Supplementary information

Do low-confidence individuals decrease group judgments' accuracy? Investigations in terms of the wisdom of crowds framework

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Supplementary information 1

the procedure for picking up questions in a population inference task

We picked up 140 questions among 210 questions (i.e., all possible 105 pairs by using 15 Japanese cities in "difficult list", and 105 pairs by using 15 Japanese cities in "easy list"[1]) in the following procedure:

1) For each difficulty list, we sorted all questions according to the question number in the original study[1].
2) We omitted questions whose question numbers were multiples of 3, and picked up the question numbers 1, 2, 4, 5, 7, …, 203, 205, 206, 208, 209 (one-hundred and forty questions in total).
3) We split them into two question sets. The question numbers 1, 4, 7, …, 205, and 208 were called "population inference set A" (70 questions), while 2, 5, …, 203, 206, and 209 were called "population inference set B" (also 70 questions).

question list (population inference task; 140 questions)

altCorrect	city_large_En	city_large_popu	altFalse	city_small_En	city_small_popu	difficultyLevel	qidx	assign
横浜市	Yokohama-shi	3724844	大阪市	Osaka-shi	2691185	easy	1	A
横浜市	Yokohama-shi	3724844	名古屋市	Nagoya-shi	2295638	easy	2	B
横浜市	Yokohama-shi	3724844	福岡市	Fukuoka-shi	1538681	easy	4	A
横浜市	Yokohama-shi	3724844	神戸市	Kobe-shi	1537272	easy	5	B
横浜市	Yokohama-shi	3724844	広島市	Hiroshima-shi	1194034	easy	7	A
横浜市	Yokohama-shi	3724844	仙台市	Sendai-shi	1082159	easy	8	B
横浜市	Yokohama-shi	3724844	新潟市	Niigata-shi	810157	easy	10	A
横浜市	Yokohama-shi	3724844	浜松市	Hamamatsu-shi	797980	easy	11	B
横浜市	Yokohama-shi	3724844	岡山市	Okayama-shi	719474	easy	13	A
横浜市	Yokohama-shi	3724844	鹿児島市	Kagoshima-his	599814	easy	14	B
大阪市	Osaka-shi	2691185	札幌市	Sapporo-shi	1952356	easy	16	A
大阪市	Osaka-shi	2691185	福岡市	Fukuoka-shi	1538681	easy	17	B
大阪市	Osaka-shi	2691185	京都市	Kyoto-shi	1475183	easy	19	A
大阪市	Osaka-shi	2691185	広島市	Hiroshima-shi	1194034	easy	20	B
大阪市	Osaka-shi	2691185	千葉市	Chiba-shi	971882	easy	22	A
大阪市	Osaka-shi	2691185	新潟市	Niigata-shi	810157	easy	23	B
大阪市	Osaka-shi	2691185	熊本市	Kumamoto-shi	740822	easy	25	A
大阪市	Osaka-shi	2691185	岡山市	Okayama-shi	719474	easy	26	B
名古屋市	Nagoya-shi	2295638	札幌市	Sapporo-shi	1952356	easy	28	A
名古屋市	Nagoya-shi	2295638	福岡市	Fukuoka-shi	1538681	easy	29	B
名古屋市	Nagoya-shi	2295638	京都市	Kyoto-shi	1475183	easy	31	A
名古屋市	Nagoya-shi	2295638	広島市	Hiroshima-shi	1194034	easy	32	B
名古屋市	Nagoya-shi	2295638	千葉市	Chiba-shi	971882	easy	34	A
名古屋市	Nagoya-shi	2295638	新潟市	Niigata-shi	810157	easy	35	B
名古屋市	Nagoya-shi	2295638	熊本市	Kumamoto-shi	740822	easy	37	A

