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ORIGINAL PAPER

Cue polarization and representation in mouse home base behaviors

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Abstract
The nature of the representation guiding spatial navigation has been investigated extensively; however, most of this work has used behavioral tasks that involved learning the location of food reward or an escape platform. In contrast, relatively few studies have focused on the spatial representation of a home base, a ubiquitous feature of open-field behavior, and its ability to be encoded relative to environmental cues. The current set of experiments investigated acquisition and retention of the location of home base establishment. In general, proximal cues anchored the position of the home base during acquisition sessions across all four experiments. Although mice established a home base during retention sessions, previous experience did not influence its position during retention sessions. These observations demonstrate that stimulus control of home base position depends on access to proximal cues. Further work is needed to determine the extent that home base establishment may provide a framework to encode goal-directed spatial behaviors.

Keywords Home base · Open field · Cues · Representation · Cognitive map

Introduction

The study of an animal's umwelt, or perception of their environment (Von Uexküll et al. 2010), has been of interest in explaining how the environment is represented in the brain. An umwelt is typically considered the unique subject-centered layout of the environment, and is observed to influence the behavior of the subject. One of the first theories considering an umwelt maintained that animals use an abstract representation, like a map. For instance, Tolman et al. (1946) trained rats to locate a food reward within a T-maze. One group of rats, the response group, was trained to always travel to the right arm regardless of how the T-maze was rotated relative to environmental room cues. The second group, the place group, was trained to go to the absolute location relative to environmental room cues, regardless of how the T-maze was rotated. Tolman et al. (1946) found that the place group was more efficient at learning the correct location of the food reward. This study opened the doors to future research examining the nature of the representation of an animal's environment and was the first evidence to support that the environment may be represented as a cognitive map.

An alternative theory of environmental representation was proposed, specifically, that animals use a vector-based system employing the use of direction and distance (Blodgett et al. 1949). For example, in Tolman et al.'s (1946) study, rats were trained to go to the same place and direction, potentially influencing the efficiency at which these animals learned the location of the food reward. When place and direction information was controlled, rats that were trained to a consistent direction were more efficient at learning the location of the food reward when the T-maze was rotated, as opposed to rats that were trained to a consistent place (Blodgett et al. 1949). Directional responses have been observed in other goal-directed tasks such as open-field (Skinner et al. 2003; Köppen et al. 2013) and water-maze studies when the pool was shifted (Hamilton and Sutherland 1999; Hamilton et al. 2002, 2007, 2009; Akers et al. 2007; Köppen et al. 2013). These studies suggest that a directional response is not limited to one task or one specific species and support a vector-based coordinate system representation of the environment (Cheng 1986).

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Goal-directed behaviors have typically been used to investigate the nature of the representation mediating spatial learning; however, this representation may depend on the organization of open-field behaviors. One organizational feature observed in a variety of animal species is the spontaneous establishment of a discrete location within the environment where an animal will find refuge to avoid predation, engage in grooming behaviors, and reorient itself, termed the home base (Eilam and Golani 1989; Altmann and Samuels 1992; Fonio et al. 2009; Stewart et al. 2010; Woodgate et al. 2016; Burke and Whishaw 2020; Frostig et al. 2020). Once this home base location has been established, animals will organize their movement around it. Typically, rodents will exhibit slow circuitous progressions away from the home base and relatively fast non-circuitous progressions toward the home base (Tchernichovski and Golani 1995; Wallace et al. 2006; Osterlund Oltmanns et al. 2021; Schaeffer et al. 2022). Throughout the duration of the open-field session, the animal's stops become more tightly clustered, resulting in a highly stable home base position. Several factors are observed to focus home base position, including manipulating proximal and distal visual cues. Previous literature in rats has observed that distal (e.g., bookcase) and proximal cues (e.g., cue card, tactile cues) exert stimulus control over home base position (Clark et al. 2005; Hines and Whishaw 2005; Lehmann et al. 2007). When the proximal cues were removed, rats maintained their previous home base position, suggesting distal visual sources of information were encoded and used to represent the home base position in the environment. In contrast, species differences have been observed, such that mice did not establish a home base in the same position after a familiar proximal cue was removed (Clark et al. 2006). Therefore, it is of interest to further understand potential species-specific differences in home base mnemonics. Home base establishment is a ubiquitous feature of an animal's open-field behavior, and the nature of this spatial representation has yet to be investigated. It is possible that the representation of a home base includes position information derived from distal environmental cues. This series of studies manipulated environmental cue information to assess potential changes in the position of home base establishment in the open field.

Experiment 1

The current study evaluated the effect of varying proximal cue salience on the organization of mouse open-field behavior. The mice were exposed to a circular open-field across three sessions with the cue present and two sessions with the cue removed.

Methods

Subjects

Twelve female and 12 male C57BL/6 mice (90 days old) were bred at Northern Illinois University (NIU) Animal Care facility for this experiment. The mice were housed on a 12/12-h dark–light schedule in a temperature- and humidity-controlled room. Food and water were provided ad libitum. All procedures were conducted during the light phase of their cycle and were ran in two cohorts containing a mix of sex and group conditions. All protocols were approved by the NIU Institutional Animal Care and Use Committee.

Apparatus

The open-field apparatus was a circular table without walls that spanned 122 cm in diameter and was positioned 34.5 cm above the floor (Fig. 1). The apparatus was placed in a white rectangular room with dark gray flooring that was illuminated by florescent lights located on the ceiling. The lighting was consistent and equally illuminated the table and cues to avoid shadows. The room contained other various distal cues (e.g., sink, cabinets, wooden boards, etc.) which were covered by white sheets (Fig. 1C). The visual cue condition (Fig. 1A) consisted of a similar black box ($43 \times 46 \times 62$ cm) placed 30 cm away from the edge accounting for approximately 26 degrees of the table. The tactile–visual cue condition (Fig. 1B) consisted of a black plastic tab (20×5 cm) attached to the side of the apparatus which also spanned 26 degrees of the table. Although previous research has observed there is greater stimulus control with proximal rather than distal environmental cues (Clark et al. 2006), these studies used two competing cues. Therefore, this combination of cues for the current study was selected to determine the influence of single cue salience on home base behaviors. As supported by previous studies, black was chosen for both the visual cue and tactile–visual cue for similar salience in relation to the white room (Hines and Whishaw 2005).

Procedure

Mice were transferred from their home cage individually into a clear plexiglass holding cage with a metal cage top covered by a towel. The holding cage was walked from the colony room to the experimental room in a circuitous path to minimize using the location of the testing room, in relation to the colony room, to guide movement. Once inside the testing room, the experimenter uncovered the holding

Fig. 1 Experiment 1–4: images of the visual (**A**) and tactile–visual (**B**) cue used within the current study. Additionally, images of the layout of the room with non-salient room cues (**C**) and salient room cues (**D**)

cage and placed the mouse in the center of the table. If the mouse fell during the session, the experimenter entered the room and placed the mouse back onto the center of the table and recorded the fall. A threshold of five falls during a session was used as a cut off to exclude mice from the current study. During the entirety of the session, the testing room was illuminated by florescent ceiling lights. Following the exploration session, the experimenter placed the mouse back into the holding cage, covered the cage with the towel, and returned to the colony room following a different circuitous path. This procedure was used to reduce the mice learning the location of the experimental room, relative to the colony room. Previous work has observed this procedure does not appear to increase the amount of behaviors indicative of spatial disorientation (Blankenship et al. 2017; Donaldson et al. 2018, 2019; Banovetz et al. 2021; Osterlund Oltmanns et al. 2021, 2022a, b; Schaeffer et al. 2022). Tables and tactile cues were wiped with an ammonia solution between mice. Additionally, cue position on the table was counterbalanced within each group. To counterbalance, both types of cues were rotated 90 degrees around the table between mice; however, the table remained in the same position for every mouse. Exploratory sessions were recorded at 30 frames/second for offline analysis using an overhead bullet camera.

Sessions

Mice went through a total of five open-field sessions in which the mouse was left to explore for 30 min. During the three acquisition sessions (A1–A3), the cue remained in the same position in the room and the sessions occurred approximately 24 h apart. Both retention sessions (R1 and R2) involved removing the cue. The first retention session (R1) occurred approximately 24 h after the last acquisition session, and the second retention session (R2) occurred one week following the R1.

Behavioral analysis

Twenty minutes of each 30-min session was analyzed after the first bout of grooming that usually occurs within two minutes, as supported by previous literature of home base establishment (Eilam and Golani 1989; Donaldson et al. 2019; Osterlund Oltmanns et al. 2021). The position of the mouse during the selected 20 min (two min after the mouse was placed on the table) was captured and converted into

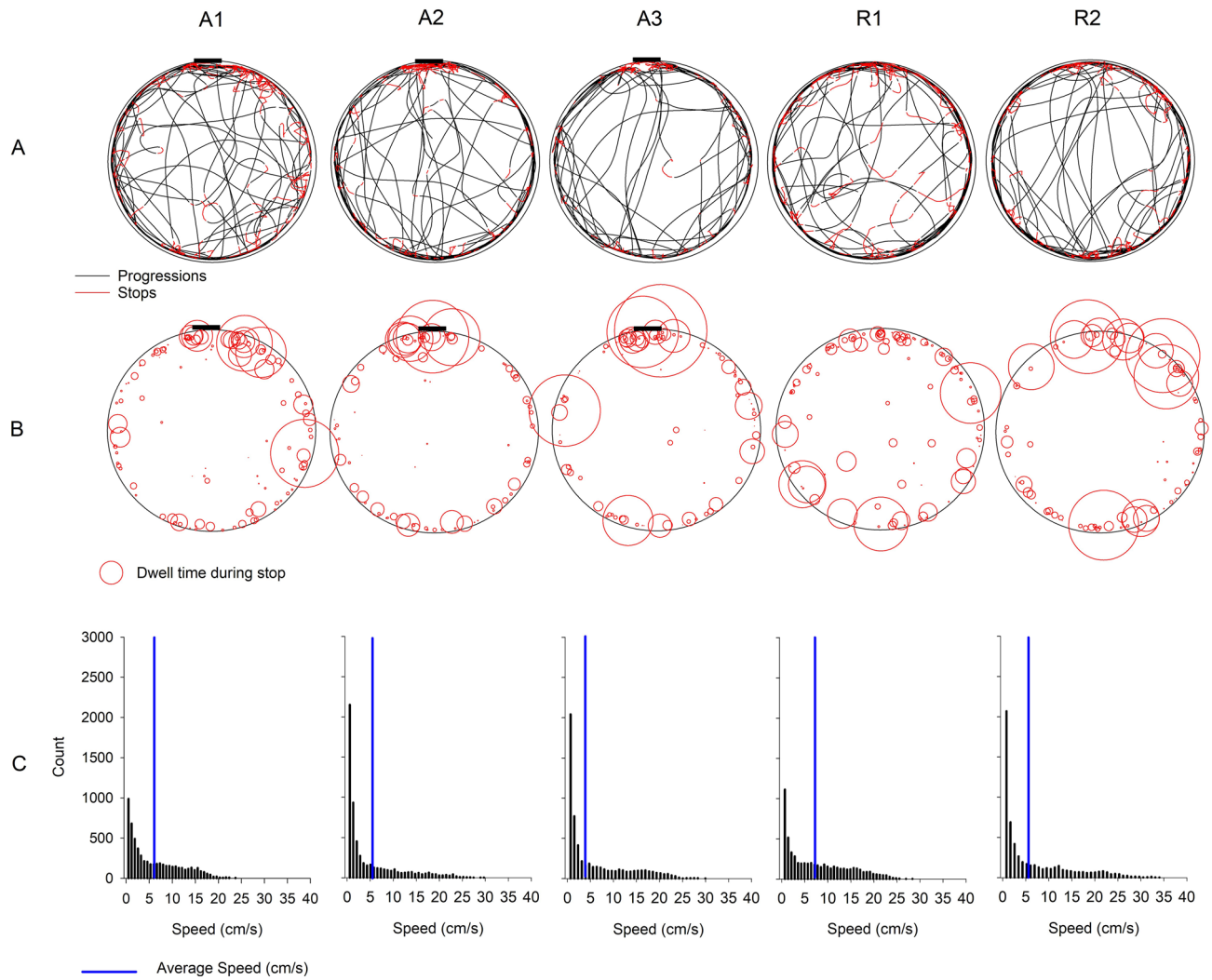

Fig. 2 Experiment 1: progressions (black lines) and stops (red lines) are plotted for a representative mouse from the tactile–visual group for each of the acquisition (A1–A3) and retention (R1 and R2) sessions (**A**). Additionally, the duration of stops is represented by the red circles for each session, the longer the mouse was stopped in the location the larger the diameter of the circle (**B**). Histograms of the mouse's speed during each session is plotted with the average speed cut off represented by the blue line (**C**). Colour figure available online

