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Background and Behavioral Cue Weighting in Current Versus Age-60 Disease-Risk Judgments: Two Cross-Disease Scenario Studies

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Research Article

Keywords: age framing, disease-risk judgment, behavioral cues, background cues, risk perception, health communication, construal-level theory

Posted Date: November 6th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11155530/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Disease-risk judgments combine stable background characteristics with behaviors that may change. We examined whether cue weights differed between judgments of current risk and risk at age 60. Because the age-60 prompt changes both temporal perspective and target age, construal-level theory was treated as one interpretive lens rather than the mechanism tested.

Methods

We reanalyzed two archived questionnaire data sets. Study 1 included 1,190 undergraduates who evaluated hypertension and osteoporosis; Study 2 included 869 participants who evaluated nasopharyngeal carcinoma and gallstones. Complementary questionnaire forms paired one disease with a current-risk judgment and the other with an age-60 judgment. Random allocation was not documented. Temporal frame was form-defined; sex, ancestry, family history, and behavioral scores were measured characteristics. Perceived likelihood was the primary outcome. Disease-specific linear models used continuous behavioral cues and HC3 robust standard errors; cross-disease models used participant-clustered standard errors. False-discovery-rate correction was applied within defined testing families.

Results

Guangdong ancestry was more strongly associated with perceived likelihood of nasopharyngeal carcinoma in the age-60 frame than in the current frame (B = 0.645, SE = 0.173, 95% CI 0.305 to 0.985, p = 0.000197, q = 0.001577). The frame-by-female-sex interaction for osteoporosis was also supported (B = 0.638, SE = 0.204, 95% CI 0.237 to 1.038, p = 0.001791, q = 0.008588), although sample-restriction sensitivity remained. The hypertension frame-by-salt-intake estimate was smaller and did not survive multiplicity correction (B = 0.187, SE = 0.092, 95% CI 0.005 to 0.368, p = 0.043616, q = 0.096388). No key gallstone interaction was detected. Most cross-disease three-way interactions were non-significant or multiplicity-sensitive, and outcome components showed different patterns.

Conclusions

The relative weight of background and behavioral cues differed between current and age-60 disease-risk judgments. Differences were clearest for Guangdong ancestry in nasopharyngeal carcinoma and female sex in osteoporosis; the hypertension pattern was weaker, and no consistent gallstone pattern emerged. The findings suggest that health messages may work better when the age frame matches the risk cue and links it to clear preventive or screening action. Because the age-60 prompt also changes objective age-related risk, direct intervention testing is needed.

Background

Disease-risk judgments are assembled rather than simply retrieved. A person may know that a condition is more common in a particular sex, family, or region, yet also think about salt intake, smoking exposure, diet, or other habits that feel closer to daily life. These sources of information do not carry fixed psychological weight. Their influence depends on whether the cue seems relevant, whether the person can picture the outcome, and what kind of judgment is being made. That makes cue weighting a useful meeting point for health psychology and public health communication: it asks not only whether people know a risk factor, but when that risk factor enters their own judgment.

A broad distinction can be drawn between relatively stable background cues and more changeable behavioral cues. Background cues often summarize membership in a risk category - for example, a family history of hypertension, female sex in osteoporosis, or geographic ancestry in a disease with a marked regional distribution. Behavioral cues describe what a person does or is exposed to. The distinction is not absolute. Behaviors may be habitual and hard to change, and background characteristics may matter only through social or environmental pathways. Still, the contrast is psychologically meaningful because stable cues can be read as category-level information, whereas behaviors often arrive as details of an individual case.

Construal-level theory (CLT) provides one account of why the balance between these cues might shift. Classic work proposes that distant events are represented in broader, more abstract terms, while near events are represented with more concrete and contextual detail [1–4]. Higher-level construal can also promote attention to superordinate goals and self-control [5]. Applied to health judgment, this suggests that a distant frame could increase reliance on stable or category-like information, while a near frame could leave more room for concrete behavior. Prior consumer research has used this logic to study base-rate and case information in health-risk judgments [6, 7]. The theory is useful here, but it does not dictate a simple result. A behavior can itself become a high-level symbol of a healthy or unhealthy life, and a background cue can be ignored when it feels remote, unfamiliar, or weakly diagnostic.

Temporal framing research in health communication is correspondingly mixed. Small changes in how a time horizon is expressed can alter perceived proximity, concern, and intentions [6]. Field and laboratory studies have examined diabetes screening, vaccination, smoking, diet, and other behaviors, often finding that temporal frames work differently depending on the audience, the endpoint, and the message itself [8–11]. A recent multilevel meta-analysis concluded that temporal framing effects vary substantially across outcomes and study contexts rather than operating as a universal persuasion device [8]. That heterogeneity is important. It argues against importing one successful message frame from one disease into another without first asking what cue the frame is making salient.

The contrast used in the archived questionnaires - risk now versus risk at age 60 - adds a further complication. It is tempting to label it temporal distance, but age 60 is not merely the present self moved forward on a calendar. It is a different objective age, and age changes the base rate and clinical meaning of many diseases. Hypertension and osteoporosis become more common with age; nasopharyngeal

carcinoma and gallstone disease have their own age and population distributions [19–22]. Participants may therefore be responding to epidemiologic knowledge, stereotypes about ageing, expectations about future behavior, or a less familiar future self. Any observed interaction belongs to the whole age-60 frame. It cannot be assigned specifically to abstract construal.

The outcome matters as much as the frame. Perceived likelihood is a deliberative estimate, even when it is rough. Worry is affective. An intention to seek examination or screening is closer to action, though still not the action itself. A self-assessed disease-status item may draw on symptoms, identity, and a felt sense of vulnerability. Work on the Tripartite Model of Risk Perception makes a similar distinction among deliberative, affective, and experiential risk [12–14]. These components are related, but they are not interchangeable, and their links with behavior are usually modest [15–18]. Pooling them can create a tidy total score while hiding the component that actually produced an association.

The four diseases in the archived project offered a useful, if imperfect, set of contexts. Hypertension was paired with salt intake and family history; osteoporosis with milk-drinking frequency and sex; nasopharyngeal carcinoma with environmental/dietary exposure and Guangdong ancestry; and gallstones with dietary regularity and sex. These pairings do not form a controlled taxonomy of disease threat or controllability. They do, however, place behavioral and background information side by side in judgments that matter to prevention, awareness, and screening communication.

