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ARTICLE

Risk-taking propensity and its influence on lexical decision performance: a comparative study of high- and low-risk groups

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Abstract
We examined the impact of risk-taking propensity on lexical decision performance in neurologically intact participants. Following the classification of participants into high- and low-risk-taking propensity groups using the Balloon Analogue Risk Task, we assessed lexical decision-making with behavioral responses (RTs, ACC), signal detection measures (hit, false alarm, miss, correct rejection) and qualitative processing using lexical variable effects (number of syllables, first syllable frequency, stem frequency, word frequency) between the groups. As a result, high-risk-taking individuals showed slower and less accurate word recognition, characterized by biased responses toward nonwords and words. However, both groups displayed similar patterns of lexical variable effects in word recognition, suggesting risk-taking propensity does not contribute to qualitative disparities in visual word recognition. These findings highlight the influential role of risk-taking propensity in shaping behavioral performance during lexical decision, emphasizing the need for further exploration of the intricate interplay between risk-taking behavior and lexical decision-making processes.

Keywords: lexical decision; response bias; risk-taking propensity; signal detection theory; visual word recognition

1. Introduction

Risk-taking plays a fundamental role in the decision-making process when faced with situations that encompass uncertainty and unknown probabilities of outcomes, including rewards and negative consequences. Previous studies have established a strong association between risk-taking propensity and reading disorder (RD) (e.g., Maniadaki & Kakouros, 2011; Shelley-Tremblay et al., 2007). Such association suggests that individuals with an elevated inclination toward risk-taking may exhibit diminished lexical access capabilities, a conjectured grounded in the observation that RD often manifests as a salient trait within the broader spectrum of risk-oriented behaviors. This diminished lexical prowess is attributed to the propensity of high-risk individuals to allocate lesser attention to meticulous language processing tasks, such as lexical decision tasks (LDTs), a tendency further compounded by their susceptibility to extraneous stimuli and engaging activities (de-Juan-Ripoll et al., 2021). Furthermore, this demographic is posited to demonstrate a preference for efficient yet error-prone lexical decisions, a byproduct of inherent impulsivity (Elsey et al., 2016). Simultaneously, there is a noticeable shift toward holistic or integrative processing methods rather than analytical approaches, making it particularly challenging to distinguish between lexically valid and invalid constructs during LDTs (Humphreys et al., 2013). Despite these insights, the complex relationship between risk-taking propensity and lexical access proficiency remains unclear, warranting further investigation into the potential impacts of risk-oriented tendencies on lexical access capabilities.

To advance our comprehension of RD in individuals with a high propensity for risk-taking, it is essential to first scrutinize the influence of this risk orientation on isolated word recognition. This investigation serves as a crucial foundation for a deeper understanding of word processing during natural reading in such individuals. In natural reading, the adjacent words of the fixated word significantly affect the fixated-word processing (e.g., Schotter et al., 2012), which ultimately hinders identifying the effects of risk-taking. Instead, isolated-word studies, such as using the LDT can eliminate the possible confounding effects from adjacent words around a fixated word, enabling to evaluate the effect of risk-taking on visual word processing. Given that the LDT requires participants to judge the validity of visually presented letter strings as words or nonwords, risk-taking propensity may influence the establishment of decision criteria in the lexical decision process (Wagenmakers et al., 2008). Moreover, both the LDT and eye-tracking natural reading tasks have demonstrated consistent findings concerning the influence of lexical variables, including word frequency (Dirix et al., 2019; Rayner & Duffy, 1986; Rubenstein et al., 1970), and word length (Hudson & Bergman, 1985; Vitu et al., 1990). These findings imply a shared aspect of word processing, such as lexical access, between the LDT and reading tasks. Thus, the parallel effects of the lexical variables observed in these tasks indicate that the LDT serves as a credible indirect method for investigating the relationship between reading proficiency and propensity for risk-taking, given our focus on exploring the qualitative dimension of word processing. This assertion is particularly relevant given our study's focus on examining how individual propensities for risk-taking influence lexical variables. We expected that risk-taking propensity might affect fixated lexical decision-making, potentially leading to reading difficulties. Thus, the aim of the current study was to investigate the impact of risk-taking propensity on lexical decision-making in the general population using the LDT. By examining the effects of risk-taking on lexical decision-making in individuals without diagnosed reading disabilities, we sought to minimize confounding factors related to medical conditions and clarify the pure relationship between lexical decision-making and risk-taking propensity.

In contexts where participants engage in lexical decision-making with arbitrary letter strings, individuals with a high-risk-taking propensity are anticipated to exhibit biased responses, showing a preference for either words over nonwords or vice versa, due to their inherent risk-taking tendencies. Conversely, individuals with a low-risk-taking propensity are expected to adopt more conservative decision criteria, leading to less biased lexical decisions compared to their risk-taking counterparts. This biased visual letter recognition might disrupt the formation of coherent lexical word representations.