x- and y-coordinates through a motion tracking software, Ethovision XT 13 (Noldus) at five samples/second.

Mice segment their movement into stops and progressions (Fig. 2A and B). Since the tracked x- and y-coordinates exhibit instances of jitter/artifact, the change in x- and y- coordinates does not result in the mice traveling at speeds of zero. Therefore, average speed is commonly used as a cut off to segment instances of progressions and instances of small movement not resulting in change of position (i.e., stops) as it is often skewed (Fig. 2C) (Banovetz et al. 2021; Osterlund Oltmanns et al. 2021, 2022a, b; Schaeffer et al. 2022). In general, the mice in the

Table 1 Average speed of mouse

	A1	A2	A3	R1	R2
Experiment 1	6.458 (1.276)	5.200 (1.469)	5.175 (0.984)	5.938 (1.699)	5.371 (1.242)
Experiment 2	5.733 (0.979)	4.564 (1.305)	5.211 (1.463)	5.900 (1.411)	5.278 (1.425)
Experiment 3	5.354 (0.706)	4.529 (0.956)	3.883 (1.013)	4.783 (1.179)	4.750 (1.216)
Experiment 4	5.806 (0.952)	5.782 (1.429)	5.047 (1.433)	5.889 (1.864)	4.159 (1.317)

Values indicate average speed in cm/s (SD)

current study exhibited similar average speeds (Table 1); however, the mouse's average speed served as their individualized cut off used to differentiate between periods of stops and progressions to characterize movement most accurately within each session. Progressions were characterized as movement greater than or equal to the individual mouse's average speed. Stops were characterized as movement less than the individual mouse's average speed. From these components, general measures such as total distance traveled and total time stopped were calculated as measures of general locomotion.

The average x- and y- coordinate of each stop was converted into a polar coordinate system (r, theta), relative to the center of the table to conduct the following stop clustering analyses (Batschelet 1981). Parameter of concentration ranged from 1, indicating all stops were clustered in the same direction, to 0, indicating stops were uniformly distributed around the edge of the table. The within-sample parameter of concentration measured the concentration of stops within each of the four five-minute samples. The between-sample home base parameter of concentration measured the strength of clustering of each sample average heading of stops across the four samples which were used to index home base stability. The session average stop heading was used to calculate the between-session parameter of concentration. As supported by previous literature on home base establishment, the estimated between-sample home base heading was used to define the location of the mouse's home base (Blankenship et al. 2017; Donaldson et al. 2019; Schaeffer et al. 2022). This location was referred to as the mouse's home base heading, which ranged from 0 to 359°. To determine the uniformity of stops during the acquisition and retention sessions, mice home base headings were normalized relative to the cue, and separate modified Rayleigh (*V*) tests were conducted for each group. This test assesses if headings are randomly dispersed or if they are significantly clustered in one heading direction.

Statistical analysis

Separate Repeated-Measures Analysis of Variances (ANOVA) for the acquisition sessions (A1–A3) and for the retention sessions (R1 and R2), were used to analyze the main effect of Session, Group, and the corresponding Session by Group interaction. The partial eta squared (η_p^2) value was used as a measure of effect size. Tukey HSD and polynomial contrasts were used for post hoc analysis. Independent-sample t-tests were used to analyze the differences between groups for between-session parameter of concentration. All analyses were conducted using JASP 0.16.0. statistical software with an alpha set at 0.05.

Results

Acquisition

No mice were excluded from analysis due to falls. Total stop time and distance traveled were used to characterize open-field general locomotion. The total stop time analysis did not reveal any significant effects (Table 2). For total distance traveled, there was a significant main effect of Session and Group (Table 2). However, the Session by Group interaction was not significant for total distance traveled. In general, mice decreased their total distance traveled, supported by a significant linear trend of session [t (44) = − 3.927, $p < 0.001$]. Additionally, mice in the tactile–visual group traveled less distances than the visual cue group. Although

Table 2 Experiment 1

	Acquisition				Retention			
	df	*F*	*p*	η^2p	*df*	*F*	*p*	η^2p
Total distance traveled								
Session	2, 44	12.810	< 0.001*	0.368	1, 22	2.956	0.100	0.118
Group	1, 22	5.611	0.027*	0.203	1, 22	0.832	0.371	0.036
Session x group	2, 44	2.112	0.138	0.088	1, 22	0.349	0.561	0.016
Total stop time								
Session	1.351, 29.718	3.524	0.059	0.138	1, 22	25.059	< 0.001*	0.532
Group	1, 22	0.172	0.683	0.008	1, 22	0.072	0.791	0.003
Session x group	1.351, 29.718	1.157	0.309	0.050	1, 22	0.680	0.418	0.030
Between-sample parameter of concentration								
Session	2, 44	0.354	0.704	0.016	1, 22	1.862	0.186	0.078
Group	1, 22	9.842	0.005*	0.309	1, 22	1.694	0.206	0.072
Session x group	2, 44	1.349	0.270	0.058	2, 44	0.319	0.578	0.014

*indicates $p < 0.05$

both groups showed a decrease in total distance traveled, the visual cue group traveled greater distances.

Several stop measures were used to assess home base stability (Table 2). For a representative mouse from the tactile–visual group (Fig. 3A), the four headings in each sample are plotted (black lines) which were used to calculate the between-sample heading and parameter of concentration (red lines). There was not a significant main effect of Session or Session by Group interaction for the between-sample parameter of concentration. However, the tactile–visual group displayed more concentrated stop clustering between the four five-minute samples. For a representative mouse in the tactile–visual group (Fig. 3B), the three between-sample headings for each acquisition session are plotted (red lines) which were used to calculate the between-session heading and parameter of concentration

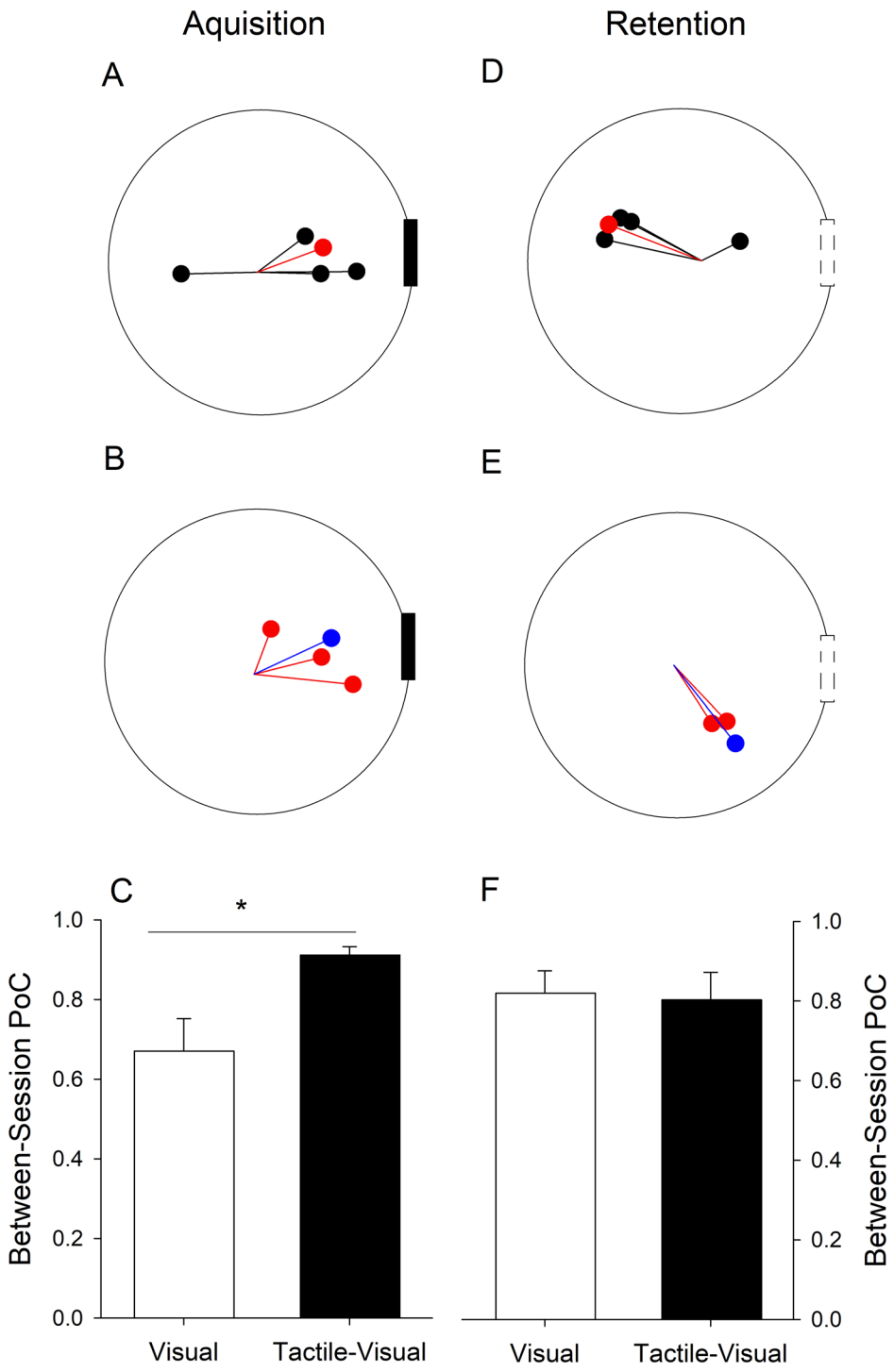

Fig. 3 Experiment 1: the estimated heading for each five-minute sample (black lines) and between-sample heading (red line) is plotted for a representative tactile–visual cue mouse during an acquisition (**A**) and retention sessions (**D**). The estimated between-sample heading (red lines) and estimated between-session heading (blue line) is plotted for a representative tactile–visual cue mouse across the acquisition (**B**) and retention (**E**) sessions. The between-session parameter of concentration is graphed by cue group across session for acquisition (**C**) and retention (**F**) sessions. Colour figure available online

(blue line). The tactile–visual group displayed more consistent home base headings across sessions (Fig. 3C) [$t(22) = -2.868$, $p = 0.009$, Cohen's $d = -1.171$]. Stop clustering measures indicate the tactile–visual cue exerts greater stimulus control over the organization of open-field behavior.