The original project had been described as four independent experiments. Data auditing showed a different structure: two samples, each completing a complementary cross-disease questionnaire. The present reanalysis therefore asks three narrower questions. First, does the association of a behavioral or background cue with perceived disease likelihood differ between current and age-60 frames? Second, is that difference distinguishable across the two diseases evaluated by the same participants? Third, does the pattern recur in worry, examination intention, self-assessed status, or a composite response index? We treat these questions as exploratory. CLT remains one possible explanation, alongside age-related risk knowledge, future-self representation, and perceived cue diagnosticity. The public health aim is equally restrained: to identify message-design hypotheses worth testing, not to claim that the questionnaire frames already changed real-world behavior.

Methods

Study design and reporting approach

This study is an exploratory reanalysis of two existing questionnaire data sets. The analytical plan was rebuilt after auditing the raw files, variable coding, missingness, and measurement structure. The report no longer treats the project as four independent 2 × 2 × 2 experiments and does not reproduce the earlier analyses that divided continuous behavior scores into high, middle, and low groups. Instead, it describes two paired cross-disease studies and analyzes behavioral cues continuously. Because the frame was

form-defined while the remaining predictors were self-reported characteristics, reporting follows observational-study principles where they are applicable [27].

The available sample size was fixed by the archived data. No post hoc power calculation was used. Precision is conveyed through robust standard errors and 95% confidence intervals.

Participants and complementary questionnaire forms

Study 1: hypertension and osteoporosis

Study 1 contained 1,190 undergraduate participants, of whom 745 (62.8%) were women. Every participant evaluated both hypertension and osteoporosis. One questionnaire form presented current hypertension risk and age-60 osteoporosis risk; the complementary form presented age-60 hypertension risk and current osteoporosis risk. Hypertension was evaluated in the current frame by 577 participants and in the age-60 frame by 613. Osteoporosis was evaluated in the current frame by 612 and in the age-60 frame by 577; one osteoporosis response record was incomplete.

Study 2: nasopharyngeal carcinoma and gallstones

Study 2 contained 869 participants, including 551 women (63.4%). Every participant evaluated nasopharyngeal carcinoma and gallstones. One form presented current nasopharyngeal-carcinoma risk and age-60 gallstone risk; the other presented age-60 nasopharyngeal-carcinoma risk and current gallstone risk. Nasopharyngeal carcinoma was evaluated in the current frame by 413 participants and in the age-60 frame by 456. Gallstones were evaluated in the current frame by 456 participants and in the age-60 frame by 413.

Assigned frame and measured participant characteristics

Questionnaire form determined the frame attached to each disease. Frame was coded 0 for current-risk judgment and 1 for age-60-risk judgment. The archived materials did not include an allocation log. We therefore use the neutral language “completed” or “received” a questionnaire form and do not describe allocation as random.

No other predictor was assigned. Sex, first-degree family history of hypertension, Guangdong ancestry, salt intake, milk-drinking frequency, secondhand-smoke exposure, preserved-food preference, breakfast frequency, fruit-and-vegetable frequency, and high-calorie-food intake were self-reported participant characteristics. We refer to them as background and behavioral cues because they may enter a participant’s judgment, not because they were experimentally presented or manipulated.

Cue operationalization

Table 1 summarizes the cue definitions. Behavioral scores were oriented so that higher values indicated greater putative behavioral risk. They were then standardized within disease before modeling. Binary background cues were mean-centered. This coding makes the two focal interactions easier to compare: a frame-by-behavior coefficient represents the difference between age-60 and current slopes per 1-SD higher behavioral-risk score; a frame-by-background coefficient represents a difference-in-differences across frames and background categories.

The osteoporosis behavior score was calculated as 8 minus the original milk-drinking-frequency response, so that a higher value indicated less frequent milk consumption. This is a directional recoding, not a claim that the item is a validated measure of osteoporosis risk. Models using the original frequency direction were retained as coding-sensitivity analyses. The gallstone behavior score corrected the original direction inconsistency by reverse-scoring breakfast and fruit-and-vegetable frequency before averaging these components with high-calorie-food intake.

Table 1
Study structure and cue operationalization

Study	Disease and frame counts	Background cue	Behavioral cue	Primary model N
1	Hypertension: current 577; age 60, 613	First-degree family history (yes/no)	Salt-intake score; higher = greater risk	1,185
1	Osteoporosis: current 612; age 60, 577	Sex; female coded as higher-risk category	8 - milk-drinking frequency; higher = less frequent milk consumption	1,186
2	Nasopharyngeal carcinoma: current 413; age 60, 456	Guangdong ancestry (yes/no)	Mean of secondhand-smoke exposure and preserved-food preference	869
2	Gallstones: current 456; age 60, 413	Sex; female coded as higher-risk category	[(6 - breakfast) + (6 - fruit/vegetables) + high-calorie food]/3	869

Note. Frame counts describe disease-level judgments. The same participant contributed both disease judgments within a study. All cues except the questionnaire frame were measured participant characteristics. Behavioral cues were standardized before regression; binary background cues were centered.

Outcomes and measurement hierarchy

For each disease, participants completed four 7-point items: perceived likelihood of developing the disease, disease-related worry, intention to undergo examination or screening, and self-assessed disease status. Perceived likelihood was designated the primary outcome because it most directly represented a disease-risk judgment. Worry, examination intention, and self-assessed status were treated as three parallel secondary outcomes.

A four-item mean was computed when at least three items were available. It is called a composite risk-response index and is used only as a sensitivity outcome. The label matters. The items span deliberative, affective, intentional, and experiential content, and the archived questionnaire was not developed as a validated unidimensional scale. Internal consistency ranged from acceptable to good, but one-factor confirmatory models fit poorly across diseases. Configural and stronger current-versus-age-60 measurement-invariance models were not supported. These diagnostics are reported in Additional file 1. In line with measurement-invariance guidance [25, 26], reliability alone was not taken as evidence that the same latent construct had been measured in the same way across frames.

Data audit, missingness, and record handling

In Study 1, participant number 613 appeared on two rows. The rows differed across 39 fields and were not treated as duplicate submissions. Both were retained with unique row identifiers in the primary analysis; deleting one row was a sensitivity analysis. Study 1 contained one missing behavioral-cue value, four missing background-cue values, one missing osteoporosis outcome item, and 40 invalid or missing body mass index (BMI) values. Study 2 contained no duplicate identifiers and no missing primary cue or outcome values; 56 BMI values were invalid or missing. BMI entered only covariate sensitivity models.

No outcome-driven outlier deletion was performed. The principal variables were bounded ratings, and there was no defensible distributional threshold that would distinguish an extreme but valid response from an error. Each model used complete records for the variables it required. The composite index was calculated only when at least three of its four items were present.

