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Psychometric data and regression-based norms for the virtual environments navigation assessment for young and middle-aged adults (VIENNA Young)

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ABSTRACT

Spatial navigation is critical for daily functioning and frequently impaired in neurological disorders. However, the extent of these impairments and their contribution to overall disability remain unclear due to a lack of standardized and accessible assessments with robust psychometric properties and appropriate normative data. Furthermore, current video-game-like paradigms can introduce biases based on the level of gaming experience, limiting their applicability in diverse populations. Grounded in a cognitive framework emphasizing visuospatial and executive processes of navigation, we aimed to develop and validate a brief, inclusive navigation assessment with strong potential for research in clinical populations, and to identify individual factors that accurately contextualize navigation performance. Here, we present the Virtual Environments Navigation Assessment for young and middle-aged adults (VIENNA Young), a 16-min neuropsychological test for both in-person and remote use that employs an intuitive navigation task and minimizes manual dexterity demands. We enrolled 422 healthy participants (18–67 years) in a hybrid onsite/online study design. VIENNA Young showed high feasibility in both settings, and psychometric analyses identified favorable internal consistency, test-retest reliability, and construct validity. VIENNA Young performance was higher among younger individuals, men, people with high exposure to spatial tasks, urban versus rural residents, and participants playing video games, especially allocentric or map-based games. Consequently, we provide regression-based normative models that account for gaming experience in addition to age and gender. VIENNA Young is a novel, accessible, scalable, and psychometrically sound navigation assessment for cognitive research, featuring a pioneering integration of gaming experience into norms for computerized cognitive tests.

1. Introduction

Despite its high relevance for everyday life and independence, patient's spatial navigation and topographical orientation abilities are commonly only assessed using unstructured qualitative observations rather than objective neuropsychological assessments. Indeed, there is a great clinical unmet need to routinely assess spatial navigation abilities in clinical populations considering relevant navigation and spatial orientation impairments in many neurological disorders. This includes patients with Alzheimer's disease (Bierbrauer et al., 2020; T. F. Levine et al., 2020), Parkinson's disease (Thurm et al., 2016), and stroke (Claessen et al., 2017), but also disorders affecting younger populations, e.g., multiple sclerosis (Němá et al., 2021), autoimmune encephalitis (Finke et al., 2012) and temporal lobe epilepsy (Amlerova et al., 2013).

A wide range of experimental navigation paradigms has been developed that reflect the diversity of everyday navigation experiences and use virtual environments to substitute the three-dimensionality of navigation in the physical world [e.g., computer-based: Virtual Silcton (Weisberg et al., 2014), tablet-based: SPACE (Colombo et al., 2024)]. Computerized and gamified assessments offer numerous advantages over paper-pencil assessments, including richer stimuli that can be manipulated systematically, greater ecological validity, and more precise measurements (Allen et al., 2024). However, trade-offs need to be made between time efficiency, construct scope, psychometric rigor, and accessibility. Paradigms range from brief, single-stimulus tests targeting multiple navigation subdomains like the Leiden Navigation Test (van der Ham et al., 2020) to extensive multi-item assessments like Sea Hero Quest (Coutrot et al., 2018), and from passive, screen-based formats

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(Wiener et al., 2020) to immersive setups with idiothetic cues (Kuhrt et al., 2021). For an overview of current VR-based navigation assessments, including their relationship to conventional neuropsychological tests and their psychometric properties, we refer readers to recent systematic reviews that map the field from both methodological and clinical translation perspectives (Mancuso et al., 2024; Sánchez-Escudero et al., 2024).

However, these navigation assessments primarily assess navigation with a focus on spatial memory and path integration. This poses a challenge for some research and clinical questions, i.e., when aiming to identify informed spatial navigation abilities beyond spatial episodic memory deficits that are typically identified using well-established spatial episodic memory tests. Patients with episodic memory impairments might perform poorly, even though their ability to navigate with a map on hand might be preserved.

While we gain significant insight into clinical questions from these experimental navigation paradigms, their translation to clinical neuropsychological assessments is, however, currently running behind research advances. Navigation assessments need to meet neuropsychological standards for computerized cognitive assessment (Bauer et al., 2012), including but not limited to end-user friendly devices, application and interpretation, data security, and appropriateness for diverse participants. Particularly for navigation paradigms, we need to be specific about what kind of spatial navigation our paradigm measures and ensure that it meets psychometric standards, including a representative demographic set-up of the normative sample (Newcombe et al., 2023).

In the context of appropriate normative interpretation, it is crucial to recognize the limitations of traditional control variables like age, education, and sex or gender for spatial navigation performance. While these factors can also impact navigation ability (Coutrot et al., 2018), other important predictors include rural vs. urban upbringing (Coutrot et al., 2022), everyday exposure to or expertise in navigation (Fernandez-Velasco & Spiers, 2024), and video game experience (Murias et al., 2016; Yavuz et al., 2024). Beyond its impact on spatial navigation ability, video game experience is also crucial to consider, because individuals who frequently play video games may perform better on assessments that resemble computer games, regardless of their actual cognitive performance.

Here, we introduce VIENNA Young as an adaptation of the validated Virtual Environments Navigation Assessment – VIENNA (Rekers & Finke, 2024) tailored for young and middle-aged adults. VIENNA is a neuropsychological test designed to assess spatial navigation through passive navigation, and optimizing measurement precision with 12 brief items of increasing difficulty to accommodate diverse participant needs. Unlike paradigms focused on memorizing and recalling spatial information (e.g., Sea Hero Quest, Leiden Navigation Test), VIENNA emphasizes processing visible spatial cues in unfamiliar, dynamic environments. Participants navigate using an on-screen map, representing a navigation scenario where a map of the environment is available. This operationalization of informed navigation focuses on the spatial and executive components of navigation since participants are provided with all relevant spatial information during navigation and do not rely on episodic memory. VIENNA's passive design eliminates the need for a controller-based interaction, enabling a motor function-independent assessment of navigation performance. In contrast to VIENNA, VIENNA Young contains more complex trials to account for age-related performance variation and can be administered both onsite and remotely via an online assessment.

1.1. Aims & hypotheses

In this study, we aimed (a) to investigate the psychometric properties of the VIENNA Young navigation assessment; (b) to identify demographic, environmental, behavioral, and cognitive factors that influence test performance in healthy adults; and (c) to provide normative data, offering insight into expected test scores depending on significant predictors of navigation performance.

We hypothesize that (i) VIENNA Young scores will demonstrate at least acceptable psychometric properties, including objectivity, reliability, and validity; (ii) VIENNA Young performance demonstrates convergent validity with measures of visuospatial short-term and working memory, mental rotation ability, inhibition, information processing speed, and self-reported sense of direction and divergent validity with selective attention, visual episodic memory, and verbal episodic memory; (iii) VIENNA Young performance will be negatively associated with age and the use of public transportation as the main mode of travel, while no significant differences will be observed between different genders; (iv) individuals with higher education, everyday engagement with spatial tasks, greater gaming experience, and who live in rural or complex areas will show better navigation test outcomes.

2. Methods

2.1. VIENNA Young paradigm

The Virtual Environments Navigation Assessment (VIENNA; Rekers & Finke, 2024) is a passive spatial navigation paradigm designed to assess informed navigation, in 12 increasingly complex virtual environments. It simulates a map-assisted navigation scenario in unfamiliar, grid-like, indoor environments. In each trial, participants are presented with a new virtual hallway environment and are tasked with mentally tracking the character's position in the video on the accompanying map (Fig. 1). At the end of each trial, they must indicate which door the character selected by clicking on the corresponding door. This design minimizes the reliance on episodic memory consolidation and retrieval, allowing the task to focus primarily on spatial and executive functions, and thus enables the identification of spatial navigation performance even in patients with known episodic memory deficits. To ensure participants perceive each trial as a new hallway environment, consecutive trials always use different carpet colors. Trial complexity increases progressively by increasing path length, environment size, and/or number of turns in the character's path.

VIENNA Young was adapted from VIENNA for use in younger and middle-aged adults. To this end, we increased VIENNA Young's difficulty to reduce ceiling effects in younger adults by including the six most challenging items from the original VIENNA, featuring double-turn (two turns along the path) and full-turn (one 180° turn) items, along with six newly developed, more complex trials. New items include maps where the map is misaligned with the video orientation, as well as angled layouts with non-90° orientations and turns (Fig. 1). This design is based on recent evidence showing that navigation is more difficult when environmental geometry layouts deviate from 90° perspectives typically encountered by navigators (Bellmund et al., 2020).

Scoring in VIENNA Young was based on the VIENNA scoring system. Participants received two points for correctly selecting the target door. Items where participants made updating errors (i.e., selecting a door parallel or adjacent to the correct one) or perspective rotation errors (i.e., choosing the door opposite the correct one) were awarded one point. The total VIENNA Young score calculated across all 12 trials serves as the primary outcome measure. Additionally, the number of updating and perspective rotation errors were recorded as supplementary measures.

2.2. Access options

VIENNA Young is available in German, English, Spanish, and French. It can be downloaded from the OSF [osf.io/4h65p/] and run using the open-source Python application PsychoPy (Peirce et al., 2019). For a solution that does not require installation or running scripts, the navigation paradigm can be accessed through a web application by requesting a token from the corresponding author. Alternatively, for larger online studies, it can be applied via gorilla.sc where VIENNA

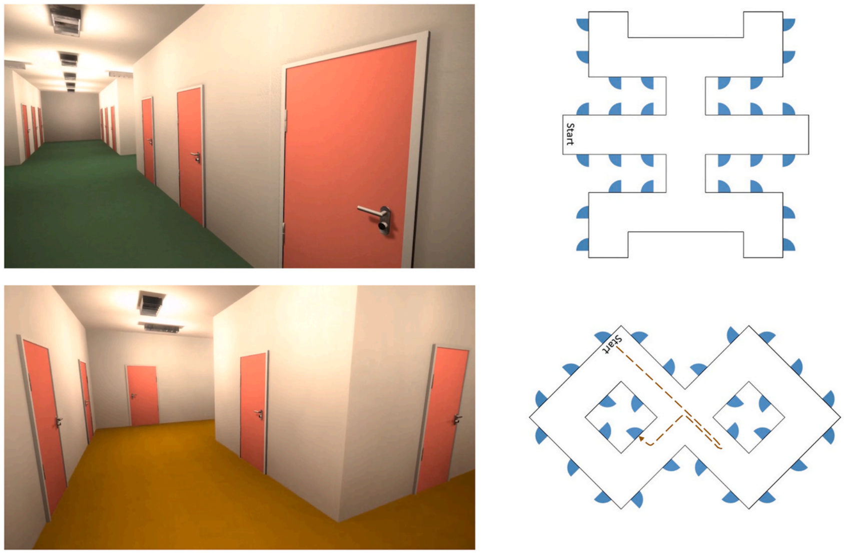

Fig. 1. Visualization of the VIENNA Young navigation paradigm. The top panels display a screenshot of item 7. On the left is a video of the first-person view of the hallway, on the right is the corresponding allocentric map of the environment, rotated by 90° to the orientation in the video. The bottom panels depict trial 10, which illustrates the participants' task of mentally tracing the character's movement on the map and identifying the door that the character selects at the end of the trial.

Young is published in the open materials [app.gorilla.sc/openmaterials/918995].

2.3. Regulatory considerations

The VIENNA Young spatial navigation assessment was developed for research purposes. It is intended to evaluate cognitive performance related to spatial navigation within the context of behavioral and cognitive research. The application focuses on basic science. This procedure has no medical purpose. It does not affect the normal clinical routine in any way. Accordingly, it does not constitute a medical device under applicable regulatory frameworks (e.g., EU MDR 2017/745 or FDA CFR), as it is not intended for the diagnosis, prevention, monitoring, treatment, or alleviation of any disease or health condition.

2.4. Participants

Since previous studies with VIENNA showed significant age effects, and gender effects are commonly found in navigation, we recruited participants stratified by age and gender in four different groups via the Prolific database. We set a maximum of 125 participants per group based on a-priori power analysis to detect small effects of $r = .23$ in each age-gender group at a significance level of $\alpha = .05$ and power (1-β) = .80 and to avoid overrepresentation of younger participants due to lower recruitment rates in the older groups. We recruited a total of 390 participants online (group #1, 18 - 35 years, female, n = 112; #2, 18 - 35 years, male or diverse, n = 112; #3, 36 - 65 years, female, n = 77; #4, 36 - 65 years, male or diverse, n = 89). To assess the validity of the online assessment, an additional 70 participants were assessed onsite, of whom 46 participants completed only VIENNA Young onsite and 24 participants completed all questionnaires and tests onsite. Written informed consent was obtained from all participants and the study was approved by the local ethics committee (EA4/047/21).

Inclusion criteria for participation in the study were German as the first language and normal or corrected-to-normal vision. Exclusion criteria included relevant neurological disorders or psychiatric disorders with significant impact on daily life, cognitive impairment or current medication with CNS side effects. Considering the ongoing COVID-19 pandemic during recruitment, we also explicitly included hospitalization for COVID-19, persistent cognitive symptoms due to COVID-19, and fatigue as exclusion criteria.

A total of 454 participants were recruited across both onsite and online settings (Fig. 2), with 390 participants assessed online and 70 assessed onsite. Six online participants were excluded due to technical

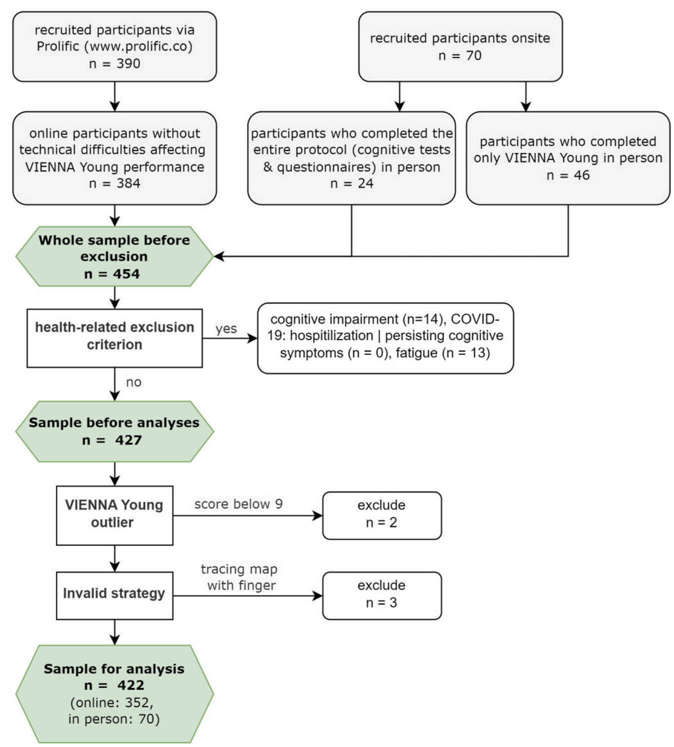

Fig. 2. Flowchart of the recruitment and exclusion process. Health-related questions, had yes/no response options: **Cognitive Impairment**: Are you currently impaired in thinking or mental performance (e.g. memory/attention) due to a mental/psychiatric or neurological disorder or due to medication for its treatment?; **COVID-19:** Hospitalization for several days or persisting symptoms of impaired thinking or impaired mental performance due to COVID-19; **Fatigue**: Do you currently have problems with an extreme form of tiredness, also known as fatigue? This extreme form of tiredness is an uncontrollable state of fatigue, exhaustion and lack of energy that occurs suddenly, regardless of any clear external causes. It does NOT refer to individual events that everyone experiences during the course of the day, after exertion or after a sleepless night!.

difficulties affecting the VIENNA Young assessment, 14 participants were excluded for reporting current cognitive impairment, and 13 because they reported fatigue, resulting in a sample of 427 participants whose VIENNA Young data was assessed. Six reported impaired color vision, and seven participants reported impaired spatial vision and their performance on spatial and color-based tests was evaluated. Of these, no one scored below average in the VIENNA Young, but for the PTT, block tapping tests, and spatial recall test, one participant each scored below average according to a one-sample z-test and their data were treated as missing. Of the 427 participants analyzed, two were treated as outliers based on their VIENNA Young performance, and three were excluded from further analyses because they reported an invalid VIENNA Young strategy (i.e., tracing the position of the character with their finger). This resulted in a total sample of 422 participants for analysis (online: n = 352, onsite: n = 70).