The between-sample headings were normalized relative to the cue to assess the uniformity of headings (Fig. 4). The visual cue group exhibited non-uniform distribution of headings across acquisition session 1 [$V(12) = 2.53$, $p < 0.05$] and acquisition session 3 [$V(12) = 2.016$, $p < 0.05$]. However, the visual cue group had randomly distributed home base headings during acquisition session 2 [$V(12) = 1.242$, $p > 0.05$]. The tactile–visual group also had non-uniform distributions of headings across acquisition session 1 [$V(12) = 3.132$, $p < 0.05$], acquisition session 2 [$V(12) = 4.206$, $p < 0.05$], and acquisition session 3 [$V(12) = 3.879$, $p < 0.05$]. In general, mouse stopping behavior was clustered around the cue throughout acquisition.

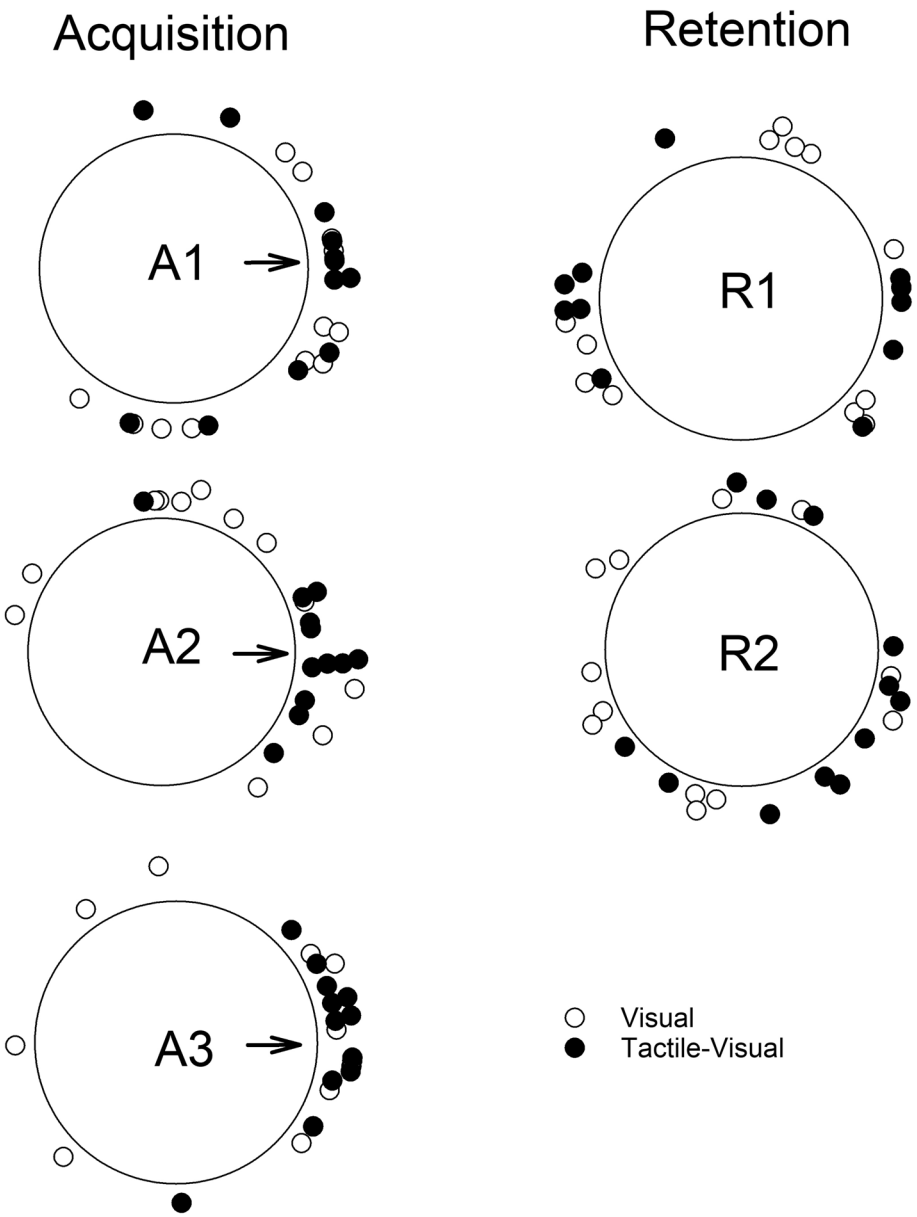

Fig. 4 Experiment 1: the normalized estimated home base headings and cue (black arrow) are plotted across acquisition (A1–A3) and retention (R1 and R2) for the visual (white dots) and tactile–visual (black dots) group

Retention

Mice were given two sessions with the environmental cue removed to assess retention of cue position one day and one week after the last acquisition session. General locomotion was characterized by total distance traveled and total stop time (Table 2). There were no differences in total distance traveled associated with the main effect of Session, Group, or corresponding Session by Group interaction. Additionally, there were no significant effects of Group or Session by Group interaction in total stop time; however, mice stopped more on the second retention session than the first retention session. Measures of general locomotion did not differ during retention based on previous environmental cue position.

Stop measures were used to quantify home base stability and memory of cue position. There was no observed significant differences in between-sample parameter of concentration (Table 2) for Session, Group, or corresponding Session by Group interaction. As mentioned previously, the between-sample estimated heading (Fig. 3D) was used to calculate the between-session parameter of concentration (Fig. 3E). Both groups displayed consistent home base headings across retention sessions (Fig. 3F) [$t\,(22) = 0.193$, $p = 0.849$]. The preceding stop measures indicate no group differences in the amount of cue control.

The uniformity of headings was calculated separately for each group during retention (Fig. 4). The visual cue group home base headings did not significantly differ from a uniform distribution during retention session 1 [$V\,(12) = 0.557$, $p > 0.05$] and 2 [$V\,(12) = 1.250$, $p > 0.05$]. Similarly, the home base headings of the tactile–visual group did not significantly differ from a uniform distribution during retention session 1 [$V\,(12) = 0.142$, $p > 0.05$]. However, the tactile–visual group displayed a non-uniform distribution of home base headings during retention session 2 [$V\,(12) = 1.80$, $p < 0.05$] clustered with the average heading 26.6 degrees away from the previous location of the cue. The established home base location was stable for both groups between retention sessions with an average difference in stop cluster heading of 58.54 degrees (SE = 12.17) for the visual group and 61.07° (SE = 13.23) for the tactile–visual group. In general, all mice displayed stable home base headings both within and between open-field sessions.

Discussion

This experiment investigated the role of different environmental cues on the organization of open-field behavior. Although mice tended to establish their home base near the location of the cue, the tactile–visual cue appeared to be more polarizing. These results suggest proximal environmental cues anchor home base behavior more than distal environmental cues. Stimulus control was observed when proximal cues were available during acquisition; however, cue removal during retention sessions resulted in uniform distribution of home bases headings. This distribution of home base headings indicates previous home base location did not influence subsequent location during retention sessions. Mice in the current experiment experienced the cues in the same relative (direction) and absolute (place) position; however, manipulating cue position information may elicit encoding of the home base position, relative to distal environmental cues. Since the tactile–visual cue appeared to anchor home base behaviors more than the visual cue, the tactile–visual cue was utilized in Experiment 2.

Experiment 2

The following experiment examined the effect of varying access to environmental information on stimulus control and memory of cue location. During the acquisition sessions, the apparatus was rotated 90° across the three successive sessions and cue placement was altered based on group assignment. During retention, the apparatus was not rotated between the two sessions and proximal cues were removed. Since all mice experienced the same stimulus during the retention sessions, differences in performance may reflect information encoded during the acquisition sessions. Specifically, the proximal cue information experienced during acquisition would promote a directional, place, or no representation of the home bases within the environment.

Methods

Subjects

Eighteen female and 18 male C57BL/6 mice (90 days old) were bred at NIU Animal Care facility for this experiment. The mice were housed at a 12/12-h dark–light schedule in a temperature- and humidity-controlled room. Food and water were provided ad libitum. All procedures were conducted

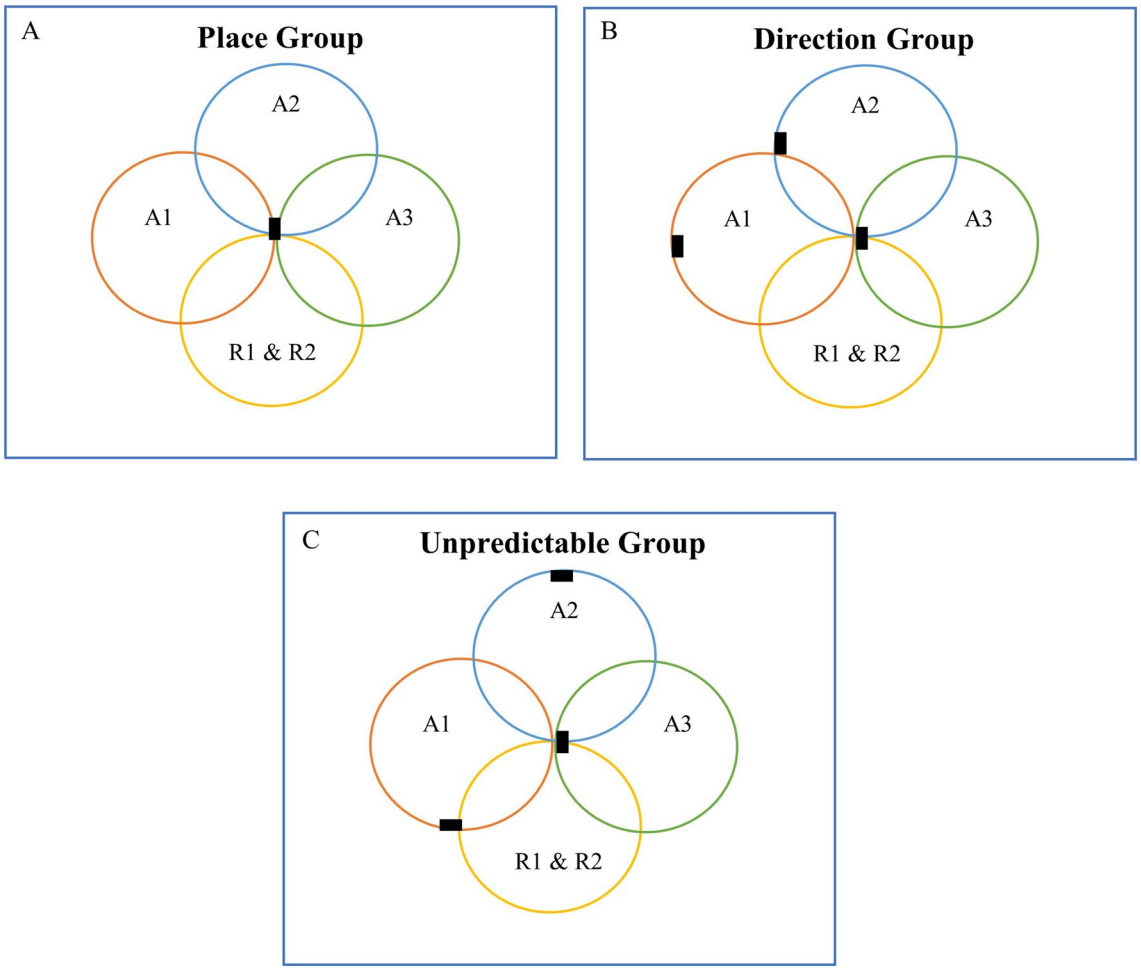

Fig. 5 Experiment 2: this schematic represents the apparatus and cue rotations during acquisition (A1–A3) and retention (R1 and R2) for the place group (**A**), the direction group (**B**), and the unpredictable group (**C**) in Experiment 2

during the light phase of their cycle and were run in five cohorts containing a mix of sex and group conditions. All protocols were approved by the NIU Institutional Animal Care and Use Committee.

