Being near home enhances strategic risk-taking in immersive environments

Francisco Rocabado[1*], Jon Andoni Duñabeitia[1]

[1] Centro de Investigación Nebrija en Cognición (CINC), Universidad Nebrija, Department of Education, Madrid, 28015, Spain

Corresponding Author

Francisco Rocabado

Nebrija Research Center in Cognition (CINC)

Nebrija University

Calle de Formento 17, 3L

Telephone: +34 677724174

Email: jrocabado@nebrija.es

Word Count

Abstract: 246 words

Manuscript text: 6.738words

Author Note

This manuscript has not been previously published, nor is it under consideration for publication elsewhere. No preprint version of this manuscript has been posted online.

The data reported in this manuscript have not been used in any prior publications.

This research was approved by the Research Ethics Committee of Nebrija University (approval code UNNE-2022-0017). All participants provided written informed consent prior to participation.

This work was supported by the Ministerio de Ciencia e Innovación (grant PID2024-161331NB-I00). The funding source had no role in the study design, data collection, analysis, interpretation of the data, or the decision to submit the manuscript for publication.

The authors declare that they have no conflicts of interest, financial or otherwise.

Correspondence concerning this article should be addressed to Francisco Rocabado, Nebrija University, jrocabado@nebrija.es.

Abstract

Decision-making in digital environments depends not only on task demands but also on whether the surrounding environment feels familiar. This study tested whether pre-existing environmental familiarity influences risk regulation in a VR version of the Balloon Analogue Risk Task. Twenty-five participants inflated virtual balloons to earn points. Each pump increased the potential reward, but the balloon could explode, causing the points from that trial to be lost. Participants could stop at any time to collect the points earned. Each participant completed the task in two immersive environments, a panoramic reconstruction of their home entrance and a comparable unfamiliar location. Participants earned significantly more points in the familiar than in the unfamiliar environment. This advantage was statistically significant for balloons with a higher range of possible pumps before exploding, allowing greater behavioral regulation, but not for medium and low explosion-threshold range balloons. Within these higher-range trials, the advantage of being near home was bigger at the beginning of the task and significantly decreased as performance in the unfamiliar environment improved. In an additional analysis restricted successful unexploded high explosion-threshold trials , participants still earned significantly more points in the familiar environment, although the change over the course of the task was no longer statistically significant. These findings suggest that familiar virtual environments may support early behavioral calibration under uncertainty without increasing failed risky responses. More broadly, VR environments are not neutral; familiarity can shape decision-making and should be considered when designing immersive assessments, training systems, and interventions.

Keywords: risk-taking behavior, balloon analog risk task, virtual reality, context, behavioral assessment.

Being near home enhances strategic risk-taking in immersive environments

In everyday life, people often make decisions under uncertainty in environments that vary in their degree of familiarity. For example, a person may behave differently when taking a risk near their own home than when making the same decision in an unfamiliar street, even when the objective consequences of the decision are identical. The present study examined this idea using a Virtual Reality adaptation of the Balloon Analogue Risk Task (BART), a behavioral task in which participants inflate virtual balloons to earn points. Each pump increases the potential reward, but the balloon can explode, causing the participant to lose the points accumulated on that trial. Participants can stop pumping at any moment and collect the points earned. In the present study, the same task was completed in two immersive 360° environments. One based on the entrance to the participant's own home and another based on a structurally comparable but unfamiliar location. Thus, familiarity was manipulated through the surrounding virtual environment, while the decision-making task itself remained equivalent across contexts.

Risk-taking is a central component of decision-making that underlies a wide spectrum of behaviors in everyday life. Whether individuals are investing in the stock market, making important health decisions, or engaging in potentially harmful activities like gambling, their propensity to take risks can have significant personal, financial, or societal consequences. A range of psychological factors influence risk-taking, including cognitive biases, emotional states, and perceived rewards. These elements interact to shape how people weigh potential gains against possible losses (Frey et al., 2017; Rolison, 2023; Weber & Milliman, 1997). For instance, when someone perceives a potential reward as substantial or believes that the possible losses are relatively minor, they may find themselves more willing to take risks. On the other hand, even the slightest chance of a severe negative outcome can be enough to dissuade us from pursuing a course of action that might otherwise offer significant benefits (Rolison, 2023). In the present study, risk-taking was operationalized through BART performance, particularly the number of points earned per trial, which reflects how participants balanced the possibility of gaining more points against the possibility of losing the points accumulated on a given balloon.

In parallel, the increasing use of interactive and immersive technologies has raised important questions about how realistic digital environments themselves shape behavioral patterns of decision-making, attention, and action that emerge when individuals engage within a virtual setting (Russell et al., 2024; Safikhani et al., 2024). Virtual Reality, in particular, offers users a sense of spatial presence and environmental immersion that can meaningfully influence cognitive and affective processes during decision-making. Understanding risk-taking within these technologically mediated contexts is therefore essential, not only for advancing psychological theory but also for informing the design of digital systems that aim to support, assess, or modify user behavior. This question becomes especially relevant when VR environments reproduce places that are personally familiar and meaningful to the user, because these settings may activate prior spatial knowledge, emotional associations, and autobiographical memories that are not available in unfamiliar virtual environments.

The study of risk-taking behavior increasingly recognizes the importance of contextual and emotional factors, with environmental familiarity emerging as a critical modulating force in how individuals appraise and navigate uncertainty. Familiar environments may reduce perceived ambiguity and support feelings of control, thereby shaping confidence and promoting more assertive behavior in risky situations (Zayadin et al., 2023). From a psychological perspective, this link is relevant because perceived control has been associated with the way individuals anticipate and respond to potentially aversive outcomes, and perceived control and agency have been linked to lower perceived risk and greater willingness to engage in risk-taking behavior (Damen, 2019; Nordgren et al., 2007; Thompson, 1981). More broadly, risk-taking depends not only on objective task contingencies, but also on how individuals perceive the decision situation (de-Juan-Ripoll et al., 2021). Perceived control has also been associated with greater willingness to accept risk (Abdellaoui et al., 2011; Fischer & Frewer, 2009; Song & Schwarz, 2009) and to experience heightened confidence in their decision-making (Abdellaoui et al., 2011; Fischer & Frewer, 2009; Song & Schwarz, 2009). Conversely, unfamiliar or unpredictable environments often generate uncertainty, leading to more conservative decision-making strategies (Triandhari et al., 2017; Zhong et al., 2009). When environmental cues are missing or difficult to interpret, perceived risks may be amplified, prompting individuals to rely on protective heuristics or to exhibit heightened risk aversion (Baker & Maner, 2009; Damirchi et al., 2019). Accordingly, the present study does not assume that familiar environments necessarily increase risk-taking in a general sense. Rather, it examines whether pre-existing environmental familiarity changes how individuals regulate risk assumptions when potential rewards and losses must be managed under uncertainty.

Notably, familiarity can be derived from repeated exposure, perceived controllability, or emotional resonance (Halko et al., 2015), and many of its effects operate through subtle, incidental processes that influence perception, memory, and judgment (Isarida & Isarida, 2010; Qin et al., 2014). Collectively, these patterns illustrate what is commonly referred to as familiarity bias: a pervasive cognitive tendency to favor what is known over what is not. This bias is well documented in financial, consumer, and socio-cultural contexts, where individuals prefer familiar brands, home-country stocks, and predictable situations even when alternatives may be objectively advantageous (Almansour & Arabyat, 2017; Yu et al., 2012). Early literature in this domain frequently points to the mere-exposure effect, establishing that repeated encounters with a stimulus foster preference even without deliberate learning (Bornstein, 1989; Zajonc, 1968; see Montoya et al., 2017 for a recent review on the topic). While these foundational studies highlight the effects of familiarity, the present study shifts focus to a different source; pre-existing environmental familiarity, understood here as familiarity with a personally familiar real-world environment rather than familiarity produced by repeated experimental exposure.

