.

Key words: *Turning behavior, initial conditions, speed of locomotion, humans*

Resumen

Evaluamos la conducta de giro de los participantes en un procedimiento de ensayo único, que enfatiza el análisis de las condiciones iniciales para el aprendizaje. En dos experimentos, a hombres y mujeres universitarios (Experimento 1) y jugadores de fútbol hombres (Experimento 2), se les pidió caminar o correr a través de una pista en forma de T (10.8 m de longitud) y regresar por el lado derecho o izquierdo de la pista. No se encontraron diferencias significativas entre las condiciones de caminar y correr sobre la conducta de giro. Sin embargo, en la condición de correr los futbolistas presentaron la mayor proporción de giros a la izquierda, seguidos de los estudiantes hombres. Cuando se analizaron los datos de la condición de correr en términos de velocidad (m/s), los participantes que corrieron a una velocidad baja y media prefirieron girar hacia la derecha; por el contrario, cuando corrieron a una velocidad alta, los participantes prefirieron girar hacia la izquierda. Se sugiere que la aproximación ecológica para el aprendizaje puede proveer de un marco conceptual para el estudio de la conducta de giro.

Palabras clave: *Conducta de giro, condiciones iniciales, velocidad de locomoción, humanos*

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> "The distinctions (left and right) besides those already enumerated… are distinctions of function and not of position… [m]en hop easier on the left leg; for the nature of the right is to initiate movement, that of the left is to be moved"
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> (Aristotle, *On the Gait of Animals,* 705b15-706a1).

Some patterns of locomotion in animals occur apparently in the absence of explicit reinforcement. For example, on the second of two consecutive trials, animals exposed to a T- or Y-maze tend to choose the arm that was not selected in the first trial. This behavioral pattern, called spontaneous alternation behavior (SAB), has been observed by exposing a given animal to multiple tests, or by assessing the performance of many animals on two trials (Richman, Dember, & Kim, 1986). SAB has been reported for many species, including rats (Montgomery, 1952), hamsters (Hughes, 1987), gerbils (Dember & Kleinman, 1973), hens (Haskell, Forkman, & Waddington, 1998), and humans (Schultz, 1964). Hull (1943) proposed that SAB occurred because the act of entering one arm generated reactive inhibition to that arm, which produced a tendency to go into the other, uninhibited, one. Other authors have offered different explanations as to why SAB occurs, such as curiosity behavior (Dember & Earl, 1957), foraging strategies (Estes & Schoeffler, 1955), exploratory tendencies (Montgomery, 1954), and stimulus satiation (Glanzer, 1953).

Turning behavior is another pattern of locomotion that is not maintained apparently by explicit reinforcement. This locomotive pattern refers to a preference for turning left or right as recorded by exposing a subject to multiple trials. Turning behavior has been reported in rats, which show a preference for the right arm of a T-maze (Andrade, Alwarshetty, Sudha, & Chandra, 2001; Rodriguez, Gomez, Alonso, & Afonso, 1992), but the left side of an open area (Sherman, Garbanati, Rosen, Yutzey, & Denenberg, 1980). Even in a T-maze in which both arms deliver the same quantity and quality of food, rats showed higher velocity and acceleration when turning left than when turning right (Covarrubias, Guzmán, Cabrera, & Jiménez, 2011). Thus, it has been suggested that turning behavior in animals is related to the lateralized components of their motor activity (Andrade et al., 2001; Rodriguez et al., 1992).

Studies of turning behavior in humans have also attributed right or left preference to components of lateralization, such as handedness, or footedness. The relation between handedness and turning direction has been evaluated using a long-term turning task (Bracha, 1987) in which partial (90°) or full (360°) turns were recorded using an electronic device. Mohr and colleagues (Mohr, Brugger, Bracha, Landis, & Viaud-Delmon, 2004; Mohr, Landis, Bracha, & Brugger, 2003) asked participants to wear this device for a total of 20 hours on 3 consecutive days, and found that right-handers and non-right-handers consistently turned in the opposite direction to their dominant side. This turning behavior away from the handedness side, however, was not reported in the absence of visual information when blindfolded participants were asked to walk straight forward, or march in place. In both of these cases, participants failed to show any consistent side preference, suggesting that visual cues also contribute to the direction of turning (Mohr et al., 2004).