Apparatus

The apparatus for the current experiment was the same as in the previous experiment, except all groups used the tactile–visual cue (Fig. 1B and C).

Procedure

The procedure for the current experiment was the same as the previous experiment with the following exceptions.

Sessions

The timeline of sessions for Experiment 2 was the same as in Experiment 1, except the tables and cues were rotated depending on random assignment of group (Fig. 5). During acquisition sessions 1–3 and retention session 1, the table was rotated 90 degrees and in retention session 2, the table remained in the same location as in retention session 1. The place group ($N = 12$, 6 females, 6 males) had the

Table 3 Experiment 2

	Acquisition				Retention			
	df	*F*	*p*	η^2p	*df*	*F*	*p*	η^2p
Total distance traveled								
Session	1.681, 55.465	14.901	< 0.001*	0.311	1, 33	11.036	0.002*	0.251
Group	2, 33	0.034	0.966	0.002	2, 33	2.051	0.145	0.111
Session x group	3.362, 55.465	0.618	0.624	0.036	2, 33	0.634	0.537	0.037
Total stop time								
Session	2, 66	1.264	0.289	0.037	1, 33	2.494	0.124	0.070
Group	2, 33	2.785	0.076	0.144	2, 33	0.415	0.664	0.025
Session x group	4, 66	0.923	0.456	0.053	2, 33	0.133	0.876	0.008
Between-sample parameter of concentration								
Session	1.613, 53.226	2.719	0.086	0.076	1, 33	0.509	0.481	0.015
Group	2, 33	2.068	0.143	0.111	2, 33	0.608	0.550	0.036
Session x group	3.226, 53.226	2.383	0.075	0.126	2, 33	1.592	0.219	0.088

*indicates $p < 0.05$

cue remain in the same absolute location within the room during acquisition 1–3 (Fig. 5A). The direction group ($N = 12$, 6 females, 6 males) had the cue in the same location relative to the table (Fig. 5B). Finally, the unpredictable group ($N = 12$, 6 females, 6 males) experienced the cue in an unpredictable place or direction during acquisition sessions 1–3 (Fig. 5C). For all groups, the table was in the same location in the room during retention session 1 and when tested a week later in retention session 2.

Behavioral analysis

General locomotor and stop clustering data from the current experiment were processed the same as the previous experiment (Table 1).

Statistical analysis

The statistical analysis for the current experiment was the same as the previous experiment.

Results

Acquisition

No mice were excluded from analysis due to falls. Total distance traveled and total stop time was used to quantify general locomotion (Table 3). For total distance traveled, Mauchly's test revealed a significant deviation in sphericity [X^2 (2) = 6.741, $p = 0.034$]; therefore, a Greenhouse–Geisser correction was used. No significant main effect of Group or Session by Group interaction was observed in total distance traveled; however, there was a significant main effect of Session. In general, mice traveled less distances on the second session, supported by a significant quadratic trend of session [t (66) = 5.201, $p < 0.001$]. For total stop time, there were no observed differences between Session, Group, or corresponding Session by Group interaction. Measures of general locomotion indicate groups did not differ in distance traveled or time stopping across the acquisition sessions.

Several stop measures were used to assess home base stability. The clustering of stops within each five-minute sample was used to calculate the between-sample parameter of concentration. For the between-sample analysis (Table 3), Mauchly's test revealed a significant deviation in sphericity [X^2 (2) = 8.782, $p = 0.012$]; therefore, a Greenhouse–Geisser correction was used. For between-sample parameter of concentration, there were no observed differences between Session, Group, or Session by Group interaction. Each of the between-sample headings were used to calculate the between-session parameter of concentration (Fig. 6A). The between-session analysis (Fig. 6B) revealed a non-significant effect of Group [F (2, 33) = 1.526, $p = 0.232$, η^2p = 0.085]. Across groups, mice established stable home bases both between-sample and across the acquisition sessions.

The uniformity of headings was calculated separately for each group during the acquisition sessions to assess even dispersion or clustering (Fig. 7). For the direction group, the between-sample home base headings were non-uniformly distributed during acquisition session 1 [V (12) = 4.770, $p < 0.05$], acquisition session 2 [V (12) = 3.996, $p < 0.05$], and acquisition session 3 [V (12) = 4.184, $p < 0.05$].

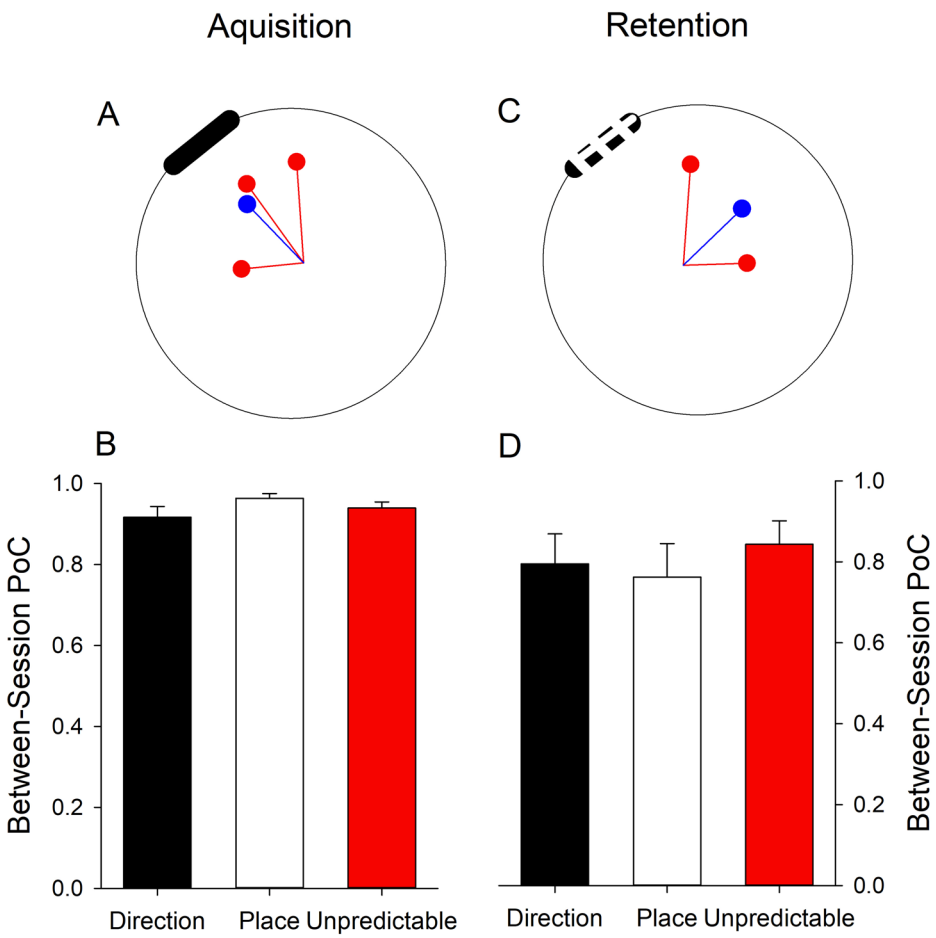

Fig. 6 Experiment 2: the estimated between-sample heading (red lines) and estimated between-session heading (blue line) is plotted for a representative direction mouse across the acquisition (**A**) and retention (**C**) sessions. The between-session parameter of concentration is graphed by cue group across session for acquisition (**B**) and retention (**D**) sessions. Colour figure available online

Non-uniform distribution of headings indicate stops were clustered around the same location, relative to the cue, across mice. Similarly, the between-sample home base headings were non-uniformly distributed for the place group during acquisition session 1 [$V\,(12) = 4.642$, $p < 0.05$], acquisition session 2 [$V\,(12) = 4.727$, $p < 0.05$], and acquisition session 3 [$V\,(12) = 4.598$, $p < 0.05$]. Finally, the unpredictable group also exhibited non-uniformly distributed home base headings during acquisition session 1 [$V\,(12) = 4.720$, $p < 0.05$], acquisition session 2 [$V\,(12) = 4.680$, $p < 0.05$], and acquisition session 3 [$V\,(12) = 4.242$, $p < 0.05$]. Home base headings were clustered around the cue location and not evenly dispersed, indicating the environmental cue exerted similar stimulus control over the home base establishment for each respective group.

Retention

Retention consisted of two sessions, one week apart, with tactile–visual cues removed. General locomotion measures included total distance traveled and total stop time (Table 3). For total distance traveled, there was a non-significant effect of Group and Session by Group interaction; however, there was a significant main effect of Session. In general, mice traveled greater distances on retention session 1 than on retention session 2. For total stop time, there were no observed differences between Session, Group, or corresponding Session by Group interaction. The results indicate sources of environmental cue information did not affect measures of general locomotion.

Several stop measures were used to assess home base stability and position representation (Table 3). The estimated home base heading for each of the four five-minute samples was used to calculate the between-sample parameter of concentration. For between-sample parameter of concentration, there were no observed significant effects of Session, Group, or corresponding Session by Group interaction. The estimated between-sample heading of each retention session was used to calculate the between-session parameter of concentration (Fig. 6C). Across retention sessions (Fig. 6D), no significant group differences in between-session parameter of concentration was observed [$F\,(2, 33) = 0.318$, $p = 0.730$, $\eta^2 p = 0.019$]. In general, the mice displayed stable home base headings between the two retention sessions.