Critically, however, familiarity is not a unitary construct. In much of the decision-making literature, familiarity is operationalized as an outcome of repeated exposure within the task or laboratory setting, often closely intertwined with comparative ignorance and ambiguity-related processes (Fox & Tversky, 1995), as well as fluency-based heuristics through which lower familiarity increases perceived risk (Song & Schwarz, 2009). We refer to this form of familiarity as task-based familiarity, because it emerges through repetition, feedback, or exposure to the task contingencies. Yet outside the laboratory, pre-existing environmental familiarity frequently reflects contextual knowledge grounded in autobiographical and spatial memory, where a place is not merely recognized but is connected to the person's prior experience. This distinction is supported by work showing close links between environmental navigation and autobiographical memory, as well as by environmental psychology research indicating that place attachment and familiarity contribute to how individuals know, interpret, and emotionally relate to places (Pullano et al., 2024; Teghil et al., 2021). Spatial familiarity has been shown to shape affective responses and perceived comfort in environments, and memory for familiar environments is structured in ways that support rapid orientation and interpretation of contextual cues (Hatzipanayioti et al., 2021; Kim et al., 2021; Pullano et al., 2024). Thus, in the present work, autobiographical context refers specifically to the home-based familiar environment used in the experiment, whereas task-based familiarity refers to familiarity acquired during the experiment through repeated exposure to the BART contingencies.

Despite the growing interest in how familiarity modulates risk-taking, a key conceptual issue concerns the heterogeneous and often overly abstract way previous research has defined and operationalized familiarity. Common approaches include repeated exposure to stimuli, or the presentation of loosely familiar cues (Craig et al., 2012; Scharfe-Scherf & Russwinkel, 2021). While these perspectives have yielded valuable insights, they typically capture task-based familiarity, that is, familiarity created through repetition and feedback within the task, rather than pre-existing environmental familiarity, which characterizes many daily-life decisions. This distinction matters theoretically and practically. Theoretically, it implies different temporal dynamics. Task-based familiarity predicts progressive adjustment across trials, whereas pre-existing environmental familiarity may support an early advantage before task-based learning has occurred. In practice, this distinction is critical because VR systems are increasingly used for training, assessment, and behavioral intervention. If behavior differs depending on whether a virtual environment is autobiographically familiar or merely unfamiliar, then the design of VR environments may influence performance independently of the task itself. Consequently, the present study adopts an ecologically grounded operationalization, using a personally familiar home-based environment to test whether pre-existing environmental familiarity supports early strategic regulation under uncertainty.

To implement this approach without compromising experimental control, we embedded a well-established behavioral paradigm within Virtual Reality (VR). This approach builds on previous work showing that classical laboratory tasks can be adapted to VR while preserving controlled experimental conditions, that yields reliable behavioral patterns (Rocabado et al., 2025) and allow for more elaborated experimental designs (Caballero-Picazo et al., 2026). Specifically, participants completed a VR-based version of the Balloon Analogue Risk Task (BART, Lejuez et al., 2002), while immersed in a home-based familiar environment, a 360° panoramic image of their own home entrance rendered via Google Street View, contrasted with an unfamiliar but structurally similar location. This design isolates the influence of pre-existing environmental familiarity on risk-taking behavior, while still allowing task-based learning to unfold across trials. The BART is well-suited to probe adaptive decision-making under uncertainty; each balloon inflation increases potential reward while raising the risk of explosion, prompting participants to adjust behavior based on prior outcomes (Rolison, 2023; van Ravenzwaaij et al., 2011).

This combination of the BART with familiar and unfamiliar immersive environments is informative because the task already contains an objective source of uncertainty. Participants must decide when continued pumping is worth the potential gain without knowing the exact explosion point of each balloon. The surrounding environment may therefore influence performance by shaping the broader context in which this uncertainty is experienced. In a home-based familiar environment, participants are immersed in a place for which they already possess spatial knowledge, affective associations, and autobiographical links (Hatzipanayioti et al., 2021; Kim et al., 2021; Pullano et al., 2024). By contrast, an unfamiliar environment provides fewer personally meaningful cues and may add contextual uncertainty to the uncertainty already imposed by the task itself.

Therefore, if pre-existing environmental familiarity makes the decision context more interpretable, predictable, or controllable, participants should be better able to regulate risk-taking in a way that maximizes reward without simply increasing explosions. This interpretation is consistent with evidence linking familiarity, perceived control, agency, and processing fluency to lower perceived risk and greater willingness to engage with uncertain outcomes (Abdellaoui et al., 2011; Song & Schwarz, 2009; Thompson, 1981). It is also consistent with applied work showing that unfamiliar roads are perceived as riskier than familiar roads, that route familiarity influences speed choice, and that familiarity with a traffic situation affects perceived complexity and action decisions in automated-driving scenarios (Budak et al., 2021; Colonna et al., 2016; Scharfe-Scherf & Russwinkel, 2021). Although these studies involve different tasks, they support the broader idea that familiarity with a spatial context can reduce perceived uncertainty and influence how individuals act under risk.

Within the BART, this familiarity advantage should be especially evident when the task allows room for strategic calibration. High explosion-threshold range balloons provide more opportunities to continue pumping before the explosion threshold is reached, making them particularly sensitive to differences in how participants balance potential gains against potential losses (Lejuez et al., 2002).

Accordingly, we expected the familiar environment to support higher earnings particularly in this range. At the same time, because participants acquire task-based familiarity through repeated exposure to the BART contingencies (Panno et al., 2015), the initial advantage of the familiar environment should decrease over time, especially as the unfamiliar context becomes more predictable through experience (Kóbor et al., 2021).

Based on this theoretical framework, the study was guided by the following hypotheses:

H1: Participants will earn more points per balloon in the familiar virtual environment than in the unfamiliar environment, reflecting more effective risk-taking regulation in the context of pre-existing environmental familiarity.

H2: The familiarity advantage will be primarily driven by trials that permit strategic risk regulation, reflected in a significant interaction between Context and Balloon Explosion Range, with larger context differences for high explosion-threshold range balloons.

H3: The familiarity advantage will be strongest early in the task and will decrease as participants gain experience with the task contingencies, reflected in a Context by Presentation Order interaction.

In addition, we conducted a complementary analysis restricted to successful high explosion-threshold trials to examine whether the Context by Presentation Order pattern remained when trials ending in balloon explosions were excluded. This analysis was used to assess whether the familiarity advantage reflected strategic calibration rather than an increased rate of balloon explosions.

Method

Data and Material Availability

The data supporting the findings of this study, together with video samples of the virtual reality task and the Python code used to implement the experiment, are available via the Open Science Framework (OSF) at: https://osf.io/u28bw/

Due to ethical and privacy considerations, the 360° images used in the virtual environments cannot be publicly shared (see Materials subsection). These images depict real-world locations associated with participants' personal environments, and their release could allow indirect identification or tracing of participants' locations. Access to these materials is therefore restricted in accordance with data protection regulations and the conditions approved by the institutional ethics committee.

Participants

Twenty-five University students participated (20 female, Mage = 21.5, SD = 4.51; 5 male, Mage = 20.2, SD = 1.92). All had normal or corrected-to-normal vision and hearing, preserved cognitive skills (Cognitive Assessment Battery Pro; CogniFit Inc., San Francisco, US), and were native Spanish speakers. Inclusion required participants to be registered as Madrid residents and to have lived at the same address for at least the previous five years, thereby ensuring that the familiar environment represented a stable source of pre-existing environmental familiarity. Written informed consent was obtained from all participants before any study procedures took place, including the preparation of personalized experimental materials and their participation in the VR task, and all procedures were conducted in accordance with the Declaration of Helsinki. The study was approved by the Research Ethics Committee at Nebrija University (UNNE-2022-0017).

Power analysis and sample size sensitivity

An a priori G*Power analysis (version 3.1.9.7; Faul et al., 2009), based on a medium effect size for a repeated-measures design with one group and six within-participant measurements, corresponding to the combination of three balloon explosion ranges and two environmental contexts (familiar, unfamiliar), indicated that 24 participants would be sufficient. However, to evaluate the sensitivity of the final sample size (N = 25), we conducted a simulation-based power and sensitivity analysis for the target Context by Presentation Order interaction in high explosion-threshold range BART trials. This interaction was selected because it tested the temporal prediction that the familiar-context advantage would be strongest early in the task and would decrease as participants gained experience with the task contingencies. The study followed a within-participant design, with each participant completing high explosion-threshold trials in both the familiar and unfamiliar contexts; therefore, the simulation reproduced the trial-level structure of this analysis, with 30 high explosion-threshold trials per context and participant. This interaction was used as the focal effect because it involved a within-participant change in the context effect across task progression and therefore provided a demanding test of the temporal prediction.

