Supplemental Materials:

Moral Judgment Under Uncertainty: A CNI Model Analysis

Nyx L. Ng, Dillon M. Luke, Bertram Gawronski

University of Texas at Austin

Re-analyses Using CAN Algorithm

Because the processes underlying the CNI model parameters may not be ordered hierarchically in the way stipulated by the CNI model processing tree, we re-analysed the data from all four studies using the CAN algorithm (Liu & Liao, 2021). Unlike the CNI model, the CAN algorithm algebraically calculates the three model parameters concurrently rather than hierarchically. The data and analysis codes for the re-analyses can be accessed at https://osf.io/hdq3x/. Table S1 details the means and 95% confidence intervals for the three CAN algorithm parameters. Tables S2 and S3 compare the conclusions reached when the data were analysed using the CAN algorithm versus the CNI model (group-level analysis and individual-level analysis, respectively). Table S4 details the correlations between the CAN algorithm parameters and the manipulation-check measures. Table S5 details the results of the analyses of covariance, which controlled for the correlation between the CAN algorithm's *C* and *N* parameters.

Across all four studies, re-analyses of the data using the CAN algorithm revealed a significant experimental effect of uncertainty on the *C* parameter, such that participants in the low outcome-certainty condition were less sensitive to consequences than those in the high outcome-certainty condition. Contrary to the CNI model, which did not yield a consistent experimental effect on norm sensitivity, a significant between-condition difference was found for the CAN algorithm's *N* parameter, such that participants in the high outcome-certainty condition were less sensitive to moral norms than participants in the low outcome-certainty condition across all four studies. Both the *I* parameter of the CNI model and the *A* parameter (i.e., overall action/inaction preferences) of the CAN algorithm did not consistently differ between the two experimental conditions across the four studies.

Because the CAN algorithm's *N* parameter showed a strong negative correlation with the CAN algorithm's *C* parameter across studies (see Table S4), we conducted follow-up analyses of covariance to assess the effects of outcome certainty after controlling for the shared variance of the two parameters (see Table S5). When the *C* parameter was entered as a covariate, outcome certainty did not predict differences in sensitivity to moral norms in any of the four studies. In contrast, when the *N* parameter was entered as a covariate, the experimental effect of outcome certainty remained statistically significant in all four studies. These findings indicate that, unlike the robust experimental effect on the *C* parameter, the identified experimental effect on the CAN algorithm's *N* parameter was driven by its strong negative correlation with the CAN algorithm's *C* parameter.

Consistent with the correlational analyses of the CNI model's individual-level parameters and the manipulation-check measures, the CAN algorithm's *N* parameter was negatively correlated with subjective certainty (Studies 1, 3 and 4), whereas the *C* parameter was not correlated with any of the manipulation-check measures. The re-analyses thus similarly suggest that the experimental effect of outcome certainty on sensitivity to consequences was likely not driven by subjective certainty (Studies 1, 3, and 4), subjective likelihood (Study 2), or general state uncertainty (Study 3). Whereas the CNI model's *I* parameter was consistently uncorrelated with the manipulation checks, a significant correlation was found between the CAN algorithm's *A* parameter and subjective certainty in Study 3 but not Studies 1 and 4.

Re-analyses Excluding Dilemmas with Action Confound

In two out of the nine scenarios included in the moral dilemma battery, the moral norm manipulation included a confound such that the moral action in question is not only proscribed or prescribed by a moral norm, but also has a direct or indirect effect on the dilemma outcomes. To

address the confound, we excluded these two sets of dilemmas from the computation of the action and inaction indices before conducting the group-level and individual-level CNI model analyses. We also re-analysed the correlations between the individual-level CNI model parameters and mean subjective certainty (Studies 1, 3, and 4). The results of the reanalyses are presented in Table S6.