The uniformity of headings was analyzed for each group during the two retention sessions separately (Fig. 7). For

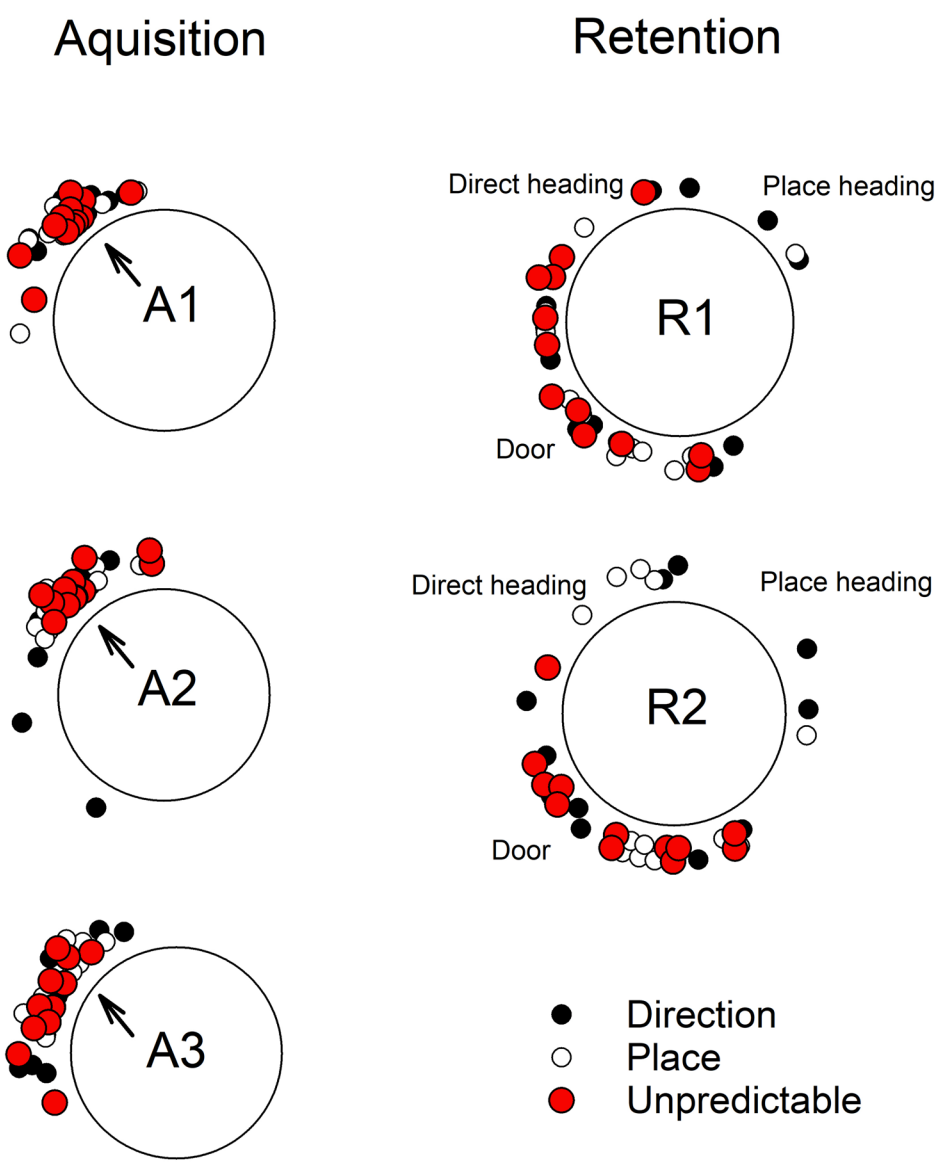

Fig. 7 Experiment 2: the normalized estimated home base headings and cue (black arrow) are plotted across acquisition (A1–A3) and retention (R1 and R2) for the direction (black dots), place (white dots), and unpredictable (red dots) groups. Additionally, the place, direction, and door headings around the table are represented during the retention sessions. Colour figure available online

the direction group, the between-sample home base headings were uniformly distributed during retention session 1 [V (12) = 1.252, $p > 0.05$] and retention session 2 [V (12) = 1.323, $p > 0.05$]. The place group exhibited non-uniformly distributed between-sample home base headings during retention session 1 [V (12) = 2.967, $p < 0.05$] but uniformly distributed for retention session 2 [V (12) = 1.182, $p > 0.05$]. Finally, the unpredictable group exhibited non-uniformly distributed home base headings during retention session 1 [V (12) = 2.970, $p < 0.05$] and retention session 2 [V (12) = 3.651, $p < 0.05$]. Furthermore, mice in the direction (M = 59.34°, SE = 14.78), place (M = 66.87°, SE = 15.00), and unpredictable group (M = 51.96°, SE = 12.52) exhibited similar average differences between the two stop clustering headings. This indicates home base headings were clustered around one direction, consistent across both sessions.

Discussion

The current experiment manipulated cue information in a consistent absolute place, direction, or in an unpredictable place and direction. The proximal cue exerted stimulus control over the location of home base establishment, regardless of available spatial information. This finding replicates what was observed in Experiment 1 and suggests salient environmental cues anchor home base position. When cues were removed during retention, there were observed group differences in the uniformity analyses. The direction group's headings were evenly dispersed, which indicates mice established home bases in idiosyncratic directions. The place and the unpredictable group displayed non-uniform heading distributions; however, the headings were not clustered at the

previous cue location (135°); rather, they were clustered around the entry point of the room (225°). This suggests mice may not remember the previous home base/cue location and used other distal environmental cues in the room to guide organization of open-field behavior which has been observed previously in the open-field (Nemati and Whishaw 2007; Burke and Whishaw 2020) and water-maze (Devan et al. 2002) work. Based on the results of Experiments 1 and 2, mice do not appear to show evidence that they encode the position of the home base relative to distal environmental cues; therefore, implementing cue information conflict, rather than cue removal, may aid in understanding the representation of a home base.

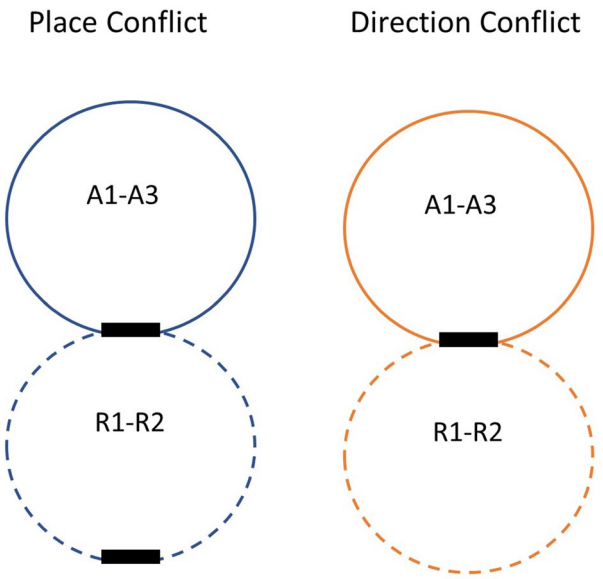

Fig. 8 Experiment 3: this schematic represents the apparatus and cue rotations during acquisition (A1–A3) and retention (R1 and R2) for the place conflict and direction conflict groups in Experiment 3

Experiment 3

Experiment 3 focused on cue information conflict to quantify if directional or location information is more important for representing a home base. In the following experiment, all mice experienced the cue in the same direction and location during acquisition sessions. During the retention sessions, the table was shifted the diameter of the table diagonally and the cue was moved based on random assignment to information conflict groups. One group experienced place information conflict where the cue remained in the relative position (direction) across retention sessions. The other group experienced direction information conflict where the cue remained in the absolute position (place).

Methods

Subjects

Twelve female and 12 male C57BL/6 mice (65–100 days old) were bred at NIU Animal Care facility for this experiment. The mice were housed at a 12/12-h dark–light schedule in a temperature- and humidity-controlled room. Food

Table 4 Experiment 3

	Acquisition				Retention			
	df	*F*	*p*	η^2p	*df*	*F*	*p*	η^2p
Total distance traveled								
Session	2, 44	18.575	< 0.001*	0.458	1, 22	0.212	0.650	0.010
Group	1, 22	0.320	0.577	0.014	1, 22	1.461	0.131	0.101
Session x group	2, 44	1.459	0.244	0.062	1, 22	0.004	0.951	< 0.01
Total stop time								
Session	2, 44	1452.6	< 0.001*	0.985	1, 22	0.125	0.727	0.006
Group	1, 22	0.072	0.791	0.003	1, 22	2.061	0.165	0.086
Session x Group	2, 44	0.517	0.600	0.023	1, 22	0.384	0.542	0.017
Between-sample parameter of concentration								
Session	1.242, 27.331	2.440	0.124	0.100	1, 22	0.311	0.583	0.014
Group	1, 22	0.405	0.531	0.018	1, 22	2.615	0.120	0.106
Session x group	1.242, 27.331	0.263	0.663	0.012	1, 22	0.390	0.539	0.017

*indicates $p < 0.05$

and water were provided ad libitum. All procedures were conducted during the light phase of their cycle and were run in two cohorts containing a mix of sex and group conditions. All protocols were approved by the NIU Institutional Animal Care and Use Committee.

Apparatus

The apparatus for the current experiment was the same as in the previous experiments (Fig. 1B and C).

Procedure

The procedure for the current experiment was the same as in the previous experiments with the following exceptions.

Sessions

During acquisition sessions 1–3, all mice experienced the cue and apparatus in the same location and direction (Fig. 8). During retention session 1, the table was shifted diagonally 122 cm in the room and the cue position varied based on group membership. Twelve mice were assigned to the place conflict group with the cue in the same direction as the acquisition sessions. The remaining 12 mice were assigned to the direction conflict group with the cue in the same place as the acquisition sessions. The cue and table remained in the same position for each respective group for retention session 2.

Behavioral analysis

General locomotor and stop clustering data from the current experiment were processed the same as the previous experiments (Table 1).