To assess test-retest reliability, we retested 92 participants after an average retest interval of 14 weeks (range: 13.43–17.86, SD = 0.96). One participant was excluded because of technical issues and one participant was identified as an outlier considering the absolute difference between their first and second examination (z = 5, >3 SD above the rest of the sample), resulting in a retest sample of 90 participants.

2.5. Procedure

A total of 390 participants completed questionnaires and cognitive tasks online using the Gorilla Experiment Builder (Anwyl-Irvine et al., 2020) in a remote (unsupervised) test setting with instructions adjusted for unsupervised assessment and several evidence-based checks and settings included to ensure participation as intended (Peer et al., 2022; Rodd, 2024). This included extensive piloting, clear communication during recruitment that the purpose of data collection was to develop normative reference models for research use, including studies involving clinical populations, specific instructions for test setting, setting appropriate expectations for study duration and performance variability, commitment and answer style checks where non-compliance with study instructions (e.g., cheating, carelessness, lying, or deception) could be self-declared without impact on compensation, and focus checks at the beginning, in the middle, and at the end.

To avoid and identify technical difficulties we integrated a minimum connection speed of 4Mbp and three options to report technical difficulties. Additionally, participants could only use computers and were instructed to use their largest screen; smartphones or tablets were not supported. Participants could contact the examiner via the Prolific chat function and, when necessary or appropriate to ensure participant well-being and data fidelity, were contacted after study participation to respond to questions or remarks in the free-text fields and to clarify ambiguous answers. A detailed flowchart outlining this procedure is provided in the supplementary materials.

Onsite participants were tested individually by trained psychology and medical students and psychologists. The median duration of the study protocol, including all forms, questionnaires, and cognitive tests, was 70 min for both online and onsite testing. Each cognitive test was inspected for comparability between onsite and online testing and was assessed for improbable data and outliers.

2.6. Tests & questionnaires

Participants completed questionnaires that assessed demographic information including upbringing and living environment, main mode of transportation, their daily exposure to navigation and visuospatial skills, computer and phone use, and gaming experience. In the onsite assessment, participants were not asked about their current place of living, resulting in 24 missings on that question. In order to accurately estimate participants' gaming exposure, we derived the median gaming frequency and average weekly gaming hours by considering their gaming behavior during their initial, peak, and current gaming periods. Subjective memory performance and memory satisfaction were assessed using the Ability and Satisfaction scales of the German Multifactorial Memory Questionnaire – MMQ (Rekers et al., 2024; Troyer & Rich, 2002). Self-reported sense of direction was assessed using the German translation of the Santa Barbara Sense of Direction Scale – SBSOD (Hegarty et al., 2002; Meilinger & Knauff, 2004).

Cognitive assessment beyond VIENNA Young included the following tests, which were administered as intended for the onsite assessment. For the online assessment, we built analogues resembling the original task and applied them in the following order. Selective attention and inhibition were assessed using a speeded baseline color bar naming task and a Stroop-like color-word task. In the latter, participants identified the color the word was printed in, which was incongruent to the color-word itself (Stroop, 1935). Visual episodic memory and retrieval were assessed by a 10/36 grid task similar to the Spatial Recall Test – SPART (Rao et al., 1984). Verbal memory was assessed using a word list task adapted from the German translation of the Rey Auditory Verbal Learning Test (Schmidt, 1996), the Verbal Learning and Memory Test – VLMT (Helmstaedter et al., 2001). For episodic memory, we specifically examined the two outcomes total learning (sum of the learning trials) and forgetting rate (last learning trial – recall trial/last learning trial). We then applied the Perspective Translation Test (PTT) as a screening test of participants' ability to translate an egocentric to an allocentric perspective of a scene. This test presents four standardized and validated virtual objects (Tromp et al., 2020) arranged on a table from an egocentric viewpoint, alongside three top-down views—one displaying the same arrangement and two with shuffled arrangements. The objects become progressively less familiar, and participants must correctly identify the matching top-down view across 10 trials. Visuospatial short-term and working memory were assessed using a block tapping task forward and backward similar to the Wechsler Memory Scale-Revised (Wechsler, 1987) but presented from a 2D top-down perspective. Information processing speed, visual scanning, shifting and cognitive flexibility were assessed using a computerized adaptation of the Symbol Digit Modalities Test – SDMT (Smith, 1982), while the oral version was administered onsite. Lastly, mental rotation was assessed using an adaptation of Vandenberg's Mental Rotation Test – MRT (Vandenberg & Kuse, 1978).

2.7. Analyses

Data preprocessing, quality checks, and statistical analyses were conducted using the software environment *R*, version 4.3.3 (R Core Team, 2016). The manuscript was prepared using the *R* package *papaja*, version 0.1.2 (Aust & Barth, 2020). All *R* scripts, along with the specific versions of the used packages, are available on the OSF at [osf.io/4h65p/]. Additionally, we have provided PDFs that outline the processes for those unfamiliar with *R*.

The α level was set to 0.05 for all analyses. Outliers were defined as those scoring more than 2.5 standard deviations from the mean on the task. For skewed distributions, the adjusted boxplot method (Hubert & Vandervieren, 2008) was applied. Participants identified as outliers based on the VIENNA Young score were excluded, while outliers on other cognitive tests were treated as missing data and not imputed.

Since the instruction and evaluation of VIENNA Young is automated, objectivity was tested by comparing the test settings online (unsupervised) and in-person (supervised). To assess whether the performance scores of the matched participants tested online and onsite were equivalent, independent t-tests and a *two one-sided tests* (TOST) procedure (Lakens, 2017; Schuirmann, 1987) was conducted, to formally test whether the difference between the groups is small enough to be considered practically insignificant. We defined the equivalence bounds based on Cohen's d = 0.2, representing a small effect size.

Internal consistency was assessed using the polychoric ordinal α and corrected item-total correlations were assessed using Wilson's e, to account for the ordinal nature of the VIENNA Young items. To assess the factor structure, we tested three models based on the item constructs: a one-factor model, a 2-factor model based on the aligned (items 1 to 6) vs. rotated starting points (items 7 to 12), and a 4-factor model based on the four item-types: double-turn (items 1 to 3), full-turn (items 4 to 6), rotated-start (items 7 to 9), and angled-layout (items 10 to 12). To account for ordinal items, we based the model fit on diagonally weighted least squares (DWLS), with unconstrained covariances between the latent variables. Considering the small number of items (three) per factor in the 4-factor model, we constrained the factor loadings to be equal within each factor to achieve tau-equivalence. This constraint ensures that each item contributes equally to the latent factor, providing consistency in measurement. Additionally, this approach helps to avoid issues with local identification, ensuring that the model parameters are estimable.

Group differences were evaluated using two-sample t-tests. To examine the influence of multiple variables on spatial navigation performance, we employed multiple regression analysis. Additionally, analysis of covariance (ANCOVA) was used to control for variability introduced by covariates during group comparisons. Relationships between two approximately metric variables were assessed using product-moment correlation; if one variable exhibited a clear ordinal structure, Spearman's correlation was applied instead.

To assess test-retest reliability, we employed both product-moment correlation and intra-class correlation (ICC). To evaluate the construct validity of the VIENNA Young, we examined the relationship between the measure and various cognitive markers described above. A marker was confirmed as divergent if the association with spatial navigation performance was small or negligible, indicated by an effect size of $|r| \leq .20$.

Strategy labels were derived from strategies reported by 50 randomly selected participants and then applied to all participants by two independent raters. Each participant could be assigned several labels. Where the rating of the two raters disagreed, the two raters conferred together with a third rater to come to agreement on the labels. Detailed descriptions of all labels can be found in the supplementary materials.

Normative data were generated using regression-based norming based on the generalized additive models for location, scale, and shape – GAMLSS (Rigby & Stasinopoulos, 2005; Stasinopoulos et al., 2017; Timmerman et al., 2021; Voncken et al., 2019). This method accommodates non-linear relationships and ceiling effects by using a truncated distribution. Given that VIENNA Young scores consist of fewer than 25 categories, GAMLSS is particularly suitable for treating the data as ordered categorical rather than approximately continuous. Furthermore, the beta-binomial (BB) distribution is suggested as a good fit for the data, despite its original application being in the context of dichotomous items.

3. Results

We first assessed whether VIENNA Young performance was equivalent between online and onsite testing conditions. To this end, we compared the VIENNA Young score of 70 onsite participants to an age-, education-, and gender-matched online subsample. The analysis revealed no significant mean difference in performance between the two groups (onsite: $\overline{M} = 19.60$, $SD = 3.48$; online: $\overline{M} = 18.84$, $SD = 4.22$; $t(138) = -1.16$, $p = .249$). Additionally, the difference between the VIENNA Young scores was small enough to be considered statistically equivalent within the predefined equivalence bounds (lower bound: $t(133.23) = 3.42, p < .001$, upper bound: $t(133.23) = -5.73$, $p < 0.001$). This was also the case for the PTT ($t(137) = -0.26; p = .798$) and the VIENNA Young updating errors ($t(138) = -0.55; p = .580$) and rotation errors ($t(138) = 1.01; p = .316$). In the 24 participants who also completed the neuropsychological tests in-person, we found that the matched subsample in the online setting yielded similar results for most tests conducted online. However, significant differences were observed in the following outcome measures: Visual learning, Symbol Digit Modalities Test, and Stroop (Color bar time and ratio). Detailed statistics for all neuropsychological tests can be found in Table A1.

In line with our hypothesis, we found a left-skewed distribution of the spatial navigation score in younger adults (age <45 years, $\gamma_1 = -1.23$) and an approximately normal distribution of the VIENNA Young score in middle-aged and older adults (age 45–67 years) with mild skewness ($\gamma_1 = -0.73$). As visualized in Fig. 3, the VIENNA Young score for the entire sample showed moderate and significant (left) skewness ($\gamma_1 = -1.11$). We, therefore, applied outlier detection for skewed a distribution and identified a score of 9 as the lower bound.

3.1. Sample information

After exclusion, the total sample size was $n = 422$, of whom 376 completed all tests and questionnaires (24 onsite, 352 online), while 46 participants only completed VIENNA Young onsite. Participants' age ranged from 18 to 67 years with a mean age of 34.7 years ($SD = 12.2$). 224 participants identified as female, 193 participants identified as male, and five participants identified as gender-diverse. The latter were excluded from analyses taking gender into account. Further demographic details of participants are provided in Table 1 and Table 2.

3.2. Psychometric properties

3.2.1. Feasibility and administration time

VIENNA Young performance ranged from 9 to 24 points with a mean performance of 20.37 points ($SD = 3.54$) and a median performance of 21 points ($MAD = 2.97$). We did not identify any systematic disadvantage for participants with impaired spatial and/or color vision ($t(10.91) = 1.70$; $p = .117$). The median time to complete VIENNA Young including instructions and practice trials was 16 min ($MAD = 1$ min). No participant reported any adverse events such as nausea, headache, or eyestrain.

3.2.2. Reliability

The polychoric ordinal α indicated excellent internal consistency ($\alpha = 0.86$, 95 % CI [0.84, 0.88]) showing that the VIENNA Young items measure the same underlying construct. This is also confirmed on item level (Table 3) by the corrected item-total correlations which indicates that all items are consistent with the overall scale. Furthermore, we conducted a confirmatory factor analysis to test the fit of the theoretical constructs of the item types to the empirical data. Standardized factor loadings of the one-factor model indicate that all items align well with the underlying construct, consistent with the ordinal α and corrected item-total correlations. All models showed excellent model fit (scaled test statistics for three models are summarized in Table 4). While the scaled χ^2 difference test does not show significant differences in the four-factor model over the one-factor model ($p = .585$) and the two-factor model ($p = .600$), the fit indices slightly favor the four-factor model, supporting the theoretical construct underlying the VIENNA Young items.

The test-retest reliability of the VIENNA Young score indicated a moderate to good reliability using both product-moment correlation ($r = .67$, 95 % CI [.53, .77], $t(88) = 8.40$, $p < .001$) and intraclass correlation coefficients (ICC) based on a two-way mixed effects model with the time points as fixed effects (individual: ICC(3,1) = .66, 95 % CI [.53, .76], $F(89, 89) = 4.93$, $p < 0.001$; average: ICC(3,k) = .80, 95 % CI [.69, .87], $F(89, 89) = 4.93$, $p < 0.001$). A comparison of the mean VIENNA Young scores at baseline and retest indicated a small practice effect ($d = 0.24$, 95 % CI $[0.06, 0.41]$) with significantly higher spatial navigation performance at the second examination point ($M_D = 0.69$, 95 % CI [0.19, 1.19], $t(89) = 2.74$, $p = .007$). However, a longer retest interval was associated with a smaller absolute difference between the VIENNA

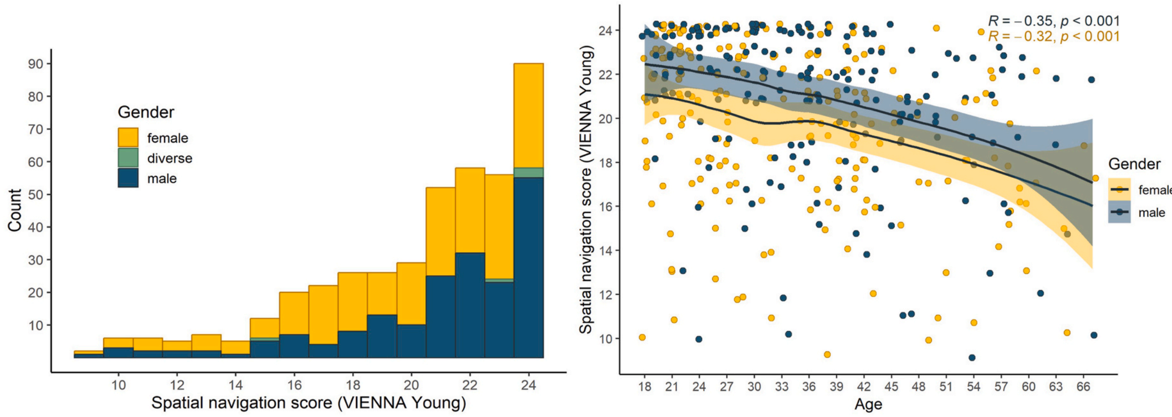

Fig. 3. Histogram of the VIENNA Young score by gender (left) and scatterplot of age and VIENNA Young score with gender-specific LOESS lines (right).

Table 1
Summary of categorical environmental and gaming information in the sample.

Variable	Level	*n*	%
Upbringing	city	170	45
	rural	206	55
Living (most of the time during the last year)	city	208	59
	rural	144	41
Spatial occupation[1]	no	341	91
	yes	35	9
Main mode of transportation	car	151	40
	motor bike	3	1
	bike	64	17
	public transport	115	31
	foot	43	11
Gaming	no	126	34
	yes	250	66
Egocentric gaming	no	108	43
	yes	142	57
Allocentric gaming	no	134	54
	yes	116	46
Map-based gaming	no	67	27
	yes	183	73

Note. [1] engage a considerable amount with orientation, navigation, maps, spatial perspectives, or 3D objects in their everyday life or profession.

Table 2
Descriptive statistics of demographic and behavioral variables in the sample.

Variable	*n*	$\overline{M}$	*SD*	$\widetilde{M}$	MAD	Min	Max
Age	422	34.66	12.15	33.00	13.34	18.00	67.00
Years of education	422	15.90	2.23	16.00	2.97	9.00	19.00
Computer use frequency	376	5.84	0.45	6.00	0.00	2.00	6.00
Smartphone/ tablet use frequency	376	5.95	0.38	6.00	0.00	2.00	6.00
Gamers: Gaming frequency	249	5.43	0.80	6.00	0.00	1.00	6.00
Gamers: Gaming hours per week	250	17.34	11.89	15.00	10.87	0.33	56.00

Note. $\overline{M}$ = Mean, *SD* = Standard Deviation, $\widetilde{M}$ = Median, MAD = Median Absolute Deviation, Frequency: 5 = several times a week, 6 = daily. Gaming hours and frequency are averaged across past, current, and highest.

Young performances at the two timepoints ($r_s = -.26$; $S = 153,437.82$; $p = .012$).