Statistical analysis

For each disease and outcome, we fitted an ordinary least-squares regression containing frame, standardized behavioral cue, centered background cue, frame-by-behavior, frame-by-background, and behavior-by-background terms. HC3 heteroskedasticity-consistent standard errors were used because they perform well under common forms of heteroskedasticity and unequal leverage [23]. The focal coefficients were the two interactions involving frame. The unstandardized coefficient B remained in the 7-point outcome metric. Positive values indicated that the association of the cue with the outcome was stronger, or more positive, in the age-60 frame than in the current frame.

The interpretation differs slightly by cue type. For a continuous behavior score, B is the age-60-minus-current difference in outcome slope for a 1-SD increase in behavioral risk. For a binary background cue, B is the age-60-minus-current difference in the contrast between background categories. We report B, robust SE, 95% CI, exact p value, Benjamini-Hochberg false-discovery-rate q value where applicable [24], and model R^2 and adjusted R^2. These are association estimates. They are not causal effects of salt intake, sex, ancestry, or any other measured characteristic.

To compare the paired diseases, each data set was reshaped to long format. Joint models included disease, frame, behavioral cue, background cue, all lower-order terms required by the model, and disease-by-frame-by-behavior and disease-by-frame-by-background interactions. Standard errors were clustered by participant because each person contributed two disease evaluations. Study 1 contributed 2,371 disease-level observations and Study 2 contributed 1,738.

Multiplicity was handled in defined exploratory families. Benjamini-Hochberg correction was applied to the eight composite-index frame-by-cue tests and separately to the 32 item-level frame-by-cue tests (four diseases × four outcomes × two cue types). The four primary-outcome cross-disease three-way tests formed another family. We report exact unadjusted *p* values alongside *q* values and do not treat a nominal *p* below 0.05 as sufficient evidence when the adjusted result differs.

Sensitivity analyses (1) reproduced the original restricted samples, (2) deleted one repeated-number record in Study 1, (3) adjusted for available demographic and health variables, (4) compared risk-aligned and original osteoporosis behavior coding, and (5) compared item-level findings with the composite index. Because the project was not preregistered and the analysis was reconstructed after data auditing, all inference is explicitly exploratory.

Use of generative AI in manuscript preparation

OpenAI ChatGPT was used during manuscript restructuring and English-language editing. It was not used to generate data, alter statistical output, or decide which results to report. The authors reviewed the revised text, checked all numerical values against the analysis outputs, and take responsibility for the final manuscript.

Results

Participant records and form comparability

The primary disease-specific models included 1,185 hypertension records, 1,186 osteoporosis records, and all 869 records for each disease in Study 2. Differences between questionnaire-form groups were generally small, but they were not absent. In Study 1, age and occupation differed modestly by form, and high-normalized differences appeared for family history and osteoporosis history. In Study 2, sex and occupation showed modest form differences. These imbalances are another reason not to infer randomized allocation from the archived files. Full form comparisons, missing-data counts, and standardized differences appear in Additional file 1.

Primary outcome: perceived disease likelihood

Table 2 and Fig. 1 present the eight focal frame-by-cue estimates for perceived likelihood. Two background-cue interactions survived false-discovery-rate correction. The two behavior-cue estimates that crossed the nominal 0.05 threshold did not. This split is more informative than a simple count of “significant” diseases: it indicates that the clearest age-frame differences involved stable background

characteristics, while behavior-related evidence was weaker and more dependent on the outcome examined.

Study 1: hypertension and osteoporosis

For hypertension, the frame-by-salt-intake coefficient was $B = 0.187$ ($SE = 0.092$, 95% CI 0.005 to 0.368, $p = 0.043616$, $q = 0.096388$). The point estimate suggested a somewhat steeper relationship between the salt-risk score and perceived likelihood in the age-60 frame, but the result did not survive item-level multiplicity correction. The frame-by-family-history estimate was $B = 0.294$ ($SE = 0.169$, 95% CI -0.038 to 0.626, $p = 0.082691$, $q = 0.147006$). The model explained $R^2 = 0.244$ of the outcome variance (adjusted $R^2 = 0.241$).

For osteoporosis, the frame-by-female-sex interaction was larger and remained below the FDR threshold: $B = 0.638$ ($SE = 0.204$, 95% CI 0.237 to 1.038, $p = 0.001791$, $q = 0.008588$). In practical terms, the female-versus-male contrast in perceived likelihood was more positive in the age-60 frame. The frame-by-less-frequent-milk-consumption estimate was $B = 0.204$ ($SE = 0.102$, 95% CI 0.004 to 0.404, $p = 0.045182$, $q = 0.096388$). Again, the nominal result weakened after correction. The osteoporosis model R^2 was 0.096 (adjusted $R^2 = 0.092$).

Study 2: nasopharyngeal carcinoma and gallstones

For nasopharyngeal carcinoma, Guangdong ancestry showed the strongest primary-outcome interaction in the study: $B = 0.645$ ($SE = 0.173$, 95% CI 0.305 to 0.985, $p = 0.000197$, $q = 0.001577$). The ancestry contrast was therefore more pronounced in age-60 judgments. The behavior interaction, based on secondhand-smoke exposure and preserved-food preference, was essentially null: $B = 0.005$ ($SE = 0.103$, 95% CI -0.197 to 0.207, $p = 0.960433$, $q = 0.960433$). The model R^2 was 0.222 (adjusted $R^2 = 0.216$).

For gallstones, neither focal interaction was detected. The frame-by-behavior estimate was $B = 0.135$ ($SE = 0.105$, 95% CI -0.071 to 0.342, $p = 0.199254$, $q = 0.318806$), and the frame-by-female-sex estimate was $B = 0.116$ ($SE = 0.204$, 95% CI -0.284 to 0.517, $p = 0.568788$, $q = 0.674119$). The model R^2 was 0.116 (adjusted $R^2 = 0.109$). These intervals do not establish equivalence or absence of any interaction; they show that the present data did not provide clear evidence for the specified effects.

Table 2
Frame-by-cue interactions for perceived disease likelihood

Disease	Interaction	B (robust SE)	95% CI	p	FDR q	R^2 (adj.)
Hypertension	Frame × behavior	0.187 (0.092)	0.005 to 0.368	0.043616	0.096388	0.244 (0.241)
Hypertension	Frame × background	0.294 (0.169)	-0.038 to 0.626	0.082691	0.147006	0.244 (0.241)
Osteoporosis	Frame × behavior	0.204 (0.102)	0.004 to 0.404	0.045182	0.096388	0.096 (0.092)
Osteoporosis	Frame × female sex	0.638 (0.204)	0.237 to 1.038	0.001791	0.008588	0.096 (0.092)
Nasopharyngeal carcinoma	Frame × behavior	0.005 (0.103)	-0.197 to 0.207	0.960433	0.960433	0.222 (0.216)
Nasopharyngeal carcinoma	Frame × Guangdong ancestry	0.645 (0.173)	0.305 to 0.985	0.000197	0.001577	0.222 (0.216)
Gallstones	Frame × behavior	0.135 (0.105)	-0.071 to 0.342	0.199254	0.318806	0.116 (0.109)
Gallstones	Frame × female sex	0.116 (0.204)	-0.284 to 0.517	0.568788	0.674119	0.116 (0.109)

Note. *B* values are unstandardized interaction coefficients in 7-point outcome units. Behavioral cues were standardized within disease; binary background cues were centered. Positive *B* values indicate a stronger or more positive cue association in the age-60 frame. HC3 robust standard errors were used. FDR *q* values come from the 32-test item-level family.

