SUPPORTING INFORMATION FOR THE PAPER

Unraveling the Aging Skein: Disentangling Sensory and Cognitive Predictors of Age-related Differences in Decision Making

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1. Example items of A-DMC tasks

Resistance to Framing (example of attribute framing)

<u>Instructions;</u>
Each of the following problems asks you to rate your judgment of a product or a situation. Each problem is presented with a scale ranging from 1 (representing the worst rating) through 6 (representing the best rating). For each problem, please circle the number on the scale that best reflects your judgment.

Problem 2

Imagine the following situation. You are entertaining a special friend by inviting them for dinner. You are making your favorite lasagna dish with ground beef. Your roommate goes to the grocery store and purchases a package of ground beef for you. The label says 80% lean ground beef.

What's your evaluation of the quality of this ground beef?

1	2	3	4	5	6
Very low					Very high

Problem 5

Imagine the following situation. You are entertaining a special friend by inviting them for dinner. You are making your favorite lasagna dish with ground beef. Your roommate goes to the grocery store and purchases a package of ground beef for you. The label says 20% fat ground beef.

What's your evaluation of the quality of this ground beef?

1	2	3	4	5	6
Very low					Very high

Applying Decision Rules

The following questions are about other people choosing between DVD players, like the ones above. Please read each question carefully, because they ask for different answers. For each question, think about how each person makes their choice, then pick the DVD they choose. But be careful, because the DVD players will change from question to question.

Very Low	Low	Medium	High	Very High
1	2	3	4	5

Question 2:

Features

		Picture Quality	Sound Quality	Programming Options	Reliability of Brand	Price
DVD	A	2	5	5	5	$369
	B	5	4	4	5	$369
	C	5	3	2	5	$369
	D	3	5	2	2	$369
	E	4	4	4	5	$369

Sally first selects the DVD players with the best Sound Quality. From the selected DVD players, she then selects the best on Picture Quality. Then, if there is still more than one left to choose from, she selects the one best on Programming Options.

Which **one** of the presented DVD players would Sally prefer?

Under/Overconfidence

For each of the following statements, circle true or false to indicate your answer. Then circle a number on the scale to indicate how sure you are of your answer. The scale ranges from 50% (meaning that you were just guessing) to 100% (meaning that you were absolutely sure).

8. Muscles do not burn calories when you are at rest.

This statement is [True / False].

50%	60%	70%	80%	90%	100%
just guessing					absolutely sure

2. Correlation matrix between the measures used for structural equation modeling

	Age	SOIT	Education	Letter-digit Substitution	Letter Comparison	Pattern Comparison	Block Design	2 Back	Reading Span	Framing	Applying Decision Rules
Age	1										
SOIT	-.408***	1									
Education	-.402***	.275***	1								
Letter-digit Substitution	-.605***	.333***	.347***	1							
Letter Comparison	-.498***	.243***	.310***	.647***	1						
Pattern Comparison	-.585***	.325***	.260***	.660***	.619***	1					
Block Design	-.556***	.320***	.377***	.442***	.406***	.441***	1				
2 Back	-.451***	.270***	.281***	.407***	.361***	.322***	.449***	1			
Reading Span	-.242***	.193***	.300***	.241***	.229***	.229***	.306***	.277***	1		
Framing	-.110**	.119**	.179***	.119**	.117**	.061	.172***	.217***	.153***	1	
Applying Decision Rules	-.351***	.290***	.403***	.327***	.289***	.251***	.403***	.357***	.236***	.225***	1
Under/Overconfidence	-.170***	.117**	.195***	.118**	.084*	.124**	.168***	.198***	.146**	.107*	.190***

Pairwise correlations on imputed data. Significance levels are as follows: $p < .05$ *, $p < .01$ **, $p < .001$ ***.

3. Control analyses

Four kinds of control analyses were carried out to appraise the robustness of our findings. These analyses consisted of (1) appraising the fit of lesion versions of the models; (2) changing the sensory functioning indicator; (3) using single decision-making manifest variables as criterion tasks; (4) checking whether the results are robust even when applying an alternative method to assess mediation (Schmiedek & Li, 2004). It is worth pointing out that using single decision-making manifest variables as criterion tasks is not a mere control analysis but allows gaining valuable insights on the specificity of each decision-making task. We will present here a summary of the findings of these control analyses; the full set of results is available from the first author.