To our knowledge, no previous studies have directly examined the specific subject matter addressed in this study. However, insights can be gleaned from research focusing on adolescents, as this developmental period is characterized by increasing challenges and susceptibilities to engaging in risky behaviors, including drug use, sexual activity, antisocial behavior and delinquency (e.g., Cosden, 2001; McNamara et al., 2008; McNamara & Willoughby, 2010; Poon & Ho, 2016). For instance, McNamara and Willoughby (2010) conducted a longitudinal study examining risk-taking behavior among adolescents with learning disabilities (LDs), including RD. Their findings indicated that, relative to their non-learning disabled counterparts, adolescents with LDs exhibited a higher frequency of certain risk-taking behaviors, including smoking, marijuana use, acts of delinquency, acts of aggression and gambling. These results imply that the trajectory of engagement in specific risk-taking behaviors may differ between adolescents with and without LDs. Moreover, McNamara et al. (2008) investigated the relationship between risk-taking behavior and the presence of LD, including RD, or attention–deficit/hyperactivity disorder (ADHD) in adolescents. By comparing the risk-taking behavior of adolescents with LD, those with comorbid LD/ADHD, and those without LD or ADHD, they revealed that adolescents with LD and comorbid LD/ADHD exhibited significantly greater engagement in risky behaviors compared to the other experimental groups. This suggests that adolescents with LD and comorbid LD/ADHD may necessitate additional support when making decisions pertaining to risk-taking behaviors. Furthermore, Poon and Ho (2016) employed the Balloon Analogue Risk Task (BART) to assess risk-taking propensity, sensitivity to punishment and delinquency outcomes in adolescents displaying symptoms of ADHD and/or RD. Although they did not find a difference in risk-taking scores on the BART between adolescents with RD and healthy controls, the group of adolescents with RD displayed a sixfold larger standard deviation in the BART score compared to the control group (healthy control = 16.14, RD = 111.77, see Table 3 in Poon & Ho, 2016). This finding raises doubts about the presence of a distinction between the two experimental groups. Based on these considerations, the present study aimed to investigate the impact of risk-taking propensity on lexical decision performance in a nonclinical population without medical conditions.

1.1. The current study

In exploring the relationship between propensity for risk-taking and performance in LDTs, we utilized the BART as a robust measure of risk-taking tendencies (Lejuez et al., 2002). Participants were divided into two distinct groups based on the median split of risk-taking scores obtained from the BART, distinguishing between high- and low-risk-taking behaviors for the purposes of this study. Subsequently, we applied the established LDT to ascertain variations in lexical processing across the delineated cohorts. Our investigation encompassed three main objectives. First, we sought to establish the influence of risk-taking propensity by scrutinizing behavioral responses through the comparison of response times (RTs) and accuracy (ACC) in the LDT. Second, individuals prone to high-risk behavior show distinct patterns in the task, especially when faced with orthographically valid nonwords, making the differentiation between words and nonwords more challenging (Kim & Nam, 2023b; Ratcliff et al., 2004). This difficulty arises from their tendency toward risk-prone decision-making in the LDT context. To assess this behavior, the current study uses signal detection measures, which are effective in evaluating response bias in LDTs. Signal detection theory identifies four types of responses: hits, misses, false alarms and correct rejections. The study particularly focuses on the rates of misses (errors in word recognition) and false alarms (errors in nonword recognition), providing insights into the error patterns in LDT performance among high-risk individuals. If risk-taking behavior indeed impacts lexical decision-making, we anticipated that the two experimental groups would display distinct patterns of miss and false alarm rates. Specifically, the high-risk-taking group was expected to demonstrate higher miss and false alarm rates compared to the low-risk-taking group, given their propensity for engaging in risky behavior during decision-making scenarios, including LDTs. Furthermore, the risk-taking behavior may have implications for lexical decision performance, potentially resulting in diminished ACC manifested through heightened error rates in both word and nonword responses. These increased error rates may be attributed to impulsive decision-making tendencies. Moreover, we might expect longer reaction times in this context, reflecting a deliberate strategy to mitigate perceived risks in the decision-making process, especially within LDTs. This contrasts with the rapid responses typically observed in tasks involving potential risks or rewards, particularly in financial, social, or personal contexts. However, we expected that risk-taking behavior, which leads to the manifestation of risky decision-making, would not influence the foundational aspects of lexical processing. This supposition stems from the understanding that the decision-making phase transpires in the latter stages of cognitive processes subsequent to lexical processing in the domain of visual word recognition. Lexical processing fundamentally involves the recognition of words and nonwords based on their visual or phonological attributes, representing an initial stage of word recognition. In contrast, risky decision-making is a complex cognitive process that entails evaluating potential risks and rewards and making decisions based on those evaluations. Therefore, it is plausible that the complexities of risky decision-making emerge in the later stages of cognitive processing, distinctly following the lexical processing of visual words within the framework of lexical decision-making. In light of this understanding, our expectations were oriented toward the anticipation that risk-taking behavior would exert a discernible impact on signal detection metrics (encompassing hits, misses, false alarms and correct rejections) and behavioral responses (comprising RTs and ACC). Simultaneously, it was envisaged that the influence of lexical variables on RTs would remain largely unaffected by the presence of risk-taking behavior.