Secondary outcomes and component-specific patterns

The 24 secondary-outcome interactions are shown in Additional file 1. Figure 2 and Table 3 focus on the cue that was most informative for each disease. The purpose is not to select only favorable results, but to show why the four response components could not be treated as interchangeable. The same frame-by-cue term could be clear for one component, borderline for another, and absent for a third.

In hypertension, the largest frame-by-salt interaction appeared for self-assessed disease status (B = 0.498, 95% CI 0.341 to 0.656, p = 5.34 × 10^-10, q = 1.71 × 10^-8). Worry was nominally associated (B = 0.228, p = 0.041217, q = 0.096388), and examination intention was imprecise (B = 0.224, p = 0.058466, q = 0.110054). The composite hypertension interaction was also clear (B = 0.284, 95% CI 0.142 to 0.426, p

= 0.0000879, q = 0.000352). The combined pattern suggests that the original total-score effect was driven mainly by how participants located themselves on a disease-status continuum, not by an equally strong change in probability judgment, worry, and examination intention.

The osteoporosis frame-by-female-sex interaction was broader across components. It was present for worry (B = 1.118, 95% CI 0.678 to 1.557, q = 9.94 × 10^-6), examination intention (B = 0.789, 95% CI 0.317 to 1.261, q = 0.006776), and self-assessed status (B = 0.537, 95% CI 0.170 to 0.905, q = 0.015952), as well as perceived likelihood. The composite interaction was B = 0.772 (95% CI 0.458 to 1.085, p = 1.41 × 10^-6, q = 1.13 × 10^-5). This consistency strengthens the descriptive case that female sex carried more weight in age-60 osteoporosis judgments, even though sensitivity to sample restriction prevents a stronger causal or confirmatory claim.

For nasopharyngeal carcinoma, the frame-by-Guangdong-ancestry interaction was clear for perceived likelihood and self-assessed status (B = 0.495, 95% CI 0.183 to 0.808, q = 0.008588). Worry and examination intention had positive point estimates, but their adjusted results were not below 0.05. The composite estimate was B = 0.510 (95% CI 0.217 to 0.802, p = 0.000638, q = 0.001701). Thus, ancestry was not simply elevating every response in parallel; the more stable signals were likelihood and experiential status judgments.

For gallstones, the overall picture remained weak. The frame-by-behavior interaction was not detected for perceived likelihood, worry, examination intention, or the composite index. A single secondary result appeared for self-assessed status (B = 0.296, 95% CI 0.092 to 0.501, p = 0.004487, q = 0.015952). Because neither the primary outcome nor the composite supported the pattern, this item-level result was not elevated into a disease-level conclusion.

Table 3
Component-specific interactions for focal disease cues

Disease and focal cue	Outcome	B (robust SE)	95% CI	p	FDR q
Hypertension - salt behavior	Likelihood	0.187 (0.092)	0.005 to 0.368	0.043616	0.096388
	Worry	0.228 (0.111)	0.009 to 0.446	0.041217	0.096388
	Examination intention	0.224 (0.118)	-0.008 to 0.455	0.058466	0.110054
	Self-assessed status	0.498 (0.080)	0.341 to 0.656	5.34 × 10^-10	1.71 × 10^-8
Osteoporosis - female sex	Likelihood	0.638 (0.204)	0.237 to 1.038	0.001791	0.008588
	Worry	1.118 (0.224)	0.678 to 1.557	6.21 × 10^-7	9.94 × 10^-6
	Examination intention	0.789 (0.241)	0.317 to 1.261	0.001059	0.006776
	Self-assessed status	0.537 (0.187)	0.170 to 0.905	0.004165	0.015952
Nasopharyngeal carcinoma - Guangdong ancestry	Likelihood	0.645 (0.173)	0.305 to 0.985	0.000197	0.001577
	Worry	0.428 (0.211)	0.015 to 0.840	0.042432	0.096388
	Examination intention	0.472 (0.248)	-0.015 to 0.959	0.057647	0.110054
	Self-assessed status	0.495 (0.159)	0.183 to 0.808	0.001879	0.008588
Gallstones - behavior	Likelihood	0.135 (0.105)	-0.071 to 0.342	0.199254	0.318806
	Worry	0.167 (0.129)	-0.087 to 0.420	0.197138	0.318806
	Examination intention	-0.026 (0.142)	-0.304 to 0.251	0.852681	0.880187

Note. Focal cues were selected to display the principal disease-specific pattern: salt-related behavior for hypertension, female sex for osteoporosis, Guangdong ancestry for nasopharyngeal carcinoma, and the dietary behavior score for gallstones. The complete 32-test item-level family, including the second cue for every disease, is reported in Additional file 1.

Disease and focal cue	Outcome	B (robust SE)	95% CI	p	FDR q
	Self-assessed status	0.296 (0.104)	0.092 to 0.501	0.004487	0.015952

Note. Focal cues were selected to display the principal disease-specific pattern: salt-related behavior for hypertension, female sex for osteoporosis, Guangdong ancestry for nasopharyngeal carcinoma, and the dietary behavior score for gallstones. The complete 32-test item-level family, including the second cue for every disease, is reported in Additional file 1.

Cross-disease joint models

The joint models asked a stricter question than the disease-specific analyses: did the frame-by-cue relationship itself differ between the two diseases evaluated by the same participants? In Study 1, neither primary-outcome three-way interaction was detected. The disease-by-frame-by-behavior coefficient was B = -0.018 (95% CI -0.274 to 0.239, p = 0.893433), and the corresponding background coefficient was B = -0.344 (95% CI -0.875 to 0.188, p = 0.204984). The composite background three-way term was nominally present (B = -0.557, 95% CI -0.980 to -0.134, p = 0.009811), but it was unstable under the original restricted-sample rule.