CNI model group-level analysis

Group-Level Analysis. The model fit was poor for the group-level analysis of Study 1's data, $G^2(2) = 12.51$, $p = .002$, $w = 0.040$, Study 2's data, $G^2(2) = 9.02$, $p = .01$, $w = 0.035$, Study 3's data, $G^2(2) = 22.76$, $p < .001$, $w = 0.055$, and Study 4's data, $G^2(4) = 19.75$, $p < .001$, $w = 0.035$. Consistent with the original analyses, there was a significant difference in the *C* parameter across the two outcome-certainty conditions in Studies 1 to 3, $\Delta G^2(1)$s ≥ 14.90, ps $< .001$, ds > 0.471. In Study 4, we also found a significant group difference on the *C* parameter, $\Delta G^2(2) = 48.50$, $p < .001$, $w = 0.054$. Question frame did not qualify the effect of outcome certainty, $\Delta G^2(1) = 2.38$, $p = .123$, $w = 0.012$, with the difference in sensitivity to consequences between the high and low certainty conditions emerging for both the action and acceptability conditions, $\Delta G^2s(1) \geq 23.06$, ps $< .001$, ds > 0.558. The effect of question frame was not significant for the *C* parameter, $\Delta G^2(2) = 0.25$, $p = .882$, $w = 0.004$, and outcome certainty did not qualify the effect of question frame, $\Delta G^2(1) = 0.19$, $p = .667$, $w = 0.003$.

Constraining the *N* parameter to be equivalent across the two outcome-certainty conditions did not result in a significant reduction in model fit in Study 1, $\Delta G^2(1) = 1.42$, $p = .23$, $d = 0.144$, and Study 3, $\Delta G^2(1) = 1.95$, $p = .16$, $d = 0.169$, suggesting no differences in norm sensitivity. However, there was a significant group difference on the *N* parameter in Study 2, $\Delta G^2(1) = 7.46$, $p = .006$, $d = 0.471$, and Study 4, $\Delta G^2(2) = 8.53$, $p = .014$, $w = 0.023$. Although

the analyses suggest that question frame did not qualify the effect of outcome certainty on the *N* parameter, $\Delta G^2(1) = 2.37$, $p = .124$, $w = 0.012$, the difference on the *N* parameter between the high and low certainty conditions emerged for Study 4's action condition, $\Delta G^2(1) = 5.45$, $p = .020$, $d = 0.271$, but not the acceptability condition, $\Delta G^2(1) = 3.08$, $p = .079$, $d = 0.205$. We also found a significant effect of question frame on the *N* parameter, $\Delta G^2(2) = 9.82$, $p = .007$, $w = 0.024$, which was qualified by outcome certainty, $\Delta G^2(1) = 7.49$, $p = .006$, $w = 0.021$, such that there was a significant difference on the *N* parameter between the action and acceptability conditions in the high certainty condition, $\Delta G^2(1) = 8.66$, $p = .003$, $d = 0.343$, but not low certainty condition, $\Delta G^2(1) = 1.16$, $p = .281$, $d = 0.126$.

Constraining the *I* parameter to be equivalent across the two outcome-certainty conditions did not result in a significant reduction in model fit in all studies, $\Delta G^2 s(1) \leq 2.18$, *p*s > .10, Studies 1 to 3's *d*s < 0.179 , Study 4's $w = 0.013$. We found a significant effect of question frame in Study 4, $\Delta G^2(2) = 14.89$, $p = .001$, $w = 0.030$. The analyses suggest the effect of question frame was qualified by outcome certainty, $\Delta G^2(1) = 4.78$, $p = .029$, $w = 0.017$, although the difference on the *I* parameter across the question frame conditions emerged for both the high certainty condition, $\Delta G^2(1) = 5.06$, $p = .025$, $d = 0.261$, and low certainty condition, $\Delta G^2(1) = 9.83$, $p = .001$, $d = 0.366$.

CNI model individual-level analysis.

For the individual-level CNI model parameters, we again found a statistically significant difference in the mean *C* parameter score across certainty conditions in Studies 1 to 3, *p*s < .001, *d*s ≥ 0.502. In Study 4, we found a statistically significant main effect of certainty on the *C* parameter, $F(1, 584) = 39.40$, $p < .001$, $\eta_p^2 = 0.063$. The main effect of certainty on the *C* parameter was not qualified by question frame, $F(1, 584) = 2.21$, $p = .138$, $\eta_p^2 = 0.001$, such that

the effect of certainty on the *C* parameter emerged in both the action, $F(1, 584) = 21.18$, $p < .001$, $\eta_p^2 = 0.035$ and acceptability conditions, $F(1, 584) = 18.29$, $p < .001$, $\eta_p^2 = 0.030$. Question frame did not significantly influence the *C* parameter, $F(1, 584) = 0.27$, $p = .601$, $\eta_p^2 < 0.001$.