3.2.3. *Validity*

Most hypotheses regarding construct validity could be confirmed (see Table 5), with at least medium-sized correlations (effect size $|r| > .20$) observed between the VIENNA Young score and the convergent markers: subjective sense of direction (SBSOD), short-term and working memory (blockspan forward and backward), mental rotation (Vandenberg MRT), and shifting and cognitive flexibility (SDMT). We also found small or negligible correlations (effect size $|r| \leq 0.20$) with the divergent markers visual and verbal episodic memory (learning and forgetting rate). Furthermore, we assessed whether subjective memory ability (MMQ-Ability) or memory satisfaction (MMQ-Satisfaction) were associated with VIENNA Young scores and did not observe any associations of meta-memory markers with navigation performance (MMQ-Ability: $t(374) = 0.84$, $p = .402$, MMQ-Satisfaction: $t(374) = 0.72$, $p = .469$).

In contrast to our expectations, hypotheses regarding the convergent marker inhibition (Stroop ratio) and divergent marker reaction time (Color bar time) had to be rejected since we found only a small association with the inhibition marker and a medium-sized association with the reaction time marker. Importantly, since onsite and online performances in the SDMT, Stroop ratio, Color bar time, and visual learning differed significantly, these associations need to be replicated in onsite settings. Nonetheless, the associations of VIENNA Young with shifting and visual learning showed consistent effect size patterns in onsite and online settings (onsite: SDMT: $r = .32$, 95 % CI $[-.10, .64]$, $t(22) = 1.56$, $p = .133$; SPART learning: $r = .18$, 95 % CI $[-.24, .54]$, $t(22) = 0.84$, $p = .408$). However, results relating to reaction time and especially Stroop ratio associations differed between online and onsite testing (onsite: color bar time: $r = -.20$, 95 % CI $[-.56, .22]$, $t(22) = -0.96$, $p = .346$; Stroop ratio: $r = .09$, 95 % CI $[-.32, .48]$, $t(22) = 0.44$, $p = .662$).

Likewise, the validity of the VIENNA Young error scores could be confirmed. Rotation errors were significantly associated with mental rotation performance ($r_s = -.38$; $S = 12,216,465.04$; $p < .001$) and updating errors were significantly associated with short-term memory ($r_s = -.21$; $S = 10,181,288.31$; $p < .001$) and working memory ($r_s = -.23$; $S = 10,411,433.01$; $p < .001$). The Perspective Translation Test (PTT) identified one of the two participants who were VIENNA Young outliers, one participant who had spatial vision impairment, and did not correlate with VIENNA Young performance in our normative sample ($S = 11,883,200.20$; $p = .363$).

3.3. *VIENNA strategies*

A qualitative evaluation assigning labels to strategies reported in a free-text field assigned 667 labels to 376 reported strategies. We found that 50 % of strategies could be labeled with “allocentric visualization” (n = 149), “counting” (n = 99), and “synchronize map and video” (n = 91). Other commonly reported strategies included “egocentric visualization” (n = 71) and “focus on direction changes” (n = 57). Together, these 5 strategies cover 70 % of all the strategies mentioned. More

Table 3
Properties of the VIENNA Young items.

Item	Item Type	$\overline{M}$	E	s^2	e	1FM	2FM-FL1	FL2	4FM-FL1	FL2	FL3	FL4
1	double-turn	1.89	0.21	0.14	0.67	0.65	0.65		0.60			
2	double-turn	1.90	0.43	0.16	0.55	0.56	0.56		0.60			
3	double-turn	1.48	0.19	0.51	0.53	0.61	0.61		0.60			
4	full-turn	1.92	0.80	0.10	0.56	0.50	0.50			0.68		
5	full-turn	1.88	0.62	0.11	0.56	0.59	0.59			0.68		
6	full-turn	1.86	0.50	0.13	0.58	0.57	0.57			0.68		
7	rotated-start	1.71	0.25	0.33	0.59	0.73		0.73			0.60	
8	rotated-start	1.55	0.23	0.59	0.48	0.57		0.57			0.60	
9	rotated-start	1.72	0.23	0.35	0.46	0.51		0.51			0.60	
10	angled-layout	1.59	0.21	0.51	0.59	0.67		0.67				0.60
11	angled-layout	1.35	0.17	0.67	0.47	0.61		0.61				0.60
12	angled-layout	1.51	0.28	0.53	0.49	0.59		0.59				0.60

Note. Mean performance in the sample ($\overline{M}$), expected value (E) given the number of doors and number of partially correct answers in the respective trial; the variance (s^2); and corrected item-total correlation quantified by Wilson's e. Standardized factor loadings (FL) of the 1-factor model (1FM), 2-factor model (2FM), and 4-factor model (4FM) from confirmatory factor analyses.

Table 4
Model Fit for three models reporting scaled test statistics.

Model	χ^2	*df*	*p*	*TLI*	*CFI*	*RMSEA*	*SRMR*	*SRMR − B*
one-factor	60.95	54	0.240	0.99	0.99	0.02	0.07	0.06
2-factor	61.34	53	0.202	0.99	0.99	0.02	0.07	0.06
4-factor	56.42	56	0.459	1.00	1.00	0.00	0.07	0.06

Note. CFI = Comparative fit index, TLI = Tucker-Lewis index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Squared Residual, SRMR-B= Bentler's SRMR, modified SRMR that incorporates a correction for non-normality.

Table 5
Correlates of VIENNA Young performance.
Variables before the first midrule include data from both online and onsite setting, while values after use data from the online setting only. Stroop ratio and color bar time were not consistent between online and onsite testing and need to be interpreted with caution.

Variable	r	p_{BH}
Santa Barbara Sense of Direction Scale [c]	0.22	<0.001
Block span forward [c]	0.39	<0.001
Block span backward [c]	0.31	<0.001
Vandenberg Mental Rotation Test [c]	0.50	<0.001
Verbal learning [d]	0.07	0.192
Verbal forgetting rate [d]	−0.10	0.065
Visual forgetting rate [d]	−0.05	0.380
Visual learning [d]	0.18	<0.001
Symbol Digit Modalities Test [c]	0.40	<0.001
Stroop ratio [c]	−0.14	0.014
Color bar time [d]	−0.31	<0.001

Note. [c] = convergent marker, [d] = divergent marker, r = product-moment correlation coefficient, p_{BH} = p-value after correcting for multiple comparison using Benjamini Hochberg.

details on all strategy labels and reported strategies can be found in the online supplementary materials.

3.4. Impact of demographic and environmental factors and video gaming

Next, we tested the impact of demographic factors to elucidate their association with VIENNA Young navigation performance and identify control variables for the normative data. In line with our hypothesis, we identified a medium-sized negative association between VIENNA Young performance and age ($r = -.31$, 95 % CI $[-.39, -.22]$, $t(420) = -6.68, p < .001$). Men scored significantly higher than women ($\Delta M = -1.17$, 95 % CI $[-1.84, -0.49]$, $t(415) = -3.40$, $p < .001$), and this effect of gender remained significant when controlling for age ($b = 1.37$, 95 % CI $[0.73, 2.01]$, $t(414) = 4.20$, $p < .001$; see Fig. 3). Furthermore, VIENNA Young performance was not associated with participants' years of education ($r = -.02$, 95 % CI $[-.11, .08]$, $t(420) = -0.35, p = .729$).

Furthermore, we confirmed our hypothesis that the 35 participants who engage significantly with orientation, navigation, maps, spatial perspectives, or 3D objects in their everyday life or profession performed better on the VIENNA Young compared to those who do not ($\Delta M = -1.00$, 95 % CI $[-1.95, -0.05]$, $t(49.95) = -2.12$, $p = .039$). This effect remained significant when controlling for age and gender ($b = 1.20$, 95 % CI $[0.02, 2.38]$, $t(367) = 2.01, p = .045$).

We observed no significant difference in VIENNA Young performance between individuals raised in urban versus rural areas ($t(350.96) = -0.23; p = .814$). Interestingly, people currently living in cities exhibited significantly higher navigation performance compared to those residing in rural areas ($\Delta M = 1.63$, 95 % CI $[0.88, 2.38]$, $t(282.46) = 4.26$, $p < .001$). This effect on navigation performance persisted when controlling for education and age ($b = -1.40$, 95 % CI $[-2.14, -0.66]$, $t(348) = -3.72, p < .001$). A model that controlled for demographic factors (age, gender, education) and included both upbringing and current residency confirmed this pattern and revealed a positive effect of rural upbringing when current living environment was accounted for ($b = 0.93$, 95 % CI $[0.16, 1.70]$, $t(345) = 2.37, p = .019$; see Fig. 4).

Further exploring these findings, we found that city dwellers also outperformed rural residents on larger VIENNA Young items that required more travel time ($\Delta M = 1.36$, 95 % CI $[0.79, 1.94]$, $t(279.84) = 4.67, p < .001$). In the group of city dwellers, those who moved from a rural area performed better than those who were raised in the city ($\Delta M = -0.94$, 95 % CI $[-1.77, -0.11]$, $t(205.69) = -2.24$, $p = .026$). This finding was supported by a significant interaction effect between the incongruence of upbringing and current living environment ($b = 1.82$, 95 % CI $[0.07, 3.57]$, $t(348) = 2.04, p = .042$). However, no such difference was observed in the rural residents ($t(36.45) = -1.08$; $p = .287$).

Additionally, we analyzed data for the 105 participants who were brought up in, and the 119 participants who live in, one of the 10 largest

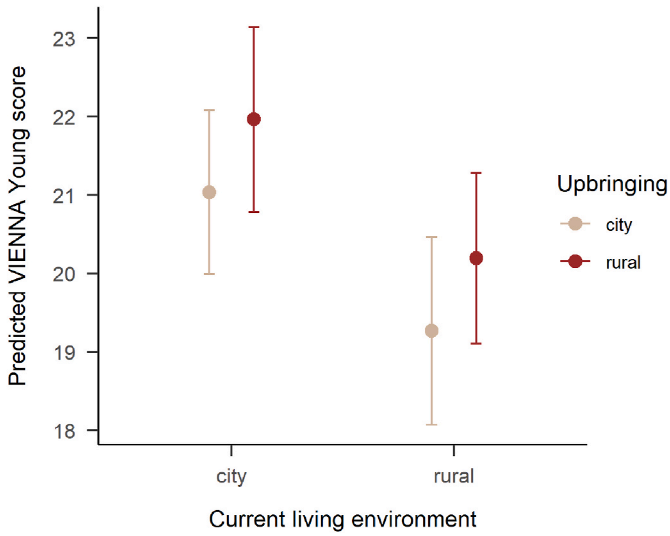

Fig. 4. Estimated marginal means plot illustrating the effect of upbringing (city vs. rural) on predicted navigation performance when current living environment is considered. Predictions are based on a linear model controlling for age, gender, and education. Points represent group-level estimated marginal means and error bars reflect 95 % confidence intervals.

cities in their country (primarily Germany) and obtained their street network entropy (SNE) value as provided by Coutrot et al. (2022). We found no significant association between navigation performance and the SNE value for either those raised in cities ($t(103) = -0.27$; $p = .787$) or those currently living in cities ($t(117) = -1.33$; $p = .187$).

Finally, individuals who primarily use personal transportation and ambulate themselves (e.g., biking, driving, walking) performed worse on the VIENNA Young compared to those who use public transportation $\Delta M = -0.97$, 95 % CI $[-1.68, -0.26]$, $t(279.07) = -2.69$, $p = .008$. However, this effect was largely attributed to living in a city and was no longer significant when controlling for city dwelling ($t(349) = 1.24$; $p = .216$).

Next, we were interested in the impact of video gaming on VIENNA Young performance. Descriptive statistics of our sample's computer, phone, and video gaming habits are detailed in Table 2. In line with our hypothesis, we found that non-gamers performed worse on the spatial navigation test compared to gamers ($\Delta M = -1.82$, 95 % CI $[-2.61, -1.02]$, $t(213.60) = -4.50$, $p < .001$). The effect of gaming on navigation performance remained significant even after controlling for age and gender ($b = 1.31$, 95 % CI $[0.58, 2.04]$, $t(367) = 3.54$, $p < .001$) and the mean group difference between non-gamers and gamers remained significant when controlling for age, gender, and executive functions (shifting/information processing speed) in an ANCOVA ($F(1, 341) = 17.82$, $p < .001$, $\hat{\eta}^2_G = .050$, 90 % CI $[.019, .092]$).

The median gaming frequency (averaged across past, current, and highest frequencies) was not significantly associated with navigation performance ($S = 2{,}387{,}542.70$; $p = .257$); however, the average mean gaming hours per week showed a small but significant correlation with the VIENNA Young score ($r = .18$, 95 % CI $[.06, .30]$, $t(248) = 2.94$, $p = .004$). As illustrated in Fig. 5, the strongest association between gaming hours and VIENNA Young performance was observed up to the inflection point of 18.33 gaming hours/week ($r = .21$, 95 % CI $[.06, .35]$, $t(156) = 2.68$, $p = .008$). Beyond this inflection point, additional gaming hours did not result in a significant increase in VIENNA Young performance ($t(90) = 0.78$; $p = .439$).

Our second hypothesis regarding computer game experience (i.e., that individuals who primarily play computer games where they control a character's movement from their own perspective would show better VIENNA Young performance) was partially confirmed. Among the 250 gamers, those who play egocentric games (first- or third-person perspective) did not outperform those who do not play egocentric games ($t(192.60) = -1.36$; $p = .176$). However, gamers who play allocentric games (top-down view of one or more characters) performed better than those who do not play allocentric video games ($\Delta M = -0.89$, 95 % CI $[-1.69, -0.09]$, $t(245.89) = -2.18$, $p = .030$). Lastly, we observed that individuals who primarily play map-based computer games performed better on the VIENNA Young than those who do not ($\Delta M = -1.29$, 95 % CI $[-2.25, -0.32]$, $t(105.00) = -2.65$, $p = .009$).

3.5. Normative data

In order to create precise normative values for each age rather than summarizing by age groups, we created regression-based norm data using the GAMLSS framework (Rigby & Stasinopoulos, 2005) and a beta binomial distribution to account for the skewness of the VIENNA Young score. To identify the best model, we followed the free order model selection approach outlined by Timmerman et al. (2021) and Voncken et al. (2019). Compared to linear regression models and truncated Box-Cox power exponential models, the beta binomial models demonstrated superior fit. We identified four models depending on the desired control variables: (1) age, gender, and gaming, (2) age and gender, (3) age and gaming, and (4) age alone. If all information is available and a binary gender attribution is appropriate, we recommend using the model that adjusts for age, gender, and gaming, as it offers the best fit

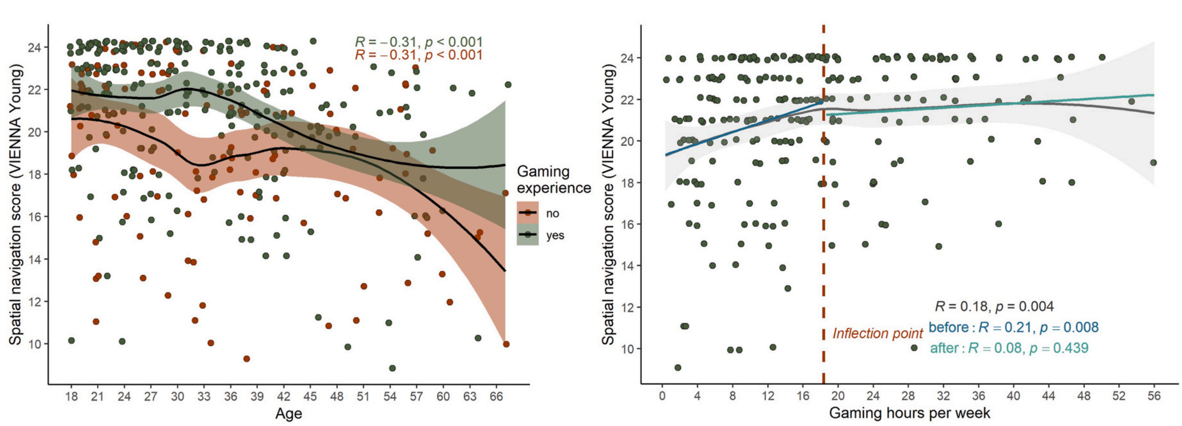

Fig. 5. Scatterplots illustrating the relationship between navigation performance and gaming experience. Left panel: The impact of gaming experience (yes/no) on navigation performance across different ages, with LOESS lines depicting trends for each group. Right panel: The relationship between average gaming hours per week and navigation performance. A LOESS line (grey) shows the overall trend, while segmented linear regression lines and correlation coefficients (R) highlight the association before (blue) and after (green) the inflection point of 18.33 gaming hours per week.

and parsimony (BIC = 1726.05), followed by the models adjusting for age and gaming (BIC = 1736.13) and age and gender (BIC = 1954.75), with the model adjusting for age only showing the lowest model fit (BIC = 1971.05).