Third, we aimed to explore the qualitative aspects of lexical processing by analyzing the linear correlation between RTs and various lexical variables. This analysis was conducted by employing sublexical and lexical variables, including word frequency (e.g., Kim et al., 2020; Monsell et al., 1989), stem frequency (e.g., Giraudo & Grainger, 2000; Kim et al., 2020), first syllable frequency (e.g., Kim et al., 2023; Kwon et al., 2023; Lee et al., 2023; Perea & Carreiras, 1998) and the number of syllables (e.g., Chetail, 2014; Kim et al., 2022). These sublexical and lexical variables are of central importance in studies involving LDTs. These variables could be instrumental in

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probing the potential associations between lexical variable effects and cognitive capacities, including behavioral suppression abilities assessed through the BART in the current study. This approach aligns with prior research exploring the intricate relationship between lexical variable effects and cognitive functions, particularly emphasizing the prominent role of attention in LDTs (Kim et al., 2023). Consequently, we divided the study's purpose into two distinct aims, recognizing the potential for differing qualitative information processing despite identical quantitative behavioral responses. For example, consider a theoretical scenario with two experimental conditions, both reporting RTs of approximately 600 ms. Although these conditions exhibit comparable behavioral responses, variations in accompanying lexical variables may lead to divergent qualitative lexical processing. This distinction in qualitative processing is significant, occurring despite the similarity in quantitative aspects, with both conditions showing RTs around 600 ms.

The present study proposed several hypotheses. First, it was hypothesized that the high-risk-taking group would display more biased responses, manifesting as a tendency to classify nonwords as words and vice versa. This bias was predicted to result in higher false alarm and miss rates for the high-risk-taking group. Second, it was hypothesized that the high-risk-taking group would demonstrate poorer performance in LDTs compared to the low-risk-taking group due to risk-taking propensity, showing slower RTs and lower ACC for both words and nonwords in the high-risk-taking group. Finally, it was hypothesized that there would be no significant difference in qualitative lexical processing between the two experimental groups. It was reasoned that risky behavior, in the context of LDTs, would have limited influence on the mechanisms underlying lexical processing. Thus, both the high- and low-risk-taking groups were expected to exhibit similar patterns of lexical effects.

2. Methods

2.1. Participants

A total of 51 native Korean speakers were recruited, consisting of 22 males and 29 females ranging in age from 19 to 25 years (M = 21.86, SD = 1.61). None of the participant data was excluded, as all individuals successfully completed the experimental protocol without any complications. All participants had normal or corrected-to-normal vision in both eyes, and individuals with documented neurological impairments resulting from brain injury or stroke were excluded from the study. Furthermore, all participants attested to a medical history devoid of RDs, and they provided informed consent before engaging in the study.

2.2. Experimental tasks

2.2.1. Balloon Analogue Risk Task

The current task examines individuals' capacity for behavioral suppression, employing a task developed within a theoretical framework that considers the delicate equilibrium between potential risks and benefits in hazardous situations (Lejuez et al., 2002). Previous studies have established a significant correlation between this task and self-reported measures of addictive, health and safety risk behaviors, underscoring its efficacy in capturing proclivities for risk-taking. Notably, these investigations have indicated a negative association between behavioral suppression ability and risk-taking tendencies, implying that a higher aptitude for behavioral suppression corresponds to a reduced inclination for risk-taking.

At the onset of the experimental session, participants are provided with detailed instructions, followed by the display of a central balloon on the screen. Positioned beneath the balloon are two buttons: a 'push' button, serving to inflate the balloon and a 'stop' button, depositing coins and facilitating balloon's reset. By pressing the 'stop' button prior to balloon rupture, participants accrue monetary rewards proportionate to the size of the balloon, with the accumulated sum prominently exhibited on the right side of the screen. Each depression of the 'push' button incrementally enlarges the balloon by approximately 1° (0.125 in or 0.3 cm), concurrently accumulating 0.5 coins for yellow balloons, 1 coin for blue balloons and 5 coins for red balloons in a provisional reserve. However, if the balloon bursts, the funds in the temporary reserve are forfeited. Participants must judiciously press the 'stop' button before balloon explosion, signaled by an auditory 'pop', to secure the accrued earnings. Although participants retain agency to cease balloon inflation and press the 'stop' button at their discretion, it is crucial to note that each colored balloon (red, blue and yellow) carries a distinct burst probability. Consequently, this task serves to evaluate individuals' behavioral suppression ability in regulating the risk–benefit equilibrium without explicit knowledge of burst probabilities. Operationally, this ability is quantified through the calculation of the total number of clicks in all trials, the average number of clicks in successful trials, the average number of clicks in all trials, success rate and total score. For example, in the context of total score assessment, it is evident that individuals with a propensity for high-risk-taking behavior may exhibit a notably elevated mean count of clicks in successful trials as compared to their counterparts characterized by a propensity for low-risk-taking behavior. This disparity can be attributed to the fact that a heightened inclination toward risk-taking compels individuals to engage in a greater number of clicking actions, in contrast to individuals with lower risk-taking tendencies. Consequently, this heightened activity among high-risk-taking individuals may lead to a diminished rate of success in their endeavors, as opposed to their low-risk-taking counterparts.

2.2.2. Lexical decision task

Participants were engaged in the LDT that involved the evaluation of orthographically legal pseudowords. During the task, a fixation point was presented at the center of the screen for a duration of 400–600 ms, followed by the appearance of arbitrary letter strings in the central vision for 1200 ms. Subsequently, after the disappearance of the letter strings, participants were instructed to determine, within a time window of 900 ms, whether the presented stimuli constituted a real word or not. To provide their responses, participants utilized a keyboard positioned in front of the monitor, using the index finger of their right hand to press the '/' key for word responses and the index finger of their left hand to press the 'z' key for pseudoword responses. The stimuli themselves were presented in white letters against a gray background.