In contrast to the studies by Mohr and colleagues, other research has found that subjects preferentially turn towards the direction that corresponds to their dominant side. Scharine and McBeath (2002), for example, arranged a T-maze in a university library using a set of parallel bookshelves. Participants were asked to walk through the T-maze to locate a target that was pasted on the opposite end of one of the two bookshelves. There, turning behavior was defined as the side that participants chose to search for the hidden target. Using a single-trial procedure, they found that 70% of right-handers preferred searching on the right bookshelf, while only 30% of left-handers searched on that side. Thus, they concluded that handedness was a strong predictor of turning direction. In another approach, studies focusing on the role of gender on turning behavior have shown that right-turning behavior among right-handers was more pronounced in female participants compared to males (Mead & Hampson, 1996, 1997).

The human studies described above recorded turning direction by asking participants to walk, but Lenoir, Van Overchelde, De Rycke, and Musch (2006) increased the motor demands in their turning behavior task by imposing time pressure on participants' performance. In their work, subjects were instructed to run back-and-forth between two lines that were 9 m long and placed 9.5 m apart, under the following conditions: (1) free walking; (2) running; and, (3) turning with the signaled foot. Participants performed 12 trials per condition in groups of 8-13 at a time. The running condition consisted of jogging from one line to the other for a 2-min period (no time pressure imposed). Under the signaled-foot condition, participants were required to go forward at low speed and upon hearing a whistle signal return as quickly as possible. The signal was programmed to correspond to the foot that participants placed in front, so as to force them to turn right or left. Between tests, and upon completing the entire set of trials, subjects were allowed to walk freely to recover or "cool-down" (considered the free-walking condition). Regardless of handedness or footedness, and based on a measure of preference, the rotation index, RI (i.e., the number of left turns divided by the total number of turns), the participants judged to be left-turners (RI > 65%) corresponded to 43.9% under the free-walking condition. For the running condition, the number of left-turners increased to 68.2%. Finally, for the right- and left-foot-signaled conditions, the proportion of left-turners was 64.5% and 62.6%, respectively. According to Lenoir et al. (2006), turning behavior in unrestricted conditions (i.e., walking) can be overruled by imposing time pressure (i.e., running) because higher speeds of locomotion increase the stability of the gait pattern, thus reducing the possibility of switching between right- and left-turning.

As mentioned previously, since turning behavior occurs apparently without explicit reinforcement (that is, not under an operant contingency), it may be considered outside the scope of behavior-analytic theory (Staddon, 1983). However, according to Timberlake (1993), even before conditioning, animals come to any learning situation equipped with stimulus sensitivity, response components and motivational states. In this sense, they exhibit niche-related responses that are deemed candidates for selection by the operant contingency and so are called proto-operants (Timberlake, 2004). Earlier studies have classified as proto-operants the unconditioned lever presses that underlie the operant level (Cabrera, Sanabria, Jiménez & Covarrubias, 2013). As such, these proto-operants show a well-organized configuration (Cabrera et al., 2013; Timberlake, 2004).

In the present study, we proposed that the pattern of turning behavior may be considered a proto-operant behavior. Since niche-related responses or proto-operants arise in functional contexts (Timberlake, 1984), turning behavior would be sensitive not only to the participants' components of motor activity but also to the task requirements; in this case, temporal requirements (i.e., walking or running). Although the relationship between temporal constraints and turning behavior has been assessed previously (Lenoir et al., 2006), no earlier study has tested this relationship by assessing the performance of many participants on one single trial. The purpose of implementing this procedure was to characterize the initial conditions for the learning of turning behavior (Timberlake, 1993), and to extend the generality of the relationship between the temporal constraints of the task and turning behavior.

Therefore, the present experiment was designed to examine turning behavior in a T-shaped runway under two conditions, walking and running, but with the innovation of implementing a single-trial procedure (see Scharine & McBeath, 2002) that emphasized assessing participants in a pre-learning situation; that is, evaluating turning behavior as a proto-operant behavior.