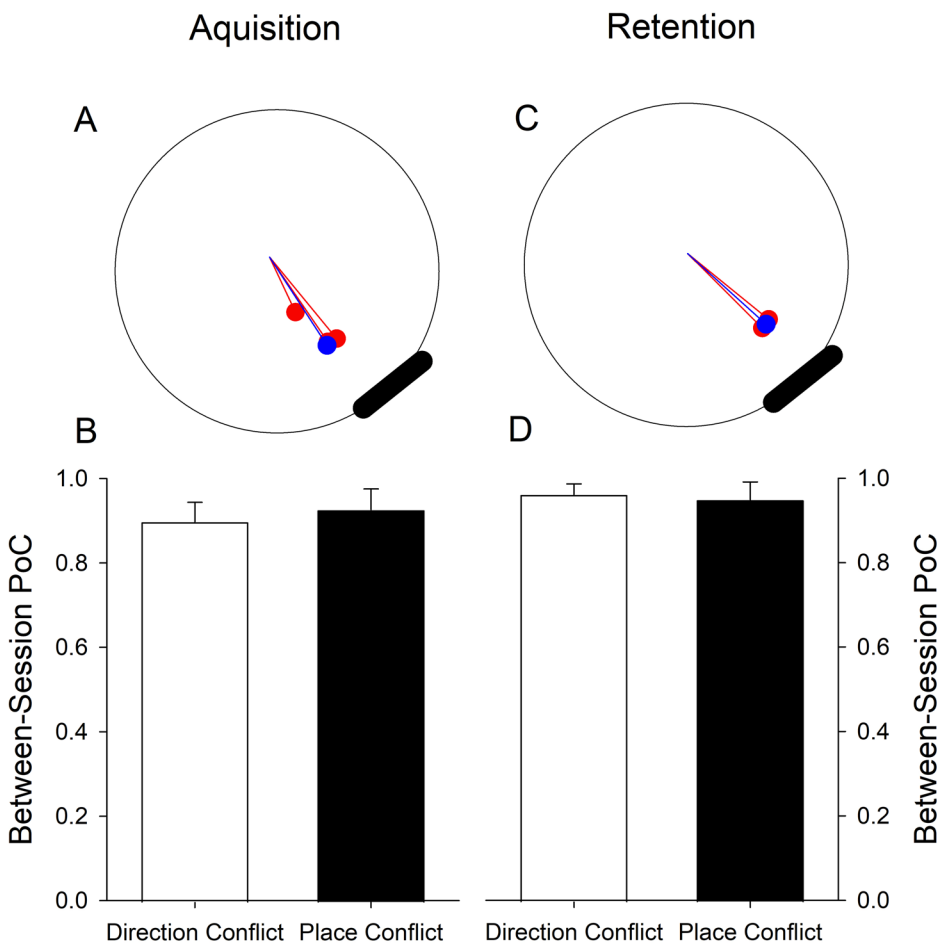

Fig. 9 Experiment 3: the estimated between-sample heading (red lines) and estimated between-session heading (blue line) is plotted for a representative place conflict mouse across the acquisition (**A**) and retention (**C**) sessions. The between-session parameter of concentration is graphed by cue group across acquisition (**B**) and retention (**D**) sessions. Colour figure available online

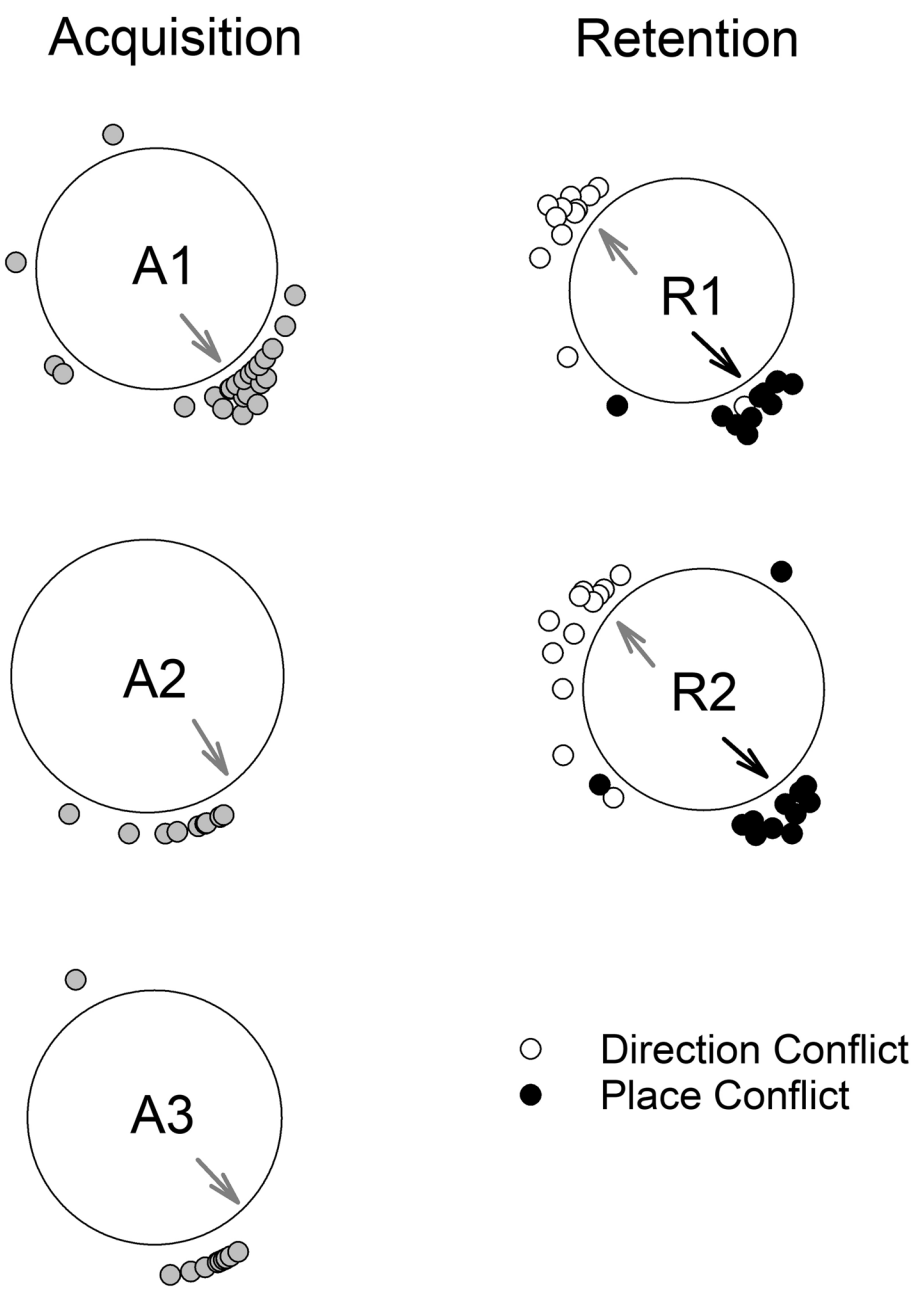

Fig. 10 Experiment 3: the normalized estimated home base headings and cue (gray arrow) are plotted across acquisition (A1–A3) for each mouse (gray dots). Additionally, the estimated home base headings are plotted during retention (R1 and R2) for the direction conflict (white dots) and place conflict (black dots) groups. Colour figure available online

Statistical analysis

The statistical analysis for the current experiment was the same as the previous experiments.

Results

Acquisition

No mice were excluded from analysis due to falls. Several measures were used to quantify general locomotion (Table 4). There were no observed differences in total distance traveled or total stop time for Group or Session by Group interaction. However, mice in general decreased their

total distance across sessions supported by a significant linear trend of Session [t (44) = 4.819, $p < 0.001$]. In parallel, mice increased their total time stopped across the sessions linearly [t (44) = 46.73, $p < 0.001$]. During acquisition, all mice displayed similar general locomotion behaviors.

Stop measures were used to assess home base behaviors during acquisition. Between-sample and -session home base headings are plotted for a representative place conflict mouse during the acquisition sessions. The analysis revealed a significant deviation in sphericity [X^2 (2) = 19.769, $p < 0.001$]; therefore, a Greenhouse–Geisser correction was used. The ANOVA conducted on the between-sample parameter of concentration (Table 4) revealed non-significant effects of Session, Group, and Session by Group interaction. Additionally, the t test conducted on the between-session parameter of concentration (Fig. 9A and B) revealed a non-significant effect of group [t (22) = 0.184, $p = 0.672$]. In general, all mice established a stable home base both between samples and between sessions while the cue remained in the same place and direction during acquisition.

Procedures for group membership were identical through acquisition but differed during the retention sessions; therefore, between-sample headings were collapsed to assess the uniformity of home base headings (Fig. 10). Mice exhibited non-uniform distribution of home base headings across acquisition session 1 [V (24) = 5.110, $p < 0.05$] clustered at 302°, acquisition session 2 [V (24) = 6.225, $p < 0.05$] clustered at 305°, and acquisition session 3 [V (24) = 6.035, $p < 0.05$] clustered at 305.9°. During the three acquisition sessions, mice clustered their home base heading in proximity to the heading of the cue during acquisition (315 degrees).

Retention

There were no observed significant effects of Session, Group, and Session by Group interaction for either total distance traveled or total stop time (Table 4). In general, the type of information conflict did not influence general measures of locomotion.

Several stop clustering measures were used to assess home base behaviors during cue conflict (Table 4). First, the ANOVA conducted on the between-sample parameter of concentration revealed null effects for Session, Group, and Session by Group interaction. Additionally, there was no observed effect of Group for the between-session parameter of concentration [t (22) = 0.252, $p = 0.804$] (Fig. 9C and D). In general, the type of cue conflict did not influence home base stability or home base heading from the location of cue.

The distribution of home base headings was used to assess the influence of cue conflict (Fig. 10). Uniformity analyses revealed the distribution of home base headings for the place conflict groups were significantly clustered around the location of the cue in retention session 1 [V (12) = 4.47,

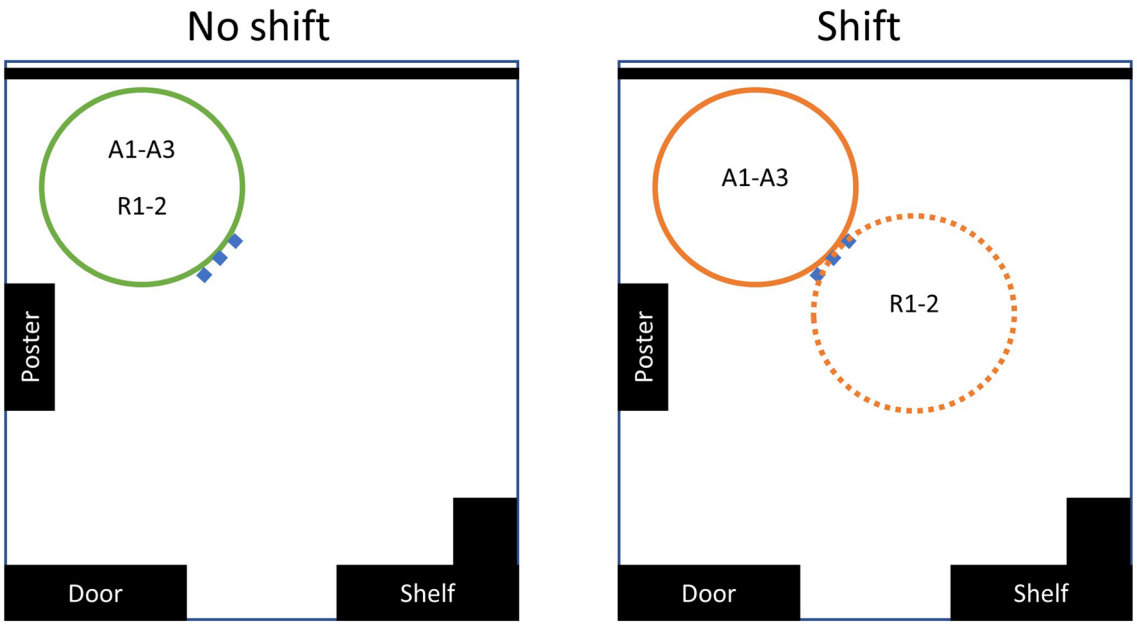

Fig. 11 Experiment 4: this schematic represents the apparatus, proximal cues, and room cues during acquisition (A1–A3) and retention (R1 and R2) for the shift and no shift group in Experiment 4

$p < 0.05$] and retention session 2 [V (12) = 3.82, $p < 0.05$]. Additionally, the direction conflict group's home base headings were significantly clustered around the cue during retention session 1[V (12) = 3.67, $p < 0.05$] and retention session 2 [V (12) = 3.93, $p < 0.05$]. Regardless of cue information conflict, mice clustered their home base headings around the position of the cue during both retention sessions.