A total of 406 Korean visual words and 406 pseudowords were utilized in the task. The selection of word stimuli encompassed diverse sources, consisting of movies (10%), newspapers (20%), books (30%) and internet blogs or posts (40%), while adhering to the Korean Sejong Corpus (Kang & Kim, 2009) as a point of reference. The pseudowords employed in the study were designed to be orthographically legal and pronounceable, generated by random combinations of syllables derived from

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existing Korean words (Kim et al., 2023; Kim et al., 2024a, 2024b; Kim & Nam, 2023a, 2023b).

The present study employed four critical lexical variables to investigate sublexical and lexical processing in the context of LDTs (Kim et al., 2022, 2023). These variables encompassed word frequency, stem frequency, first syllable frequency and the number of syllables. All frequency variables were calculated using data from the Korean Sejong Corpus (Kang & Kim, 2009). However, acknowledging the presence of pronounced skewness and extended right-tail distributions in the frequency variables, we applied logarithmic transformations to mitigate the potential adverse influences of outliers during the statistical analyses (Sedgwick, 2012). With regard to first syllable frequency, the evaluation considered the token syllable frequency of the first syllable. It offers a more advantageous indicator for exploring the influence originating from activated candidates, taking into account the frequency of each activated candidate (Conrad et al., 2008; Kim et al., 2023; Kwon et al., 2023; Lee et al., 2023). This approach presents an advantage over type syllable frequency, which merely tallies the number of distinct types among the activated candidates (Lee et al., 2023). These four pivotal lexical variables played a central role in visual recognition studies employing the LDT, and they were integrated into the statistical analyses using linear mixed-effect regressions to assess RTs. A comprehensive description of these lexical attributes is available in Table 1.

2.3. Signal detection theory

In signal detection theory, the establishment of a yes/no decision in signal detection involves four response options: two on signal trials and two on noise trials (Stanislaw & Todorov, 1999). Signal trials encompass the hit and miss rates, where the hit rate reflects the probability of responding yes to signal trials (Correct answer YES/Actual answer YES), while the miss rate pertains to the probability of responding no to yes trials (Correct answer YES/Actual answer NO). Conversely, noise trials comprise the correct rejection rate and false alarm rate, with the correct rejection rate denoting the probability of responding no to noise trials (Correct answer NO/Actual answer NO), and the false alarm rate representing the probability of responding yes to noise trials (Correct answer NO/Actual answer YES). Signal detection theory incorporates two essential factors based on these response options. The first factor, sensitivity, gauges the extent of overlap between the signal and noise distributions (Stanislaw & Todorov, 1999), thereby providing insights into the observer's ability to detect the signal. Heightened sensitivity in signal detection signifies an enhanced capacity to discriminate between the signal and noise. The second factor, response bias, assesses the observer's general inclination toward 'yes' or 'no' responses. The magnitude of the

Table 1. Descriptive statistics of four lexical variables, including word frequency, stem frequency, first syllable frequency and number of syllables

Lexical variable	Range	Average	Standard deviation	*N*
Number of syllables	3–4	3.5	.50	406
First syllable frequency (token)	347–503016	59315	75378	406
Stem frequency	1–23776	2600	4038	406
Word frequency	1–5303	288	525	406

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response bias is determined by the absolute value, with positive and negative values indicating 'yes' and 'no' response biases, respectively. The strength of the bias increases as the value approaches a larger positive or negative magnitude. The response bias offers valuable information about the criteria employed by the observer to make decisions in yes/no tasks, often based on their experience or inherent attributes related to the decision-making process. In the context of lexical decision, for example, observers utilize their lexical knowledge or experience to ascertain whether an arbitrary letter string constitutes a lexical item or not.

Thus, risk-taking behavior can manifest in LDTs, where participants are presented with visual stimuli and are required to make decisions. For instance, individuals with a propensity for high-risk behavior are expected to manifest heightened effects, particularly when confronted with orthographically valid nonwords within the LDT since the task difficulty in lexical decision increases (Kim & Nam, 2023a, 2023b; Ratcliff et al., 2004). More specifically, it renders the differentiation between nonwords and words challenging for high-risk takers, as they tend to exhibit a predisposition for risk-prone decision-making within the context of the LDT. Thus, we conducted an evaluation of risk-taking behavior within the context of LDTs by employing signal detection measures, a method well-suited for the assessment of response bias. Signal detection theory encompasses four possible response options: hit, miss, false alarm and correct rejection. Our focus lays on the miss and false alarm rates, where the miss rate represents error rates in word recognition, while the false alarm rate pertains to error rates in nonword recognition during the LDT.

3. Results

The present study is structured into two primary sections to examine the results. The first section delineates the classification of participants into two distinct experimental cohorts, grounded on their risk-taking propensities. This categorization was based on their performance in a behavior suppression ability assessment (Kim, Koo, & Nam, 2022), conducted using the BART. The second section delves into the evaluation of lexical decision-making in these groups, employing the tripartite analytical approach. The objective of this multifaceted analysis was to examine the complex cognitive mechanisms that underlie the interrelation between risk-taking tendencies and lexical decision processes. By contrasting the behavioral patterns manifested by the groups with high- and low-risk-taking groups, the current study aimed to shed light on the cognitive dynamics at the intersection of risk-taking and lexical decision-making. The details of this analysis are presented as follows.