The models were fitted on two overlapping data sets: one that lacked information on gaming experience for all participants (n = 417) and a subset of participants with gaming experience data (n = 371). These data sets did not differ significantly in average VIENNA Young performance ($t(773.56) = -0.13$; $p = .897$), age ($t(779.22) = 1.04$; $p = .300$), or gender (χ^2 (1) = 0.74, $p = .391$). Given the limited data for participants over 60 years of age (see Fig. 6), we do not recommend adjusting for gaming experience for individuals in this age group.

The model adjusting for age and gender and the model adjusting for age, gender, and gaming experience are likely the most relevant and are visualized in Fig. 6. Percentile tables in the Appendix and the accompanying *R* script can be used to identify the percentiles. Formulas below report the beta binomial model parameters μ, representing the mean success probability, and σ, representing the dispersion.

Adjusting for age (in years), gender (male = 1, female = 0), and gaming experience (yes = 1, no = 0), the formulas are:

$$\mu = \frac{e^{\left(2.405 - 0.032 \cdot \text{age} + 0.446 \cdot \text{gender\_male} + 0.405 \cdot \text{gaming\_yes}\right)}}{1 + e^{\left(2.405 - 0.032 \cdot \text{age} + 0.446 \cdot \text{gender\_male} + 0.405 \cdot \text{gaming\_yes}\right)}}$$

$$\sigma = e^{-2.075}$$

Adjusting for age and gender, the formulas are:

$$\mu = \frac{e^{\left(2.661 - 0.031 \cdot \text{age} + 0.486 \cdot \text{gender\_male}\right)}}{1 + e^{\left(2.661 - 0.031 \cdot \text{age} + 0.486 \cdot \text{gender\_male}\right)}}$$

$$\sigma = e^{-2.049}$$

Adjusting for age and gaming experience, the formulas are:

$$\mu = \frac{e^{\left(2.466 - 0.030 \cdot \text{age} + 0.508 \cdot \text{gaming\_yes}\right)}}{1 + e^{\left(2.466 - 0.030 \cdot \text{age} + 0.508 \cdot \text{gaming\_yes}\right)}}$$

$$\sigma = e^{-2.031}$$

Adjusting for age only, the formulas are:

$$\mu = \frac{e^{(2.821 - 0.030 \cdot \text{age})}}{1 + e^{(2.821 - 0.030 \cdot \text{age})}}$$

$$\sigma = e^{-1.990}$$

For most applications, the percentiles derived from the beta binomial function provide adequate normative estimates for interpreting the VIENNA Young score. However, to calculate *z*-scores and standard errors (e.g., for 95 % confidence intervals), we recommend evaluating performance at the item level. This is because the VIENNA Young score cannot be adequately mapped onto a normal distribution as visualized in the supplementary materials. We provide item parameters from a graded response IRT model with a single latent factor in Table 6 and for a four-factor model in Table 7. These models align closely with the CFA models reported earlier. Factor scores can be derived from the IRT model tables or using the provided *R* code in the supplementary materials. The *R* code also includes IRT models that account for gender and gaming experience, allowing for detailed interpretation of performance based on the exact response patterns.

4. Discussion

We introduce VIENNA Young, a spatial navigation paradigm designed for accessible and precise evaluation in diverse research populations. We found favorable psychometric properties including (i) a short application time; (ii) comparable results in onsite and (unsupervised) online test settings; (iii) excellent internal consistency and factor structure confirming the item construct; (iv) acceptable test-retest reliability; and (v) confirmed construct validity of VIENNA Young using questionnaires and neuropsychological tests of neighboring cognitive domains. Moreover, (vi) we identified age, gender, and video gaming experience as significant predictors which are accounted for in regression-based normative data provided with the paradigm.

4.1. VIENNA Young's utility for research in clinical populations

Cognitive research and diagnostics are shifting from abstract and

Table 6
Item Response Theory (IRT) model parameters for a graded response model with a single latent factor, including Discrimination(a) and Difficulty 1 and 2.

Item	Discrimination (a)	Difficulty 1	Difficulty 2
item 1	1.73	5.06	3.34
item 2	1.36	4.08	3.35
item 3	1.35	2.48	0.64
item 4	1.23	5.11	3.24
item 5	1.35	6.18	2.66
item 6	1.28	5.69	2.40
item 7	1.88	3.97	1.92
item 8	1.20	2.01	1.30
item 9	1.06	2.99	1.63
item 10	1.50	2.60	1.35
item 11	1.22	1.67	0.42
item 12	1.25	2.33	0.86

Note. Discrimination (a) refers to the slope parameter, and Difficulty 1 and 2 refers to the thresholds.

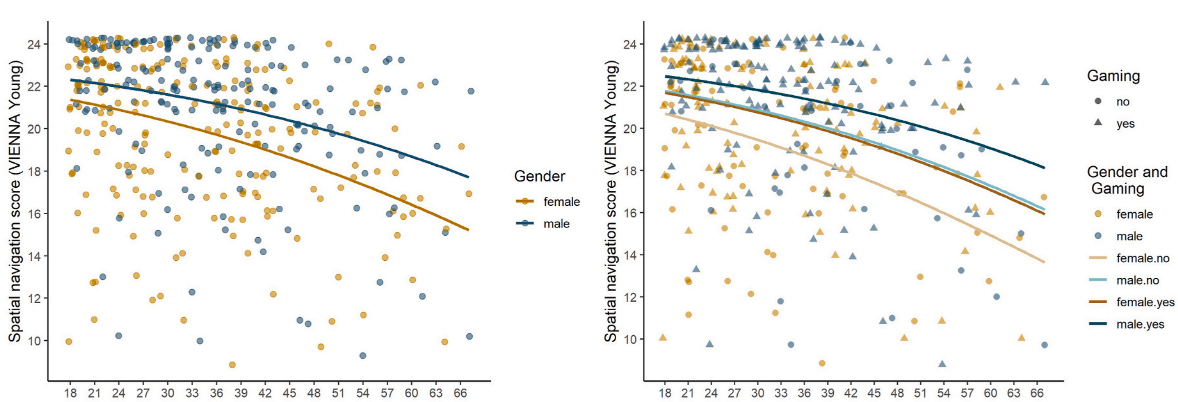

Fig. 6. Scatterplots visualizing beta binomial models using age and gender (left) and age, gender, and gaming experience (right) to predict VIENNA Young performance.

Table 7
Item Response Theory (IRT) Model parameters for a four-factor graded response model, including Discrimination(a) of the four factors and Difficulty 1 and 2.

Item	*Discrimination(a)*				Difficulty 1	Difficulty 2
	Factor 1	Factor 2	Factor 3	Factor 4		
item 1	1.474				4.77	3.08
item 2	1.144				3.85	3.14
item 3	1.522				2.60	0.66
item 4		1.802			5.90	3.82
item 5		1.559			6.52	2.83
item 6		1.846			6.51	2.83
item 7			1.883		3.98	1.92
item 8			1.157		1.97	1.26
item 9			1.108		3.02	1.65
item 10				1.645	2.67	1.39
item 11				1.243	1.65	0.40
item 12				1.013	2.15	0.78

Note. Discrimination (a) refers to the slope parameter, and Difficulty 1 and 2 refers to the thresholds.

artificial paradigms toward ecologically valid tests that mirror real-life challenges (Vigliocco et al., 2024). VIENNA Young leverages the possibilities of virtual environments to create an assessment with everyday relevance, using environmental affordances that streamline the approach to the task (Gregorians & Spiers, 2022) while precisely defining the cognitive processes being measured. This supports valid research conclusions, particularly in a broad domain like spatial navigation, where diverse task designs capture very different aspects of orientation and navigation performance. By using an intuitive interaction design and a passive navigation approach, VIENNA Young requires no training and can also be applied in populations with motor and cognitive impairment.

In contrast to VIENNA, which is optimized for research in older adults, VIENNA Young's increased task complexity is best suited for research where the majority of the target population includes younger and middle-aged adults. The overlapping age ranges reflect the practical need to accommodate broad age distributions in research samples, allowing researchers to apply a single, appropriately calibrated paradigm across the full sample. VIENNA Young's multiple application options (web-based and local Python-based), along with open materials and data, ensure high accessibility, transparency, and flexibility. In the current study, VIENNA Young was administered both remotely (web-based on gorilla.sc) and in-person (local using PsychoPy). Importantly, equivalence testing showed no significant differences between settings. This supports the viability of VIENNA Young for both remote and onsite testing and confirms the applicability of the reported norm data in either setting.

4.2. Psychometric properties

VIENNA Young proved feasible for a wide age range (18–67 years) and features a brief administration time of approximately 16 min, making it well-suited for research in clinical settings. Although the left-skewed distribution of scores indicates a ceiling effect that limits variability among high-performing individuals, this characteristic does not diminish its sensitivity for lower performances. Instead, it enhances the assessment's capacity to effectively capture spatial navigation performance in its primary target population—individuals with potential cognitive impairments.

We also observed favorable reliability markers for VIENNA Young. From both classical test theory and item response theory perspectives, the item-total correlations and factor loadings demonstrated excellent internal consistency, validating the theoretical foundation of the test construction. The retest reliability of VIENNA Young after a 3-month interval indicated moderate to good reliability with a small practice effect. This is a reasonable result considering that a parallel version of VIENNA Young is not yet available. Notably, the absolute difference in scores decreased with longer retest intervals, suggesting that moderately extending the interval between repeated administrations may enhance reliability in this version of VIENNA Young.

In line with the test conceptualization and construction, we were able to confirm most hypotheses about VIENNA Young's construct validity. Importantly, convergent and divergent markers were defined based on effect size thresholds rather than significance levels, given that the large sample size in this study confers high statistical power. Moreover, because cognitive tests often measure overlapping constructs and healthy individuals tend to perform consistently across tasks via factors like general cognitive function or test-taking skill (Harvey, 2019), performances can correlate significantly even in tests targeting separate domains.

We confirmed the convergent construct validity of VIENNA Young, particularly its visuospatial and executive components, which aligns with findings from the previous VIENNA version (Rekers & Finke, 2024). The positive association with subjective sense of direction supports both construct validity and suggests VIENNA Young's ecological validity, as performance is positively correlated with self-reported real-world navigation ability. Convergent cognitive markers were medium to large positive associations with visuospatial short-term and working-memory, mental rotation, and the executive functions (shifting/information processing speed), as measured by the SDMT, which is in line with findings in other navigation paradigms like Sea Hero Quest (Garg et al., 2024) or the VR-Road Map task (Morganti et al., 2013). Although SDMT performance differed between onsite and online settings, both the effect size and direction of the association with VIENNA Young performance were consistent across settings, supporting the robustness of this result.

VIENNA Young scores showed no or only small associations with objective and subjective episodic memory markers, thereby extending previous findings (Rekers & Finke, 2024) by including both verbal and visual episodic memory tests. While memory and spatial navigation are not distinct constructs, their overlap depends on task design (Ekstrom & Hill, 2023). In contrast to VIENNA Young, navigation paradigms that explicitly require participants to memorize or recall landmarks, routes, or environments, like the virtual reality navigation task (Mohammadi et al., 2018) or the virtual radial arm maze (Lee et al., 2014), are intentionally designed to engage episodic memory processes and therefore unsurprisingly these tasks show diverging findings with at least medium-sized correlations with episodic memory markers. By reducing reliance on episodic memory, VIENNA and VIENNA Young could help accurately capture informed navigation abilities, particularly in patients with known episodic memory impairment.

Our hypotheses—based on prior findings using VIENNA in older adults (Rekers & Finke, 2024) and other navigation paradigms (Stangl et al., 2018)—that inhibition would be a convergent and selective attention a divergent marker were not confirmed. The relationship between VIENNA Young and Stroop task measures for selective attention (baseline color naming time) and inhibition (ratio of color-word incongruence to baseline) remains inconclusive, with inconsistent associations between online and onsite assessments. Indeed, previous studies indicate that computerized Stroop tasks likely elicit not enough interference effect and insufficiently measure processing speed compared to the oral version (Basu, 2023; Penner et al., 2012).

We confirmed the validity of VIENNA Young rotation errors, which demonstrated a significant negative association with mental rotation performance, and updating errors, which were negatively associated with short-term and working memory performance. These findings suggest that the number of specific errors may serve as valuable auxiliary measures for identifying whether a subfunction of navigation is the primary contributor to lower performance levels. Such cases should then be further evaluated using targeted mental rotation or short-term and working memory tests. Furthermore, PTT identified one of the two VIENNA Young outliers and one participant with spatial vision impairment. This indicates that the PTT could be useful for identifying basic perspective translation challenges that hinder accurate interpretation of VIENNA Young results.

Further evidence supporting the validity of VIENNA Young comes from the qualitative analysis of reported strategies. The results revealed a homogeneous approach to the task with half of all strategies falling under three labels ("allocentric visualization", "counting", and "synchronize map and video") and 70 % covered by the five most common strategies (adding "egocentric visualization" and "focus on direction changes"). This highlights how navigational affordances such as landmarks, paths and boundaries, and spatial configurations are used in VIENNA Young (Gregorians & Spiers, 2022). Although a map is provided as a navigational aid rather than mentally constructed, VIENNA Young still measures spatial navigation, specifically a form of informed navigation where individuals rely on external spatial symbols to assist in navigation (Jeffery et al., 2024; Wiener et al., 2011). This alignment with everyday navigational tasks enhances VIENNA Young's face validity, providing users with an intuitive and accessible way to engage with the task.

4.3. Demographics

Consistent with our hypothesis, we found a negative association between age and VIENNA Young performance, replicating a well-established finding in navigation research across diverse paradigms (Lester et al., 2017). We also identified a robust gender difference, with men outperforming women, which was in contrast to our expectations based on findings from the VIENNA version for older adults, but aligns with a broad body of evidence from diverse passive and active navigation tasks (Chrastil & Warren, 2013; Nazareth et al., 2019). Notably, this gender difference persisted even after controlling for other demographic variables and gaming experience, consistent with findings from active navigation paradigms (Yavuz et al., 2024). While gender differences in navigation are often attributed to variations in strategy use—particularly the reliance on survey strategies (Castelli et al., 2008)—the standardized nature of VIENNA Young makes this an unlikely explanation for the observed effect. An alternative explanation could involve motivational factors (Schinazi et al., 2023), which we did not account for in this study.

Additionally, we found no significant association between VIENNA Young scores and years of education, even in this large cohort, which contrasts with our expectations based on results from a multinational study (Coutrot et al., 2022). The relationship between education and spatial navigation ability varies considerably across studies and cultural contexts, with generally small effects, even in large datasets (Coutrot et al., 2023). This was also the case in the previous VIENNA version, where the small effect of education did not reach significance in healthy older adults.

4.4. Environmental contexts

We found no performance difference between individuals who were raised in cities versus rural areas, unless we also controlled for current residency which is when we saw a positive effect of being brought up in a rural environment. This is in line with previous findings on higher entropy countries like Germany (Coutrot et al., 2022). However, in contrast to Coutrot et al. (2022), we surprisingly found that city dwellers outperformed rural residents in VIENNA Young, even on items with longer trajectories. This may stem from the grid-like structure and relatively short paths of the VIENNA Young items (max. travel time: 82 s), which may better align with urban spatial characteristics. Interestingly, among city dwellers, individuals who moved to the city from rural areas outperformed those raised in urban settings. This result could reflect greater navigation demands of rural-to-urban transitions, though other unexamined factors—such as socioeconomic variables beyond education (Coutrot et al., 2018; S. C. Levine et al., 2005)—may also play a role and merit further investigation.

The lack of an association between street network entropy (SNE) values and VIENNA Young performance may be attributed to differences in analytical approaches and the more culturally homogeneous nature of our sample. While Coutrot et al. (2022) derived the SNE values at the national level by averaging data from the 10 largest cities in each country, we focused on the individual SNE values of the specific cities reported by the participants. Additionally, the contrasting findings regarding urban living and the absence of an SNE association might reflect a loss of resolution in distinguishing high-performing navigators, due to the mild ceiling effects of VIENNA Young in healthy young adults. This limitation suggests that such differences may predominantly emerge among individuals with higher navigation abilities.

Notably, participants' main mode of transportation showed no effect on VIENNA Young performance when controlling for urban living. Contrary to our hypothesis, individuals actively navigating through self-ambulation did not outperform those primarily relying on passive modes, i.e. public transport, despite the higher cognitive engagement required in self-ambulation (Chrastil & Warren, 2012).