名古屋市	Nagoya-shi	2295638	岡山市	Okayama-shi	719474	easy	38	B
札幌市	Sapporo-shi	1952356	福岡市	Fukuoka-shi	1538681	easy	40	A
札幌市	Sapporo-shi	1952356	神戸市	Kobe-shi	1537272	easy	41	B
札幌市	Sapporo-shi	1952356	広島市	Hiroshima-shi	1194034	easy	43	A
札幌市	Sapporo-shi	1952356	仙台市	Sendai-shi	1082159	easy	44	B
札幌市	Sapporo-shi	1952356	新潟市	Niigata-shi	810157	easy	46	A
札幌市	Sapporo-shi	1952356	浜松市	Kumamoto-shi	797980	easy	47	B
札幌市	Sapporo-shi	1952356	岡山市	Okayama-shi	719474	easy	49	A
札幌市	Sapporo-shi	1952356	鹿児島市	Kagoshima-his	599814	easy	50	B
福岡市	Fukuoka-shi	1538681	京都市	Kyoto-shi	1475183	easy	52	A
福岡市	Fukuoka-shi	1538681	広島市	Hiroshima-shi	1194034	easy	53	B
福岡市	Fukuoka-shi	1538681	千葉市	Chiba-shi	971882	easy	55	A
福岡市	Fukuoka-shi	1538681	新潟市	Niigata-shi	810157	easy	56	B
福岡市	Fukuoka-shi	1538681	熊本市	Kumamoto-shi	740822	easy	58	A
福岡市	Fukuoka-shi	1538681	岡山市	Okayama-shi	719474	easy	59	B
神戸市	Kobe-shi	1537272	京都市	Kyoto-shi	1475183	easy	61	A
神戸市	Kobe-shi	1537272	広島市	Hiroshima-shi	1194034	easy	62	B
神戸市	Kobe-shi	1537272	千葉市	Chiba-shi	971882	easy	64	A
神戸市	Kobe-shi	1537272	新潟市	Niigata-shi	810157	easy	65	B
神戸市	Kobe-shi	1537272	熊本市	Kumamoto-shi	740822	easy	67	A
神戸市	Kobe-shi	1537272	岡山市	Okayama-shi	719474	easy	68	B
京都市	Kyoto-shi	1475183	広島市	Hiroshima-shi	1194034	easy	70	A
京都市	Kyoto-shi	1475183	仙台市	Sendai-shi	1082159	easy	71	B
京都市	Kyoto-shi	1475183	新潟市	Niigata-shi	810157	easy	73	A
京都市	Kyoto-shi	1475183	浜松市	Hamamatsu-shi	797980	easy	74	B
京都市	Kyoto-shi	1475183	岡山市	Okayama-shi	719474	easy	76	A
京都市	Kyoto-shi	1475183	鹿児島市	Kagoshima-his	599814	easy	77	B
広島市	Hiroshima-shi	1194034	千葉市	Chiba-shi	971882	easy	79	A
広島市	Hiroshima-shi	1194034	新潟市	Niigata-shi	810157	easy	80	B
広島市	Hiroshima-shi	1194034	熊本市	Kumamoto-shi	740822	easy	82	A
広島市	Hiroshima-shi	1194034	岡山市	Okayama-shi	719474	easy	83	B
仙台市	Sendai-shi	1082159	千葉市	Chiba-shi	971882	easy	85	A

仙台市	Sendai-shi	1082159	新潟市	Niigata-shi	810157	easy	86	B
仙台市	Sendai-shi	1082159	熊本市	Kumamoto-shi	740822	easy	88	A
仙台市	Sendai-shi	1082159	岡山市	Okayama-shi	719474	easy	89	B
千葉市	Chiba-shi	971882	新潟市	Niigata-shi	810157	easy	91	A
千葉市	Chiba-shi	971882	浜松市	Hamamatsu-shi	797980	easy	92	B
千葉市	Chiba-shi	971882	岡山市	Okayama-shi	719474	easy	94	A
千葉市	Chiba-shi	971882	鹿児島市	Kagoshima-his	599814	easy	95	B
新潟市	Niigata-shi	810157	熊本市	Kumamoto-shi	740822	easy	97	A
新潟市	Niigata-shi	810157	岡山市	Okayama-shi	719474	easy	98	B
浜松市	Hamamatsu-shi	797980	熊本市	Kumamoto-shi	740822	easy	100	A
浜松市	Hamamatsu-shi	797980	岡山市	Okayama-shi	719474	easy	101	B
熊本市	Kumamoto-shi	740822	岡山市	Okayama-shi	719474	easy	103	A
熊本市	Kumamoto-shi	740822	鹿児島市	Kagoshima-his	599814	easy	104	B
川口市	Kawaguchi-shi	578112	町田市	Machida-shi	432348	difficult	106	A
川口市	Kawaguchi-shi	578112	高崎市	Takasaki-shi	370884	difficult	107	B
川口市	Kawaguchi-shi	578112	郡山市	Koriyama-shi	335444	difficult	109	A
川口市	Kawaguchi-shi	578112	佐世保市	Sasebo-shi	255439	difficult	110	B
川口市	Kawaguchi-shi	578112	八戸市	Hachinohe-shi	231257	difficult	112	A
川口市	Kawaguchi-shi	578112	山口市	Yamaguchi-shi	197422	difficult	113	B
川口市	Kawaguchi-shi	578112	高岡市	Takaoka-shi	172125	difficult	115	A
川口市	Kawaguchi-shi	578112	都城市	Miyakonojo-shi	165029	difficult	116	B
川口市	Kawaguchi-shi	578112	今治市	Imabari-shi	158114	difficult	118	A
川口市	Kawaguchi-shi	578112	足利市	Ashikaga-shi	149452	difficult	119	B
町田市	Machida-shi	432348	津市	Tsu-shi	340973	difficult	121	A
町田市	Machida-shi	432348	郡山市	Koriyama-shi	335444	difficult	122	B
町田市	Machida-shi	432348	松本市	Matsumoto-shi	243293	difficult	124	A
町田市	Machida-shi	432348	八戸市	Hachinohe-shi	231257	difficult	125	B
町田市	Machida-shi	432348	日立市	Hitachi-shi	185054	difficult	127	A
町田市	Machida-shi	432348	高岡市	Takaoka-shi	172125	difficult	128	B