3.1 Lesion models

We first appraised the fit of lesion models as a further assessment of the postulated role of specific predictors or relations. This control was applied in two forms. The first form of lesion consisted in removing an entire predictor and its indicators (e.g., working memory) from the full-path partial-mediation model (Figure 1_{si}, left side), and then appraising the lesion model fit and its loss in predictive capacity in relation to the decision-making latent variable. The second form of lesion consisted in removing the direct link between age and a given predictor (e.g., age→working memory) in the working memory partial mediation model, to appraise the loss in fit (with the χ^2 difference test) and the loss in predictive power associated to the absence of that specific mediation path (Figure 1_{si}, right side). The results of these two forms of model lesion are presented in Figure 1_{si}.

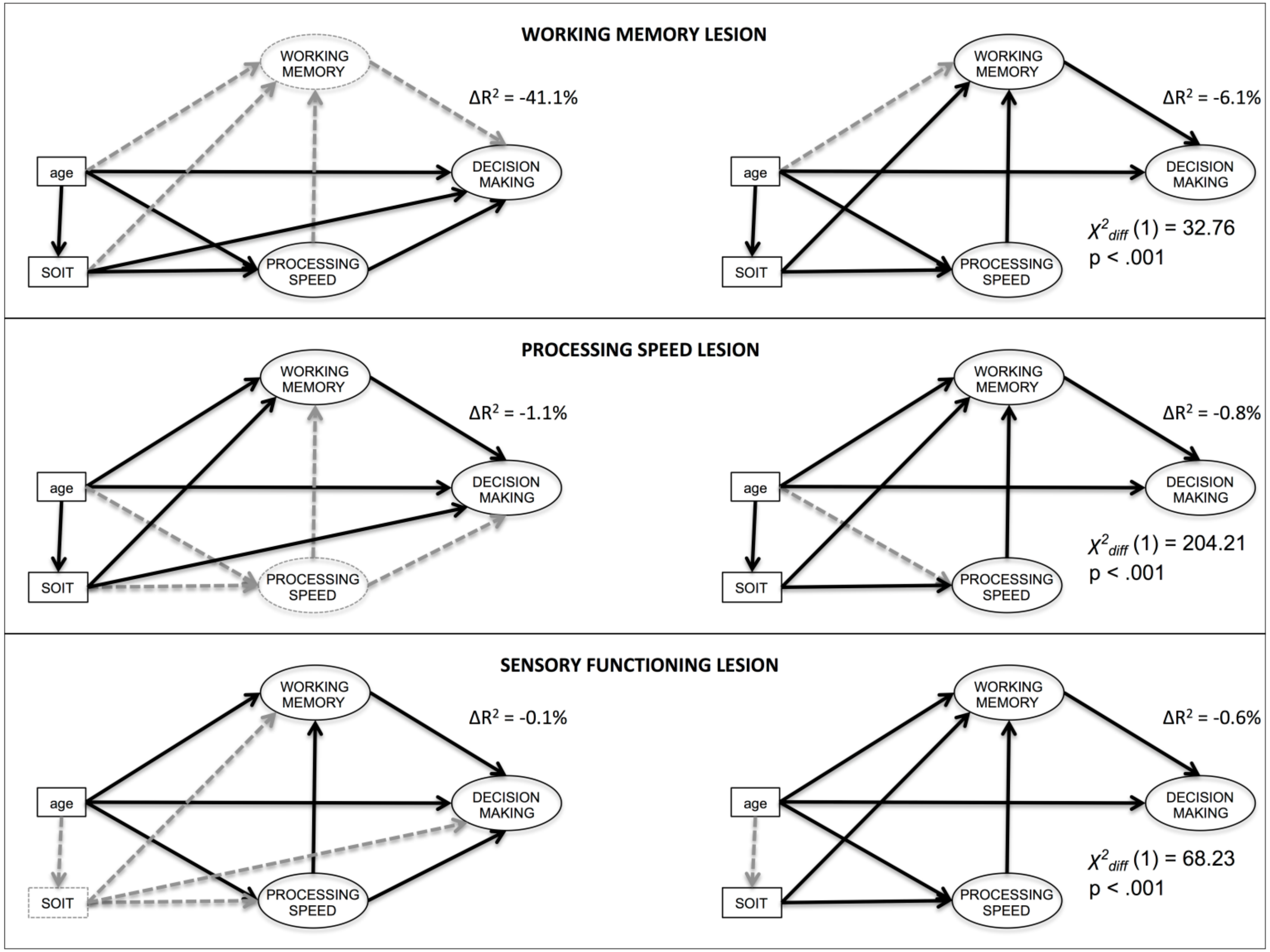
WORKING MEMORY LESION
WORKING MEMORY
ΔR² = -41.1%
age
DECISION MAKING
SOIT
PROCESSING SPEED
WORKING MEMORY
ΔR² = -6.1%
age
DECISION MAKING
χ²diff (1) = 32.76
p < .001
SOIT
PROCESSING SPEED
PROCESSING SPEED LESION
WORKING MEMORY
ΔR² = -1.1%
age
DECISION MAKING
SOIT
PROCESSING SPEED
WORKING MEMORY
ΔR² = -0.8%
age
DECISION MAKING
χ²diff (1) = 204.21
p < .001
SOIT
PROCESSING SPEED
SENSORY FUNCTIONING LESION
WORKING MEMORY
ΔR² = -0.1%
age
DECISION MAKING
SOIT
PROCESSING SPEED
WORKING MEMORY
ΔR² = -0.6%
age
DECISION MAKING
χ²diff (1) = 68.23
p < .001
SOIT
PROCESSING SPEED