The smallest effect size of interest (SESOI) was defined from prior research using the Balloon Analogue Risk Task rather than from the observed effect in the present dataset. Meta-analytic evidence indicates that associations between psychological predictors and BART performance typically cluster around $r \approx .14–.15$ (Lauriola et al., 2014, 2019). Experimental studies examining trial-to-trial adaptation in the BART paradigm also report small-to-moderate effects (e.g., Kóbor et al., 2021; Panno et al., 2015). Based on this converging evidence, $r = .15$ was used as a standardized small-effect anchor. Because the target parameter was a Context by Presentation Order interaction expressed in points earned per trial, this value was operationalized on the dependent-variable scale rather than treated as a direct mathematical conversion to an unstandardized regression coefficient. Presentation Order was standardized, so the interaction coefficient represents the change in the familiar-minus-unfamiliar difference per 1-SD increase in task progression. Using an outcome-scale standard-deviation anchor of 10 points, the SESOI was specified as $\beta = –1.5$, with the negative sign reflecting the predicted temporal convergence between contexts.

Sensitivity was estimated using the simr package (version 1.0.8; Green & MacLeod, 2016) in R (version 4.3.3; R Core Team, 2024). The primary simulation used a parsimonious mixed-effects model including fixed effects of Context, Presentation Order, and their interaction, together with random intercepts for participants. This model estimates sensitivity for the average Context by Presentation

Order fixed effect while allowing participants to differ in their baseline level of earnings. The random-effects structure was specified to keep the simulation transparent and reproducible. Although maximal random-effects structures are often recommended for confirmatory mixed-effects analyses when supported by the design (Barr et al., 2013), using such structures in a simulation also requires specifying plausible values for each additional participant-level variance component and, in correlated structures, the correlations among them. In the present case, random slopes for Context, Presentation Order, and their interaction would have required assumptions about individual differences in the context effect, the order effect, and their temporal coupling. Because no prior data were available from the same personalized VR-BART paradigm to justify these parameters independently, the random-intercept model was used as the primary simulation model. This approach is consistent with the broader view that random-effects specification should balance design structure, estimability, Type I error control, and statistical power (Bates et al., 2015; Matuschek et al., 2017).

The variance assumptions were treated separately from the literature-derived SESOI. Because no prior personalized VR-BART data were available to provide variance estimates for this specific trial-level design, observed high explosion-threshold trials was used during revision only as a pragmatic reference point for defining plausible simulation anchors. These values were then increased for the primary simulation to avoid relying directly on the observed variance estimates. Specifically, participant-level baseline variability was set to SD = 4.0 and residual trial-level variability to SD = 6.0. Additional sensitivity scenarios examined the separate and combined impact of higher variance assumptions and a smaller target interaction. The higher-variance scenario increased participant-level variability to SD = 6.0 and residual variability to SD = 9.0 while retaining $\beta = -1.5$. The smaller-effect scenario retained the primary variance assumptions but reduced the target interaction to $\beta = -1.0$. The stress-test scenario combined both harsher assumptions.

To examine whether the results depended on the parsimonious random-intercept specification, we ran also random-slope sensitivity checks. These simulations added plausible participant-level variability in the Context effect, the Presentation Order effect, and the Context by Presentation Order interaction, using uncorrelated random-effects structures because no prior personalized VR-BART data were available to justify correlations among these components. These random-slope simulations were treated as sensitivity checks rather than as estimates of the true participant-level variance components.

Under the primary random-intercept SESOI scenario, estimated power at $N = 25$ was .997, 95% CI [.996, 1.000]. Estimated power remained high when only the variance assumptions were increased, power = .878, 95% CI [.856, .898], and when only the target interaction was reduced to $\beta = -1.0$, power = .896, 95% CI [.875, .914]. Under the combined stress-test scenario, estimated power was more modest, power = .561, 95% CI [.530, .592]. In the random-slope sensitivity check, estimated power under the primary SESOI assumptions was .980, 95% CI [.969, .988], whereas the random-slope stress-test estimate was .516, 95% CI [.485, .547]. The complete stand-alone R script, output files, session information, and power-curve figure are available on OSF.

Materials and Apparatus

For each participant, address information was collected and used to obtain a personalized 360° high-resolution panorama (6656 × 3328 pixels) from Google Street View via Street View Download 360 (version 4.0.5, Orlita, 2022) These images served as the home-based familiar context in the experiment and were used to operationalized pre-existing environmental familiarity. To create the unfamiliar context, participants' addresses were matched to new ones based on average net income per capita from other Spanish cities, such as Málaga, Sevilla, Zaragoza, or Santander, using data from a public repository (Spanish Statistical Office, 2021, www.ine.es). These new locations were selected to share similar architecture and urban layout with the familiar locations while remaining geographically unfamiliar to participants. The corresponding 360° unfamiliar context panoramas were generated using the same procedure as for the familiar panoramas.

To ensure comparability between contexts in terms of income, a paired-samples t-test was conducted, revealing no significant difference between the average net incomes associated with each pair of locations, $t(24) = 1.16$, $p = .256$. Additionally, a Two One-Sided Test (TOST) with an equivalence margin of ±500 € confirmed that income values were statistically equivalent. In equivalence testing, significance indicates that group differences fall within the predefined bounds. Both the lower and upper TOST bounds were significant, $t(24) = 2.34$, $p = .014$; $t(24) = -4.66$, $p = .001$, supporting the conclusion that the two income indicators were comparable across the familiar and unfamiliar contexts.

The experimental setting was programmed and designed using Python 3 and Vizard 7 (Worldviz, 2020). The experimental environments and stimuli were displayed using the HTC VIVE Pro HMD, which offers a rendering resolution of 2880×1600 pixels (1440×1600 pixels per eye), a 90 Hz refresh rate, and a 110° field of view. The participant’s viewpoint location was fixed throughout the task, irrespective of their real-world movements.

Procedure

The virtual reality adaptation of the Balloon Analogue Risk Task (BART) followed the structure outlined by Lejuez et al. (Lejuez et al., 2002), preserving key task characteristics while adapting the environment and interaction mechanics to a VR setting. Participants completed the task twice, once in a familiar context and once in an unfamiliar context. This resulted in a within-participant design, with all participants completing both environmental contexts. The order of these conditions was counterbalanced across participants. To prevent familiarity with the explosion probabilities from being directly transferred between contexts, different balloon color sets were used in each condition. The first context included blue, yellow, and orange balloons corresponding respectively to high, medium, and low explosion-threshold ranges. The second context introduced green, gray, and cyan balloons with the same explosion-threshold ranges used in the first context. Moreover, the assignment of balloon colors to the familiar and unfamiliar contexts was counterbalanced across participants.

Between the two BART sessions, participants completed an unrelated VR language decision task. This task was included to separate the two BART blocks, reduce immediate carryover between contexts, and prevent participants from experiencing the second BART session as a direct continuation of the first one. Each BART session consisted of 90 trials, where participants inflated a virtual balloon by pulling the right-hand trigger on a VR controller. Each trigger pull corresponded to a one-point increase in the participant’s score. At any point during a trial, participants could collect their accumulated points by pulling the left-hand trigger, transferring them to their total score. If the balloon exploded before collection, all uncollected points associated with that trial were lost, and the next trial began (see Figure 1).