Experiment 1

Method

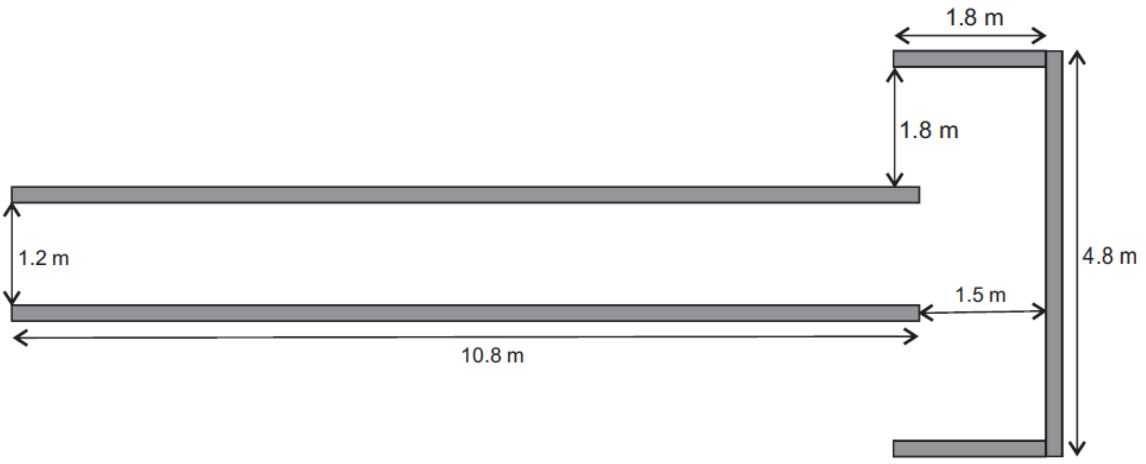
Participants

A total of 151 university students aged 18-40 years participated (74 men, 77 women) (mean age for men= 21.68, SD= 3.2; mean age for women= 20.66, SD= 3.4). Data from three subjects were discarded due to errors during the experiment. All volunteers were informed that the study concerned human locomotion and gave their verbal consent to participate.

Settings and materials

A T-shaped runway was arranged. The boundaries of the runway were made with white paperboard strips (8.0-cm wide) covered with translucent plastic and fixed to the ground. The dimensions of the main and secondary lanes were 10.8 long m x 1.2 m wide and 4.8 m x 1.5 m, respectively (see Figure 1).

Figure 1. Schematic diagram and dimensions of the runway used in the experiment.



Procedure

Handedness was evaluated by asking participants which hand they used for writing (Hart & Gabbard, 1997). The T-shaped runway was placed on the lawn of an open, rectangular area (approximately 40 m × 30 m) of the university campus. Other studies have isolated the testing area from stimuli that could potentially affect turning behavior (see Lenoir et al., 2006), but this technique was not possible in the present experiment, so we randomly oriented the runway towards the four cardinal compass points in an effort to impede extra-runway stimuli from biasing students' turning behavior. As orientation was randomly distributed, approximately 25% of the sample participated in the experiment with the runway pointing towards each one of the four cardinal points.

Participants were assigned randomly to either the walking or running condition. They stood at the starting point of the runway; that is, on the midpoint for accessing the main lane. They were then instructed to walk or run along the T-shaped runway and return to the starting point by either the left or right side. The directions, given by one of the experimenters, were as follows (translated from Spanish):

Walking condition: "You have to walk along the runway, and at the end you must choose one of the two sides to return to the starting point".
Running condition: "You have to run along the runway as fast as possible, and at the end you must choose one of the two sides to return to the starting point.
We will register your time."

The experimenter issued these directions while standing beside the participants (on either their right or left side). Her/his location was also counterbalanced. As far as we know, no other experiment on turning behavior has implemented this type of control. The time elapsed between initial movement and the return to the starting point was recorded for the running condition only. Participants were not allowed to see others' performances to eliminate the possibility of imitation.

Results and Discussion

In terms of handedness, participants in this experiment were predominantly right-handed (96%). Using a Chi-square (χ^2) analysis, we evaluated whether two extra-runway variables might have biased the direction of turning: namely, the orientation of the T-shaped runway (four conditions: north, south, east, west); and the experimenter's location with respect to participants (two conditions: right, left). Non-significant interactions between runway orientation and turning behavior were found for both the walking and running conditions; however, in the case of the experimenter's location, a main effect was obtained under the running condition, $\chi^2(1, N= 71) = 3.9$, $p = 0.048$; that is, when the experimenter stood on the right side of participants exposed to the running condition, more of them turned in that direction.