In Study 2, the primary-outcome disease-by-frame-by-background term was B = 0.542 (95% CI 0.011 to 1.072, p = 0.045419). After correction within the four primary three-way tests, q was approximately 0.181. The behavior three-way term was not detected (B = -0.126, 95% CI -0.435 to 0.183, p = 0.425037). Composite three-way terms were also non-significant. The joint models therefore do not support a broad claim that the four diseases form contrasting experimental demonstrations of one underlying moderator.

Sensitivity analyses

The nasopharyngeal-carcinoma ancestry interaction was the most stable result. It remained evident after covariate adjustment (B = 0.564, p = 0.0013) and in the original restricted sample (B = 0.695, p < 0.001). The osteoporosis female-sex interaction remained in the covariate-adjusted model (B = 0.529, p = 0.0086) but was not detected under the original restricted-sample rule (p = 0.120). The hypertension behavior interaction weakened after covariate adjustment (p = 0.052) and in the restricted sample (p = 0.122). Deleting one of the repeated-number records did not materially alter the main conclusions. Additional coding and sample checks are reported in Additional file 1.

Summary of the empirical pattern

Three points organize the results. First, the most reproducible frame differences concerned stable background cues: Guangdong ancestry for nasopharyngeal carcinoma and, more conditionally, female sex for osteoporosis. Second, the hypertension pattern depended on which response was examined; it was strongest for self-assessed status and the composite index, not for perceived likelihood or examination intention. Third, gallstones and most cross-disease three-way tests did not provide clear

evidence. The data therefore support a heterogeneous cue-weighting account, not a single “near behavior versus distant background” rule.

Discussion

Principal findings

The reanalysis changed the story in a useful way. Once the actual questionnaire arrangement, continuous cue scores, item-level outcomes, and multiple testing were respected, the data no longer looked like four parallel experiments confirming a common disease-property moderator. They looked like two cross-disease samples in which some cues became more strongly associated with risk responses under an age-60 frame, while others did not. The clearest pattern was the greater weight of Guangdong ancestry in nasopharyngeal-carcinoma likelihood judgments. Female sex in osteoporosis showed a similarly positive frame interaction across several response components, though its sensitivity to the original sample restriction makes it less secure. Hypertension provided a different kind of result: salt-related behavior mattered most for self-assessed status and the legacy composite. Gallstones did not yield a coherent focal pattern.

This matters methodologically as well as substantively. A result that appears strong in a composite can be produced by one unusually responsive item. Here, the hypertension total-score signal might easily have been described as a broad change in risk perception. The item analysis showed something narrower. Participants with higher salt-risk scores placed themselves closer to the disease category under the age-60 frame, but their perceived probability, worry, and examination intention did not all shift to the same degree. The distinction is not cosmetic. It changes what the finding could mean and what a public health intervention would need to measure.

What can the current-versus-age-60 contrast tell us?

CLT remains a plausible organizing perspective. Stable background cues can function like broad categories, while personal behaviors can function like concrete case information. The stronger age-60 ancestry and sex associations are compatible with the idea that a future frame can increase the weight of category-level information [1–7]. Yet compatibility is not diagnosis. The study did not measure mental abstraction, perceived distance, desirability, feasibility, or the level at which participants represented each disease. It also did not manipulate background and behavioral information within standardized vignettes. The data therefore cannot show that a shift in construal produced the observed interactions.

The age-60 prompt also changes objective meaning. A 20-year-old asked about current osteoporosis risk and the same person asked about risk at age 60 are not judging two equally plausible outcomes separated only by time. The latter prompt may activate simple age-disease knowledge. It may also make female sex seem more diagnostic for osteoporosis, or Guangdong ancestry more relevant for a disease known to have a regional distribution. Participants may imagine different diets, occupations, environments, or access to care at age 60. The observed coefficients capture that bundle. Calling it an “age-frame effect” is therefore more accurate than calling it a pure temporal-distance effect.

Cue diagnosticity may offer a particularly direct explanation. A background characteristic matters in judgment when people believe it meaningfully separates higher- from lower-risk groups in the target context. Age 60 may make some of those distinctions easier to recognize. That account does not oppose CLT; it sits alongside it. Future studies could manipulate temporal distance while holding target age constant, then independently vary cue type and stated diagnostic value. Without that separation, theory risks being inferred from whichever disease happened to show an interaction.

Why the response components diverged

The component-specific findings fit a broader health-psychology literature in which deliberative likelihood, affective worry, and experiential vulnerability are related but distinct [12–16]. They also align with evidence that increasing perceived risk does not automatically produce behavior. Experimental meta-analysis suggests that risk appraisals tend to have modest effects on intentions and behavior, and that coping appraisals such as response efficacy and self-efficacy often determine whether concern becomes action [17]. Message-framing reviews reach a similar conclusion: outcome choice and context matter, and persuasive effects are rarely uniform [8, 18].

For osteoporosis, the female-sex interaction extended from likelihood to worry, examination intention, and self-assessed status. That breadth may mean the cue was already familiar and readily connected to several forms of response. It may also reflect a simple age-related stereotype rather than well-calibrated knowledge. A stronger subjective response is not necessarily a more accurate one. The study contains no benchmark against clinical risk, so it cannot tell whether participants were underestimating current risk, overestimating age-60 risk, or improving calibration.

For nasopharyngeal carcinoma, the Guangdong-ancestry interaction was strongest for likelihood and self-assessed status. Worry and examination intention moved in the same positive direction but were less precise after correction. This pattern could mean that the cue affected perceived susceptibility more readily than action planning. It could also reflect uncertainty about what examination or screening would be appropriate. In a public health setting, a message that increases susceptibility without pairing it with a clear and clinically sound response may create concern without useful action.

The hypertension result is a reminder that an experiential item can dominate a total score. Salt-related behavior may have helped participants imagine themselves as “the sort of person” who could have hypertension at age 60. That is a meaningful psychological response, but it is not the same as a calibrated probability estimate. Nor is it evidence that they would reduce salt intake. The gallstone self-status result deserves the same restraint: a single adjusted item-level association, in the absence of a primary or composite pattern, is better treated as a lead for replication than as a positive disease-level finding.

Public health implications

The practical contribution is not that one frame “works.” It is that message designers may need to match the frame to the cue and the desired response. For conditions in which stable characteristics identify people who may need earlier awareness or tailored advice, an age-anchored message could make long-term susceptibility easier to see. The osteoporosis and nasopharyngeal-carcinoma results offer examples. Such messages should avoid fatalism: sex or ancestry is not destiny, and a background cue should be paired with concrete, evidence-based actions and a clear account of who may benefit from clinical assessment.