Figure 1_{si}. Model lesion analysis. On the left side of the figure, entire predictors (dotted gray lines) are removed from the full-path model, and the loss in predictive power (ΔR^2) in relation to decision making is computed. On the right side of the figure, specific relations between age and a target predictor are removed (dotted gray lines) from the working memory partial mediation model, and both the significance of the loss in model fit (χ^2_{diff}) and the loss in predictive power (ΔR^2) in relation to decision making are computed.

The findings show that removing the working memory predictor from the full-path model has a dramatic negative consequence on predictive capacity (-41%), while removing processing speed and SOIT produces very limited losses. When a single link between age and each of the three candidate predictors is removed from the working memory partial mediation model, the fit of the models is always significantly decreased, but the decrease in predictive capacity shows a noticeable loss (approximately 6%) only when the age→working memory link is removed. Thus, summarizing, working memory seems to convey a substantial predictive capacity in relation to decision making but, in the working memory partial mediation model, all the links between age and each of the three candidate predictors are needed to provide an accurate representation of the relationships between the variables. These findings nicely agree with the ones provided by comparative modeling and by the estimation of indirect effects of age on decision making.

3.2 Changing the indicator of sensory functioning

We appraised whether substituting the SOIT with other indicators of sensory functioning affects the result. To this aim, we replaced the SOIT with the alternative sensory functioning measures in all the models mediating the effects of age on decision making. In particular, we used as substitutes of the SOIT the FMHT, the visual tests from 3 and 5 meters, and the hearing losses from the left and right ears. We provide here a verbal summary of the findings, with the complete results being available on request. No appreciable differences emerged in relation to the prominent role of working memory vs. processing speed or sensory functioning in the full-path models and in the working memory partial mediation models. However, the models using the alternative sensory measures did not show significant relations between the sensory measure and the cognitive mediators (processing speed and working memory). Moreover, the mediation models centered on sensory functioning did not present a significant direct relation between the sensory functioning indicators and decision making and thus displayed a reduced predictive capacity vs. the SOIT-centered model. Therefore, in line with the correlational findings and previous studies (e.g., Olofsson et al., 2009), the SOIT proved to be a particularly good predictor of cognitive measures (including decision making) as compared to other indicators of sensory functioning.

3.3 Single decision-making variables as criterion tasks

The mediation models estimated in the present study were used to predict decision making as a latent variable, which was built from three cognitively-demanding A-DMC tasks. The best model explained a very large fraction of variance in this decision-making construct. This latent variable approach increased the reliability of the measured construct and thus the capability of detecting relationships between constructs (see e.g. Miyake et al., 2000), but it may have obscured interesting differences between specific A-DMC decision-making tasks (Del Missier et al., 2013). Thus, to complement this analysis, we re-estimated all the models by using single A-DMC tasks as criterion variables.

The results, presented in Table 1_{si}, show that the partial mediation working memory model is still the best fitting model for the Resistance to Framing and Applying Decision Rules tasks, thus confirming the findings obtained when using the latent-variable approach. Indeed, for these two tasks, working memory partial mediation models have the best fit vs. the models centered on alternative mediators, and they are marginally or significantly better than their full-mediation versions (χ^2_{diff} (1) = 3.707, p = .054 and χ^2_{diff} (1) = 6.827, p < .01, respectively). However, in line with a previous investigation (Del Missier et al., 2013), a total mediation model centered on working memory was more tenable than a partial mediation one in the case of the Under/Overconfidence task (see the structural coefficients in Table 1_{si} and the nonsignificant difference between the full mediation and partial mediation models: χ^2_{diff} (1) = 0.252, *p* = .616). Note that the analyses on single A-DMC tasks, in line with our previous investigation, explain much less variance than the analysis on the decision-making latent variable. This can be explained by the fact that the decision-making latent variable captures cognitive operations that are common to the three cognitively-demanding A-DMC task (see the hypothesis section), and thus it is more strongly related to working memory, while performance on single decision-making tasks may also require other skills and be affected by task-specific factors. Additionally, measurement at the latent variable level is more reliable. To summarize, the results on single decision-making tasks support the findings of our study about the relative role of the three general predictors of decision making, complementing them with task-specific indications.