4.5. Gaming experience

We found a clear advantage in spatial navigation performance for participants with gaming experience, in line with previous findings (Murias et al., 2016; Yavuz et al., 2024). The observed group differences between gamers and non-gamers were robust, even after controlling for age, gender, and executive functions. Considering that VIENNA Young does not involve controller-based interaction or active movement control, this finding provides compelling evidence that the advantage associated with familiarity with video gaming extends beyond the use of specific interface devices. We also identified specific video gaming styles that most significantly contributed to better navigation performance. First, our analyses showed that the total hours spent gaming—particularly up to 18 h per week—were positively associated with better VIENNA Young performance. Second, participants familiar with allocentric, top-down character control outperformed other gamers who were not, whereas individuals accustomed to first-person, egocentric gaming did not show a similar advantage. This finding challenges the assumption that egocentric, shooter-style gaming provides the greatest benefit to navigation skills and highlights the potential of allocentric gaming. Additionally, map-based gameplay emerged as particularly advantageous, which is intuitive given that such games foster familiarity with spatial symbols and the interpretation of maps.

4.6. Rational for norming approach

The robust advantage observed in individuals with gaming experience prompted the inclusion of gaming experience as a control variable in the development of norm data. Alternative methods to account for gaming experience, such as those employed by Coutrot et al. (2018), involve normalizing the distance traveled in active navigation tasks based on performance in baseline tasks. However, this approach is not suitable for passive navigation tasks like VIENNA Young. Notably, as demonstrated in this study, the influence of gaming experience extends beyond enhanced dexterity acquired through gaming practice and persists in a task where the strategic approach is more standardized. This underscores the broader impact of gaming experience on navigation performance and indicates that it merits consideration in computerized cognitive assessments for other domains as well.

Neuropsychological test norms generally only consider age, gender, and education with a few exceptions (e.g., parental education; Van der Elst et al., 2011). We provide normative models that account for gaming experience because it aligns with our intended reference group, providing relevant context for VIENNA Young performance. While we do not aim to measure differences in age, gender, or gaming experience, they inadvertently affect performance. In contrast, we do not adjust for spatial skills—developed by employment in spatially demanding jobs or high exposure to spatial tasks in everyday life—because they are an integral aspect of navigation ability and warrant direct assessment in our navigation test.

The norm data presented here were collected from a German-speaking population. Although VIENNA Young primarily uses language only in its instructions, cultural and environmental factors shape navigational habits (Fernandez-Velasco & Spiers, 2024), and data using Sea Hero Quest in diverse populations across the world (Coutrot et al., 2018) indicate performance differences between countries even when materials are not language-based. It is therefore reasonable to assume that the normative models presented here can be applied in some populations but will need to be extended to others. Studies assessing VIENNA Young in non-German speaking populations are currently in preparation.

The normative models presented here are derived from two overlapping but not identical data sets, because information on gaming experience was only available for 89 % of the sample. This approach neither compromises nor enhances the interpretability of the scores; rather, it increases flexibility and model precision by accounting for specific factors such as age, gender, and gaming experience. It also prevents inappropriate generalization, such as applying male or female norms to a non-binary individual. Consequently, the choice of an appropriate normative model should be guided by the sample's or individual's characteristics to ensure optimal accuracy.

We chose a regression-based norming approach using flexible models that can accommodate non-linear relationships. This approach allows for a more precise reference for the target population while significantly enhancing the efficiency of required sample sizes by leveraging the entire distribution of the norm sample to estimate expected values for individuals. Unlike traditional norming approaches that rely on age bands and that create artificial groupings, regression-based norming provides a more accurate and nuanced interpretation of test scores (Kiselica et al., 2024; Oosterhuis et al., 2016). The accompanying script further enhances the utility of this method by streamlining and automating norm interpretation, ensuring both efficiency and accuracy. Automation is particularly advantageous for larger samples, where manual referencing of norm tables can be not only cumbersome but also error-prone.

Additionally, we capitalize on the strengths of both classical test theory and item-response theory (IRT) by reporting percentiles and z-scores. Given the non-normal distribution of VIENNA Young scores, z-scores derived directly from the mean and standard deviation may not correspond accurately to percentiles, and extreme z-scores may not reflect equivalent deviations from the mean as they would in a normal distribution (see Fig. A3). To address this, we provide IRT-based methods for calculating z-scores, ensuring a more accurate and meaningful representation of score deviations.

4.7. Limitations

Our study has some limitations. Including unsupervised assessments allowed us to achieve a better representation, larger sample size and validate the remote approach of VIENNA Young. To ensure the highest quality of the remote unsupervised online assessment, extensive evidence-based measures were taken for a reliable assessment (Peer et al., 2022; Rodd, 2024). However, this approach still resulted in some shortcomings. Specifically, the external construct validity markers of selective attention and inhibition, measured by an online implementation of the Stroop task, and the executive functions information processing speed/shifting marker, assessed by an online implementation of the SDMT, showed differences between onsite and online assessment that go beyond a difference one would expect using a written instead of the oral version (Fellows & Schmitter-Edgecombe, 2020). Yet, the consistent pattern of association with the SDMT across settings reinforces confidence in the link between VIENNA Young performance and complex visual scanning but has to be confirmed in a separate sample with uniform test setting. Importantly, VIENNA Young emulates a specific type of navigation scenario—map-assisted wayfinding in structured, grid-like indoor environments typical of urban settings in the Global North—which may not generalize to the broader diversity of navigation experiences across cultures, environments, and task demands. Furthermore, VIENNA Young is not appropriate to differentiate above average navigation performance considering its left skewness and performance should not be extrapolated to navigation relying on the retrieval and recognition of learned spatial layouts and landmarks. This should also be taken into account when interpreting the findings on associations of VIENNA Young performance, where very high performing individuals might shape associations that are not captured with the current version of the tasks.

4.8. Outlook

Future adaptations of VIENNA Young may incorporate step-wise adaptive testing in more complex environments, potentially capturing above-average navigation performance more effectively in younger individuals. However, such enhancements would likely increase testing time. As it stands, VIENNA Young strikes a practical balance between testing time and resolution, making it well-suited for research in clinical populations. Furthermore, the small practice effect warrants caution when interpreting repeated VIENNA Young assessments over short intervals. To address this, parallel versions of the test are currently in development. Ongoing research aims to establish VIENNA Young's relationship to functional impairments across clinical populations and its associations with neuropathological markers. Future studies should also investigate VIENNA Young's ecological validity by assessing how well performance corresponds to real-world navigation scenarios that rely on available spatial information. Additionally, further efforts are needed to establish representative normative benchmarks across cultural contexts and to investigate the role of socioeconomic variables. These steps are essential for advancing VIENNA Young's potential use as a clinical diagnostic tool.

5. Conclusion

There are numerous excellent spatial navigation paradigms available, particularly in experimental settings. This diversity is highly advantageous, as it enables users to tailor their choice of assessment to specific research questions. However, only a few paradigms provide published data on their psychometric properties, including external validity markers and normative data—critical elements for the accurate interpretation of test results. VIENNA Young was specifically designed and rigorously tested to assess spatial navigation with a focus on visuospatial and executive components, while minimizing the influence of episodic memory in the test. This approach enables the evaluation of spatial navigation abilities beyond known episodic memory deficits. Moreover, VIENNA Young offers flexible application options, supported by an innovative regression-based norming approach that can be tailored to identify the most accurate reference group and even account for gaming experience. These features ensure that the assessment can meet diverse user needs and provide precise interpretations of test results, making VIENNA Young a valuable resource for research in clinical settings.

CRediT authorship contribution statement

Sophia Rekers: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Tessa Christin Meyer:** Writing – review & editing, Software, Methodology, Investigation. **Carsten Finke:** Writing – review & editing, Supervision, Resources, Methodology, Funding acquisition, Conceptualization.

Data availability

All materials related to VIENNA Young, including the paradigm itself, analysis and normative interpretation scripts, and the data associated with this article, are available at the Open Science Framework (osf.io/4h65p/) and via app.gorilla.sc/openmaterials/918995.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT in the writing process in order to improve the readability and language of the manuscript. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Declaration of competing interest

The authors declare the following financial interests/personal relationships not related to this work: Sophia Rekers reports a relationship with the German Federal Ministry of Education and Research that includes: funding grants (Grant Number: 13GW0566D). The other authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Additional information on the procedure and sample

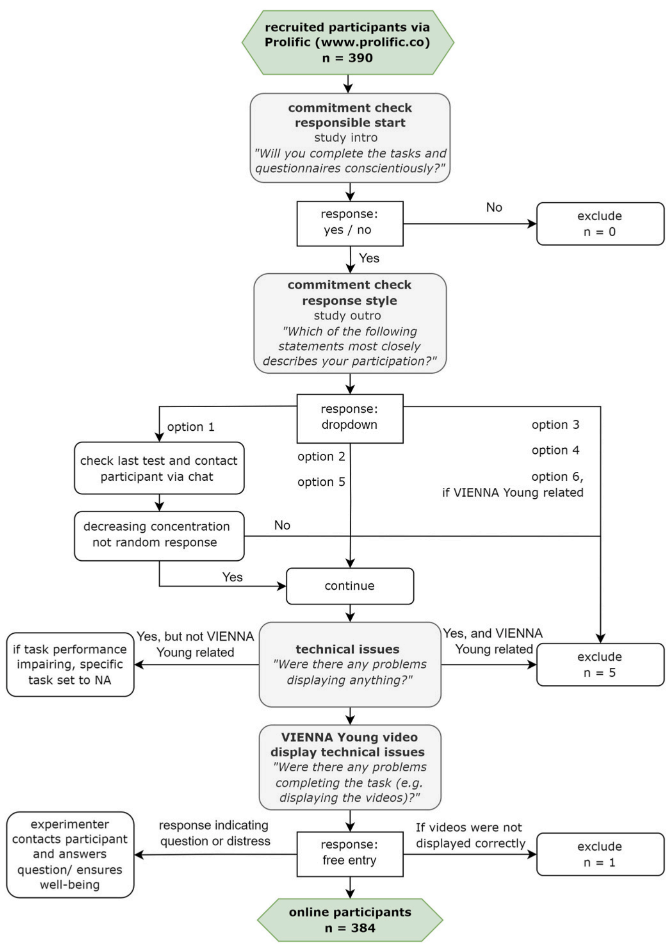

Fig. A1. Flowchart illustrating the data fidelity check among online participants. At the end of the study, participants chose one of six statements describing their engagement or technical issues: 1) "I only made an effort at the beginning and towards the end I just clicked on anything." 2) "I made an effort to complete the tasks as well as I could and to answer the questions truthfully." 3) "I only clicked when I had to and otherwise did something else." 4) "I lied on some of the questions." 5) "I was sometimes unsure, but I answered as best I could." 6) "I had major technical difficulties and was unable to complete some parts.".

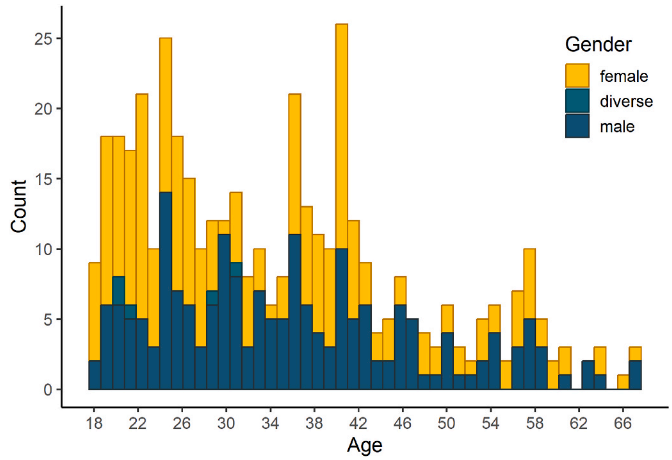

Fig. A2. Histogram of the age and gender distribution in the norm sample.

Table A1
Summary on the neuropsychological tests beyond VIENNA Young including number of complete observations in the total sample, the mean performance in the onsite subsample, mean performance in an age, gender, and education matched subsample of 24 online participants, and two sample *t*-test statistics comparing the mean performances.

	n	$\overline{M}$ onsite	$\overline{M}$ online	*t*-test statistics
Block span forward	370	9.04	8.58	$t(46) = -0.80$, $p = .430$
Block span backward	370	8.04	8.08	$t(46) = 0.09$, $p = .931$
Vandenberg Mental Rotation Test	376	7.12	9.08	$t(46) = 1.61$, $p = .114$
Verbal learning	344	64.17	60.21	$t(46) = -1.67$, $p = .101$
Verbal forgetting rate	346	0.04	0.08	$t(46) = 0.91$, $p = .369$
Visual forgetting rate	366	0.05	0.10	$t(46) = 1.28$, $p = .208$
Visual learning	366	22.12	24.79	$t(46) = 2.81$, $p = .007$
Symbol Digit Modalities Test	373	62.29	41.38	$t(46) = -7.94$, $p < .001$
Stroop ratio	368	1.64	1.10	$t(46) = -9.42$, $p < .001$
Color bar time in seconds	372	44.58	124.83	$t(46) = 29.53$, $p < .001$

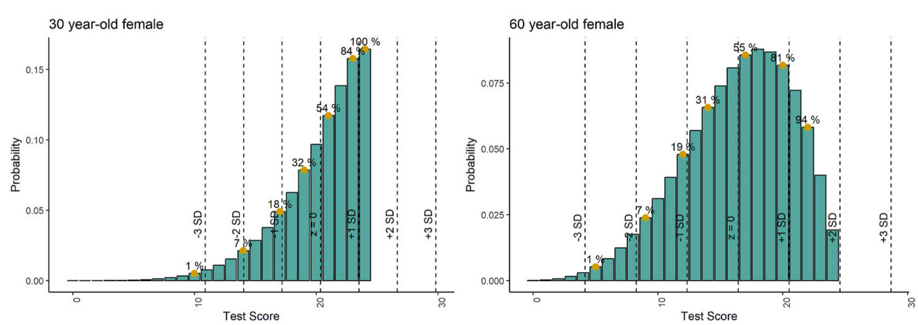

Fig. A3. Impact of data skewness on *z*-scores and percentile translation. The histograms depict the relationship between *z*-scores, percentiles, and test scores for two age groups: 30-year-old and 60-year-old females. The beta-binomial distribution is visualized, with vertical lines indicating standard deviations from the mean (-3SD to +3SD). Yellow points and corresponding percentages highlight the cumulative proportions of the population at each standard deviation, illustrating how skewness influences the mapping of *z*-scores to percentiles across different age groups.

Appendix B. Percentile Tables

The normative data and percentile tables provided below are intended solely for research purposes. They are designed to help contextualize spatial navigation performance in diverse populations as part of behavioral and cognitive studies. These values are not intended for clinical interpretation or individual diagnosis and should not be used to inform medical or therapeutic decisions. Identify the row corresponding to your participant's age and the column corresponding to their VIENNA Young score. When you want to report only one number instead of a range, please use the lower percentile reported in the range.

Table B1: Percentiles for female participants. Use when information on gaming experience is not available.
Table B2: Percentiles for male participants. Use when information on gaming experience is not available.
Table B3: Percentiles for female participants without gaming experience.
Table B4: Percentiles for female participants with gaming experience.
Table B5: Percentiles for male participants without gaming experience.
Table B6: Percentiles for male participants with gaming experience.

Table B7: Percentiles for participants without gaming experience. Use when binary gender categorization does not apply.
Table B8: Percentiles for participants with gaming experience. Use when binary gender categorization does not apply.
Table B9: Percentiles for participants without controlling for gender or gaming experience.

Table B1
Percentiles for female participants. Use when information on gaming experience is not available.