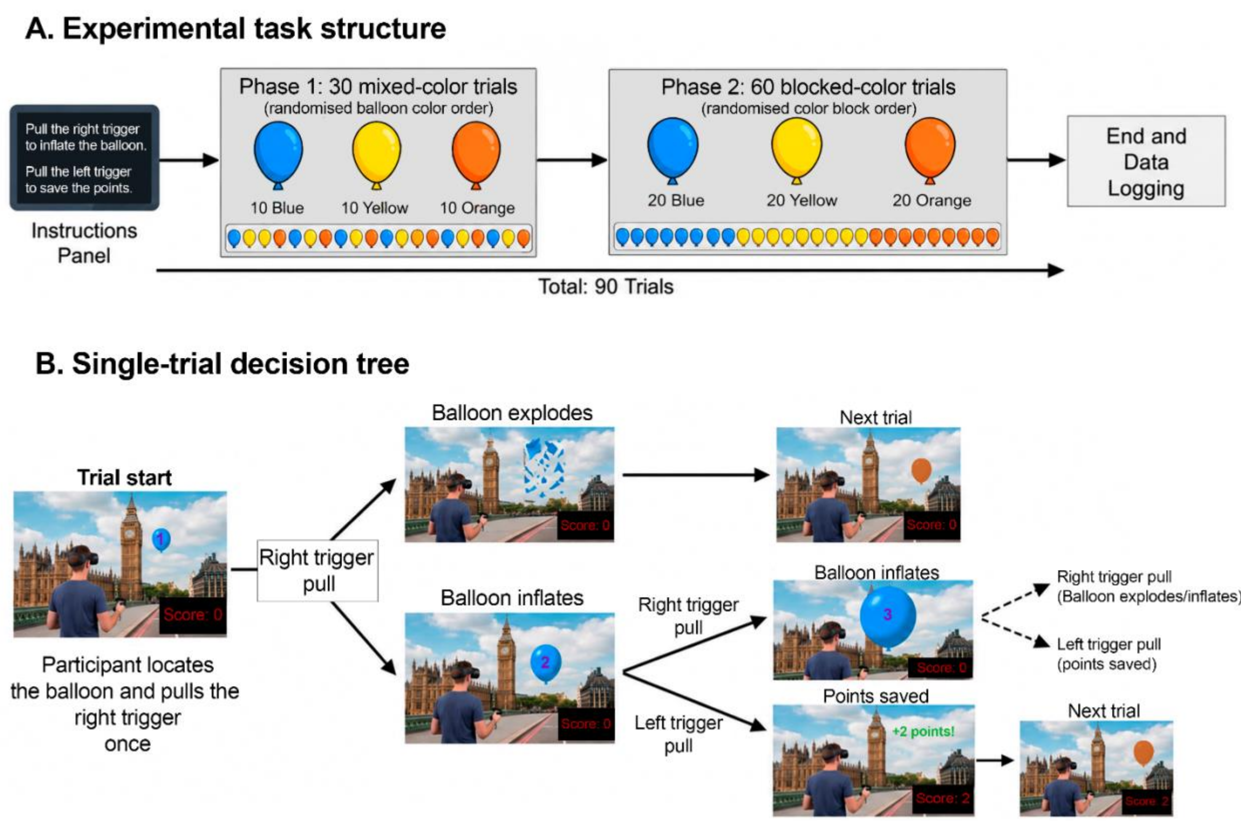

Figure 1. Panel A shows the organization of one example 90-trial BART session, including the initial mixed phase and the later blocked phase. Panel B shows the sequence of decisions within a single trial. Participants could inflate the balloon using the right-hand trigger, increasing both potential reward and explosion risk, or collect the accumulated points using the left-hand trigger. If the balloon exploded before collection, the points accumulated on that trial were lost. The surrounding 360° environment within the task was replaced for each participant according to the familiar and unfamiliar context conditions.

Similar to previous 2D implementations of this task (Lejuez et al., 2002), each balloon type had a specific explosion probability threshold. The high explosion-threshold range balloons had an average break point of 64 pumps (range: 1–128, SD = 31.7), the medium explosion-threshold range balloons had an average break point of 16 pumps (range: 1–32, SD = 6.98), and the low explosion-threshold range balloons had an average break point of 4 pumps (range: 1–8, SD = 1.29). Participants were not informed of these explosion range probabilities and were instructed only that their goal was to accumulate the highest possible score.

Participants sat on a swivel chair, allowing them to rotate freely. The balloons appeared in a fully immersive 360° virtual environment at a fixed distance of 5 virtual meters from the participant. Their initial diameter was 15 cm for all balloons, and each pump increased the balloon size by 0.05%. To promote active exploration of the immersive environment, participants had to locate the balloon at the beginning of each trial before deciding whether to pump or collect. The location of each balloon was randomized across the full 360° horizontal space, requiring participants to turn to locate the balloon presented in each trial. Balloons appeared one at a time, requiring active spatial exploration.

A counter displayed in front of each balloon indicated the number of pumps participants had made. A virtual progress panel, positioned at a 45° angle from the horizon, displayed the participant's total accumulated score to ensure continuous performance monitoring without disrupting the immersive experience.

As in earlier studies with this same task, each BART session was divided into two phases. In the first 30 trials, balloons of all three explosion-threshold categories (i.e., high, medium and low) appeared in a randomized sequence. In the remaining 60 trials, balloons were presented in blocks of 20 consecutive trials of the same explosion-threshold category, allowing participants to gradually recognize and adapt to the different risk contingencies associated with each balloon type. This structure preserved the fundamental decision-making dynamics of the original BART while incorporating spatial exploration as an additional task component.

Data Processing and Statistical Analysis

All data were processed and prepared using R (R Core Team, 2020) within the RStudio environment (RStudio Team, 2022). Linear mixed-effects models (LMMs) were conducted in Jamovi (The jamovi project, 2022) using the GAMLj module (Gallucci, 2019).

The dependent variable in all analyses was the number of points earned per trial. Each participant completed 30 trials for each explosion-threshold category (high, medium, low) in both context conditions (familiar and unfamiliar), resulting in a total of 4500 observations. Analyses were conducted in a stepwise fashion, starting with all trials to examine overall earnings across balloon types. The focus was then narrowed to high explosion-threshold balloons only (1500 observations), as these allowed greater variability in risk-taking strategy, and finally to successful unexploded high explosion-threshold trials, which allowed us to examine whether the familiarity advantage remained when trials ending in explosions were excluded (1351 observations).

Fixed effects included Context (familiar vs. unfamiliar), Balloon Explosion-Threshold Range (high, medium, low), and Presentation Order (trial order, centered as a continuous covariate), depending on the analysis. All models incorporated random intercepts for participants and balloon type, as well as by-participant random slopes for Context. Post hoc comparisons and simple effects were obtained using estimated marginal means with Bonferroni corrections. Inferential statistics are reported with

Satterthwaite approximate degrees of freedom, including F values, p values, standard errors, and 95% confidence intervals.

Results

To evaluate the hypotheses outlined in the Introduction, analyses were conducted in a hierarchical sequence corresponding directly to H1, H2, and H3. First, to test whether pre-existing environmental familiarity was associated with higher earnings in the BART (H1), we examined context effects on earnings across all trials. Second, to determine whether any familiarity advantage was specifically driven by trials that permit strategic regulation (H2), we tested the interaction between Context and Balloon Explosion Range. Third, to evaluate whether familiarity effects were strongest early in the task and diminished with experience (H3), we examined the Context by Presentation Order interaction for high explosion-threshold range balloons. Finally, as a complementary analysis, we repeated this analysis using only successfully unexploded high explosion-threshold trials to examine whether any familiarity advantage reflected strategic calibration rather than an increased rate of balloon explosions.

Context Effects Across Balloon Types

To test H1, which predicted higher earnings in the familiar virtual environment than in the unfamiliar environment, we first examined overall earnings across contexts. A significant main effect of Context emerged, $F(1, 24) = 5.03$, $p = .034$, with participants earning more points in the familiar than in the unfamiliar environment (see Figure 2). This finding supports H1 and indicates that pre-existing environmental familiarity was associated with more effective behavioral calibration, allowing participants to balance risk and reward more successfully. In practical terms, participants accumulated more points per balloon in the familiar context, whereas they earned fewer points in the unfamiliar context. Observed descriptive statistics and post hoc comparisons are reported in Table 1, whereas Figure 2 displays the corresponding model-estimated marginal means.