3.1. Categorization of participants into two experimental groups based on their propensity for risk-taking

Data were collected encompassing various metrics in the BART, including the total number of clicks in all trials, the average number of clicks in successful trials, the average number of clicks in all trials, success rate and total score. Participants were classified into two distinct groups based on their behavioral suppression abilities, assessed using behavioral indicators from the BART: high-risk-taking group (individuals with low behavioral suppression ability) (N = 26) and the low-risk-

Table 2. The measures employed in the BART for the two experimental groups, accompanied by bracketed values indicating the standard deviation

	Number of clicks in total trials	Average number of clicks in success trials	Average number of clicks in total trials	Success rate (%)	Total score
High-risk-taking group	1332 (200)	53 (11)	44 (7)	60 (12)	926 (155)
Low-risk-taking group	588 (226)	21 (9)	20 (8)	81 (10)	497 (175)

taking group (individuals with high behavioral suppression ability) (N = 25). Dichotomization was performed using the median value of the average number of clicks in successful trials (Kim et al., 2022). A comparative analysis conducted between the two experimental groups uncovered significant discrepancies across various parameters (average clicks in successful trials, total clicks, average clicks in all trials, success rate and total score) through the utilization of one-way analysis of variance. Specifically, noteworthy distinctions were observed in the number of clicks in total trials ($F(1, 49) = 155.139$, $p < .001$, $\eta^2 = .760$), the average number of clicks in successful trials ($F(1, 49) = 126.844$, $p < .001$, $\eta^2 = .721$), the average number of clicks in all trials ($F(1, 49) = 154.699$, $p < .001$, $\eta^2 = .759$), the success rate ($F(1, 49) = 47.435$, $p < .001$, $\eta^2 = .492$) and the total score ($F(1, 49) = 86.027$, $p < .001$, $\eta^2 = .637$). Detailed results and statistical comparisons between the experimental groups are provided in Table 2.

3.2. Assessment of lexical decision-making within the two experimental groups

Data pertaining to RTs and ACC in the LDT were gathered. Importantly, all participants' RTs for words and nonwords in the two experimental groups fell within three standard deviations, thereby obviating the need for any data exclusions during the final analysis. It is worth noting that no log-transformation was applied to the RT data for words and nonwords in the two experimental groups, as the normality assumption was met according to the results of the Shapiro–Wilk test.

We examined lexical decision-making processes in each group. This involved analyzing response behaviors in the LDT to determine if there were significant differences in RTs and ACC for words and nonwords, along with signal detection measures (hits, false alarms, misses, correct rejections), and effects of lexical variables, thus investigating the influence of risk-taking propensity on lexical decision performance.

3.2.1. Behavioral responses in RTs and ACC

Comprehensive behavioral responses, encompassing RTs and ACC, across the various experimental conditions are presented in Table 3, accompanied by a visually informative Figure 1.

The initial analysis centered on RTs and employed linear mixed-effect model using the lmer function in R (R Core Team, 2012) (Table 4). The model integrated fixed effects for lexicality (word vs. nonword), group (high vs. low risk-taking) and their interaction (lexicality × group), alongside random intercepts to accommodate variability across participants and items. Results revealed significant main effects of

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Table 3. Subject-based mean RTs and ACC of the two experimental groups in the LDT, accompanied by bracketed values denoting the standard deviation

	Words		Nonwords	
	RTs (ms)	ACC	RTs (ms)	ACC
High-risk-taking group	528 (69)	.919 (.077)	559 (74)	.928 (.084)
Low-risk-taking group	508 (51)	.942 (.032)	536 (49)	.953 (.062)

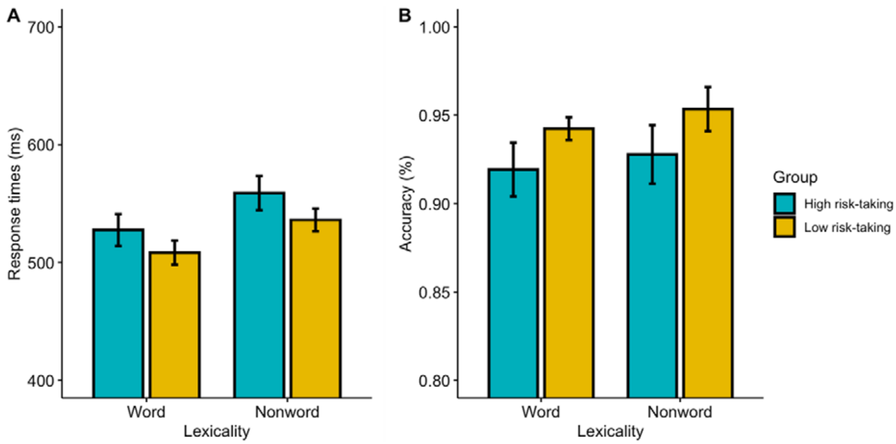

Figure 1. Illustration of subject-based mean RTs and ACC observed in the LDT for the two distinct experimental groups. The bars in the graph are accompanied by lines indicating the standard errors, providing a visual representation of the variability associated with the measurements.

Table 4. Results of linear mixed-effects regressions in RTs (*** p < .001)

		Estimate	Standard error	Degrees of freedom	*t*-value	Pr(>|t|)
RTs	(Intercept)	.553	.009	26.35	56.314	<.001***
	Lexicality	−.015	.001	750.21	−15.550	<.001***
	Group	.010	.001	37841.28	17.794	<.001***
	Lexicality × group	−.001	.001	37830.06	−2.102	.036*

lexicality ($\beta = -.015$, $SE = .001$, $t = -15.550$, $p < .001$) and group ($\beta = .010$, $SE = .001$, $t = 17.794$, $p < .001$). Notably, an interaction effect between lexicality and group was also observed ($\beta = -.001$, $SE = .001$, $t = -2.102$, $p = .036$). The significant main effect of lexicality indicated faster RTs for words compared to nonwords. Additionally, the significant main effect of group suggested that the low-risk-taking group exhibited faster RTs in LDTs than the high-risk-taking group. Moreover, the interaction effect between lexicality and group indicated that the low-risk-taking group responded more quickly to both words ($\beta = .009$, $SE = .001$, $t = 10.890$, $p < .001$) and nonwords ($\beta = .011$, $SE = .001$, $t = 14.370$, $p < .001$) than the high-risk-taking group.