Discussion

In general, all mice established their home base headings around the heading of the cue, even when the position conflicted with previous learned information. This indicates conflict of previous cue information may not interfere with creating a new representation of a moved cue. Changing the salience of environmental cues may aid in configuring a representation of space, relative to a home base.

Experiment 4

As demonstrated by the previous experiments, no evidence has been observed that supports mice encode the position of the home base relative to distal environmental cues. However, the distal environmental cues in the previous three experiments had limited salience (e.g., white walls, covered door), which may have interfered with the mice establishing a representation of space. The current experiment increased the salience of distal environmental cues by positioning the table to create asymmetrical geometry, increased the contrast of distal room cues, and reduced the salience proximal cues by using a transparent tab attached to the edge of the table. During retention, the transparent tab was removed, and the table was shifted diagonally depending on group membership (shift or no shift).

Methods

Subjects

Eight female and nine male C57BL/6 mice (80–90 days old) were bred at NIU Animal Care facility for this experiment. The mice were housed at a 12/12-h dark–light schedule in a temperature- and humidity-controlled room. Food and water were provided ad libitum. All procedures were conducted during the light phase of their cycle and were run in two cohorts containing a mix of sex and group conditions. All protocols were approved by the NIU Institutional Animal Care and Use Committee.

Apparatus

The apparatus for the current experiment was the same as in Experiments 2 and 3 (Fig. 1B) with the following exceptions. The room cues were made more salient by placing horizontal stripes (30 cm wide) across one of the walls in the room. Additionally, other room cues were made available (e.g., shelves, posters, door) on the subsequent walls (Fig. 1D). Instead of a black plastic tab, a transparent tab was used with the same measurements (20 × 5 cm).

Procedure

The procedure for the current experiment was the same as the previous experiments with the following exceptions.

Table 5 Experiment 4

	Acquisition				Retention			
	df	*F*	*p*	η^2p	*df*	*F*	*p*	η^2p
Total distance traveled								
Session	2, 30	2.268	0.121	0.131	1, 15	55.873	< 0.01*	0.788
Group	1, 15	0.118	0.736	0.008	1, 15	0.390	0.542	0.025
Session x group	2, 30	1.654	0.208	0.099	1, 15	< 0.001	0.998	< 0.01
Total stop time								
Session	1.411, 21.158	1.217	0.301	0.075	1, 15	0.523	0.481	0.034
Group	1, 15	0.100	0.756	0.007	1, 15	0.087	0.772	0.006
Session x group	1.411, 21.158	1.004	0.357	0.063	1, 15	0.897	0.359	0.056
Between-sample parameter of concentration								
Session	2, 30	0.322	0.727	0.021	1, 15	1.023	0.328	0.064
Group	1, 15	0.033	0.858	0.002	1, 15	0.036	0.853	0.002
Session x group	2, 30	0.423	0.659	0.027	1, 15	0.569	0.462	0.037

*indicates $p < 0.05$

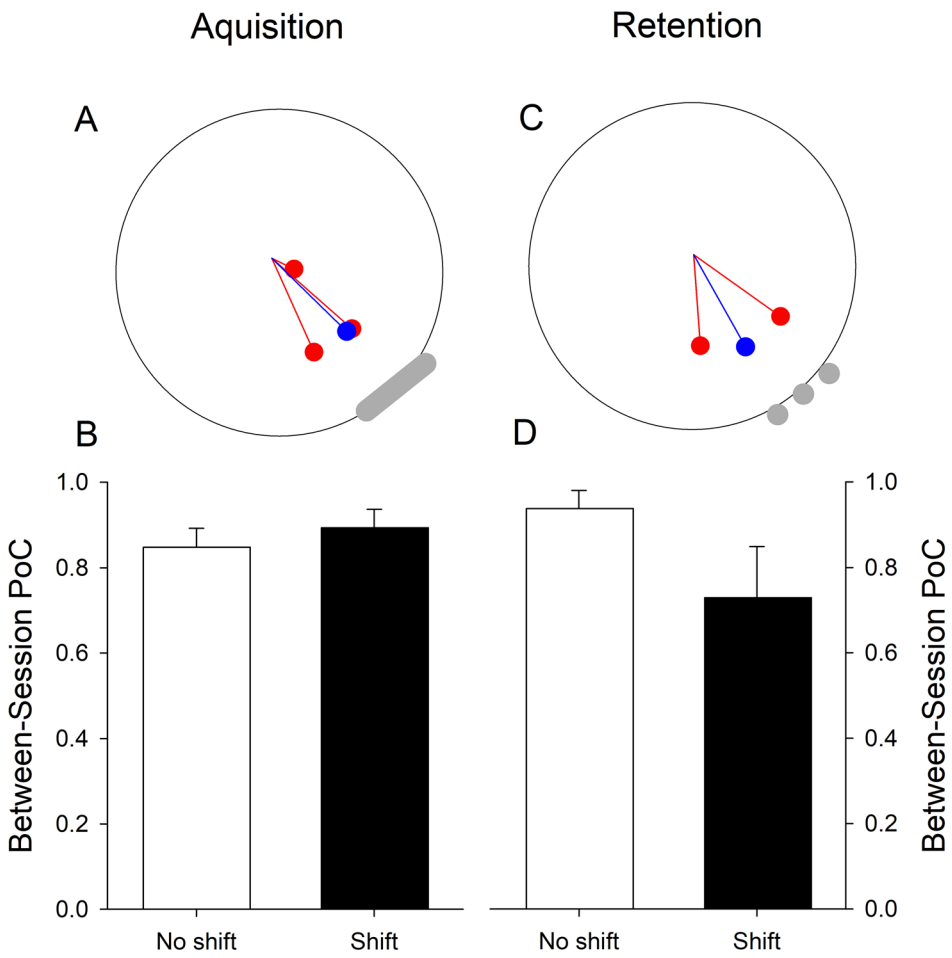

Fig. 12 Experiment 4: the estimated between-sample heading (red lines) and estimated between-session heading (blue line) is plotted for a representative shift mouse across the acquisition (**A**) and retention (**C**) sessions. The between-session parameter of concentration is graphed by shift group across acquisition (**B**) and retention (**D**) sessions. Colour figure available online

Sessions

The timeline of sessions for the current experiment was the same as in the previous experiments; however, tables and cues were shifted depending on group membership during the retention sessions (Fig. 11). All mice experienced the cue and table in the same location and direction during acquisition sessions. During both retention sessions, the tab cue was removed, and the table either remained in the same location ($n=8$) or shifted diagonally 122 cm ($n=9$).

Behavioral analysis

General locomotor and stop clustering data from the current experiment were processed the same as the previous experiments (Table 1).

Statistical analysis

The statistical analysis for the current experiment was the same as the previous experiments.

Results

Acquisition

No mice were excluded from analysis due to falls. Total distance traveled and total stop time were used to quantify general locomotion (Table 5). For total stop time, there was a significant deviation in sphericity [X^2 (2) = 7.576, $p=0.023$]; therefore, a Greenhouse–Geisser correction was used. There were no observed differences in total distance or total stop time for Session, Group, and Session by Group interaction. During acquisition, all mice displayed similar general locomotion behaviors.

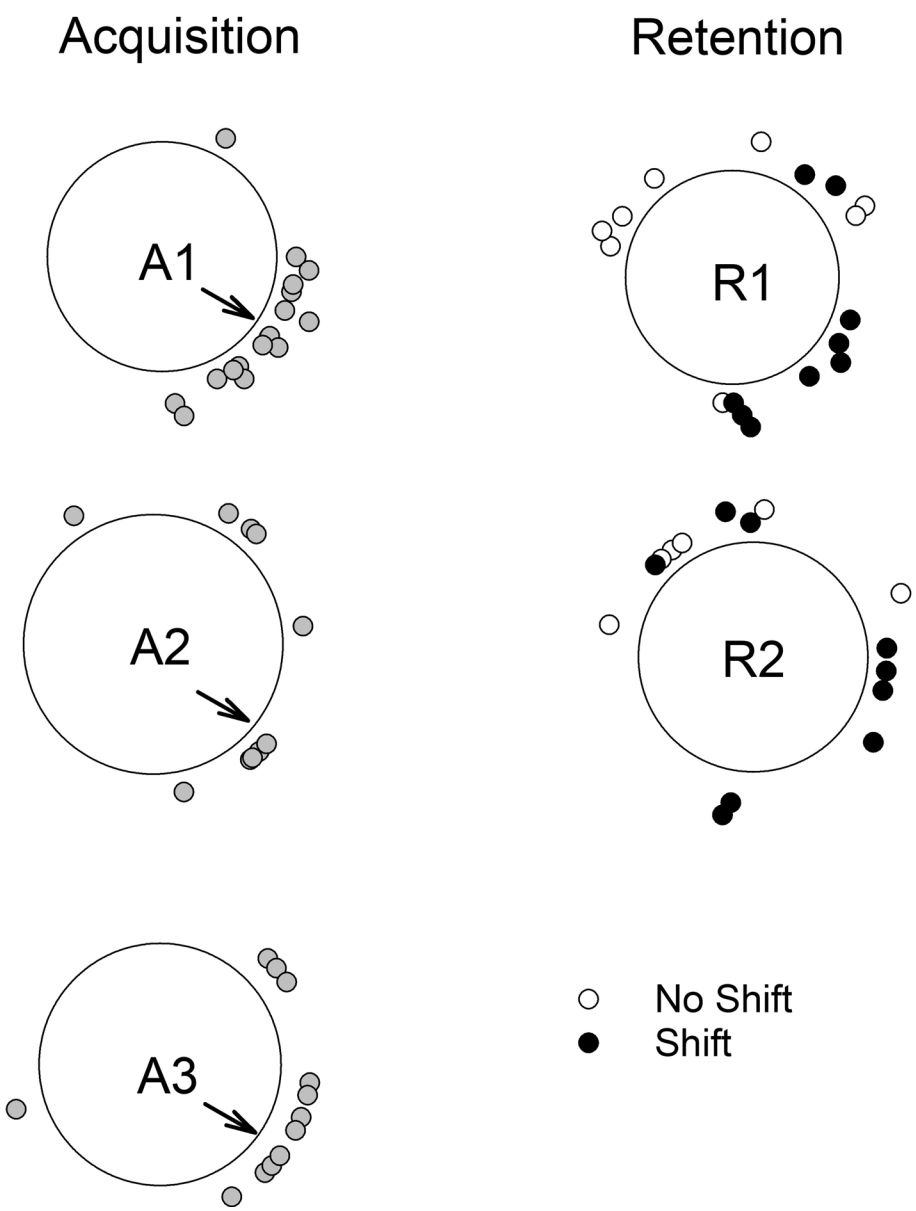

Fig. 13 Experiment 4: the normalized estimated home base headings and cue (gray arrow) are plotted across acquisition (A1–A3) for each mouse (gray dots). Additionally, the estimated home base headings are plotted during retention (R1 and R2) for the no shift (white dots) and shift (black dots) groups. Colour figure available online

Stop measures were used to assess home base behaviors during acquisition. Between-sample and between-session (Fig. 12A) home base headings are plotted for a representative shift mouse during the acquisition sessions. In general, all mice established a stable home base both between samples and between sessions while cue and table remained in the same place during acquisition. There was no effect of Session, Group, and Session by Group interaction for the between-sample parameter of concentration. Additionally, the *t* test conducted on the between-session parameter of concentration (Fig. 12B) revealed a non-significant effect of group [$t\,(15) = 1.870$, $p = 0.081$]. Procedures for group membership were identical through acquisition but differed during the retention sessions; therefore, between-sample headings were collapsed to assess the uniformity of headings (Fig. 13). Mice exhibited non-uniform distribution of home base headings across acquisition session 1 [$V\,(17) = 4.862$, $p < 0.05$] clustered at 324°, acquisition session 2 [$V\,(17) = 2.437$, $p < 0.05$] clustered at 1.79°, and acquisition session 3 [$V\,(17) = 3.479$, $p < 0.05$] clustered at 352°. During the three acquisition sessions, mice clustered their home base heading in proximity to the heading of the cue during acquisition (315°).