Table 1_{si}. Fit of structural equation models with specific A-DMC tasks as criterion variables

Model (N = 563)	χ^2, **df**	χ^2**/df**	**CFI**	**RMSEA**	**AIC**	χ^2 **diff. vs. full path**	χ^2 **diff. vs. no path**	**Standardized coefficients**				R^2 **DM**
Full path								WM→DM	Speed→DM	SOIT→DM	Age→DM	
Partial mediation ADR	47.927, 24	1.997	.988	.042	109.93	–	χ^2_{diff} (3) = 52.062***	.576***	-.057 ns	.065 ns	.119^	.342
Partial mediation FRA	50.612, 24	2.109	.985	.044	112.61	–	χ^2_{diff} (3) = 19.213***	.458***	-.115 ns	.018 ns	.171*	.108
Partial mediation UOC	49.458, 24	2.061	.986	.043	111.46	–	χ^2_{diff} (3) = 8.674*	.323**	-.118 ns	.005 ns	.016 ns	.084
Total mediation ADR	50.867, 25	2.035	.987	.043	110.87	–	χ^2_{diff} (3) = 78.359***	.484**	-.081 ns	.065 ns	–	.319
Total mediation FRA	55.717, 25	2.229	.983	.047	115.72	–	χ^2_{diff} (3) = 15.094**	.329***	-.154^	.017	–	.081
Total mediation UOC	49.501, 25	1.980	.986	.042	109.50	–	χ^2_{diff} (3) = 14.491**	.310**	-.121 ns	.005 ns	–	.082
Working memory												
Partial mediation ADR	50.661, 26	1.949	.987	.041	108.66	χ^2_{diff} (2) = 2.734 ns	χ^2_{diff} (1) = 49.328***	.573***	–	–	.131^	.339
Partial mediation FRA	52.517, 26	2.020	.985	.043	110.52	χ^2_{diff} (2) = 1.905 ns	χ^2_{diff} (1) = 17.308***	.378***	–	–	.189*	.093
Partial mediation UOC	51.395, 26	1.977	.986	.042	109.39	χ^2_{diff} (2) = 1.937 ns	χ^2_{diff} (1) = 6.737**	.235**	–	–	.036 ns	.071
Total mediation ADR	54.368, 27	2.014	.986	.042	110.37	χ^2_{diff} (2) = 3.501 ns	χ^2_{diff} (1) = 74.858***	445***	–	–	–	.309
Total mediation FRA	59.344, 27	2.198	.982	.046	115.34	χ^2_{diff} (2) = 3.627 ns	χ^2_{diff} (1) = 11.467**	.193***	–	–	–	.060
Total mediation UOC	51.647, 27	1.913	.986	.040	107.65	χ^2_{diff} (2) = 2.146 ns	χ^2_{diff} (1) = 12.345***	.199***	–	–	–	.067
Processing Speed												
Partial mediation ADR	88.703, 26	3.412	.968	.066	146.70	χ^2_{diff} (2) = 40.776***	χ^2_{diff} (1) = 11.286**	–	.212***	–	-.085 ns	.226
Partial mediation FRA	68.135, 26	2.621	.976	.054	126.13	χ^2_{diff} (2) = 17.523***	χ^2_{diff} (1) = 1.690 ns	–	.090 ns	–	.015 ns	.038
Partial mediation UOC	58.008, 26	2.231	.982	.047	116.01	χ^2_{diff} (2) = 8.550*	χ^2_{diff} (1) = 0.124 ns	–	.024 ns	–	-.093 ns	.048