Following this, ACC was examined using generalized linear mixed-effect model (the glmer function in R; R Core Team, 2012) (Table 5). The model included fixed

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Table 5. Results of generalized linear mixed-effects regressions in ACC (*** p < .001)

		Estimate	Standard error	*z*-value	Pr(>|z|)
ACC	(Intercept)	2.999	.110	27.354	<.001***
	Lexicality	−.081	.031	−2.598	.009
	Group	−.208	.020	−10.156	<.001***
	Lexicality × group	.031	.020	1.516	.130

effects for lexicality (word vs. nonword), group (high vs. low risk-taking) and their interaction (lexicality × group), alongside random intercepts to address variability across participants and items. The results demonstrated significant main effects of lexicality ($\beta = -.081$, $SE = .031$, $z = -2.598$, $p = .009$) and group ($\beta = -.208$, $SE = .020$, $z = -10.156$, $p < .001$). However, the interaction effect between lexicality and group was not statistically significant. The significant main effect of lexicality indicated higher ACC for nonwords compared to words. Furthermore, the significant main effect of group suggested that the low-risk-taking group exhibited higher ACC in LDTs than the high-risk-taking group.

3.2.2. Signal detection measures

Responses to words (hits and misses) and nonwords (false alarms and correct rejections) were independently analyzed using the generalized linear mixed-effect model. Separate generalized linear mixed-effect regressions for word and nonword responses were conducted to probe the influence of group dynamics on lexical decision biases. Each model included a fixed effect for the group (high vs. low risk-taking) and random intercepts to accommodate participant and item variability.

Initially, we utilized generalized linear mixed-effect regression analyses to investigate the impact of group dynamics on word responses, which are binary. This examination encompassed the evaluation of the hit and miss rates, providing a comprehensive assessment of the signal detection associated with word processing. The results yielded a significant main effect of group ($\beta = -.168$, $SE = .028$, $z = -6.022$, $p < .001$). This finding indicated a lower hit rate and higher miss rate in the high-risk-taking group compared to the low-risk-taking group.

Following this, we conducted generalized linear mixed-effect regression analyses on binary responses related to nonwords in order to scrutinize the impact of group dynamics on nonword processing. This analysis comprehensively encompassed the assessment of both false alarm and correct rejection rates, thereby providing a thorough evaluation of the signal detection mechanisms associated with nonword stimuli. The results unveiled a significant main effect of group ($\beta = -.250$, $SE = .030$, $z = -8.307$, $p < .001$). This observation suggested a lower correct rejection rate and higher false alarm rate in the high-risk-taking group in contrast to the low-risk-taking group.

Detailed signal detection measures obtained from the lexical decisions are presented in Tables 6 and 7, and a visual representation can be found in Figure 2. These outcomes provide valuable insights into the effects of risk-taking propensity on the discernment of signals and noise during lexical processing.

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Table 6. Subject-based mean signal detection measures assessed in the two experimental groups during the LDT, accompanied by bracket values indicating the standard deviation

	Signal detection measures			
	Hit rate	Miss rate	False alarm rate	Correct rejection rate
High-risk-taking group	.919 (.077)	.081 (.077)	.072 (.084)	.928 (.084)
Low-risk-taking group	.942 (.032)	.058 (.032)	.047 (.062)	.953 (.062)

Table 7. Results of generalized mixed-effects regressions in responses for words (hit/miss) and for nonwords (false alarm/correct rejection) (*** p < .001)

		Estimate	Standard error	*z*-value	Pr(>|z|)
Hit/miss	(Intercept)	2.908	.108	27.046	<.001***
	Group	−.168	.028	−6.022	<.001***
False alarm/correct rejection	(Intercept)	3.146	.142	22.085	<.001***
	Group	−.250	.030	−8.307	<.001***

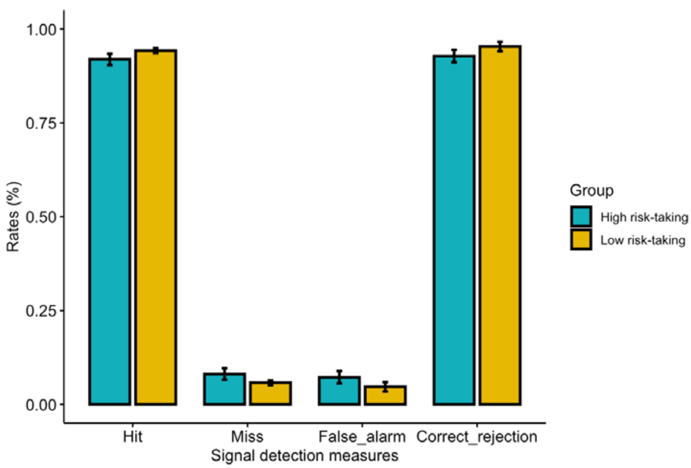

Figure 2. Subject-based mean signal detection measures obtained from the LDT for the two experimental groups. This figure displays the hit rates, which represent the rates of correct lexical decision for words as words, the miss rates, which correspond to the rates of incorrect lexical decision for words as nonwords, the false alarm rates, indicating the rates of incorrect lexical decision for nonwords as words, and the correct rejection rates, reflecting the rates of correct lexical decision for nonwords. The bars in the graph are accompanied by lines indicating the standard errors, serving to illustrate the magnitude of uncertainty associated with the measurements.