Table 1. Observed Points Earned per Trial by Environmental Context and Balloon Explosion-Threshold Range

Balloon explosion threshold	n	Trial observations per context	Familiar context M (SD)	Unfamiliar context M (SD)	Mean difference	95% CI	p	Cohen's d_z
All threshold categories	25	2250	8.69 (3.06)	7.87 (2.71)	0.82	[0.07, 1.59]	.034	0.45
High	25	750	17.77 (14.33)	15.62 (13.18)	2.15	[0.73, 3.56]	<.001	0.42
Medium	25	750	6.4 (5.76)	6.23 (5.22)	0.17	[-1.25, 1.58]	1.000	0.11
Low	25	750	1.91 (1.69)	1.75 (1.73)	0.16	[-1.25, 1.57]	1.000	0.34

Note. Descriptive statistics are observed trial-level means and standard deviations of points earned per trial. Difference values represent familiar minus unfamiliar context. The overall row refers to the main effect of Context across all balloon explosion-threshold ranges. Pairwise comparisons within each balloon explosion-threshold range are based on model-estimated post hoc comparisons with Bonferroni correction. Cohen's d_z was calculated from participant-level familiar–unfamiliar difference scores.

Given that each balloon had a different explosion-threshold range probability, a main effect of Balloon Explosion-Threshold Range was also found $F(2, 87) = 128.93$, $p < .001$. Participants earned substantially more points with high explosion-threshold range balloons than with medium explosion-threshold range balloons (mean difference = 10.38, $SE = 0.95$, $p_{Bonf} < .001$) or low explosion-threshold range balloons (mean difference = 14.86, $SE = 0.95$, $p_{Bonf} < .001$). Earnings were likewise significantly lower for low compared to medium explosion-threshold range balloons (mean difference = 4.49, $SE = 0.95$, $p_{Bonf} <$ .001), consistent with the predefined probability structure of the task (see Methods; Figure 2).

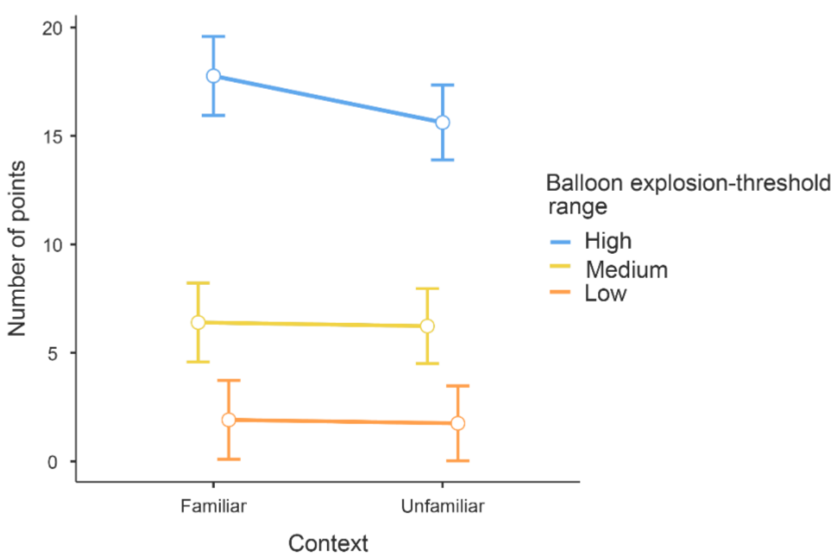

Figure 2. Effects of environmental context and balloon explosion-threshold range on BART performance. Estimated marginal means of points earned per trial are shown for familiar and unfamiliar contexts across low, medium, and high explosion-threshold range balloons. Error bars represent 95% confidence intervals.

To test H2, which predicted that familiarity effects would be most pronounced on trials that allow strategic risk regulation, we next examined whether the effect of Context varied as a function of Balloon Explosion-Threshold Range. Results showed a significant interaction, $F(2, 4359) = 8.97$, $p < .001$, indicating that the familiarity effect varied across different explosion thresholds (Figure 2). Simple effects analyses revealed that the effect of Context was present only for high explosion-threshold range balloons, with participants earning on average 2.15 more points ($SE = 0.48$) in the familiar than in the unfamiliar condition, $t(71) = -4.45$, $p < .001$. No significant effects of Context were found for medium or low explosion-threshold rangeballoons ($ts < 1$, $ps > .70$).

Context Effects Across Task Progression

To test H3, which predicted that the familiarity advantage would be strongest early in the task and would decrease as participants gained experience with the task contingencies, we analyzed earnings as a function of Presentation Order for high explosion-threshold range balloons. When focusing on these, a main effect of Context was again observed, $F(1, 24) = 4.50$, $p = .044$, with higher earnings in the familiar environment (Figure 3A). A significant main effect of Presentation Order also emerged, $F(1, 930.9) = 13.74$, $p < .001$, indicating that earnings increased progressively over the course of the task.

Estimated marginal means illustrated this trend, participants earned on average 15.1 points ($SE = 1.84$) in early trials (−1 SD of Presentation Order), 16.7 points ($SE = 1.79$) at mid-task (mean Presentation Order), and 18.3 points ($SE = 1.84$) in later trials (+1 SD of Presentation Order). This pattern reflects a general increase in points earned as participants gained experience with the task contingencies.

Crucially, the interaction between Context and Presentation Order was also significant, *F*(1, 1420.1) = 5.69, *p* = .017. Simple effects analyses showed that the familiarity advantage was most pronounced early in the task. In early trials (−1 SD of Presentation Order), participants earned significantly more points in the familiar than in the unfamiliar context (mean difference = 3.40, *SE* = 1.14), *t*(38.7) = 2.98, *p* = .005. This difference was smaller but still present at mid-task (mean Presentation Order; mean difference = 2.15, *SE* = 1.01), *t*(24) = 2.12, *p* = .044, and disappeared in later trials (+1 SD of Presentation Order), where no significant difference remained between contexts (mean difference = 0.89, *SE* = 1.14), *t*(38.7) = 0.78, *p* = .44.

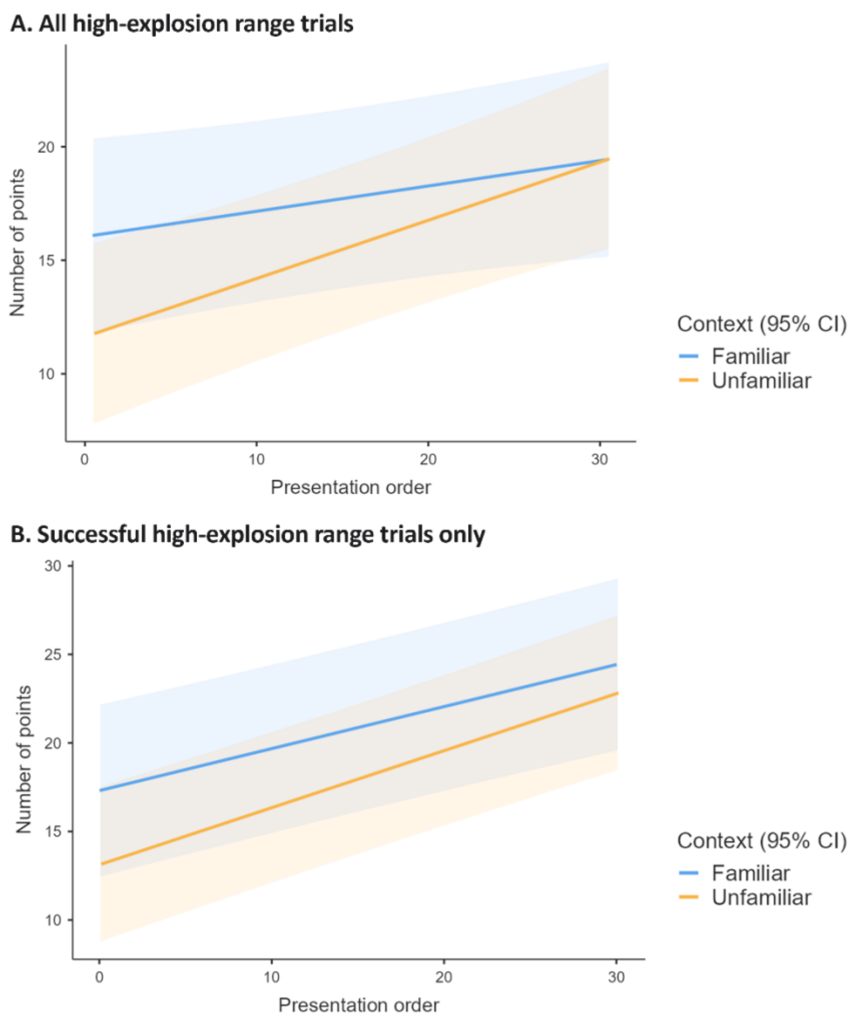

Figure 3. Effects of environmental context across task progression for high explosion-threshold range balloons. Panel A shows estimated marginal means for all high explosion-threshold range balloon trials, including trials that ended in explosions. Panel B shows estimated marginal means for successful high explosion-threshold range balloon trials only, excluding trials that ended in explosions. The x-axis displays Presentation Order across the high explosion-threshold trials from 0 to 30, whereas the simple-effects estimates reported in the text are probed at −1 SD, the mean, and +1 SD of Presentation Order. Error bars represent 95% confidence intervals.