Total mediation ADR	90.832, 27	3.364	.967	.065	146.83	χ^2_{diff} (2) = 39.965***	χ^2_{diff} (1) = 38.394 ***	–	.278***	–	–	.228
Total mediation FRA	68.186, 27	2.525	.997	.052	124.19	χ^2_{diff} (2) = 12.469**	χ^2_{diff} (1) = 2.625 ns	–	.079 ns	–	–	.037
Total mediation UOC	60.128, 27	2.227	.981	.047	116.13	χ^2_{diff} (2) = 10.627**	χ^2_{diff} (1) = 3.864 *	–	.096*		–	.046
Sensory Functioning												
Partial mediation ADR	88.988, 26	3.423	.967	.066	146.99	χ^2_{diff} (2) = 41.061***	χ^2_{diff} (1) = 11.001**	–	–	.137***	-.176***	.220
Partial mediation FRA	67.524, 26	2.597	.977	.053	125.53	χ^2_{diff} (2) = 16.912***	χ^2_{diff} (1) = 2.301 ns	–	–	.069 ns	-.020 ns	.038
Partial mediation UOC	57.443, 26	2.209	.982	.046	115.44	χ^2_{diff} (2) = 7.985*	χ^2_{diff} (1) = 0.689 ns	–	–	.038 ns	-.096*	.049
Total mediation ADR	105.386, 27	3.903	.959	.072	161.39	χ^2_{diff} (2) = 54.519***	χ^2_{diff} (1) = 23.840 ***	–	–	.194***	–	.197
Total mediation FRA	67.703, 27	2.508	.997	.052	123.70	χ^2_{diff} (2) = 11.986**	χ^2_{diff} (1) = 3.108^	–	–	.076^	–	.037
Total mediation UOC	61.449, 27	2.276	.981	.048	117.50	χ^2_{diff} (2) = 11.946**	χ^2_{diff} (1) = 2.543 ns	–	–	.069	–	.042
No path												
Partial mediation ADR	99.989, 27	3.703	.962	.069	155.99	–	–	–	–	–	-.225***	.205
Partial mediation FRA	69.825, 27	2.586	.976	.053	125.83	–	–	–	–	–	-.045 ns	.034
Partial mediation UOC	58.132, 27	2.153	.983	.045	114.13	–	–	–	–	–	-.109*	.048
Total mediation ADR	129.226, 28	4.615	.948	.080	183.23	–	–	–	–	–	–	.162
Total mediation FRA	70.811, 28	2.529	.976	.052	124.81	–	–	–	–	–	–	.032
Total mediation UOC	63.992, 28	2.285	.980	.048	117.99	–	–	–	–	–	–	.038

Note. Abbreviations: ADR = Applying Decision Rules, FRA = Framing, UOC = Under/Overconfidence, WM = working memory, DM = decision making, Speed = processing speed, SOIT = Scandinavian Odor Identification Test.. Significance levels are as follows: ^ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$.

3.4 Alternative way to assess mediation

Although we controlled for cohort-related effects in our data via the inclusion of the education variable, which already proved to be a very effective form of control on the Betula memory data making them fully comparable with the longitudinal ones after the control for practice effects (e.g. Rönnlund et al., 2005), we also prudentially estimated our best-fitting models with the alternative method introduced by Schmiedek and Li (2004). This combined set of controls should address the potential concerns in interpreting the results of cross-sectional studies of age-based mediation effects. Thus, this additional analysis aims to further show the robustness of our results in relation to possible interpretation issues within cross-sectional mediation analysis.

In the specific case of our working-memory mediation model, following the Schmiedek and Li method implies decomposing the variance for each of our decision-making manifest variables into variance explained by working memory and by the decision-making latent variable. However, rather than having decision-making indicators load only on the decision-making latent variable, each decision making measure should load on both the decision-making and the working memory latent variables. Cognitive indicators of speed and working memory still only load on their respective latent variables, and age is added as a covariate to the model (see also Li et al., 2013). In order to support our traditional mediation analyses, the findings of the new analysis should show that decision-making indicators are significantly related with the working memory latent variable, and that age is still negatively related with working memory.

The results show that the working memory partial mediation model estimated with the alternative method has an excellent fit (χ^2 = 66.088, df = 42, χ^2/df = 1.574 , CFI = .988, RMSEA = .032, AIC = 138.088). Coefficients for speed and working memory are unchanged, all decision-making indicators still load significantly on their latent variable and, importantly, all A-DMC task scores are significantly related to working memory (Table 2_{si}). The relation of age with working memory is still negative and significant while the relation with the decision-making latent variable is still positive and marginally significant. To summarize, these results are consistent with the standard cross-sectional mediation analyses and thus suggest that age differences in working memory partially explain age differences in decision making.

Table 2_{si}. Coefficients estimated with the Schmiedek and Li (2004) method.

	Framing	**Applying Decision Rules**	**Under/ Overconfidence**	**AGE**
Working Memory	WM→Framing .293***	WM→Applying .619***	WM→Under/Over .287***	AGE→WM -.366***
Decision Making	DM→Framing .246**	DM→Applying .322**	DM→Under/Over .144^	AGE→DM .514^

Note. Abbreviations: WM = working memory, DM = decision making.