3.2.3. The effect of lexical variables in lexical decisions for words

Employing the linear mixed-effect model, we investigated RTs to explore the influence of lexical variables on word processing within the context of high- and low-risk-taking cohorts (Lee et al., 2023). This investigation aimed to untangle the qualitative lexical processing patterns across the cohorts. The final model integrated fixed effects for lexical variables, including the number of syllables, first syllable frequency, stem frequency, word frequency, group (high vs. low risk-taking) and all two-way interaction terms between lexical variables and group (e.g., number of syllable × group,

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first syllable frequency × group). Based on Kim et al. (2020), the analysis underscored the pivotal role of word frequency, number of syllable, first syllable frequency and stem frequency in word recognition, although subjective familiarity and number of strokes were later excluded due to their overlapping nature with frequency and length variables, respectively. Moreover, all group fixed-effect variables within the models were coded to ensure centricity and orthogonality. The model's random intercept effects, representing the inherent variability tied to subjects and items,[1] further enhanced the robustness of our analysis. By incorporating fixed and random effects, our models provide a comprehensive framework for probing the association between risk-taking propensity and lexical decision performance. Furthermore, likelihood ratio tests were conducted to derive *p*-value for the influence of all interaction terms involving the group variable, achieved by comparing the final model against a model devoid of these group interaction terms.

As a result, significant effects were observed for stem frequency ($\beta = -.002$, $SE = .001$, $t = -2.473$, $p = .014$) and word frequency ($\beta = -.006$, $SE = .001$, $t = -8.236$, $p < .001$), while the number of syllables, first syllable frequency, group, the number of syllables × group, first syllable frequency × group, stem frequency × group and word frequency × group exhibited nonsignificant effects. The observed significance of stem frequency suggests that words with higher stem frequency elicited swifter responses, while the significant influence of word frequency points to faster responses for words with elevated word frequency.

Moreover, we incorporated an examination to assess the interpretability of the nonsignificant interaction effects observed in the final model. This was achieved by comparing the final model with an alternative model, devoid of all interaction terms associated with the group. The comparative analysis revealed an absence of significant divergence between the two models ($\chi^2(4) = 2.297$, $p = .681$). This outcome suggests that the interactions involving the group did not reach statistical significance, indicating that the experimental groups did not exhibit significant differences in the effects of lexical variables. This finding aligns with our hypothesis, which posited no significant difference in qualitative lexical processing between the two experimental groups. Consequently, it lends credence to the reliability of the interpretations derived from the final model. Detailed results of these findings, as determined through linear mixed-effect analyses, are presented in Table 8.

4. Discussion

The primary objective of the current study was to examine the influence of risk-taking propensity on behavioral performance in LDTs. Participants were divided into two groups based on their risk-taking propensities as assessed by the BART: a high-risk-taking group and a low-risk-taking group. A detailed analysis was then conducted, focusing on behavioral measures (RTs and ACC) for both words and nonwords and signal detection measures (hit rates, false alarms, miss rates, correct rejections) in the LDTs. Additionally, the study explored the qualitative aspects of

[1]The inclusion of random by-participant and by-item slopes was abstained from due to the observation of a singular fit error during the analysis (Bates et al., 2015; Bolker et al., 2013). This singular fit error serves as an indicator of the model's incompatibility with the dataset, thereby engendering challenges in elucidating the import of the fixed-effect variables.

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Table 8. Results of lexical variables effect on RTs using linear mixed-effect regression analyses (* p < .05, ** p < .01, *** p < .001)

	Estimate	Standard error	Degrees of freedom	*t*-value	Pr(>|t|)
(Intercept)	.573	.018	384.71	32.152	<.001***
Number of syllables	−.001	.003	371.21	−.392	.695
First syllable frequency (log)	−.001	.001	371.56	−.755	.451
Stem frequency (log)	−.002	.001	376.99	−2.473	.014*
Word frequency (log)	−.006	.001	375.48	−8.236	<.001***
Group	−.004	.013	268.07	−.333	.739
Number of syllables × group	−.001	.002	18766.92	−.276	.782
First syllable frequency × group	.001	.001	18769.37	.099	.921
Stem frequency × group	−.001	.001	18768.20	−.797	.426
Word frequency × group	−.001	.001	18770.75	−.750	.453

lexical processing by assessing the effect of lexical variables on RTs in the LDT for both groups.

Findings revealed that the high-risk-taking group showed poorer performance, characterized by slower RTs and lower ACC, in comparison to the low-risk-taking group (Figure 1 and Tables 3–5). In terms of signal detection measure, the high-risk-taking group exhibited notably higher miss and false alarm rates in LDTs than the low-risk-taking group (Figure 2 and Tables 6 and 7), suggesting a stronger response bias in misidentifying nonwords as words and vice versa. However, the qualitative lexical processing analysis revealed that both groups demonstrated similar effects of lexical variables on RTs (Table 8), indicating no significant difference in the qualitative aspects of lexical processing between the two groups.