We did not find any significant differences across certainty conditions for the individually estimated *N* parameter in Studies 1 to 3, *ps* > .08, *d*s < 0.213. In Study 4, the main effect of certainty on the *N* parameter was also not statistically significant, $F(1, 584) = 2.13$, $p = .145$, $\eta_p^2 = 0.004$. The post-hoc univariate analyses suggest a potential effect of certainty on the *N* parameter, $F(1, 584) = 5.36$, $p = .021$, $\eta_p^2 = 0.009$, but the interaction term between certainty and question frame did not reach statistical significance, $F(1, 584) = 3.23$, $p = .073$, $\eta_p^2 = 0.006$. There was also no main effect of question frame on the *N* parameter in Study 4, $F(1, 584) = 0.07$, $p = .788$, $\eta_p^2 < 0.001$.

Lastly, we did not find any significant differences across certainty conditions for the individually-estimated *I* parameter in Studies 1 to 3, *p*s > .13, *d*s < 0.090, as well as Study 4, $F(1, 584) = 2.21$, $p = .138$, $\eta_p^2 = 0.001$. The main effect of question frame was statistically significant for the *I* parameter, $F(1, 584) = 6.65$, $p = .01$, $\eta_p^2 = 0.011$, but it did not qualify the effect of certainty, $F(1, 584) = 0.78$, $p = .376$, $\eta_p^2 = 0.001$.

Correlational analysis.

Next, we re-analysed the associations between the CNI model parameters and mean subjective certainty without the inclusion of the two problematic dilemmas for the data of Studies 1, 3, and 4. Study 2 was excluded from the analysis because it did not include measures of mean subjective certainty. The results of the correlational analyses are presented in Table S7. After excluding the two dilemmas with the potential confound, the correlation between the *N*

parameter and mean subjective certainty largely weakened, only attaining statistical significance in Study 1, $r = -.15$, $p = .012$, and Study 4's moral acceptability condition, $r = -.24$, $p < .001$.

Table S1

Means and 95% confidence intervals of the CAN algorithm parameters

	High Outcome Certainty		Low Outcome Certainty	
	M	**95% CI**	***M***	**95% CI**
Study 1				
C parameter	.29	[.26, .32]	.20	[.18, .22]
N parameter	.43	[.39, .48]	.50	[.46, .54]
A parameter	.45	[.44, .46]	.47	[.46, .49]
Study 2				
C parameter	.28	[.25, .31]	.21	[.19, .24]
N parameter	.39	[.34, .44]	.47	[.43, .51]
A parameter	.46	[.45, .47]	.46	[.45, .47]
Study 3				
C parameter	.29	[.26, .32]	.21	[.18, .24]
N parameter	.39	[.35, .43]	.46	[.42, .51]
A parameter	.47	[.46, .48]	.46	[.44, .47]
Study 4 – Action				
C parameter	.29	[.26, .32]	.21	[.19, .23]
N parameter	.42	[.38, .46]	.51	[.47, .54]
A parameter	.45	[.44, .46]	.46	[.45, .47]
Study 4 – Acceptability				
C parameter	.28	[.25, .31]	.20	[.17, .22]
N parameter	.48	[.44, .52]	.51	[.48, .55]
A parameter	.48	[.47, .49]	.49	[.48, .50]

Table S2

Comparing the effects of outcome certainty yielded using the CNI model (group-level estimates) and CAN algorithm