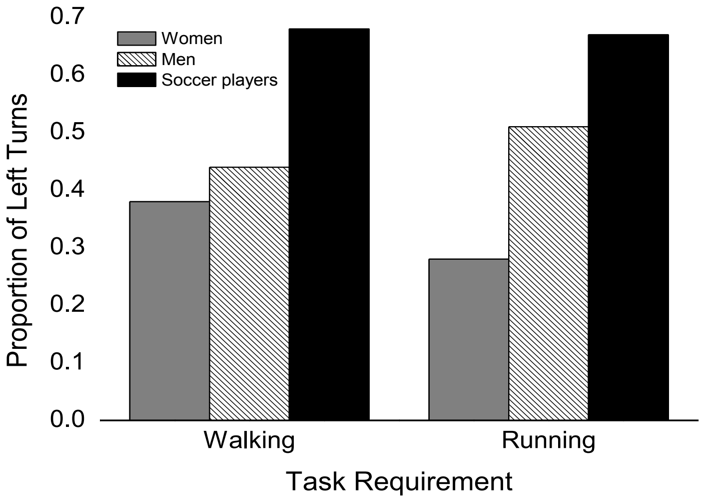
Interactions between handedness and turning behavior were not significant for either the walking or running conditions. Although these results are consistent with studies that have reported that turning behavior occurs independently of handedness or footedness (Lenoir et al., 2006), they are inconsistent with research that asserts that handedness does influence turning behavior (Mohr & Bracha, 2004; Mohr et al., 2004; Mohr et al., 2003; Scharine & McBeath, 2002).

Due to the asymmetry of the sample (i.e., a higher number of right-handed participants), and because some studies have demonstrated that handedness does influence the turning direction, in subsequent analyses we included only right-handed subjects (76 women, 69 men). A χ^2 analysis revealed non-significant interactions between task requirements (i.e., walking and running) and turning behavior, which do not extend the generality of this relationship as reported in a situation of repetitive trials (Lenoir et al., 2006), probably due to both studies used different procedures.

With respect to the relation between gender and turning behavior, non-significant interactions were found for the walking condition, but interactions for the running condition did approach significance, $\chi^2(1, N= 67) = 3.77$, $p = 0.052$. Figure 2 shows the proportion of left turns under the walking and running conditions for female and male participants. Under the walking condition, the proportions of left turns for women and men were 0.38 and 0.44, respectively; in other words, they showed a rightward preference that is consistent with some previous studies (Robinson, 1933; Scharine & McBeath, 2002). However, under the running condition the proportion of left turns by women decreased to 0.28, whereas the proportion of left turns by men increased to 0.51.

Based on the fact that the experimenter's location was related to a higher right-turning behavior under the running condition (see above), we tested whether this interaction could explain the low proportion of left turns for women in the running condition. Therefore, we analyzed data separately with the experimenter standing on the left and right side with respect to participants. This analysis confirmed an interaction between gender and turning behavior when the experimenter stood on the right side, χ^2(1, *N*= 42) = 5.34, p = 0.021; that is, under the running condition, women turned more often to the side that corresponded with the experimenter's right-location. These results may indicate that the higher proportion of right turns among women (and consequently, the lower proportion of left turns) under the running condition was induced by the location of the experimenter; however, because similar findings have been reported elsewhere but in the absence of any experimenter bias, this assumption is not completely supported. For instance, similar to our results, Lenoir et al. (2006) found a lower tendency to turn left in women (RI= 59.4%) than men (RI= 63.3%).

Figure 2. Proportion of left turns by women (grey bars), men (broken bars), and soccer players (black bars), under the two task requirements (walking and running).



Alternatively, sex differences in turning behavior under the running situation might be due to differential performance of the task. A Student's *t* test showed a significant difference between the speed (m/s) reached by female (mean= 3.01 m/s, SD= 0.33) and male participants (mean= 3.77 m/s, SD= 0.32), *t*(*df* = 65) = 9.42, p =.000 (two tails), respectively, in the running condition.