For a behavior-linked condition such as hypertension, the more promising strategy may be to connect a present habit with a believable later-life consequence. The current data suggest that salt-related behavior can become more psychologically tied to disease status under an age-60 frame. A future message experiment could test whether that connection improves risk calibration and supports practical steps such as lower-sodium choices, blood-pressure monitoring, or consultation when appropriate. The message would need to do more than make the future vivid. It should also support efficacy and avoid implying that one self-report item determines disease risk.

The gallstone findings are useful precisely because they were not persuasive. They caution against using age framing as a generic template across diseases. A message may fail because the cue is not seen as diagnostic, the action is unclear, the disease is poorly understood, or the target audience does not identify with the future self being invoked. These possibilities should be tested, not filled in after the fact. The absence of a coherent gallstone pattern also strengthens the case for disease-specific pilot testing before population-level deployment.

No claim about actual prevention, screening, or health-care use follows from this questionnaire study. Intention is not behavior, and greater worry can be helpful, unhelpful, or simply distressing. A responsible intervention study would measure calibrated understanding, appropriate action, unnecessary testing, anxiety, stigma, and fatalistic interpretations. It would also distinguish targeted screening advice from broad exhortations to seek examination. Public health value lies in making the next test sharper, not in overselling the present one.

Strengths, limitations, and a more decisive next study

The main strength of the reanalysis is transparency. It reconstructs the actual two-sample arrangement, separates the form-defined frame from measured participant characteristics, keeps behavior scores continuous, uses robust and participant-clustered standard errors, reports exact estimates and uncertainty, corrects defined testing families, and shows sensitivity analyses rather than hiding them. It also treats the four outcomes as different responses after the measurement models failed. These changes narrow the claims, but they make the remaining claims more credible.

Several limitations set hard boundaries. First, current versus age 60 confounds temporal perspective with target age and age-related objective risk. Second, sex, ancestry, family history, and behavior were not manipulated; their interactions with frame remain observational and may reflect confounding,

measurement error, or differences between questionnaire-form groups. Third, the primary outcome was a single item. The composite could not repair that weakness because its one-factor structure and cross-frame equivalence were inadequate. Fourth, the undergraduate convenience samples limit generalization to older adults, patients, and people facing real clinical decisions. Fifth, the archived records did not fully document allocation, item wording, disease knowledge, comprehension, or recruitment. Those are not minor administrative details; they affect how confidently the design can be interpreted.

The analysis was also exploratory and extensive. Two strong *q* values do not turn the study into a preregistered confirmation. The osteoporosis result changed under one historical restriction rule, the hypertension likelihood result weakened after adjustment and correction, and the Study 2 three-way background term did not survive its testing family. Non-significant estimates were not equivalence tests. The intervals permit some effects that a larger or cleaner study might detect.

A more decisive experiment could separate the moving parts. Participants could judge the same objective target age under a near versus distant time horizon, or judge present and future risk while epidemiologic age information is held constant. Background and behavioral cues could be presented experimentally with calibrated effect sizes rather than inferred from the participant's own characteristics. Cue diagnosticity, perceived distance, construal level, threat, controllability, efficacy, future-self continuity, and disease knowledge could then be measured before outcomes. A preregistered analysis would designate one primary outcome and one testing family, with real or simulated behavioral follow-up where ethical and feasible.

That design would also allow the mechanisms that were previously overinterpreted to become testable hypotheses. Disease controllability could be manipulated or rated rather than assigned by the researcher after seeing the pattern. "High-level lock-in," low-threat processing, action mindset, and prevention motivation could be specified as mediators with temporal ordering. Until those data exist, they should remain proposals, not explanations attached to a significant or non-significant coefficient.

Conclusions

The relative weight given to background and behavioral cues differed between current and age-60 disease-risk judgments. The clearest result was that Guangdong ancestry carried more weight in age-60 judgments of nasopharyngeal carcinoma. Female sex also carried more weight in age-60 judgments of osteoporosis, although that finding was less stable. The hypertension result was weaker and depended on the outcome examined, while gallstone judgments showed no consistent change.

The practical message is straightforward. Health-risk information may be easier to understand when the way it is framed matches the kind of risk cue being discussed. For stable risk factors such as sex or ancestry, an age-anchored message may help people recognize long-term susceptibility. For modifiable behaviors such as salt intake, showing how a present habit can affect later health may make the message more relevant. These ideas should now be tested in randomized studies that measure risk understanding, appropriate prevention, screening, and health-care seeking. The present study does not

show that age framing by itself changes behavior, and the comparison between current and age-60 judgments also includes real age-related changes in disease risk.

Abbreviations

BMI
body mass index
CI
confidence interval
CLT
construal-level theory
FDR
false discovery rate
HC3
heteroskedasticity-consistent covariance estimator type 3
NPC
nasopharyngeal carcinoma
OLS
ordinary least squares
SE
standard error
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the First Affiliated Hospital of Guangdong Pharmaceutical University (Approval No. ????2026?IIT?(83?)).

Consent for publication

Not applicable. The study did not involve any identifiable individual information or individual-level material requiring consent for publication.

Competing interests

The authors declare that they have no competing interests.

Authors' information

Not provided.

Funding

This research was supported by the Guangdong Provincial Health Commission and the Guangdong Medical Science and Technology Research Fund (Grant No. B2025284).

Author Contribution

CL: Conceptualization, Methodology, Supervision, Investigation, Data curation, and Writing – review & editing.WC: Formal analysis, Writing – original draft, Writing – review & editing.MF: Investigation, Data curation, Literature review, and Writing – review & editing.YL:Methodology, Formal analysis, Writing – review & editing.All authors read and approved the final manuscript.

Acknowledgements

Not applicable.

Data Availability

The datasets generated and/or analyzed during the current study are not publicly available because they contain potentially sensitive health-related and demographic information. De-identified data may be made available from the corresponding author upon reasonable request, subject to appropriate privacy protections and applicable institutional requirements. The analysis code is available from the corresponding author upon reasonable request.

References

1. Trope Y, Liberman N. Temporal construal. Psychol Rev. 2003;110(3):403–21. 10.1037/0033-295X.110.3.403.
2. Liberman N, Sagristano MD, Trope Y. The effect of temporal distance on level of mental construal. J Exp Soc Psychol. 2002;38(6):523–34. 10.1016/S0022-1031(02)00535-8.
3. Liberman N, Trope Y. The psychology of transcending the here and now. Science. 2008;322(5905):1201–5. 10.1126/science.1161958.
4. Trope Y, Liberman N. Construal-level theory of psychological distance. Psychol Rev. 2010;117(2):440–63. 10.1037/a0018963.