The present study provided empirical support for the research hypothesis concerning the influence of risk-taking on lexical decision processes. Given the broad spectrum of risky behaviors encompassed within risk-taking tendencies (Maniadaki & Kakouros, 2011; McNamara & Willoughby, 2010; Shelley-Tremblay et al., 2007), it is plausible to assume that such tendencies may extend to affect lexical decision-making. Our findings revealed that individuals classified as high risk-takers exhibited poorer behavioral responses and a greater response bias in comparison to their low-risk-taking counterparts. This suggests that biased lexical decision-making may hinder effective word recognition during LDT, potentially contributing to reading disabilities. Notably, the high-risk-taking group displayed more pronounced biases in their lexical decision processes, which could impede accurate word recognition. It may lead that the high-risk-taking group exhibited slower and less accurate lexical decision-making when compared to the low-risk-taking group. This finding implies that such biased recognition patterns might exacerbate reading difficulties in individuals with a high propensity for risk-taking.

However, our qualitative analysis of lexical processing did not reveal any discernible differences between the two experimental groups, suggesting that the nature of lexical processing is not qualitatively distinct between these groups. Despite the high-risk-taking group exhibiting poorer behavioral responses in the LDTs compared to the low-risk-taking group, the qualitative aspects of lexical processing remain similar across both groups. Notably, both experimental groups displayed significant effects of stem and word frequency in a comparable pattern. This observation aligns with traditional word recognition studies using LDTs where stem and word frequency have been identified as crucial lexical variables in the visual recognition of English words (Niswander-Klement & Pollatsek, 2006), Chinese words (Zhou & Marslen-Wilson, 1994) and Korean words (Kim et al., 2020; Kim & Nam, 2018; Lee et al., 2024). For example, in a previous study by Kim et al. (2020), employing a traditional LDT and conducting correlation analyses, a negative correlation was found between lexical decision times and stem frequency ($r = -.327$, $p < .01$), as well as between lexical decision times and word frequency ($r = -.379$, $p < .01$). These results reinforce the reliability of the findings presented in the current study.

The absence of qualitative differences in lexical processing between the two experimental groups suggests that the impact of risk-taking propensity may primarily manifest in the decision-making stage of lexical decision rather than in the sublexical/lexical processing stages for words. During the visual word processing sequence, following the sublexical and lexical processing phases, visual stimuli are subjected to a classification procedure, designated as either words or nonwords. This categorization process is predicated on the synthesis of data accrued throughout the sublexical and lexical stages, a phase recognized as the decision-making stage. The influence of risk-taking propensity on the lexical decision process is likely to affect the decision-making aspect of the final stage. Given the strong association between risky behavior and executive control functions in individuals (Blair et al., 2018; Khurana et al., 2015; Romer et al., 2009), the propensity for risk-taking appears to be related to higher-order cognitive processes involved in lexical decision-making, particularly the decision-making stage. Thus, the findings suggest that reading disabilities associated with risk-taking propensity may arise from impairments in the decision-making stage rather than the sublexical and lexical processing stages of reading.

On the one hand, the present study specifically recruited a sample of individuals from the normal population who did not have any diagnosed medical conditions. This deliberate selection aimed to minimize the confounding influence of medical conditions, such as RD on the examination of the relationship between risk-taking propensity and lexical decision. The findings of this study suggest that reading disabilities stemming from the propensity for risky behavior may originate from biased word recognition during reading, even in individuals without a diagnosed RD. This indicates that the manifestation of reading difficulties associated with biased recognition may precede the clinical diagnosis of RD. Thus, it implies that symptoms related to reading problems may emerge prior to the explicit identification of RD in clinical settings.

The findings of the present study shed light on the influential role of risk-taking propensity in shaping behavioral performance during lexical decision. Notably, individuals characterized by the high-risk-taking propensity exhibited slower and less accurate word recognition, resulting from a discernible bias toward both non-words and words. Remarkably, despite these clear biases associated with risk-taking propensity, no qualitative discrepancies in word recognition were discernible between the high- and low-risk-taking groups. The absence of interaction effects between lexical variables and group, denoting an absence of differential patterns based on the experimental groups, suggests that risk-taking propensity does not give rise to qualitative differences in lexical processing. Furthermore, the outcomes of this investigation, which concentrated on a normative population, may imply that reading difficulties stemming from risk-taking propensity may manifest prior to the explicit identification of clinical reading disabilities. Therefore, this study explored how risk-taking tendencies might affect the complex processes involved in lexical decision-making during reading, highlighting the importance of future

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research efforts to investigate the interplay between risk-taking and reading abilities in greater depth.

While the present study has provided valuable insights, its applicability to languages other than Korean, particularly Indo-European languages like English, is limited. This limitation arises from the distinct linguistic structures inherent to these language families. Korean, known for its agglutinative nature, focuses heavily on processing information through stems and syllables (e.g., Kim et al., 2022). In contrast, Indo-European languages such as English predominantly feature inflectional characteristics. This contrast suggests that the qualitative processing of lexical variables in these languages is likely to differ from what has been observed in Korean. Therefore, future research should shift toward investigating Indo-European languages to extend the findings of this study and explore the universal aspects of language processing.

Data availability statement. All research materials, including stimuli, analysis code and raw data, are available in the open material link (https://www.kaggle.com/datasets/user138833/risk-taking-propensity-on-lexical-decision).

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