To test whether differential performance in terms of speed engenders differences in turning direction, in Experiment 2 we evaluated the performance of soccer players who, presumably, can reach higher speeds of locomotion. When exposed to the walking situation, we expected that the soccer players would turn left in the same proportion as the university students. While for the running situation we predicted that turning behavior to the left would be higher for the soccer players than the university students. We included soccer players because some of the activities programmed in their training schedules resemble the movements evaluated in turning behavior studies (e.g., zigzag dribbling; see Miranda, Antunes, Pauli, Puggina, & da Silva, 2013).

Experiment 2

Method

Participants

A total of 38 amateur male soccer players, aged 18-30 participated (mean age= 21.11, SD= 2.77). All were recruited from university soccer teams.

Settings and Materials

The same T-shaped runway was used as in Experiment 1.

Procedure

The procedure was almost identical to that conducted in Experiment 1. The only difference was that the runway orientation was not counterbalanced towards the four cardinal points. Therefore, soccer players were evaluated with the direction of the runway fixed towards the segment of the area judged to present the least distracting stimuli.

Results and Discussion

The soccer players were predominantly right-handed (97%). A χ^2 analysis showed non-significant interactions between the experimenter's location and turning behavior for both task requirements (i.e., walking and running). Because only one of the soccer players was left-handed, no statistical analyses of the effects of handedness on turning behavior were performed. As in Experiment 1, all subsequent analyses included right-handers only (N= 37). Upon assessing whether walking (N= 19) or running (N= 18) engendered turning differences, non-significant interactions were found. Figure 2 includes the proportion of left turns by soccer players, which was higher than that predicted by random distribution, and similar to the figure for the walking (0.68) and running (0.67) conditions.

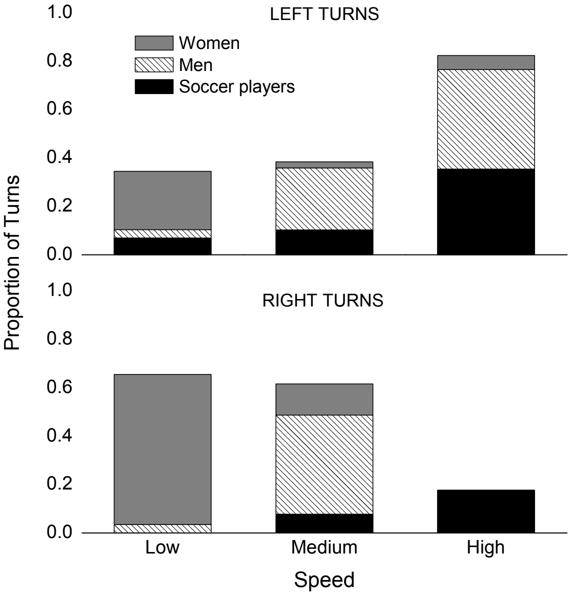
When we assessed whether the soccer players' pattern of turning behavior was different from that of the university students tested previously, a χ^2 analysis revealed non-significant interactions between the three populations and turning behavior for the walking condition. In contrast, under the running condition, significant interactions between these two variables were found, $\chi^2(2, N= 85) = 7.62$, $p = 0.022$. In other words, under the running condition men turned left more often than women, but soccer players turned left more often than both women and men; a finding that was consistent with our expectations.

Moreover, the mean speed reached by soccer players was 3.95 (m/s) (SD= 0.37), significantly higher than that reached by female students, $t(df = 48) = -9.16$, $p =.000$ (two tails), but not significantly different from that of male students. We tested whether there were significant interactions between speed of locomotion and turning behavior. For this purpose, we included in the analysis the speed scores from the three populations (including 32 female students, 35 male students and 18 soccer players). Once the minimum (2.4 m/s) and maximum (4.85 m/s) speed scores were obtained, we calculated the ranges that corresponded to low (2.4-3.21 m/s), medium (3.22-4.03 m/s), and high (4.04-4.85 m/s) speed categories, and then assigned participants to these categories according to their speed scores (low= 29 participants, medium= 39, high= 17).

Figure 3 shows the proportion of left turns (top panel) and right turns (bottom panel) as a function of the speed reached (low, medium, or high). A χ^2 analysis showed a significant interaction between speed of locomotion and turning behavior, $\chi^2(8, N= 85) = 19.59$, $p = 0.012$; that is, participants running at low and medium speeds showed similar proportions of turns, but those that reached the fastest speeds showed the highest proportion of left turns (top panel) and, consequently, the lowest proportion of right turns (bottom panel). Figure 3 also shows that women, men, and soccer players were differentially distributed in each speed category.