Age	0-3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
18	-	-	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-15	16-21	22-28	29-39	40-53	54-72	>73
19	-	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-7	8-11	12-15	16-21	22-29	30-40	41-54	55-73	>74
20	-	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-16	17-22	23-30	31-41	42-55	56-74	>75
21	-	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-17	18-23	24-31	32-42	43-56	57-75	>76
22	-	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-24	25-32	33-43	44-58	59-76	>77
23	-	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-25	26-34	35-45	46-59	60-77	>78
24	-	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-26	27-35	36-46	47-60	61-78	>79
25	-	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-20	21-27	28-36	37-47	48-61	62-79	>80
26	-	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-21	22-28	29-37	38-48	49-62	63-80	>81
27	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-16	17-21	22-29	30-38	39-50	51-64	65-80	>81
28	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-22	23-30	31-39	40-51	52-65	66-81	>82
29	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-23	24-31	32-40	41-52	53-66	67-82	>83
30	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-24	25-32	33-42	43-53	54-67	68-83	>84
31	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-25	26-33	34-43	44-55	56-68	69-84	>85
32	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-26	27-34	35-44	45-56	57-70	71-85	>86
33	-	-	-	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-27	28-35	36-45	46-57	58-71	72-85	>86
34	-	-	-	-	-	<1	1	1-2	2	3-4	5	6-8	9-11	12-16	17-21	22-28	29-37	38-47	48-59	60-72	73-86	>87
35	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-22	23-29	30-38	39-48	49-60	61-73	74-87	>88
36	-	-	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-17	18-23	24-30	31-39	40-49	50-61	62-74	75-88	>89
37	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-13	14-18	19-24	25-32	33-40	41-51	52-62	63-75	76-88	>89
38	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-33	34-42	43-52	53-64	65-76	77-89	>90
39	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-20	21-26	27-34	35-43	44-53	54-65	66-77	78-90	>91
40	-	-	-	-	<1	1	1-2	2	3-4	5	6-8	9-11	12-16	17-21	22-27	28-35	36-44	45-55	56-66	67-78	79-90	>91
41	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-22	23-29	30-36	37-46	47-56	57-68	69-79	80-91	>92
42	-	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-17	18-23	24-30	31-38	39-47	48-58	59-69	70-80	81-91	>92
43	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-13	14-18	19-24	25-31	32-39	40-49	50-59	60-70	71-81	82-92	>93
44	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-32	33-40	41-50	51-60	61-71	72-82	83-92	>93
45	-	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-33	34-42	43-51	52-62	63-73	74-83	84-93	>94
46	-	-	-	-	<1	1	2	3-4	5	6-8	9-11	12-16	17-21	22-27	28-35	36-43	44-53	54-63	64-74	75-84	85-93	>94
47	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-16	17-22	23-28	29-36	37-45	46-54	55-64	65-75	76-85	86-94	>95
48	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-17	18-23	24-30	31-37	38-46	47-56	57-66	67-76	77-86	87-94	>95
49	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-18	19-24	25-31	32-39	40-47	48-57	58-67	68-77	78-87	88-95	>96
50	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-32	33-40	41-49	50-58	59-68	69-78	79-87	88-95	>96
51	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-33	34-41	42-50	51-60	61-70	71-79	80-88	89-95	>96
52	-	-	-	<1	1	2	3-4	5-6	7-8	9-12	13-16	17-21	22-28	29-35	36-43	44-52	53-61	62-71	72-80	81-89	90-96	>97
53	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-22	23-29	30-36	37-44	45-53	54-63	64-72	73-81	82-90	91-96	>97
54	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-18	19-23	24-30	31-37	38-46	47-55	56-64	65-74	75-82	83-90	91-96	>97
55	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-31	32-39	40-47	48-56	57-66	67-75	76-83	84-91	92-96	>97
56	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-33	34-40	41-49	50-58	59-67	68-76	77-84	85-91	92-97	>98
57	-	-	<1	1	2	3	4-5	6-8	9-11	12-16	17-21	22-27	28-34	35-42	43-50	51-59	60-68	69-77	78-85	86-92	93-97	>98
58	-	-	<1	1	2	3-4	5-6	7-9	10-12	13-17	18-22	23-28	29-35	36-43	44-52	53-61	62-70	71-78	79-86	87-93	94-97	>98
59	-	-	<1	1	2	3-4	5-6	7-9	10-13	14-18	19-23	24-30	31-37	38-45	46-53	54-62	63-71	72-79	80-87	88-93	94-97	>98
60	-	<1	1	1-2	2-3	4	5-7	8-10	11-14	15-19	20-24	25-31	32-38	39-46	47-55	56-64	65-72	73-81	82-88	89-94	95-98	>99
61	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-20	21-26	27-32	33-40	41-48	49-56	57-65	66-74	75-82	83-89	90-94	95-98	>99
62	-	<1	1	2	3	4-5	6-8	9-11	12-16	17-21	22-27	28-34	35-41	42-49	50-58	59-67	68-75	76-83	84-89	90-94	95-98	>99
63	-	<1	1	2	3-4	5-6	7-8	9-12	13-17	18-22	23-28	29-35	36-43	44-51	52-59	60-68	69-76	77-84	85-90	91-95	96-98	>99
64	-	<1	1	2	3-4	5-6	7-9	10-13	14-18	19-23	24-29	30-37	38-44	45-53	54-61	62-69	70-77	78-85	86-91	92-95	96-98	>99
65	-	<1	1	2	3-4	5-7	8-10	11-14	15-19	20-24	25-31	32-38	39-46	47-54	55-62	63-71	72-79	80-85	86-91	92-96	97-98	>99
66	<1	1	1-2	2-3	4-5	6-7	8-10	11-15	16-20	21-25	26-32	33-39	40-47	48-56	57-64	65-72	73-80	81-86	87-92	93-96	97-98	>99
67	<1	1	2	3	4-5	6-8	9-11	12-16	17-21	22-27	28-34	35-41	42-49	50-57	58-65	66-73	74-81	82-87	88-92	93-96	>97	>99

Table B2
Percentiles for male participants. Use when information on gaming experience is not available.

Age	0-6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
18	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-7	8-11	12-16	17-24	25-36	37-55	>56
19	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-12	13-17	18-25	26-37	38-56	>57
20	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-12	13-18	19-26	27-38	39-57	>58
21	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-18	19-27	28-39	40-58	>59
22	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-19	20-28	29-40	41-60	>61
23	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-14	15-20	21-28	29-41	42-61	>62
24	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-20	21-29	30-42	43-62	>63
25	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-15	16-21	22-30	31-43	44-63	>64
26	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-22	23-31	32-44	45-64	>65
27	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-16	17-23	24-32	33-45	46-65	>66
28	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-12	13-17	18-24	25-33	34-46	47-66	>67

(continued on next page)

Table B2 (*continued*)

Age	0-6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
29	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-17	18-24	25-34	35-48	49-67	>68
30	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-18	19-25	26-35	36-49	50-68	>69
31	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-19	20-26	27-36	37-50	51-69	>70
32	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-27	28-37	38-51	52-70	>71
33	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-20	21-28	29-38	39-52	53-71	>72
34	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-21	22-29	30-39	40-53	54-72	>73
35	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-16	17-22	23-30	31-41	42-55	56-73	>74
36	-	-	-	-	<1	1	1-2	2	3-4	5	6-8	9-12	13-16	17-23	24-31	32-42	43-56	57-74	>75
37	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-17	18-24	25-32	33-43	44-57	58-75	>76
38	-	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-18	19-24	25-33	34-44	45-58	59-76	>77
39	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-19	20-25	26-34	35-45	46-60	61-77	>78
40	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-26	27-35	36-47	48-61	62-78	>79
41	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-15	16-20	21-27	28-36	37-48	49-62	63-79	>80
42	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-15	16-21	22-28	29-38	39-49	50-63	64-80	>81
43	-	-	-	<1	1	1-2	2	3-4	5	6-8	9-11	12-16	17-22	23-29	30-39	40-50	51-64	65-81	>82
44	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-17	18-23	24-30	31-40	41-52	53-66	67-82	>83
45	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-24	25-31	32-41	42-53	54-67	68-83	>84
46	-	-	-	<1	1	2	3	4	5-7	8-9	10-13	14-18	19-25	26-33	34-42	43-54	55-68	69-84	>85
47	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-26	27-34	35-44	45-55	56-69	70-84	>85
48	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-20	21-27	28-35	36-45	46-57	58-70	71-85	>86
49	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-15	16-21	22-28	29-36	37-46	47-58	59-71	72-86	>87
50	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-22	23-29	30-37	38-48	49-59	60-73	74-87	>88
51	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-23	24-30	31-39	40-49	50-61	62-74	75-87	>88
52	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-24	25-31	32-40	41-50	51-62	63-75	76-88	>89
53	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-32	33-41	42-52	53-63	64-76	77-89	>90
54	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-20	21-26	27-33	34-42	43-53	54-65	66-77	78-89	>90
55	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-27	28-35	36-44	45-54	55-66	67-78	79-90	>91
56	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-21	22-28	29-36	37-45	46-56	57-67	68-79	80-91	>92
57	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-22	23-29	30-37	38-47	48-57	58-68	69-80	81-91	>92
58	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-23	24-30	31-39	40-48	49-58	59-70	71-81	82-92	>93
59	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-24	25-32	33-40	41-49	50-60	61-71	72-82	83-92	>93
60	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-26	27-33	34-41	42-51	52-61	62-72	73-83	84-93	>94
61	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-27	28-34	35-43	44-52	53-62	63-73	74-84	85-93	>94
62	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-21	22-28	29-35	36-44	45-54	55-64	65-74	75-85	86-94	>95
63	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-22	23-29	30-37	38-45	46-55	56-65	66-76	77-86	87-94	>95
64	<1	1	2	3	4	5-7	8-9	10-13	14-18	19-24	25-30	31-38	39-47	48-56	57-67	68-77	78-86	87-94	>95
65	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-32	33-39	40-48	49-58	59-68	69-78	79-87	88-95	>96
66	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-33	34-41	42-50	51-59	60-69	70-79	80-88	89-95	>96
67	<1	1	2	3	4-5	6-8	9-11	12-16	17-21	22-27	28-34	35-42	43-51	52-61	62-71	72-80	81-89	90-95	>96

Table B3
Percentiles for female participants without gaming experience.

Age	0-2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
18	-	-	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-21	22-28	29-37	38-49	50-63	64-80	>81
19	-	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-16	17-22	23-29	30-39	40-50	51-64	65-81	>82
20	-	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-22	23-30	31-40	41-51	52-66	67-82	>83
21	-	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-23	24-31	32-41	42-53	54-67	68-83	>84
22	-	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-24	25-32	33-42	43-54	55-68	69-84	>85
23	-	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-25	26-34	35-43	44-55	56-69	70-84	>85
24	-	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-20	21-26	27-35	36-45	46-57	58-70	71-85	>86
25	-	-	-	-	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-21	22-27	28-36	37-46	47-58	59-72	73-86	>87
26	-	-	-	-	-	-	<1	1	1-2	2	3-4	5	6-8	9-11	12-16	17-22	23-29	30-37	38-47	48-59	60-73	74-87	>88
27	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-22	23-30	31-38	39-49	50-61	62-74	75-87	>88
28	-	-	-	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-17	18-23	24-31	32-40	41-50	51-62	63-75	76-88	>89
29	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-13	14-18	19-25	26-32	33-41	42-52	53-63	64-76	77-89	>90
30	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-26	27-33	34-42	43-53	54-65	66-77	78-89	>90
31	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-20	21-27	28-35	36-44	45-54	55-66	67-78	79-90	>91
32	-	-	-	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-16	17-21	22-28	29-36	37-45	46-56	57-67	68-79	80-91	>92
33	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-22	23-29	30-37	38-46	47-57	58-69	70-80	81-91	>92
34	-	-	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-17	18-23	24-30	31-38	39-48	49-58	59-70	71-81	82-92	>93
35	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-13	14-18	19-24	25-31	32-40	41-49	50-60	61-71	72-82	83-92	>93
36	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-33	34-41	42-51	52-61	62-72	73-83	84-93	>94
37	-	-	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-27	28-34	35-43	44-52	53-63	64-74	75-84	85-93	>94
38	-	-	-	-	-	<1	1	2	3-4	5	6-8	9-12	13-16	17-21	22-28	29-35	36-44	45-54	55-64	65-75	76-85	86-94	>95
39	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-22	23-29	30-37	38-45	46-55	56-65	66-76	77-86	87-94	>95
40	-	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-18	19-23	24-30	31-38	39-47	48-57	58-67	68-77	78-87	88-95	>96
41	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-24	25-31	32-39	40-48	49-58	59-68	69-78	79-87	88-95	>96
42	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-20	21-26	27-33	34-41	42-50	51-59	60-69	70-79	80-88	89-95	>96
43	-	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-21	22-27	28-34	35-42	43-51	52-61	62-71	72-80	81-89	90-96	>97
44	-	-	-	-	<1	1	2	3-4	5-6	7-8	9-12	13-16	17-22	23-28	29-35	36-44	45-53	54-62	63-72	73-81	82-90	91-96	>97
45	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-17	18-23	24-29	30-37	38-45	46-54	55-64	65-73	74-82	83-90	91-96	>97

(*continued on next page*)

Table B3 (*continued*)

Age	0-2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
46	-	-	-	<1	1	1-2	2-3	4	5-7	8-10	11-13	14-18	19-24	25-31	32-38	39-47	48-56	57-65	66-75	76-83	84-91	92-96	>97
47	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-32	33-40	41-48	49-57	58-67	68-76	77-84	85-91	92-97	>98
48	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-33	34-41	42-50	51-59	60-68	69-77	78-85	86-92	93-97	>98
49	-	-	-	<1	1	2	3	4-5	6-8	9-12	13-16	17-21	22-28	29-35	36-43	44-51	52-60	61-69	70-77	79-86	87-93	94-97	>98
50	-	-	-	<1	1	2	3-4	5-6	7-9	10-12	13-17	18-23	24-29	30-36	37-44	45-53	54-62	63-71	72-79	80-87	88-93	94-97	>98
51	-	-	-	<1	1	2	3-4	5-6	7-9	10-13	14-18	19-24	25-30	31-38	39-46	47-54	55-63	64-72	73-80	81-88	89-94	95-98	>99
52	-	-	<1	1	1-2	2-3	4	5-7	8-10	11-14	15-19	20-25	26-32	33-39	40-47	48-56	57-65	66-73	74-82	83-89	90-94	95-98	>99
53	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-20	21-26	27-33	34-41	42-49	50-58	59-66	67-75	76-83	84-89	90-94	95-98	>99
54	-	-	<1	1	2	3	4-5	6-8	9-12	13-16	17-21	22-27	28-34	35-42	43-51	52-59	60-68	69-76	77-84	85-90	91-95	96-98	>99
55	-	-	<1	1	2	3-4	5-6	7-9	10-12	13-17	18-22	23-29	30-36	37-44	45-52	53-61	62-69	70-77	78-85	86-91	92-95	96-98	>99
56	-	-	<1	1	2	3-4	5-6	7-9	10-13	14-18	19-24	25-30	31-37	38-45	46-54	55-62	63-71	72-78	79-85	86-91	92-96	97-98	>99
57	-	-	<1	1	2	3-4	5-7	8-10	11-14	15-19	20-25	26-32	33-39	40-47	48-55	56-64	65-72	73-80	81-86	87-92	93-96	97-98	>99
58	-	<1	1	1-2	2-3	4-5	6-7	8-11	12-15	16-20	21-26	27-33	34-41	42-49	50-57	58-65	66-73	74-81	82-87	88-92	93-96	>97	-
59	-	<1	1	2	3	4-5	6-8	9-12	13-16	17-21	22-28	29-34	35-42	43-50	51-58	59-67	68-75	76-82	83-88	89-93	94-97	>98	-
60	-	<1	1	2	3	4-6	7-9	10-12	13-17	18-23	24-29	30-36	37-44	45-52	53-60	61-68	69-76	77-83	84-89	90-93	94-97	>98	-
61	-	<1	1	2	3-4	5-6	7-9	10-13	14-18	19-24	25-30	31-38	39-45	46-53	54-62	63-70	71-77	78-84	85-90	91-94	95-97	>98	-
62	-	<1	1	2	3-4	5-7	8-10	11-14	15-19	20-25	26-32	33-39	40-47	48-55	56-63	64-71	72-78	79-85	86-90	91-94	95-97	>98	-
63	-	<1	1	2-3	4	5-7	8-11	12-15	16-20	21-26	27-33	34-41	42-49	50-57	58-65	66-72	73-80	81-86	87-91	92-95	96-97	>98	-
64	-	<1	1	2-3	4-5	6-8	9-11	12-16	17-21	22-28	29-35	36-42	43-50	51-58	59-66	67-74	75-81	82-87	88-92	93-95	96-98	>99	-
65	<1	1	2	3	4-5	6-8	9-12	13-17	18-23	24-29	30-36	37-44	45-52	53-60	61-68	69-75	76-82	83-87	88-92	93-96	97-98	>99	-
66	<1	1	2	3	4-6	7-9	10-13	14-18	19-24	25-30	31-38	39-45	46-53	54-61	62-69	70-76	77-83	84-88	89-93	94-96	97-98	>99	-
67	<1	1	2	3-4	5-6	7-10	11-14	15-19	20-25	26-32	33-39	40-47	48-55	56-63	64-71	72-78	79-84	85-89	90-93	94-96	97-98	>99	-

Table B4
Percentiles for female participants with gaming experience.