5. Fujita K, Trope Y, Liberman N, Levin-Sagi M. Construal levels and self-control. J Pers Soc Psychol. 2006;90(3):351–67. 10.1037/0022-3514.90.3.351.
6. Chandran S, Menon G. When a day means more than a year: effects of temporal framing on judgments of health risk. J Consum Res. 2004;31(2):375–89. 10.1086/422116.
7. Yan D, Sengupta J. The influence of base rate and case information on health-risk perceptions: a unified model of self-positivity and self-negativity. J Consum Res. 2013;39(5):931–46. 10.1086/666596.
8. Huang G, Xu J. Disentangling the effects of temporal framing on risk perception, attitude, behavioral intention, and behavior: a multilevel meta-analysis. Commun Res. 2024;51(1):3–27. 10.1177/00936502221102102.
9. Orbell S, Hagger MS. Temporal framing and the decision to take part in type 2 diabetes screening: effects of individual differences in consideration of future consequences on persuasion. Health Psychol. 2006;25(4):537–48. 10.1037/0278-6133.25.4.537.
10. Kim J, Nan X. Effects of consideration of future consequences and temporal framing on acceptance of the HPV vaccine among young adults. Health Commun. 2016;31(9):1089–96. 10.1080/10410236.2015.1038774.
11. Zhao X, Peterson E. Effects of temporal framing on response to antismoking messages: the mediating role of perceived relevance. J Health Commun. 2017;22(1):37–44. 10.1080/10810730.2016.1250844.
12. Ferrer RA, Klein WMP. Risk perceptions and health behavior. Curr Opin Psychol. 2015;5:85–9. 10.1016/j.copsyc.2015.03.012.
13. Ferrer RA, Klein WMP, Persoskie A, Avishai-Yitshak A, Sheeran P. The Tripartite Model of Risk Perception (TRIRISK): distinguishing deliberative, affective, and experiential components of perceived risk. Ann Behav Med. 2016;50(5):653–63. 10.1007/s12160-016-9790-z.
14. Diaz D, Schneller LM, Fix BV, Bansal-Travers M, Colder CR, O'Connor RJ. Exploring the psychometric properties of a tripartite model of risk perception (TRIRISK) in a general U.S. population sample. Health Psychol Behav Med. 2022;10(1):1110–23. 10.1080/21642850.2022.2143363.
15. Brewer NT, Chapman GB, Gibbons FX, Gerrard M, McCaul KD, Weinstein ND. Meta-analysis of the relationship between risk perception and health behavior: the example of vaccination. Health Psychol. 2007;26(2):136–45. 10.1037/0278-6133.26.2.136.
16. Weinstein ND, Kwitel A, McCaul KD, Magnan RE, Gerrard M, Gibbons FX. Risk perceptions: assessment and relationship to influenza vaccination. Health Psychol. 2007;26(2):146–51. 10.1037/0278-6133.26.2.146.
17. Sheeran P, Harris PR, Epton T. Does heightening risk appraisals change people's intentions and behavior? A meta-analysis of experimental studies. Psychol Bull. 2014;140(2):511–43. 10.1037/a0033065.
18. Gallagher KM, Updegraff JA. Health message framing effects on attitudes, intentions, and behavior: a meta-analytic review. Ann Behav Med. 2012;43(1):101–16. 10.1007/s12160-011-9308-7.

19. Compston JE, McClung MR, Leslie WD, Osteoporosis. Lancet. 2019;393(10169):364–76. 10.1016/S0140-6736(18)32112-3.
20. Mills KT, Stefanescu A, He J. The global epidemiology of hypertension. Nat Rev Nephrol. 2020;16(4):223–37. 10.1038/s41581-019-0244-2.
21. Chen YP, Chan ATC, Le QT, Blanchard P, Sun Y, Ma J. Nasopharyngeal carcinoma. Lancet. 2019;394(10192):64–80. 10.1016/S0140-6736(19)30956-0.
22. Lammert F, Gurusamy K, Ko CW, Miquel JF, Méndez-Sánchez N, Portincasa P, et al. Gallstones Nat Rev Dis Primers. 2016;2:16024. 10.1038/nrdp.2016.24.
23. Long JS, Ervin LH. Using heteroscedasticity consistent standard errors in the linear regression model. Am Stat. 2000;54(3):217–24. 10.1080/00031305.2000.10474549.
24. Benjamini Y, Hochberg Y. Controlling the false discovery rate: a practical and powerful approach to multiple testing. J R Stat Soc Ser B Stat Methodol. 1995;57(1):289–300. 10.1111/j.2517-6161.1995.tb02031.x.
25. Putnick DL, Bornstein MH. Measurement invariance conventions and reporting: the state of the art and future directions for psychological research. Dev Rev. 2016;41:71–90. 10.1016/j.dr.2016.06.004.
26. Hu LT, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct Equ Model. 1999;6(1):1–55. 10.1080/10705519909540118.
27. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP, STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet. 2007;370(9596):1453–7. 10.1016/S0140-6736(07)61602-X.