These results suggest that turning behavior was sensitive to changes in speed of locomotion, a finding supported by other authors who suggest that higher velocities increase the stability of gait pattern, thus reducing the possibility of switching between right- and left-turning (Lenoir et al., 2006; Pierotti, Brand, Gobel, Pedersen, & Clark, 1991). It is noteworthy that the interaction between speed of locomotion and turning behavior reported in this study was the result of analyzing the performance of many participants in one single trial instead of exposing participants to multiple trials. Therefore, although Lenoir et al. (2006) suggested an alternative hypothesis to explain the effects of running on the direction of turning -that left-turning preference might have been promoted as a means of saving energy in the repetitive trials-, our results are more compatible with the hypothesis that speed increases the stability of the gait pattern.

Figure 3. Proportion of turns as a function of the speed of locomotion. *Top panel*: proportion of left turns. *Bottom panel*: proportion of right turns. Participants represented in bars as in Figure 2.



Finally, to the best of our knowledge, no previous studies had included soccer players in analyses of turning behavior, though an experiment with athletes reported that right-footed expert skiers showed better performance (in terms of amplitude and force) when executing left-curving turns (Vaverka & Vodickova, 2010). Therefore, more research is needed to evaluate the influence of speed of locomotion on turning behavior in athlete populations.

General discussion

Our results showed that handedness did not influence turning behavior. However, due to the asymmetry of the sample (i.e., larger right-handed populations), this relation cannot be deemed conclusive. Task requirements (i.e., walking or running) did not consistently influence turning behavior either, although a significant ascendant tendency in the proportion of left turns among the three populations (women, men, soccer players) was observed for the running condition. In addition, upon testing whether speed affected turning behavior, we found that at greater speeds participants showed higher proportions of left turns. Although these results indicate that speed performance influenced turning behavior, a sex difference-based hypothesis (i.e., the low-speed category included mainly women) cannot be discarded. A future study including female soccer players (or similar female athletes) could test this hypothesis.

Additionally, our findings suggest that the use of a single-trial procedure is adequate for studying turning behavior in humans under walking and running conditions. This procedure makes it possible to characterize the pattern of turning behavior in the initial conditions for learning (Timberlake, 1993). In addition, because turning behavior occurs apparently in the absence of explicit reinforcement, its characteristics should depend partly on the subject's response components, which in turn depend on the functional context (Timberlake, 1984). Biomechanical properties apparently make up part of the components of responding that underlie turning behavior. Our results suggest that, although this factor was not measured, participants may have differed in terms of their biomechanical properties, which in turn may have propitiated different speeds of locomotion. Participants' strength or body equilibrium might have played an important role in determining turning direction as well. In fact, previous evidence suggests that differences in biomechanical properties –for instance, those induced by age– influence the emergence of different modes of action or behavior topographies used when reaching for an object with the arm (Jiménez, Covarrubias, & Cabrera, under review). Lateralization, on the other hand, is also apparently part of the subject's response components. However, the effects of lateralization on turning behavior are still ambiguous. In this study, we included a right-handed population only; thus future research may test whether the results reported here are replicated with a left-handed population.

Regarding the functional context, Timberlake (2004) proposed that niche-related responses are generated by mechanisms that operate in current circumstances which are similar to those that were evolutionarily selected. In that case, when organisms encounter an arbitrary task they respond with the non-arbitrary structure that best fits (Timberlake, 1993). As far as we know, a functional (evolutionary) approach to the study of turning behavior is absent in the specialized literature, though such a focus would allow researchers to design experimental settings with components that best fit with the organismic structure of animals, called *tuning* (Timberlake, 1993). As is recognized elsewhere, the inconsistent results reported in studies of turning behavior in humans possibly arise from "methodological differences like the nature of the task, whether or not sensory deprivation was applied, and the selection of participants (right-handers only versus a mixed population)" (Lenoir et al. 2006, p. 180). We suspect that a functional analysis of the characteristics mentioned by Lenoir and colleagues may support the notion that turning behavior arises as the best fit to current circumstances. Therefore, the design of experimental settings for evaluating turning behavior in humans should take into account not only the components of the motor activity, but also those characteristics of the surface layout that provide functional support to different patterns of locomotion. Empirical evidence from studies with animals is consistent with this notion. For example, Covarrubias et al. (2011) showed that the possibility of encountering a surface with the same or different layout in a T-maze influenced velocity in hamsters and rats, regardless of the effects of reinforcement.