Age	0-4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
18	-	-	-	-	-	-	-	<1	1	1-2	2	3-4	5	6-8	9-12	13-17	18-24	25-34	35-48	49-67	>68
19	-	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-18	19-25	26-35	36-49	50-68	>69
20	-	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-19	20-26	27-36	37-50	51-70	>71
21	-	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-14	15-19	20-27	28-37	38-51	52-71	>72
22	-	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-20	21-28	29-38	39-53	54-72	>73
23	-	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-15	16-21	22-29	30-40	41-54	55-73	>74
24	-	-	-	-	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-16	17-22	23-30	31-41	42-55	56-74	>75
25	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-16	17-23	24-31	32-42	43-56	57-75	>76
26	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-17	18-23	24-32	33-43	44-57	58-76	>77
27	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-18	19-24	25-33	34-44	45-59	60-77	>78
28	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-25	26-34	35-46	47-60	61-78	>79
29	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-26	27-35	36-47	48-61	62-79	>80
30	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-20	21-27	28-36	37-48	49-62	63-80	>81
31	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-21	22-28	29-38	39-49	50-64	65-80	>81
32	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-16	17-22	23-29	30-39	40-51	52-65	66-81	>82
33	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-17	18-23	24-30	31-40	41-52	53-66	67-82	>83
34	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-17	18-24	25-32	33-41	42-53	54-67	68-83	>84
35	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-25	26-33	34-43	44-54	55-68	69-84	>85
36	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-26	27-34	35-44	45-56	57-70	71-85	>86
37	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-15	16-20	21-27	28-35	36-45	46-57	58-71	72-85	>86
38	-	-	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-21	22-28	29-36	37-46	47-58	59-72	73-86	>87
39	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-22	23-29	30-38	39-48	49-60	61-73	74-87	>88
40	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-23	24-30	31-39	40-49	50-61	62-74	75-88	>89
41	-	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-18	19-24	25-31	32-40	41-51	52-62	63-75	76-88	>89
42	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-25	26-32	33-41	42-52	53-64	65-76	77-89	>90
43	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-20	21-26	27-34	35-43	44-53	54-65	66-77	78-90	>91
44	-	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-27	28-35	36-44	45-55	56-66	67-79	80-90	>91
45	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-21	22-28	29-36	37-45	46-56	57-68	69-80	81-91	>92
46	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-22	23-29	30-37	38-47	48-57	58-69	70-81	82-91	>92
47	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-18	19-23	24-31	32-39	40-48	49-59	60-70	71-82	83-92	>93
48	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-25	26-32	33-40	41-50	51-60	61-71	72-82	83-92	>93
49	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-20	21-26	27-33	34-42	43-51	52-62	63-73	74-83	84-93	>94
50	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-27	28-34	35-43	44-53	54-63	64-74	75-84	85-93	>94
51	-	-	-	<1	1	2	3-4	5-6	7-8	9-12	13-16	17-22	23-28	29-36	37-44	45-54	55-64	65-75	76-85	86-94	>95
52	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-23	24-29	30-37	38-46	47-56	57-66	67-76	77-86	87-94	>95
53	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-18	19-24	25-30	31-38	39-47	48-57	58-67	68-77	78-87	88-95	>96
54	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-32	33-40	41-49	50-58	59-69	70-78	79-88	89-95	>96
55	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-20	21-26	27-33	34-41	42-50	51-60	61-70	71-80	81-88	89-95	>96
56	-	-	<1	1	2	3	4-5	6-8	9-11	12-16	17-21	22-27	28-34	35-43	44-52	53-61	62-71	72-81	82-89	90-96	>97
57	-	-	<1	1	2	3-4	5-6	7-9	10-12	13-17	18-22	23-28	29-36	37-44	45-53	54-63	64-72	73-82	83-90	91-96	>97
58	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-18	19-23	24-30	31-37	38-46	47-55	56-64	65-74	75-83	84-90	91-96	>97
59	-	<1	1	1-2	2-3	4	5-7	8-10	11-14	15-19	20-24	25-31	32-39	40-47	48-56	57-66	67-75	76-84	85-91	92-97	>98
60	-	<1	1	2	3	4-5	6-7	8-10	11-15	16-20	21-25	26-32	33-40	41-49	50-58	59-67	68-76	77-85	86-92	93-97	>98
61	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-21	22-27	28-34	35-42	43-50	51-59	60-68	69-77	78-85	86-92	93-97	>98
62	-	<1	1	2	3-4	5-6	7-8	9-12	13-16	17-22	23-28	29-35	36-43	44-52	53-61	62-70	71-79	80-86	87-93	94-97	>98

(*continued on next page*)

Table B4 (*continued*)

Age	0-4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
63	-	<1	1	2	3-4	5-6	7-9	10-13	14-17	18-23	24-29	30-37	38-45	46-53	54-62	63-71	72-80	81-87	88-93	94-97	>98
64	<1	1	1-2	2-3	4	5-7	8-10	11-14	15-18	19-24	25-31	32-38	39-46	47-55	56-64	65-73	74-81	82-88	89-94	95-98	>99
65	<1	1	1-2	2-3	4-5	6-7	8-10	11-14	15-19	20-25	26-32	33-40	41-48	49-56	57-65	66-74	75-82	83-89	90-94	95-98	>99
66	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-27	28-33	34-41	42-49	50-58	59-67	68-75	76-83	84-89	90-95	96-98	>99
67	<1	1	2	3	4-5	6-8	9-12	13-16	17-22	23-28	29-35	36-43	44-51	52-60	61-68	69-76	77-84	85-90	91-95	96-98	>99

Table B5
Percentiles for male participants without gaming experience.

Age	0-4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
18	-	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-16	17-23	24-33	34-46	47-66	>67
19	-	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-12	13-17	18-24	25-34	35-47	48-67	>68
20	-	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-18	19-25	26-35	36-49	50-68	>69
21	-	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-18	19-26	27-36	37-50	51-69	>70
22	-	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-19	20-27	28-37	38-51	52-70	>71
23	-	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-20	21-28	29-38	39-52	53-71	>72
24	-	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-15	16-21	22-29	30-39	40-53	54-72	>73
25	-	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-21	22-30	31-40	41-55	56-73	>74
26	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-16	17-22	23-31	32-42	43-56	57-74	>75
27	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-17	18-23	24-32	33-43	44-57	58-75	>76
28	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-24	25-33	34-44	45-58	59-76	>77
29	-	-	-	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-18	19-25	26-34	35-45	46-59	60-77	>78
30	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-26	27-35	36-46	47-61	62-78	>79
31	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-20	21-27	28-36	37-48	49-62	63-79	>80
32	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-21	22-28	29-37	38-49	50-63	64-80	>81
33	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-16	17-22	23-29	30-38	39-50	51-64	65-81	>82
34	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-22	23-30	31-40	41-51	52-66	67-82	>83
35	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-23	24-31	32-41	42-53	54-67	68-83	>84
36	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-24	25-32	33-42	43-54	55-68	69-84	>85
37	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-25	26-34	35-43	44-55	56-69	70-84	>85
38	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-20	21-26	27-35	36-45	46-57	58-70	71-85	>86
39	-	-	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-21	22-27	28-36	37-46	47-58	59-72	73-86	>87
40	-	-	-	-	<1	1	1-2	2	3-4	5	6-8	9-11	12-16	17-22	23-29	30-37	38-47	48-59	60-73	74-87	>88
41	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-17	18-22	23-30	31-38	39-49	50-61	62-74	75-87	>88
42	-	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-17	18-23	24-31	32-40	41-50	51-62	63-75	76-88	>89
43	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-13	14-18	19-24	25-32	33-41	42-51	52-63	64-76	77-89	>90
44	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-26	27-33	34-42	43-53	54-65	66-77	78-89	>90
45	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-20	21-27	28-34	35-44	45-54	55-66	67-78	79-90	>91
46	-	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-16	17-21	22-28	29-36	37-45	46-56	57-67	68-79	80-91	>92
47	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-17	18-22	23-29	30-37	38-46	47-57	58-68	69-80	81-91	>92
48	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-17	18-23	24-30	31-38	39-48	49-58	59-70	71-81	82-92	>93
49	-	-	-	<1	1	2	3	4	5-7	8-10	11-13	14-18	19-24	25-31	32-40	41-49	50-60	61-71	72-82	83-92	>93
50	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-33	34-41	42-51	52-61	62-72	73-83	84-93	>94
51	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-34	35-43	44-52	53-63	64-73	74-84	85-93	>94
52	-	-	-	<1	1	2	3-4	5	6-8	9-12	13-16	17-21	22-28	29-35	36-44	45-54	55-64	65-75	76-85	86-94	>95
53	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-22	23-29	30-37	38-45	46-55	56-65	66-76	77-86	87-94	>95
54	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-18	19-23	24-30	31-38	39-47	48-57	58-67	68-77	78-87	88-95	>96
55	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-24	25-31	32-39	40-48	49-58	59-68	69-78	79-87	88-95	>96
56	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-20	21-26	27-33	34-41	42-50	51-59	60-69	70-79	80-88	89-95	>96
57	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-21	22-27	28-34	35-42	43-51	52-61	62-71	72-80	81-89	90-96	>97
58	-	-	<1	1	2	3-4	5-6	7-8	9-12	13-16	17-22	23-28	29-35	36-44	45-53	54-62	63-72	73-81	82-90	91-96	>97
59	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-17	18-23	24-29	30-37	38-45	46-54	55-64	65-73	74-82	83-90	91-96	>97
60	-	<1	1	1-2	2-3	4	5-7	8-10	11-13	14-18	19-24	25-31	32-38	39-47	48-56	57-65	66-75	76-83	84-91	92-96	>97
61	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-32	33-40	41-48	49-57	58-67	68-76	77-84	85-91	92-97	>98
62	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-33	34-41	42-50	51-59	60-68	69-77	78-85	86-92	93-97	>98
63	-	<1	1	2	3	4-5	6-8	9-12	13-16	17-21	22-28	29-35	36-43	44-51	52-60	61-69	70-78	79-86	87-93	94-97	>98
64	-	<1	1	2	3-4	5-6	7-9	10-12	13-17	18-23	24-29	30-36	37-44	45-53	54-62	63-71	72-79	80-87	88-93	94-97	>98
65	-	<1	1	2	3-4	5-6	7-9	10-13	14-18	19-24	25-30	31-38	39-46	47-54	55-63	64-72	73-80	81-88	89-94	95-98	>99
66	<1	1	1-2	2-3	4	5-7	8-10	11-14	15-19	20-25	26-32	33-39	40-47	48-56	57-65	66-73	74-81	82-88	89-94	95-98	>99
67	<1	1	2	3	4-5	6-7	8-11	12-15	16-20	21-26	27-33	34-41	42-49	50-58	59-66	67-75	76-83	84-89	90-94	95-98	>99

Table B6
Percentiles for male participants with gaming experience.

Age	0-6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
18	-	-	-	-	-	-	-	<1	1	1-2	2-3	4	5-6	7-10	11-15	16-22	23-33	34-52	>53
19	-	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-15	16-23	24-34	35-53	>54
20	-	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-16	17-23	24-35	36-54	>55
21	-	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-16	17-24	25-36	37-55	>56

(continued on next page)

Table B6 (*continued*)

Age	0-6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
22	-	-	-	-	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-17	18-25	26-37	38-56	>57
23	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-12	13-18	19-26	27-38	39-58	>59
24	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-18	19-27	28-39	40-59	>60
25	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-19	20-27	28-40	41-60	>61
26	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-20	21-28	29-41	42-61	>62
27	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-10	11-14	15-20	21-29	30-42	43-62	>63
28	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-15	16-21	22-30	31-43	44-63	>64
29	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-15	16-22	23-31	32-44	45-64	>65
30	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-16	17-23	24-32	33-45	46-65	>66
31	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-16	17-23	24-33	34-47	48-66	>67
32	-	-	-	-	-	<1	1	1-2	2	3-4	5	6-8	9-12	13-17	18-24	25-34	35-48	49-67	>68
33	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-18	19-25	26-35	36-49	50-68	>69
34	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-19	20-26	27-36	37-50	51-70	>71
35	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-14	15-19	20-27	28-37	38-51	52-71	>72
36	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-20	21-28	29-38	39-52	53-72	>73
37	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-15	16-21	22-29	30-40	41-54	55-73	>74
38	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-16	17-22	23-30	31-41	42-55	56-74	>75
39	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-16	17-23	24-31	32-42	43-56	57-75	>76
40	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-17	18-23	24-32	33-43	44-57	58-76	>77
41	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-18	19-24	25-33	34-44	45-59	60-77	>78
42	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-25	26-34	35-45	46-60	61-78	>79
43	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-26	27-35	36-47	48-61	62-79	>80
44	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-20	21-27	28-36	37-48	49-62	63-80	>81
45	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-21	22-28	29-38	39-49	50-63	64-80	>81
46	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-16	17-22	23-29	30-39	40-51	52-65	66-81	>82
47	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-17	18-23	24-30	31-40	41-52	53-66	67-82	>83
48	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-17	18-24	25-32	33-41	42-53	54-67	68-83	>84
49	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-25	26-33	34-43	44-54	55-68	69-84	>85
50	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-26	27-34	35-44	45-56	57-70	71-85	>86
51	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-15	16-20	21-27	28-35	36-45	46-57	58-71	72-85	>86
52	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-21	22-28	29-36	37-46	47-58	59-72	73-86	>87
53	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-22	23-29	30-37	38-48	49-60	61-73	74-87	>88
54	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-23	24-30	31-39	40-49	50-61	62-74	75-88	>89
55	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-18	19-24	25-31	32-40	41-50	51-62	63-75	76-88	>89
56	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-25	26-32	33-41	42-52	53-64	65-76	77-89	>90
57	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-26	27-34	35-43	44-53	54-65	66-77	78-90	>91
58	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-27	28-35	36-44	45-55	56-66	67-78	79-90	>91
59	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-21	22-28	29-36	37-45	46-56	57-68	69-80	81-91	>92
60	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-22	23-29	30-37	38-47	48-57	58-69	70-81	82-91	>92
61	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-18	19-23	24-30	31-39	40-48	49-59	60-70	71-82	83-92	>93
62	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-25	26-32	33-40	41-50	51-60	61-71	72-82	83-92	>93
63	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-26	27-33	34-42	43-51	52-62	63-73	74-83	84-93	>94
64	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-27	28-34	35-43	44-53	54-63	64-74	75-84	85-93	>94
65	-	<1	1	2	3-4	5-6	7-8	9-12	13-16	17-21	22-28	29-36	37-44	45-54	55-64	65-75	76-85	86-94	>95
66	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-23	24-29	30-37	38-46	47-55	56-66	67-76	77-86	87-94	>95
67	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-18	19-24	25-30	31-38	39-47	48-57	58-67	68-77	78-87	88-95	>96

Table B7

Percentiles for participants without gaming experience. Use when binary gender categorization does not apply.