Figures

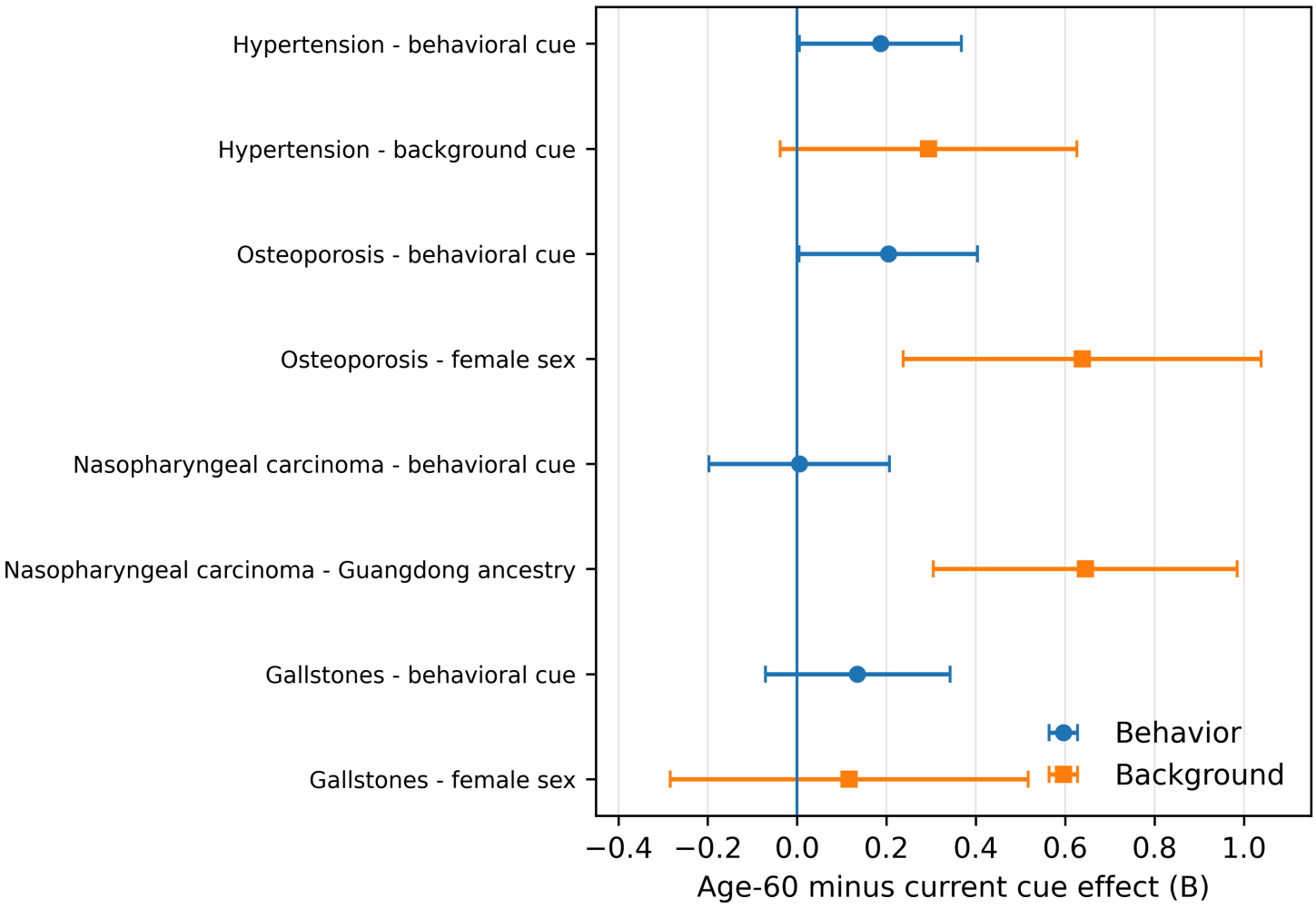


Figure 1

Frame-by-cue interactions for perceived disease likelihood

Points are unstandardized frame-by-cue coefficients; horizontal bars are 95% CIs. Positive values indicate that a cue-outcome slope or contrast was stronger in the age-60 frame. The vertical line marks *B* = 0. Behavioral cues were standardized; background cues were centered binary variables.

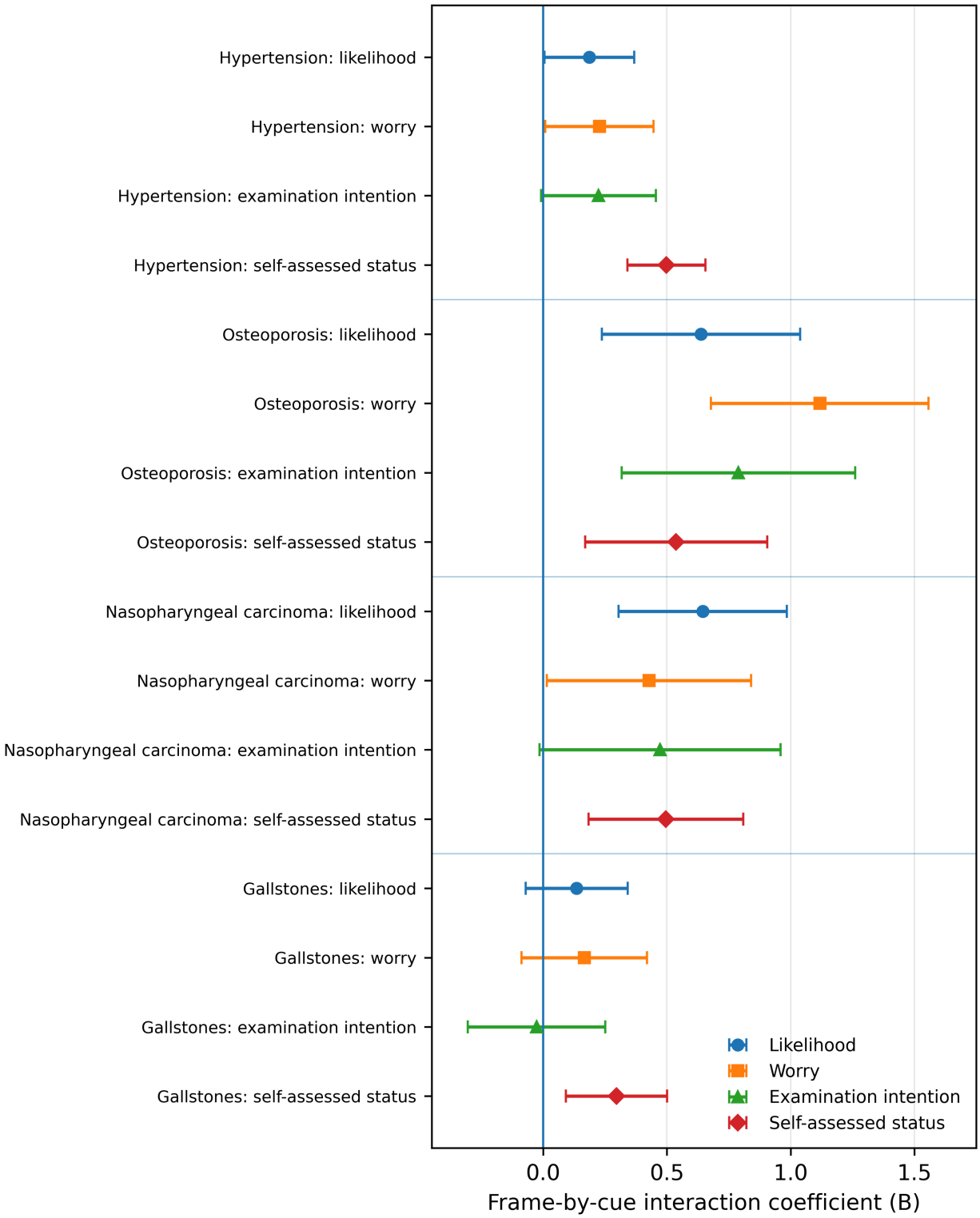


Figure 2

Frame-by-cue interactions across risk-response components

Points are unstandardized coefficients and bars are 95% CIs. The focal cue is salt-related behavior for hypertension, female sex for osteoporosis, Guangdong ancestry for nasopharyngeal carcinoma, and dietary behavior for gallstones. Estimates for all cues and outcomes appear in Additional file 1.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile1Supplementarymethodsandresults.docx