These findings indicate that performance in the unfamiliar environment gradually approached that of the familiar environment as participants gained experience, demonstrating that the familiarity advantage was strongest early in the task and diminished with accumulated task-based familiarity. This pattern directly supports H3.

Complementary Analysis of Successful High Explosion-Threshold Trials

As a complementary analysis, we examined whether the Context by Presentation Order pattern remained when analyses were restricted to successful trials. To do so, we repeated the previous analyses including only high explosion-threshold range trials that did not end in balloon explosions. This approach allowed us to evaluate whether the context effect persisted when focusing solely on trials in which participants collected the accumulated points before a balloon explosion occurred.

A significant main effect of Context remained, $F(1, 23.9) = 4.46$, $p = .045$. Participants earned on average 2.88 more points ($SE = 1.36$) in the familiar than in the unfamiliar environment (Figure 3B), demonstrating that the familiarity advantage was not driven by an increased rate of risky failures. A main effect of Presentation Order was also observed, $F(1, 77.8) = 90.93$, $p < .001$, confirming that earnings increased systematically across the task.

Estimated marginal means showed this improvement clearly, 17.0 points ($SE = 2.08$) in early trials (−1 SD of Presentation Order), 19.4 points ($SE = 2.06$) at mid-task (mean Presentation Order), and 21.9 points ($SE = 2.08$) in later trials (+1 SD of Presentation Order), reflecting ongoing strategic adaptation (Figure 3B).

Although the Context by Presentation Order interaction did not reach conventional significance in this restricted analysis, $F(1, 1276.6) = 2.96$, $p = .085$, the pattern mirrored that observed in the full dataset. The familiarity effect was strongest early in the task and gradually diminished over time. Together, these findings support the complementary analysis by demonstrating that the observed context effects were also present when analyses were limited to successful trials, suggesting that higher earnings in the familiar environment reflected strategic calibration rather than impulsive or reckless behavior. Participants initially adopted more cautious strategies in unfamiliar settings but gradually adapted as they accumulated task-based familiarity, ultimately reducing the performance gap between contexts.

Discussion

The present study investigated how pre-existing environmental familiarity influences behavior in a virtual reality adaptation of the Balloon Analogue Risk Task (BART, Lejuez et al., 2002). Beyond examining risk-taking per se, the study also illuminates how technologically mediated environments shape behavioral regulation, offering insight into the cognitive processes engaged when individuals interact with highly realistic immersive digital systems. By immersing participants in a photorealistic 360° environment derived from their actual home address and contrasting it with an unfamiliar yet structurally similar location, this study offers novel insight into how personally familiar environmental cues shape reward-oriented decision-making.

Participants demonstrated significantly higher average earnings per balloon in the home-based familiar condition, particularly during the early part of the task and in trials that allowed greater variation in pumping behavior. This effect did not stem from impulsivity or reckless behavior, as patterns held even when analyses were restricted to successful (non-exploded) trials. Instead, participants appeared to calibrate their risk taking more effectively in familiar settings. One possible interpretation is that the familiar virtual environment acted as a contextual scaffold, reducing subjective uncertainty and supporting more confident engagement with the task. However, perceived control and emotional arousal were not directly measured in the present study, and this mechanism should therefore be interpreted as a theoretically grounded explanation rather than as a direct empirical finding. This interpretation is consistent with previous work suggesting that familiarity, perceived control, and emotional responses can influence goal-directed behavior under uncertainty (Dohmen et al., 2011; Maren et al., 2013).

Although the advantage conferred by pre-existing environmental familiarity diminished over time, this was mainly because performance in the unfamiliar context gradually improved, consistent with a behavioral adaptation process to the probabilistic nature of the task (Schonberg et al., 2020). Thus, our findings not only reveal the impact of pre-existing environmental familiarity on risk-taking behavior but also align with previous research that has operationalized familiarity through repeated exposure to stimuli or environments. In the unfamiliar context, participants gradually adjusted their behavior as the task progressed, showing higher earnings and improved outcomes. This suggests that task-based familiarity, developed through experience with the task contingencies, can foster more strategic decision-making.

This temporal dissociation helps refine the theoretical interpretation of familiarity bias. A substantial portion of the literature has examined familiarity through repetition, fluency, or within-task exposure, where familiarity is tightly coupled with reduced comparative ignorance and ambiguity over time. Under these approaches, “familiarity” is largely an emergent property of repeated encounters rather than a stable contextual resource available at the outset (Fox & Tversky, 1995). The present findings suggest a complementary perspective. When familiarity is grounded in a home-based autobiographical context, that is, in a personally meaningful environment that forms part of the participant’s own life history, it may provide a source of contextual knowledge that supports early strategic regulation under uncertainty, before task-based familiarity has been acquired. This is consistent with the observed pattern, participants showed an early advantage in the familiar environment, whereas performance in the unfamiliar environment gradually improved across trials. Thus, the familiar home context did not simply function as another repeated stimulus within the task, but as a source of pre-existing environmental familiarity that may have supported earlier risk regulation under uncertainty. In this sense, familiarity bias is not only a preference for what is known, but also a possible route through which memory and contextual knowledge contribute to adaptive action selection (Gomilsek et al., 2025; Wang et al., 2022).

These implications matter for future research insofar as they suggest that familiarity should not be treated as a unitary construct or as interchangeable across operationalizations. Studies that induce familiarity solely through repeated exposure may primarily capture a learning-related trajectory, whereas studies that leverage home-based autobiographical contexts may capture an early, memory-supported calibration process. Future researchers interested in familiarity bias should therefore specify which source of familiarity is being tested, model its temporal profile explicitly, and avoid interpreting early performance differences as evidence of faster learning when such differences may reflect pre-existing environmental familiarity. This is particularly relevant for experimental paradigms in which behavior is assessed primarily at the beginning of the task, or where rapid initial calibration is theoretically central as well as for VR-based assessments, where the familiarity of the simulated environment may influence performance independently of the task itself.

These findings also open new avenues for application. In the context of automated systems, training, and safety regulation, the role of familiarity must be carefully considered. Systems that dynamically adapt to a user’s perceived familiarity or task complexity may help optimize performance and reduce cognitive overload (Scharfe-Scherf & Russwinkel, 2021). These results therefore hold future testable implications for the design of context-aware digital environments, where behavioral calibration may benefit from interfaces that reflect or leverage users’ pre-existing spatial knowledge.

In clinical, educational, or rehabilitation contexts, familiar environments may scaffold strategic engagement and enhance self-regulation. However, the physical proximity of high-risk settings to individuals' everyday environments may pose policy challenges, as easier access can facilitate risk-taking behaviors. This highlights the relevance of considering geographic accessibility in designing interventions or regulations for activities with addictive potential, such as gambling. Although this implication remains speculative in the context of the present study, it illustrates why the source and personal meaning of environmental familiarity may be relevant beyond laboratory tasks.