Finally, in addition to the consistency between the present study and the ecological approach for learning (Timberlake, 1984, 1993, 2004), our results may also be important for other theories within behavior analysis. For example, the molar approach to behavior (Baum, 2002, 2004, 2012) emphasizes the extendedness in time of most behaviors. However, most of the basic studies in behavior analysis deal with discrete responses (i.e., lever pressing or key pecking). Therefore, the study of a molar behavior, such as walking or running along a runway and turning, might be described by the molar approach, extending the generality of its scope to the analysis of turning behavior.

In summary, in the field of turning behavior, different studies have reported contradictory findings. In human studies, for example, it is not clear whether handedness consistently influences turning behavior. Apparently, imposing time pressure (i.e., running) did consistently produce a tendency to turn left. Because we implemented a single-trial procedure, which emphasized evaluating participants' performance before conditioning (i.e., the initial conditions for learning), turning behavior could be sensitive not only to the subject's response components but also to the task requirements. Our results did not confirm that running engendered more left turns than walking; however, it did show that at higher speeds a higher proportion of left turns is found. The biomechanical properties of the participants may underlie the speed of locomotion, and thus influence turning behavior; however, testing this relationship remains open for future research. Overall, we propose that the ecological approach to learning may be an adequate conceptual framework that will allow us to clarify the contradictory findings reported in studies of turning behavior.

References

Andrade, C., Alwarshetty, M., Sudha, S., & Chandra, J.S. (2001). Effect of innate direction bias on T-maze learning in rats: implications for research. *Journal of Neuroscience Methods*, *110*, 31-35.

Aristotle. On the gait of animals. Translation by David Ross (1952), *The works of Aristotle*. Oxford: Oxford University Press.

Baum, W. M. (2002). From molecular to molar: a paradigm shift in behavior analysis. *Journal of the Experimental Analysis of Behavior, 78*, 95-116.

Baum, W. M. (2004). Molar and molecular views of choice. *Behavioural Processes, 66*, 349-359.

Baum, W. M. (2012). Rethinking reinforcement: allocation, induction, and contingency. *Journal of the Experimental Analysis of Behavior, 97*, 101-124.

Bracha, H.S. (1987). Asymmetric rotational (circling) behavior, a dopamine-related asymmetry: preliminary findings in unmedicated and never-medicated schizophrenic patients. *Biological Psychiatry, 22,* 995-1003.

Cabrera, F., Sanabria, F., Jiménez, Á. A., & Covarrubias, P. (2013). An affordance analysis of unconditioned lever pressing in rats and hamsters. *Behavioural Processes, 92,* 36-46.

Covarrubias, P., Guzmán, R., Cabrera, F., & Jiménez, Á.A. (2011). Las superficies ambientales, la velocidad y la aceleración en hámsteres y ratas. In H. Martínez, J.J. Irigoyen, F. Cabrera, J. Varela, P. Covarrubias, & Á.A. Jiménez. (Eds.), *Estudios sobre comportamiento y aplicaciones. Vol. II* (pp. 95-115). México: Universidad de Guadalajara.

Dember, W.N. & Earl, R.W. (1957). Analysis of exploratory, manipulatory and curiosity behaviors. *Psychological Review, 64,* 91-96.

Dember, W.N. & Kleinman, R. (1973). Cues for spontaneous alternation by gerbils. *Animal Learning & Behavior, 1,* 287-289.

Estes, W.K., & Schoeffler, M.S. (1955). Analysis of variables influencing alternation after forced trials. *Journal of Comparative and Physiological Psychology, 48,* 357-362.

Glanzer, M. (1953). Stimulus satiation: an explanation of spontaneous alternation and related phenomena. *Psychological Review, 60*, 257-268.

Hart, S. & Gabbard, C. (1997). Examining the stabilizing characteristics of footedness. *Laterality, 2,* 17-26.