Age	0-3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
18	-	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-25	26-34	35-45	46-59	60-77	>78
19	-	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-26	27-35	36-46	47-60	61-77	>78
20	-	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-20	21-27	28-36	37-47	48-61	62-78	>79
21	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-7	8-11	12-15	16-20	21-28	29-37	38-48	49-62	63-79	>80
22	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-16	17-21	22-29	30-38	39-49	50-63	64-80	>81
23	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-22	23-30	31-39	40-50	51-64	65-81	>82
24	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-23	24-31	32-40	41-52	53-65	66-82	>83
25	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-24	25-32	33-41	42-53	54-67	68-83	>84
26	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-13	14-18	19-25	26-33	34-42	43-54	55-68	69-83	>84
27	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-26	27-34	35-43	44-55	56-69	70-84	>85
28	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-20	21-27	28-35	36-45	46-56	57-70	71-85	>86
29	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-15	16-21	22-28	29-36	37-46	47-58	59-71	72-86	>87
30	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-22	23-29	30-37	38-47	48-59	60-72	73-86	>87
31	-	-	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-12	13-17	18-23	24-30	31-38	39-48	49-60	61-73	74-87	>88
32	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-23	24-31	32-39	40-50	51-61	62-74	75-88	>89
33	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-18	19-24	25-32	33-41	42-51	52-62	63-75	76-88	>89
34	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-33	34-42	43-52	53-64	65-76	77-89	>90
35	-	-	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-34	35-43	44-53	54-65	66-77	78-89	>90
36	-	-	-	-	<1	1	1-2	2	3-4	5	6-8	9-11	12-16	17-21	22-27	28-35	36-44	45-55	56-66	67-78	79-90	>91
37	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-16	17-22	23-28	29-36	37-46	47-56	57-67	68-79	80-91	>92
38	-	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-17	18-23	24-30	31-38	39-47	48-57	58-68	69-80	81-91	>92

(*continued on next page*)

Table B7 (*continued*)

Age	0-3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
39	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-13	14-18	19-24	25-31	32-39	40-48	49-59	60-70	71-81	82-92	>93
40	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-32	33-40	41-49	50-60	61-71	72-82	83-92	>93
41	-	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-20	21-26	27-33	34-41	42-51	52-61	62-72	73-83	84-93	>94
42	-	-	-	-	<1	1	2	3-4	5	6-8	9-11	12-15	16-21	22-27	28-34	35-43	44-52	53-62	63-73	74-84	85-93	>94
43	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-22	23-28	29-35	36-44	45-53	54-64	65-74	75-84	85-93	>94
44	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-13	14-17	18-22	23-29	30-37	38-45	46-55	56-65	66-75	76-85	86-94	>95
45	-	-	-	<1	1	2	3	4	5-7	8-10	11-13	14-18	19-23	24-30	31-38	39-47	48-56	57-66	67-76	77-86	87-94	>95
46	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-31	32-39	40-48	49-57	58-67	68-77	78-87	88-95	>96
47	-	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-20	21-26	27-33	34-40	41-49	50-59	60-69	70-78	79-88	89-95	>96
48	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-21	22-27	28-34	35-42	43-51	52-60	61-70	71-79	80-88	89-95	>96
49	-	-	-	<1	1	2	3-4	5-6	7-8	9-12	13-16	17-22	23-28	29-35	36-43	44-52	53-61	62-71	72-80	81-89	90-96	>97
50	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-17	18-23	24-29	30-36	37-44	45-53	54-63	64-72	73-81	82-90	91-96	>97
51	-	-	<1	1	1-2	2-3	4	5-7	8-10	11-13	14-18	19-24	25-30	31-38	39-46	47-55	56-64	65-73	74-82	83-90	91-96	>97
52	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-31	32-39	40-47	48-56	57-65	66-75	76-83	84-91	92-96	>97
53	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-33	34-40	41-49	50-58	59-67	68-76	77-84	85-91	92-97	>98
54	-	-	<1	1	2	3	4-5	6-8	9-12	13-16	17-21	22-27	28-34	35-42	43-50	51-59	60-68	69-77	78-85	86-92	93-97	>98
55	-	-	<1	1	2	3-4	5-6	7-9	10-12	13-17	18-22	23-28	29-35	36-43	44-51	52-60	61-69	70-78	79-86	87-92	93-97	>98
56	-	-	<1	1	2	3-4	5-6	7-9	10-13	14-18	19-23	24-29	30-36	37-44	45-53	54-62	63-71	72-79	80-87	88-93	94-97	>98
57	-	<1	1	1-2	2-3	4	5-7	8-10	11-14	15-18	19-24	25-31	32-38	39-46	47-54	55-63	64-72	73-80	81-87	88-93	94-97	>98
58	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-32	33-39	40-47	48-56	57-64	65-73	74-81	82-88	89-94	95-98	>99
59	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-33	34-41	42-49	50-57	58-66	67-74	75-82	83-89	90-94	95-98	>99
60	-	<1	1	2	3	4-6	7-8	9-12	13-16	17-21	22-28	29-34	35-42	43-50	51-59	60-67	68-75	76-83	84-89	90-95	96-98	>99
61	-	<1	1	2	3-4	5-6	7-9	10-13	14-17	18-22	23-29	30-36	37-43	44-52	53-60	61-68	69-76	77-84	85-90	91-95	96-98	>99
62	-	<1	1	2	3-4	5-6	7-9	10-13	14-18	19-24	25-30	31-37	38-45	46-53	54-61	62-70	71-78	79-85	86-91	92-95	96-98	>99
63	-	<1	1	2-3	4	5-7	8-10	11-14	15-19	20-25	26-31	32-38	39-46	47-55	56-63	64-71	72-79	80-86	87-91	92-96	97-98	>99
64	<1	1	1-2	2-3	4-5	6-7	8-11	12-15	16-20	21-26	27-33	34-40	41-48	49-56	57-64	65-72	73-80	81-86	87-92	93-96	97-98	>99
65	<1	1	2	3	4-5	6-8	9-11	12-16	17-21	22-27	28-34	35-41	42-49	50-57	58-66	67-73	74-81	82-87	88-92	93-96	>97	-
66	<1	1	2	3	4-6	7-9	10-12	13-17	18-22	23-28	29-35	36-43	44-51	52-59	60-67	68-75	76-82	83-88	89-93	94-96	>97	-
67	<1	1	2	3-4	5-6	7-9	10-13	14-18	19-23	24-30	31-37	38-44	45-52	53-60	61-68	69-76	77-83	84-89	90-93	94-97	>98	-

Table B8

Percentiles for participants with gaming experience. Use when binary gender categorization does not apply.

Age	0-5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
18	-	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-19	20-28	29-40	41-60	>61
19	-	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-10	11-14	15-20	21-29	30-41	42-61	>62
20	-	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-21	22-29	30-42	43-62	>63
21	-	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-15	16-21	22-30	31-43	44-63	>64
22	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-7	8-11	12-16	17-22	23-31	32-44	45-64	>65
23	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-16	17-23	24-32	33-45	46-65	>66
24	-	-	-	-	-	-	<1	1	1-2	2	3-4	5	6-8	9-12	13-17	18-24	25-33	34-46	47-66	>67
25	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-17	18-24	25-34	35-47	48-67	>68
26	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-18	19-25	26-35	36-48	49-68	>69
27	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-19	20-26	27-36	37-50	51-69	>70
28	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-27	28-37	38-51	52-70	>71
29	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-20	21-28	29-38	39-52	53-71	>72
30	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-15	16-21	22-29	30-39	40-53	54-72	>73
31	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-15	16-21	22-29	30-40	41-54	55-73	>74
32	-	-	-	-	-	<1	1	1-2	2	3-4	5	6-8	9-11	12-16	17-22	23-30	31-41	42-55	56-74	>75
33	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-17	18-23	24-31	32-42	43-56	57-75	>76
34	-	-	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-12	13-17	18-24	25-32	33-43	44-57	58-75	>76
35	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-25	26-33	34-44	45-58	59-76	>77
36	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-26	27-34	35-46	47-60	61-77	>78
37	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-20	21-27	28-35	36-47	48-61	62-78	>79
38	-	-	-	-	<1	1	1-2	2	3	4-5	6-7	8-11	12-15	16-20	21-27	28-36	37-48	49-62	63-79	>80
39	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-15	16-21	22-28	29-38	39-49	50-63	64-80	>81
40	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-22	23-29	30-39	40-50	51-64	65-81	>82
41	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-23	24-30	31-40	41-51	52-65	66-82	>83
42	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-24	25-31	32-41	42-53	54-66	67-82	>83
43	-	-	-	-	<1	1	2	3	4	5-7	8-9	10-13	14-18	19-25	26-32	33-42	43-54	55-67	68-83	>84
44	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-33	34-43	44-55	56-69	70-84	>85
45	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-15	16-20	21-26	27-35	36-44	45-56	57-70	71-85	>86
46	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-15	16-21	22-27	28-36	37-46	47-57	58-71	72-85	>86
47	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-21	22-28	29-37	38-47	48-59	60-72	73-86	>87
48	-	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-22	23-29	30-38	39-48	49-60	61-73	74-87	>88
49	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-17	18-23	24-30	31-39	40-49	50-61	62-74	75-87	>88
50	-	-	-	<1	1	2	3	4	5-7	8-10	11-13	14-18	19-24	25-32	33-40	41-51	52-62	63-75	76-88	>89
51	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-33	34-42	43-52	53-63	64-76	77-89	>90
52	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-34	35-43	44-53	54-65	66-77	78-89	>90
53	-	-	<1	1	1-2	2	3-4	5	6-8	9-11	12-15	16-21	22-27	28-35	36-44	45-54	55-66	67-78	79-90	>91
54	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-22	23-28	29-36	37-45	46-56	57-67	68-79	80-90	>91
55	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-12	13-17	18-23	24-29	30-37	38-47	48-57	58-68	69-80	81-91	>92

(*continued on next page*)

Table B8 (*continued*)

Age	0-5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
56	-	-	<1	1	2	3	4	5-7	8-9	10-13	14-18	19-24	25-30	31-39	40-48	49-58	59-69	70-81	82-91	>92
57	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-32	33-40	41-49	50-60	61-71	72-82	83-92	>93
58	-	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-19	20-26	27-33	34-41	42-50	51-61	62-72	73-82	84-92	>93
59	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-27	28-34	35-42	43-52	53-62	63-73	74-83	84-93	>94
60	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-21	22-28	29-35	36-44	45-53	54-63	64-74	75-84	85-93	>94
61	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-22	23-29	30-36	37-45	46-54	55-65	66-75	76-85	86-94	>95
62	-	<1	1	2	3	4	5-7	8-9	10-13	14-18	19-23	24-30	31-38	39-46	47-56	57-66	67-76	77-86	87-94	>95
63	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-24	25-31	32-39	40-48	49-57	58-67	68-77	78-87	88-95	>96
64	-	<1	1	2	3	4-5	6-7	8-11	12-15	16-19	20-25	26-32	33-40	41-49	50-59	60-68	69-78	79-87	88-95	>96
65	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-33	34-42	43-50	51-60	61-70	71-79	80-88	89-95	>96
66	-	<1	1	2	3-4	5-6	7-8	9-12	13-16	17-21	22-28	29-35	36-43	44-52	53-61	62-71	72-80	81-89	90-95	>96
67	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-17	18-22	23-29	30-36	37-44	45-53	54-63	64-72	73-81	82-89	90-96	>97

Table B9
Percentiles for participants without controlling for gender or gaming experience.

Age	0-4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
18	-	-	-	-	-	-	-	<1	1	1-2	2	3-4	5	6-8	9-12	13-17	18-23	24-32	33-45	46-65	>66
19	-	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-17	18-24	25-33	34-46	47-66	>67
20	-	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-25	26-34	35-48	49-67	>68
21	-	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-26	27-35	36-49	50-68	>69
22	-	-	-	-	-	-	-	<1	1	2	3	4	5-7	8-10	11-14	15-19	20-26	27-36	37-50	51-69	>70
23	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-7	8-10	11-14	15-20	21-27	28-37	38-51	52-70	>71
24	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-7	8-11	12-15	16-21	22-28	29-38	39-52	53-71	>72
25	-	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-15	16-21	22-29	30-39	40-53	54-72	>73
26	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-11	12-16	17-22	23-30	31-40	41-54	55-73	>74
27	-	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-17	18-23	24-31	32-42	43-55	56-74	>75
28	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-17	18-24	25-32	33-43	44-57	58-75	>76
29	-	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-25	26-33	34-44	45-58	59-76	>77
30	-	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-34	35-45	46-59	60-76	>77
31	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-7	8-10	11-14	15-20	21-26	27-35	36-46	47-60	61-77	>78
32	-	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-15	16-20	21-27	28-36	37-47	48-61	62-78	>79
33	-	-	-	-	-	<1	1	1-2	2	3-4	5	6-8	9-11	12-16	17-21	22-28	29-37	38-48	49-62	63-79	>80
34	-	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-22	23-29	30-38	39-50	51-63	64-80	>81
35	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-12	13-17	18-23	24-30	31-39	40-51	52-65	66-81	>82
36	-	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-18	19-24	25-31	32-41	42-52	53-66	67-82	>83
37	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-13	14-18	19-25	26-32	33-42	43-53	54-67	68-83	>84
38	-	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-33	34-43	44-54	55-68	69-83	>84
39	-	-	-	-	<1	1	1-2	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-34	35-44	45-56	57-69	70-84	>85
40	-	-	-	-	<1	1	1-2	2	3-4	5	6-8	9-11	12-15	16-21	22-27	28-36	37-45	46-57	58-70	71-85	>86
41	-	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-22	23-28	29-37	38-47	48-58	59-71	72-86	>87
42	-	-	-	-	<1	1	2	3	4	5-6	7-9	10-12	13-17	18-23	24-29	30-38	39-48	49-59	60-72	73-86	>87
43	-	-	-	-	<1	1	2	3	4	5-7	8-9	10-13	14-18	19-23	24-31	32-39	40-49	50-61	62-73	74-87	>88
44	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-18	19-24	25-32	33-40	41-50	51-62	63-75	76-88	>89
45	-	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-33	34-41	42-52	53-63	64-76	77-88	>89
46	-	-	-	<1	1	1-2	2	3-4	5	6-8	9-11	12-15	16-20	21-26	27-34	35-43	44-53	54-64	65-77	78-89	>90
47	-	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-21	22-27	28-35	36-44	45-54	55-66	67-78	79-90	>91
48	-	-	-	<1	1	1-2	2-3	4	5-6	7-9	10-12	13-17	18-22	23-28	29-36	37-45	46-56	57-67	68-79	80-90	>91
49	-	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-17	18-23	24-30	31-37	38-47	48-57	58-68	69-80	81-91	>92
50	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-18	19-24	25-31	32-39	40-48	49-58	59-69	70-80	81-91	>92
51	-	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-32	33-40	41-49	50-59	60-70	71-81	82-92	>93
52	-	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-33	34-41	42-51	52-61	62-71	72-82	83-92	>93
53	-	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-21	22-27	28-34	35-43	44-52	53-62	63-73	74-83	84-93	>94
54	-	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-22	23-28	29-35	36-44	45-53	54-63	64-74	75-84	85-93	>94
55	-	-	<1	1	2	3	4	5-6	7-9	10-13	14-17	18-23	24-29	30-37	38-45	46-55	56-65	66-75	76-85	86-94	>95
56	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-18	19-24	25-30	31-38	39-47	48-56	57-66	67-76	77-86	87-94	>95
57	-	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-25	26-32	33-39	40-48	49-57	58-67	68-77	78-86	87-94	>95
58	-	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-33	34-41	42-49	50-59	60-68	69-78	79-87	88-95	>96
59	-	<1	1	1-2	2	3-4	5-6	7-8	9-12	13-16	17-21	22-27	28-34	35-42	43-51	52-60	61-70	71-79	80-88	89-95	>96
60	-	<1	1	1-2	2	3-4	5-6	7-9	10-12	13-17	18-22	23-28	29-35	36-43	44-52	53-61	62-71	72-80	81-89	90-95	>96
61	-	<1	1	2	3	4	5-7	8-9	10-13	14-18	19-23	24-29	30-37	38-45	46-53	54-63	64-72	73-81	82-89	90-96	>97
62	-	<1	1	2	3	4-5	6-7	8-10	11-14	15-19	20-24	25-31	32-38	39-46	47-55	56-64	65-73	74-82	83-90	91-96	>97
63	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-19	20-25	26-32	33-39	40-47	48-56	57-65	66-74	75-83	84-90	91-96	>97
64	-	<1	1	2	3	4-5	6-8	9-11	12-15	16-20	21-26	27-33	34-41	42-49	50-58	59-67	68-76	77-84	85-91	92-96	>97
65	-	<1	1	2	3-4	5-6	7-9	10-12	13-16	17-21	22-27	28-34	35-42	43-50	51-59	60-68	69-77	78-85	86-92	93-97	>98
66	<1	1	1-2	2	3-4	5-6	7-9	10-13	14-17	18-22	23-29	30-36	37-43	44-52	53-60	61-69	70-78	79-86	87-92	93-97	>98
67	<1	1	1-2	2-3	4	5-7	8-10	11-14	15-18	19-24	25-30	31-37	38-45	46-53	54-62	63-71	72-79	80-86	87-93	94-97	>98

Data availability

All materials and data related to this work are available at the Open Science Framework (osf.io/4h65p/) and via app.gorilla.sc/open-materials/918995.

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