	CNI Model Parameter	Results	CAN Algorithm Parameter	Results	Conclusion Contrast
Study 1					
	C	$\Delta G^2(1) = 27.19$, $p < .001$, $d = 0.630$	*C*	$t(254.87) = -4.84$, $p < .001$, $d = 0.586$	Identical
	N	$\Delta G^2(1) = 0.37$, $p = .545$, $d = 0.074$	*N*	$t(271) = 2.10$, $p = .036$, $d = 0.254$	Different
	I	$\Delta G^2(1) = 4.83$, $p = .028$, $d = 0.266$	*A*	$t(271) = 2.32$, $p = .021$, $d = 0.280$	Identical
Study 2					
	C	$\Delta G^2(1) = 16.67$, $p < .001$, $d = 0.498$	*C*	$t(267) = -3.54$, $p < .001$, $d = 0.430$	Identical
	N	$\Delta G^2(1) = 5.13$, $p = .023$, $d = 0.276$	*N*	$t(256.32) = 2.48$, $p = .014$, $d = 0.303$	Identical
	I	$\Delta G^2(1) = 0.00$, $p = .950$, $d = 0.008$	*A*	$t(267) = 0.05$, $p = .963$, $d = 0.006$	Identical
Study 3					
	C	$\Delta G^2(1) = 21.86$, $p < .001$, $d = 0.568$	*C*	$t(268) = -3.94$, $p < .001$, $d = 0.479$	Identical
	N	$\Delta G^2(1) = 2.15$, $p = .143$, $d = 0.177$	*N*	$t(268) = 2.42$, $p = .016$, $d = 0.295$	Different
	I	$\Delta G^2(1) = 3.27$, $p = .070$, $d = 0.219$	*A*	$t(268) = -1.40$, $p = .162$, $d = 0.171$	Identical
Study 4 – Action					
	C	$\Delta G^2(1) = 24.23$, $p < .001$, $d = 0.572$	*C*	$F(1, 584) = 19.65$, $p < .001$, $\eta_p^2 = 0.033$	Identical
	N	$\Delta G^2(1) = 4.31$, $p = .038$, $d = 0.241$	*N*	$F(1, 584) = 9.05$, $p = .003$, $\eta_p^2 = 0.015$	Identical
	I	$\Delta G^2(1) = 0.68$, $p = .411$, $d = 0.095$	*A*	$F(1, 584) = 0.49$, $p = .485$, $\eta_p^2 = 0.001$	Identical

Study 4 – Acceptability				
C	$\Delta G^2(1) = 27.59$, $p < .001$, $d = 0.615$	*C*	$F(1, 584) = 22.38$, $p < .001$, $\eta_p^2 = 0.037$	Identical
N	$\Delta G^2(1) = 2.01$, $p = .156$, $d = 0.166$	*N*	$F(1, 584) = 1.41$, $p = .235$, $\eta_p^2 = 0.002$	Identical
I	$\Delta G^2(1) = 1.17$, $p = .280$, $d = 0.126$	*A*	$F(1, 584) = 0.34$, $p = .561$, $\eta_p^2 = 0.001$	Identical

Table S3

Comparing the effects of outcome certainty yielded using the CNI model (individual-level estimates) and CAN algorithm