Haskell, M.J., Forkman, B., & Waddington, D. (1998). An investigation into the occurrence of spontaneous alternation behaviour in the domestic hen. *Behavioral Processes, 43,* 43-51.

Hughes, R.N. (1987). Spontaneous alternation behavior in hamsters. *Current Psychological Research & Reviews, 6,* 331-336.

Hull, C.L. (1943). Principles of behavior. New York: Appleton-Century.

Jiménez, Á.A., Covarrubias, P., & Cabrera, F. Análisis ecológico de una tarea de alcance con el brazo con adultos mayores (under review).

Lenoir, M., Van Overschelde, S., De Rycke, M., & Musch, E. (2006). Intrinsic and extrinsic factors of turning preferences in humans. *Neuroscience Letters, 393,* 179-183.

Mead, L.A. & Hampson, E. (1996). A sex difference in turning bias in humans. *Behavioural Brain Research*. 78, 73–79.

Mead, L.A. & Hampson, E. (1997). Turning bias in humans is influenced by phase of menstrual cycle. *Hormones and Behavior, 31*, 65-74.

Miranda, R.E.E.P.C., Antunes, H.K.M., Pauli, J.R. Puggina, E.F., & da Silva, A.S.R. (2013). Effects of a 10-week soccer training program on anthropometric, psychological, technical skills and specific performance parameters in youth soccer players. *Science & Sports, 28*, 81-87.

Mohr, C. & Bracha, H.S. (2004). Compound measures of hand-foot-eye preference masked opposite turning behavior in healthy right-handers and non-right-handers: Technical comment on Mohr et al. (2003). *Behavioral Neuroscience, 118,* 1145-1146.

Mohr, C., Brugger, P., Bracha, H.S., Landis, T., & Viaud-Delmon, I. (2004). Human side preference in three different whole-body movement tasks. *Behavioural Brain Research, 151,* 321-326.

Mohr, C., Landis, T., Bracha, H.S., & Brugger, P. (2003). Opposite turning behavior in right-handers and non-right-handers suggests a link between handedness and cerebral dopamine asymmetries. *Behavioral Neuroscience, 117,* 1448-1452.

Montgomery, K.C. (1954). Role of exploratory drives in learning. *Journal of Comparative and Physiological Psychology, 47*, 60-63.

Montgomery, K.C. (1952). Exploration behavior and its relation to spontaneous alternation in a series of maze exposures. *Journal of Comparative and Physiological Psychology, 45,* 50-57.

Pierotti, S.E., Brand, R.A., Gobel, R.H., Pedersen, D.R., & Clarke, W.R. (1991). Are leg electromyogram profiles symmetrical? *Journal of Orthopedic Research, 9,* 720-729.

Richman, C.L., Dember, W.N., & Kim, P. (1986). Spontaneous alternation behavior in animals: a review. *Current Psychological Research & Reviews, 5,* 358-391.

Robinson, E.S. (1933). The psychology of public education. *American Journal of Public Health, 23,* 123-128.

Rodriguez, M., Gomez, C., Alonso, J., & Afonso, D. (1992). Laterality, alternation, and perseveration relationships on the T-maze test. *Behavioral Neuroscience, 106,* 974-980.

Scharine, A.A. & McBeath, M.K. (2002). Right-handers and Americans favor turning to the right. *Human Factors*, *44*, 248-256.

Sherman, G.F., Garbanati, J.A., Rosen, G.D., Yutzey, D.A., & Denenberg, V.H. (1980). Brain and behavioural asymmetries for spatial preference in rats. *Brain Research, 92,* 61–67.

Schultz, D.P. (1964). Spontaneous alternation behavior in humans: implications for psychological research. *Psychological Bulletin, 62*, 394-400.

Staddon, J.E.R. (1983). *Adaptive behavior and learning.* London: Cambridge University Press.

Timberlake, W. (1984). An ecological approach to learning. *Learning and Motivation, 15*, 321-333.

Timberlake, W. (1993). Behavior systems and reinforcement: an integrative approach. *Journal of Experimental Analysis of Behavior, 60,* 105-128.

Timberlake, W. (2004). Is the operant contingency enough for a science of purposive behavior? *Behavior and Philosophy, 32*, 197-229.

Vaverka, F. & Vodickova, S. (2010). Laterality of the lower limbs and carving turns. *Biology of Sports, 2,* 129-134.