Retention

The two retention sessions, one week apart, consisted of removing the cue and shifting the table, depending on group membership. For total distance traveled (Table 5), all mice traveled greater distances during the first retention

Table 6 Uniformity summary

	A1	A2	A3	R1	R2
Experiment 1					
Visual	+	–	+	–	–
Tactile–visual	+	+	+	–	+
Experiment 2					
Direction	+	+	+	–	–
Place	+	+	+	+	–
Unpredictable	+	+	+	+	+
Experiment 3					
All mice	+	+	+		
Direction conflict				+	+
Place conflict				+	+
Experiment 4					
All mice	+	+	+		
No Shift				–	+
Shift				+	–

+indicates significant Rayleigh (*V*) test, −indicates non-significant Rayleigh (*V*) test

session ($M = 5752.2$ cm, SE = 433.8) compared to the second ($M = 4111.2$ cm, SE = 304.5); however, there was no observed significant effect of Group or Session by Group interaction. Total stop time analysis revealed non-significant effects of Session, Group, and subsequent interaction. In general, shifting the table and removing the cue did not influence general locomotion.

Stop clustering measures were used to assess home base behaviors during table shift and proximal cue removal (Table 5). The between-sample parameter of concentration analysis revealed null effects for Session, Group, and Session by Group interaction. Additionally, there was no observed effect of Group for the between-session parameter of concentration [$t\ (15) = 1.570$, $p = 0.137$] (Fig. 12C and D). In general, shifting the table and removing the cue did not influence home base stability or home base heading from location of cue.

The distribution of home base headings was used to assess the mnemonic characteristics of home base behaviors (Fig. 13). For the no shift group, the previous relative (direction) and absolute (place) heading of the cue was at 315°. Uniformity analyses revealed the distribution of headings for the no shift group were not significantly clustered around the previous location of the cue in retention session 1 [$V\ (8) = 1.500$, $p > 0.05$]. However, the no shift group displayed significant clustering around 105° during retention session 2 [$V\ (12) = 2.20$, $p < 0.05$]. For the shift group, the previous absolute (place) heading of the cue was at 135°, whereas the relative (direction) heading of the cue would be 315°. Additionally, the shift group's home base headings were significantly clustered around the cue (366°) during retention session 1[$V\ (9) = 2.839$, $p < 0.05$] but not during retention session 2 [$V\ (12) = 0.89$, $p > 0.05$]. Therefore, there appears to be more complex results indicating encoding home base heading relative to distal environmental cues.

Discussion

The current experiment increased the salience of room cues and tested memory of previous home base position during retention sessions by removing proximal cues and implementing table shifts. In general, all mice established their home base headings around the heading of the cue during acquisition sessions. However, home base establishment associated with cue removal and table shift was not suggestive of encoding the heading of a home base. Although significant clustering was observed, mice appeared to cluster around the most proximal room cue including the striped wall for the no shift group (135°) and the sink for the shift group (315°). This demonstrates that several factors may be influencing performance in the open field, including proximity of room cues.

General discussion

The current set of experiments evaluated the influence of environmental cues on the organization of open-field behavior in mice. Mice consistently used salient environmental cues to anchor home base position both within and across sessions. In general, all mice readily established their home base and organized their movement independent of environmental cue manipulations investigated during acquisition or retention sessions. When proximal cues were available during these acquisition sessions, mice consistently used these cues to anchor home base headings (Table 6). If these cues were removed, mice would typically establish their home base next to the next most proximal cue as opposed to remaining in the previous established position. Although the current study set out to describe the representation of a home base, results suggest home base position may not have been encoded relative to distal environmental cues, contrasting with previous work in rats (Clark et al. 2005; Hines and Whishaw 2005; Lehmann et al. 2007). Additionally, it is possible mice acquired a representation but did not use that information to guide home base behavior when cues were removed. Therefore, the following sections will describe the mnemonics of species-specific home base behavior and their relationship to other spatial behavior.

Species comparison in open-field behavior

Rats and mice organize open-field behavior similarly around environmental cues to optimize security. Rodents will typically optimize safety in an environment by avoiding open spaces and spending a majority of time in a refuge (Whishaw et al. 2006). Previous work indicates optimized security may be related to salient environmental cues. For example, the more contrasting and salient the environmental cue, the more likely rats and mice will anchor their home base to its location (Clark et al. 2005, 2006; Hines and Whishaw 2005; Lehmann et al. 2007). Previous literature observed that both rats (Clark et al. 2005; Lehmann et al. 2007) and mice (Clark et al. 2006) prefer to concentrate their stops closer to a proximal white partial-wall with available tactile information when also presented with a distal black box on the opposing end. Results from Experiment 1 support this literature, finding that mice within the tactile–visual group established their home base closer to the cue than the visual cue group. Although a significant group effect was found, mice within the visual cue group had a tight clustering of stops both between samples ($M = 0.625$) and between sessions ($M = 0.670$), comparable to results found in previous studies (Donaldson et al. 2019). Given this, tactile cues appear to be more salient in organizing open-field behavior in both rats and mice.

There are differences between rats and mice in the organization of open-field behavior when environmental cues are manipulated. For example, Lehmann et al. (2007) found rats did not move in congruence with a shifted cue and established a home base near the original location of the cue. Thus, cues with high stability exerted stimulus control over the organization of home base behaviors and the rats encoded the position in the environment. Conversely, environmental cues with low stability are not used to encode the position in rats. In the Hines and Whishaw (2005) study, rats would move the location of their home base in congruence with the moved environmental cue. Thus, the cue always controlled home base position in rats; however, a degree of cue stability is necessary for encoding the position within an environment. Similar observations were made in mice, based on the results of the current study. In Experiments 1 and 3, the mice experienced very stable environmental cues, similar to the rats in the Lehmann et al. (2007) study. In Experiment 2, mice experienced various degrees of cue stability, depending on group membership. The direction and place group cues were stable directionally or positionally, but the unpredictable group did not experience any cue stability, similar to the rats in the Hines and Whishaw (2005) study. In all different degrees of cue stability, there was clear stimulus control over home base position when the cues were present. In sum, the influence of environmental cue stability on stimulus control of open-field behavior does not appear to be species specific.

Although stimulus control does not appear to be species specific, there are differences between rats and mice in retention of a previously observed home base position. For example, rats (Hines and Whishaw 2005; Lehmann et al. 2007) were exposed to four open-field sessions with cues present and a fifth session with cues removed. Rats established their home base near the previous location of the cue. This is evidence to suggest that rats encoded the location of the home base in relation to the cue and retained it. In general, rats tend to exhibit a learned memory of previous home base position in the open field. Although rats consistently show memory of previous home base location across sessions, this finding has not been replicated in mice. In a series of experiments from Clark et al. (2006), mice did not exhibit a stop preference in the segment of the previous cue location. This indicates mice may not have encoded or retrieved the home base and environment association. The current study replicated Clark et al. (2006) findings in all four experiments with mice not exhibiting a stop preference in the previous location of the cue. Thus, mice appear to not display memory of a previous home base position; however, it is also possible mice remembered but did not perseverate once the 'safe' cues were removed. That is, mice may uniquely exhibit an increased drive for security in locating a new safe refuge when a previous location is compromised or changed, compared to rats. In sum, there appears to be species-specific differences in mnemonics or motivation of establishing home base position. Further work is needed to characterize mnemonics of mouse open-field behavior and how that relates to results found in other tasks.

Differences in spontaneous and goal-directed behaviors

Mice may have distinct mnemonic processing between goal-directed and spontaneous behaviors. Spontaneous behaviors such as home base establishment do not require shaping as animals typically establish a home base within two minutes of entry to an environment (Golani et al. 1993; Fonio et al. 2009). In contrast, goal-directed behaviors observed in land and water-maze assessments require a substantial amount of training and greater task demands. For example, mice typically require 16 trials of training over multiple days to reach a reliable response (Vorhees and Williams 2006; Patil et al. 2009). Therefore, it is possible mice required more sessions to associate the location of their home base, with respect to the environment, like goal-directed behaviors. Besides the amount of training, spontaneous and goal-directed behaviors in mice may elicit different attentional processing resulting in differences in mnemic function. For

example, in a homing task comparable to food hoarding, Alyan and Jander (1994; 1997a; 1997b) manipulated environmental cues as female mice retrieved their pups from the center of the table and back to the nest. After training to retrieve the pups from the nest in one location, the nest location was rotated 90 degrees. They found all of the mice returned to the new location of the nest. Therefore, mice do not appear to perseverate at previous home base locations and adjust to altered environmental cues. Based on these studies and the results of the current study, it is possible mice require greater task demands to encode and retain a previous position, which is distinct from rats. It is also possible when security is compromised by changing a previously established home base location that provides refuge, mice proceed in locating a new one. Future work should consider how mouse spontaneous open-field behaviors may be different than goal-directed behaviors in attentional processing due to task demands.

Conclusion/future directions

The current study assessed the influence of environmental cues on open-field behavior and the nature of the representation of a home base. The first experiment examined the influence of a strictly visual cue or a tactile–visual cue on the stability of home base establishment in addition to examining the retention of the previous cue location. In general, mice preferred to establish a home base closer to the tactile–visual cue as opposed to the strictly visual cue during the acquisition sessions. After cue removal, there was no evidence of memory of previously learned location of the cue. The second, third, and fourth experiments varied access to environmental information to investigate the nature of the representation of a home base. Home base behaviors are unique as they are spontaneous and do not require training compared to set goals, such as locating food or a hidden platform. Results suggest that previous mouse home base position is not remembered, contradicting previous findings in rats. Therefore, it is possible there are species-specific mnemonic processing of spontaneous behaviors that may be dependent on task demands and the type of cues available. Future studies on the environmental representation of home bases should consider the influence of the geometric layout of the experimental room and electrophysiology of spatial cells. Understanding the representation of the environment may help guide future treatments for navigational deficits commonly observed in stroke, traumatic brain injury, and Alzheimer's Disease patients.

Declarations

Conflict of interest The authors declare that they have no conflicts of interests.

Ethical approval All protocols and procedures were approved by the Northern Illinois University (NIU) Institutional Animal Care and Use Committee.

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