CNI Model Parameter	Results	CAN Algorithm Parameter	Results	Conclusion Contrast
Study 1				
C	$t(251.05) = -4.68$, $p < .001$, $d = 0.567$	*C*	$t(254.87) = -4.84$, $p < .001$, $d = 0.586$	Identical
N	$t(271) = 0.94$, $p = .348$, $d = 0.114$	*N*	$t(271) = 2.10$, $p = .036$, $d = 0.254$	Different
I	$t(271) = -1.23$, $p = .220$, $d = 0.149$	*A*	$t(271) = 2.32$, $p = .021$, $d = 0.280$	Different
Study 2				
C	$t(267) = -4.07$, $p < .001$, $d = 0.495$	*C*	$t(267) = -3.54$, $p < .001$, $d = 0.430$	Identical
N	$t(255.49) = 1.26$, $p = .207$, $d = 0.155$	*N*	$t(256.32) = 2.48$, $p = .014$, $d = 0.303$	Different
I	$t(267) = -0.39$, $p = .700$, $d = 0.064$	*A*	$t(267) = 0.05$, $p = .963$, $d = 0.006$	Identical
Study 3				
C	$t(268) = -4.24$, $p < .001$, $d = 0.515$	*C*	$t(268) = -3.94$, $p < .001$, $d = 0.479$	Identical
N	$t(266.01) = 0.61$, $p = .542$, $d = 0.074$	*N*	$t(268) = 2.42$, $p = .016$, $d = 0.295$	Different
I	$t(264.88) = 1.68$, $p = .094$, $d = 0.203$	*A*	$t(268) = -1.40$, $p = .162$, $d = 0.171$	Identical
Study 4 – Action				
C	$F(1, 584) = 19.21$, $p < .001$, $\eta_p^2 = 0.032$	*C*	$F(1, 584) = 19.65$, $p < .001$, $\eta_p^2 = 0.033$	Identical
N	$F(1, 584) = 3.16$, $p = .076$, $\eta_p^2 = 0.005$	*N*	$F(1, 584) = 9.05$, $p = .003$, $\eta_p^2 = 0.015$	Different
I	$F(1, 584) = 0.42$, $p = .519$, $\eta_p^2 = 0.001$	*A*	$F(1, 584) = 0.49$, $p = .485$, $\eta_p^2 = 0.001$	Identical

Study 4 – Acceptability				
C	$F(1, 584) = 17.87, p < .001, \eta_p^2 = 0.030$	*C*	$F(1, 584) = 22.38, p < .001, \eta_p^2 = 0.037$	Identical
N	$F(1, 584) = 0.01, p = .909, \eta_p^2 = 0.000$	*N*	$F(1, 584) = 1.41, p = .235, \eta_p^2 = 0.002$	Identical
I	$F(1, 584) = 2.67, p = .103, \eta_p^2 = 0.005$	*A*	$F(1, 584) = 0.34, p = .561, \eta_p^2 = 0.001$	Identical

Table S4

Correlations between CAN algorithm parameters and manipulation checks

		***C* parameter**	***N* parameter**	***A* parameter**
Study 1				
	C parameter	1		
	N parameter	-.45**	1	
	A parameter	-.13*	-.15*	1
	Mean subjective certainty	.01	-.19**	.08
Study 2				
	C parameter	1		
	N parameter	-.25**	1	
	A parameter	-.03	-.07	1
	Mean subjective likelihood	.10	-.09	.10
Study 3				
	C parameter	1		
	N parameter	-.34**	1	
	A parameter	-.12	-.19**	1
	Mean subjective certainty	.02	-.16**	.13*
	Mean state uncertainty	-.03	.02	-.01
Study 4 – Action				
	C parameter	1		
	N parameter	-.36**	1	
	A parameter	-.01	-.09	1
	Mean subjective certainty	.03	-.02	.11*
Study 4 – Acceptability				
	C parameter	1		
	N parameter	-.50**	1	
	A parameter	-.03	-.13	1
	Mean subjective certainty	.08	-.18**	-.00

Note. *$p < .05$, **$p < .01$, ***$p < .001$.

Table S5

Analysis of covariance controlling for the correlation between the CAN algorithm's *C* and *N* parameters

	F	*p*	η_p^2
Predicting *C* Parameter			
Study 1			
N parameter	63.56	< .001	0.191
Certainty Condition	18.76	< .001	0.065
Study 2			
N parameter	14.75	< .001	0.053
Certainty Condition	9.04	.003	0.033
Study 3			
N parameter	29.01	<.001	0.098
Certainty Condition	10.96	.001	0.039
Study 4 –Action			
N parameter	37.54	< .001	0.113
Certainty Condition	13.08	< .001	0.043
Study 4 – Acceptability			
N parameter	97.79	< .001	0.253
Certainty Condition	22.19	< .001	0.072
Predicting *N* Parameter			
Study 1			
C parameter	63.56	< .001	0.191
Certainty Condition	.00	.986	0.000
Study 2			
C parameter	14.75	< .001	0.053
Certainty Condition	2.83	.094	0.011
Study 3			
C parameter	29.01	<.001	0.098
Certainty Condition	1.48	.225	0.006
Study 4 – Action			
C parameter	37.54	< .001	0.113
Certainty Condition	2.36	.126	0.008
Study 4 – Acceptability			
C parameter	97.79	< .001	0.253
Certainty Condition	1.69	.194	0.006