These implications should be interpreted within the scope of the present design. The study used a relatively focused sample of young university students, which was appropriate for this initial test of a personalized VR manipulation, but future research should examine whether similar effects are observed in larger and more diverse samples. In addition, the familiar condition was intentionally implemented as a home-based autobiographical environment. This choice increased ecological validity, although it also means that familiarity may have involved several related components, including spatial knowledge, autobiographical memory, emotional meaning, perceived safety, and everyday accessibility. Future studies could further refine this approach by comparing different types of familiar environments, such as home, workplace or frequently visited public spaces. Moreover, the present study did not directly assess the psychological mechanisms that may underlie the familiarity advantage. Finally, perceived control, subjective uncertainty, emotional arousal, confidence, attachment with the place, and perceived safety therefore remain promising candidates for future research.

Within this context, the present study highlights the value of personalized virtual reality as a methodological bridge between experimental control and real-world complexity. By immersing participants in a home-based familiar environment, we isolated the effects of pre-existing environmental familiarity with high ecological validity (Ju & Wallraven, 2023; Marín-Morales et al., 2018). Our findings show that such familiarity shapes how individuals navigate uncertainty, participants earned more points and showed earlier strategic calibration in a risk-sensitive task, without incurring higher loss rates. These results underscore that environmental cues influence not just decision outcomes, but also the behavioral regulation processes involved in managing potential rewards and losses. If future studies confirm that familiarity reduces subjective complexity or increases perceived control, this mechanism may help explain decision patterns in real-world scenarios, such as faster adaptation during crises in familiar surroundings or excessive confidence in familiar but high-risk environments. More broadly, this work contributes to understanding how users behave within immersive technologies, reinforcing the need to incorporate environmental familiarity into human cognition and technology-mediated explanatory models of decision-making.

References

Abdellaoui, M., Baillon, A., Placido, L., & Wakker, P. P. (2011). The Rich Domain of Uncertainty: Source Functions and Their Experimental Implementation. *American Economic Review*, *101*(2), 695-723. https://doi.org/10.1257/aer.101.2.695

Almansour, B. Y., & Arabyat, Y. A. (2017). Investment decision making among gulf investors: Behavioural finance perspective. *International Journal of Management Studies*, *24*. https://doi.org/10.32890/ijms.24.1.2017.10476

Baker, M. D., & Maner, J. K. (2009). Male risk-taking as a context-sensitive signaling device. *Journal of Experimental Social Psychology*, *45*(5), 1136-1139. https://doi.org/10.1016/j.jesp.2009.06.006

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, *68*(3), 255-278. https://doi.org/10.1016/j.jml.2012.11.001

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, *67*(1), 1-48. https://doi.org/10.18637/jss.v067.i01

Bornstein, R. F. (1989). Exposure and affect: Overview and meta-analysis of research, 1968–1987. *Psychological Bulletin*, *106*(2), 265-289. https://doi.org/10.1037/0033-2909.106.2.265

Budak, N., Öztürk, İ., Aslan, M., & Öz, B. (2021). How Drivers' Risk Perception Changes While Driving on Familiar and Unfamiliar Roads: A Comparison of Female and Male Drivers. *Trafik ve Ulaşım Araştırmaları Dergisi*, *4*(1), 39-48. https://doi.org/10.38002/tuad.866934

Caballero-Picazo, E., Rocabado, F., Hinojosa, J. A., & Poch, C. (2026). Naturalistic actions modulate Working Memory prioritization in immersive virtual reality. *Scientific Reports*. https://doi.org/10.1038/s41598-026-54299-1

Colonna, P., Intini, P., Berloco, N., & Ranieri, V. (2016). The influence of memory on driving behavior: How route familiarity is related to speed choice. An on-road study. *Safety Science*, *82*, 456-468. https://doi.org/10.1016/j.ssci.2015.10.012

Craig, T., Conniff, A., & Galan-Diaz, C. (2012). The Influences of Actual and Perceived Familiarity on Environmental Preferences for the Design of a Proposed Urban Square. *Urban Studies Research*, *2012*(1), 767049. https://doi.org/10.1155/2012/767049

Damen, T. G. E. (2019). Sense of Agency as a predictor of risk-taking. *Acta Psychologica*, *197*, 10-15. https://doi.org/10.1016/j.actpsy.2019.04.015

Damirchi, E. S., Ghojebegloo, P. H., Amir, S. M. B., & gholizade, b. (2019). Predicting risk-taking behaviors based on the role of perceived social support components, emotional expression and brain- behavioral systems in addicts. *Quarterly of the Horizon of Medical Sciences*, *25*(4), 282-297. https://doi.org/10.32598/hms.25.4.282

de-Juan-Ripoll, C., Chicchi Giglioli, I. A., Llanes-Jurado, J., Marín-Morales, J., & Alcañiz, M. (2021). Why Do We Take Risks? Perception of the Situation and Risk Proneness Predict Domain-Specific Risk Taking. *Frontiers in Psychology*, *12*, 562381. https://doi.org/10.3389/fpsyg.2021.562381

Dohmen, T., Falk, A., Huffman, D., Sunde, U., Schupp, J., & Wagner, G. G. (2011). Individual Risk Attitudes: Measurement, Determinants, and Behavioral Consequences. *Journal of the European Economic Association*, *9*(3), 522-550. https://doi.org/10.1111/j.1542-4774.2011.01015.x

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149-1160. https://doi.org/10.3758/BRM.41.4.1149

Fischer, A. R. H., & Frewer, L. J. (2009). Consumer familiarity with foods and the perception of risks and benefits. *Food Quality and Preference, Institut Paul Bocuse Special Issue*, *20*(8), 576-585. https://doi.org/10.1016/j.foodqual.2009.06.008

Fox, C. R., & Tversky, A. (1995). Ambiguity Aversion and Comparative Ignorance. *The Quarterly Journal of Economics*, *110*(3), 585-603. https://doi.org/10.2307/2946693

Frey, R., Pedroni, A., Mata, R., Rieskamp, J., & Hertwig, R. (2017). Risk preference shares the psychometric structure of major psychological traits. *Science Advances*, *3*(10), e1701381. https://doi.org/10.1126/sciadv.1701381

Gallucci, M. (2019). *GAMLj: General analyses for the linear model in jamovi*.

Gomilsek, T., Gaissmaier, W., & Hoffmann, J. A. (2025). The role of familiarity and recollection in value-based decisions. *Cognition*, *263*, 106217. https://doi.org/10.1016/j.cognition.2025.106217

Green, P., & MacLeod, C. J. (2016). simr: An R package for power analysis of generalised linear mixed models by simulation. *Methods in Ecology and Evolution*, *7*(4), 493-498. https://doi.org/10.1111/2041-210X.12504

Halko, M.-L., Mäkelä, T., Nummenmaa, L., Hlushchuk, Y., & Schürmann, M. (2015). Hedonic context modulates risky choices and reward responses in amygdala and dorsal striatum. *Journal of Neuroscience, Psychology, and Economics*, *8*(2), 100-115. https://doi.org/10.1037/npe0000036

Hatzipanayioti, A., Galati, A., Pagkratidou, M., & Avraamides, M. N. (2021). Are Spatial Memories for Familiar Environments Orientation Dependent? *Journal of Cognition*, *4*(1). https://doi.org/10.5334/joc.147

Isarida, T., & Isarida, T. K. (2010). Effects of Simple- and Complex-Place Contexts in the Multiple-Context Paradigm. *Quarterly Journal of Experimental Psychology*, *63*(12), 2399-2412. https://doi.org/10.1080/17470211003736756

Ju, U., & Wallraven, C. (2023). Relationship between virtual reality balloon analogue risk task and risky decision-making. *Plos One*, *18*(2), e0282097. https://doi.org/10.1371/journal.pone.0282097

Kim, J. Y., Choi, J. K., Han, W. H., & Kim, J. H. (2021). The Influence of Users' Spatial Familiarity on Their Emotional Perception of Space and Wayfinding Movement Patterns. *Sensors (Basel, Switzerland)*, *21*(8), 2583. https://doi.org/10.3390/s21082583

Kóbor, A., Kardos, Z., Takács, Á., Éltető, N., Janacsek, K., Tóth-Fáber, E., Csépe, V., & Nemeth, D. (2021). Adaptation to recent outcomes attenuates the lasting effect of initial experience on risky decisions. *Scientific Reports*, *11*(1), 10132. https://doi.org/10.1038/s41598-021-89456-1