Table S6

Means and 95% confidence intervals of the CNI model parameters after excluding two dilemma scenarios with the confound

	Group-Level Analysis					Individual-Level Analysis				
	High Outcome Certainty		Low Outcome Certainty		Sig.	High Outcome Certainty		Low Outcome Certainty		Sig.
	M	**95% CI**	***M***	**95% CI**		***M***	**95% CI**	***M***	**95% CI**	
Study 1										
C parameter	.26	[.23, .29]	.17	[.14, .19]	***	.26	[.23, .29]	.17	[.15, .19]	***
N parameter	.61	[.58, .65]	.64	[.61, .67]	*n.s.*	.59	[.54, .65]	.65	[.61, .70]	*n.s.*
I parameter	.67	[.63, .72]	.63	[.59, .67]	*n.s.*	.59	[.54, .65]	.68	[.62, .73]	*n.s.*
Study 2										
C parameter	.25	[.22, .28]	.18	[.15, .20]	***	.26	[.23, .29]	.18	[.15, .20]	***
N parameter	.55	[.51, .58]	.62	[.58, .65]	**	.56	[.51, .62]	.62	[.58, .67]	*n.s.*
I parameter	.65	[.61, .69]	.68	[.64, .72]	*n.s.*	.72	[.67, .77]	.71	[.66, .76]	*n.s.*
Study 3										
C parameter	.27	[.24, .29]	.18	[.15, .20]	***	.27	[.23, .30]	.18	[.15, .21]	***
N parameter	.59	[.55, .62]	.62	[.59, .66]	*n.s.*	.58	[.53, .64]	.62	[.58, .66]	*n.s.*
I parameter	.61	[.57, .65]	.64	[.60, .69]	*n.s.*	.70	[.64, .75]	.69	[.64, .75]	*n.s.*
Study 4 – Action										
C parameter	.26	[.23, .29]	.17	[.15, .20]	***	.26	[.23, .29]	.18	[.16, .20]	***
N parameter	.61	[.58, .64]	.66	[.63, .69]	*	.61	[.56, .66]	.68	[.64, .72]	*n.s.*
I parameter	.71	[.67, .75]	.68	[.64, .72]	*n.s.*	.73	[.68, .78]	.72	[.67, .77]	*n.s.*
Study 4 – Acceptability										
C parameter	.26	[.23, .28]	.17	[.14, .19]	***	.25	[.22, .28]	.17	[.15, .20]	***
N parameter	.68	[.65, .71]	.64	[.61, .67]	*n.s.*	.66	[.61, .70]	.65	[.61, .69]	*
I parameter	.63	[.59, .68]	.59	[.55, .63]	*n.s.*	.69	[.63, .74]	.63	[.58, .67]	*n.s.*

Note. Dilemma scenarios excluded from the analysis are d03 and d06.

Table S7

Correlations between mean subjective certainty and individual-level CNI model parameters after excluding the two dilemmas with the confound (Studies 1, 3, and 4)

	***C* parameter**	***N* parameter**	***I* parameter**
Study 1			
C parameter	1		
N parameter	-.18**	1	
I parameter	-.03	.21**	1
Mean subjective certainty	.01	-.15*	-.04
Study 3			
C parameter	1		
N parameter	-.13*	1	
I parameter	.05	.30**	1
Mean subjective certainty	.06	-.12	-.06
Study 4 – Action			
C parameter	1		
N parameter	-.04	1	
I parameter	-.02	.15**	1
Mean subjective certainty	.09	.03	.06
Study 4 – Acceptability			
C parameter	1		
N parameter	-.19**	1	
I parameter	.00	.20**	1
Mean subjective certainty	.09	-.24**	.01

Note. *$p < .05$, **$p < .01$, ***$p < .001$. Dilemma scenarios excluded from the analysis are d03 and d06. Study 2 did not include a measure of subjective certainty and was thus excluded from this analysis.