Lauriola, M., Panno, A., Levin, I. P., & Lejuez, C. W. (2014). Individual Differences in Risky Decision Making: A Meta-analysis of Sensation Seeking and Impulsivity with the Balloon Analogue Risk Task. *Journal of Behavioral Decision Making*, *27*(1), 20-36. https://doi.org/10.1002/bdm.1784

Lauriola, M., Panno, A., & Weller, J. A. (2019). Regret-Based Decision-Making Style Acts as a Dispositional Factor in Risky Choices. *Psychological Reports*, *122*(4), 1412-1431. https://doi.org/10.1177/0033294118786687

Lejuez, C. W., Read, J. P., Kahler, C. W., Richards, J. B., Ramsey, S. E., Stuart, G. L., Strong, D. R., & Brown, R. A. (2002). Evaluation of a behavioral measure of risk taking: The Balloon Analogue Risk Task (BART). *Journal of Experimental Psychology: Applied*, *8*(2), 75-84. https://doi.org/10.1037/1076-898X.8.2.75

Maren, S., Phan, K. L., & Liberzon, I. (2013). The contextual brain: Implications for fear conditioning, extinction and psychopathology. *Nature Reviews Neuroscience*, *14*(6), 417-428. https://doi.org/10.1038/nrn3492

Marín-Morales, J., Higuera-Trujillo, J. L., Greco, A., Guixeres, J., Llinares, C., Scilingo, E. P., Alcañiz, M., & Valenza, G. (2018). Affective computing in virtual reality: Emotion recognition from brain and heartbeat dynamics using wearable sensors. *Scientific Reports*, *8*(1), Article 1. https://doi.org/10.1038/s41598-018-32063-4

Matuschek, H., Kliegl, R., Vasishth, S., Baayen, H., & Bates, D. (2017). Balancing Type I error and power in linear mixed models. *Journal of Memory and Language*, *94*, 305-315. https://doi.org/10.1016/j.jml.2017.01.001

Montoya, R. M., Horton, R. S., Vevea, J. L., Citkowicz, M., & Lauber, E. A. (2017). A re-examination of the mere exposure effect: The influence of repeated exposure on recognition, familiarity, and liking. *Psychological Bulletin*, *143*(5), 459-498. https://doi.org/10.1037/bul0000085

Nordgren, L. F., Van Der Pligt, J., & Van Harreveld, F. (2007). Unpacking perceived control in risk perception: The mediating role of anticipated regret. *Journal of Behavioral Decision Making*, *20*(5), 533-544. https://doi.org/10.1002/bdm.565

Orlita, T. (2022). *Street View Download 360* (Versión 4.0.5) [Computer software]. SVD360. https://www.svd360.com

Panno, A., Lauriola, M., & Pierro, A. (2015). Regulatory Mode and Risk-Taking: The Mediating Role of Anticipated Regret. *PLOS ONE*, *10*(11), e0143147. https://doi.org/10.1371/journal.pone.0143147

Pullano, L., Foti, F., Liuzza, M. T., & Palermo, L. (2024). The role of place attachment and spatial anxiety in environmental knowledge. *Journal of Environmental Psychology*, *94*, 102229. https://doi.org/10.1016/j.jenvp.2024.102229

Qin, X., Bochsler, T. M., Aizpurua, A., Cheong, A. M. Y., Koutstaal, W., & Legge, G. E. (2014). Incidental Memory of Younger and Older Adults for Objects Encountered in a Real World Context. *PLOS ONE*, *9*(6), e99051. https://doi.org/10.1371/journal.pone.0099051

R Core Team. (2020). *R: A Language and Environment for Statistical Computing* [Software]. R Foundation for Statistical Computing. https://www.R-project.org/

R Core Team. (2024). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. https://www.R-project.org/

Rocabado, F., Muntini, L., Jubran, O. F., Lachmann, T., & Duñabeitia, J. A. (2025). Transforming language research from classic desktops to virtual environments. *Scientific Reports*, *15*(1), 23118. https://doi.org/10.1038/s41598-025-08319-1

Rolison, J. J. (2023). The psychological drivers of self-reported risk preference. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *49*(10), 1635-1661. https://doi.org/10.1037/xlm0001266

Russell, M. D., Bonny, J. W., & Reed, R. (2024). Impact of Virtual Reality on Decision-Making and Risk Assessment During Simulated Residential Fire Scenarios. *Fire*, *7*(12), 427. https://doi.org/10.3390/fire7120427

Safikhani, S., Gattringer, V., Schmied, M., Pirker, J., & Wriessnegger, S. C. (2024). The Influence of Realism on the Sense of Presence in Virtual Reality: Neurophysiological Insights Using EEG. *Multimodal Technologies and Interaction*, *8*(11), 104. https://doi.org/10.3390/mti8110104

Scharfe-Scherf, M. S. L., & Russwinkel, N. (2021). Familiarity and Complexity during a Takeover in Highly Automated Driving. *International Journal of Intelligent Transportation Systems Research*, *19*(3), 525-538. https://doi.org/10.1007/s13177-021-00259-0

Schonberg, C. C., Russell, E. E., & Luna, M. L. (2020). Effects of past language experience and present language context on the shape bias in Spanish–English bilingual children. *Developmental Science*, *23*(2), e12879. https://doi.org/10.1111/desc.12879

Song, H., & Schwarz, N. (2009). If It's Difficult to Pronounce, It Must Be Risky: Fluency, Familiarity, and Risk Perception. *Psychological Science*, *20*(2), 135-138. https://doi.org/10.1111/j.1467-9280.2009.02267.x

The jamovi project. (2022). *Jamovi (Version 2.3)* [Software]. https://www.jamovi.org/

Thompson, S. C. (1981). Will it hurt less if I can control it? A complex answer to a simple question. *Psychological Bulletin*, *90*(1), 89-101. https://doi.org/10.1037/0033-2909.90.1.89

Triandhari, R., Safuan, S., Syamsudin, M., & Alamsyah, H. (2017). Banks' Risk Taking Behavior and the Optimization Monetary Policy. *European Research Studies Journal*, *20*, 244-258. https://doi.org/10.35808/ersj/924

van Ravenzwaaij, D., Dutilh, G., & Wagenmakers, E.-J. (2011). Cognitive model decomposition of the BART: Assessment and application. *Journal of Mathematical Psychology, Special Issue on Hierarchical Bayesian Models*, *55*(1), 94-105. https://doi.org/10.1016/j.jmp.2010.08.010

Wang, S., Feng, S. F., & Bornstein, A. M. (2022). Mixing memory and desire: How memory reactivation supports deliberative decision-making. *WIREs Cognitive Science*, *13*(2), e1581. https://doi.org/10.1002/wcs.1581

Weber, E. U., & Milliman, R. A. (1997). Perceived Risk Attitudes: Relating Risk Perception to Risky Choice. *Management Science*, *43*(2), 123-144. https://doi.org/10.1287/mnsc.43.2.123

Worldviz. (2020). *Vizard 7* [Software]. WorldViz LLC. https://www.worldviz.com/

Yu, U.-J., Lee, H.-H., & Damhorst, M. L. (2012). Exploring Multidimensions of Product Performance Risk in the Online Apparel Shopping Context: Visual, Tactile, and Trial Risks. *Clothing and Textiles Research Journal*, *30*(4), 251-266. https://doi.org/10.1177/0887302X12462059

Zajonc, R. B. (1968). Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology*, *9*(2, Pt.2), 1-27. https://doi.org/10.1037/h0025848

Zayadin, R., Zucchella, A., Anand, A., Jones, P., & Ameen, N. (2023). Entrepreneurs' Decisions in Perceived Environmental Uncertainty. *British Journal of Management*, *34*(2), 831-848. https://doi.org/10.1111/1467-8551.12612

Zhong, S., Chew, S. H., Set, E., Zhang, J., Xue, H., Sham, P. C., Ebstein, R. P., & Israel, S. (2009). The Heritability of Attitude Toward Economic Risk. *Twin Research and Human Genetics*, *12*(1), 103-107. https://doi.org/10.1375/twin.12.1.103