町田市	Machida-shi	432348	大垣市	Ogaki-shi	159879	difficult	130	A
町田市	Machida-shi	432348	今治市	Imabari-shi	158114	difficult	131	B
高崎市	Takasaki-shi	370884	津市	Tsu-shi	340973	difficult	133	A
高崎市	Takasaki-shi	370884	郡山市	Koriyama-shi	335444	difficult	134	B
高崎市	Takasaki-shi	370884	松本市	Matsumoto-shi	243293	difficult	136	A
高崎市	Takasaki-shi	370884	八戸市	Hachinohe-shi	231257	difficult	137	B
高崎市	Takasaki-shi	370884	日立市	Hitachi-shi	185054	difficult	139	A
高崎市	Takasaki-shi	370884	高岡市	Takaoka-shi	172125	difficult	140	B
高崎市	Takasaki-shi	370884	大垣市	Ogaki-shi	159879	difficult	142	A
高崎市	Takasaki-shi	370884	今治市	Imabari-shi	158114	difficult	143	B
津市	Tsu-shi	340973	郡山市	Koriyama-shi	335444	difficult	145	A
津市	Tsu-shi	340973	佐世保市	Sasebo-shi	255439	difficult	146	B
津市	Tsu-shi	340973	八戸市	Hachinohe-shi	231257	difficult	148	A
津市	Tsu-shi	340973	山口市	Yamaguchi-shi	197422	difficult	149	B
津市	Tsu-shi	340973	高岡市	Takaoka-shi	172125	difficult	151	A
津市	Tsu-shi	340973	都城市	Miyakonojo-shi	165029	difficult	152	B
津市	Tsu-shi	340973	今治市	Imabari-shi	158114	difficult	154	A
津市	Tsu-shi	340973	足利市	Ashikaga-shi	149452	difficult	155	B
郡山市	Koriyama-shi	335444	松本市	Matsumoto-shi	243293	difficult	157	A
郡山市	Koriyama-shi	335444	八戸市	Hachinohe-shi	231257	difficult	158	B
郡山市	Koriyama-shi	335444	日立市	Hitachi-shi	185054	difficult	160	A
郡山市	Koriyama-shi	335444	高岡市	Takaoka-shi	172125	difficult	161	B
郡山市	Koriyama-shi	335444	大垣市	Ogaki-shi	159879	difficult	163	A
郡山市	Koriyama-shi	335444	今治市	Imabari-shi	158114	difficult	164	B
佐世保市	Sasebo-shi	255439	松本市	Matsumoto-shi	243293	difficult	166	A
佐世保市	Sasebo-shi	255439	八戸市	Hachinohe-shi	231257	difficult	167	B
佐世保市	Sasebo-shi	255439	日立市	Hitachi-shi	185054	difficult	169	A
佐世保市	Sasebo-shi	255439	高岡市	Takaoka-shi	172125	difficult	170	B
佐世保市	Sasebo-shi	255439	大垣市	Ogaki-shi	159879	difficult	172	A
佐世保市	Sasebo-shi	255439	今治市	Imabari-shi	158114	difficult	173	B

松本市	Matsumoto-shi	243293	八戸市	Hachinohe-shi	231257	difficult	175	A
松本市	Matsumoto-shi	243293	山口市	Yamaguchi-shi	197422	difficult	176	B
松本市	Matsumoto-shi	243293	高岡市	Takaoka-shi	172125	difficult	178	A
松本市	Matsumoto-shi	243293	都城市	Miyakonojo-shi	165029	difficult	179	B
松本市	Matsumoto-shi	243293	今治市	Imabari-shi	158114	difficult	181	A
松本市	Matsumoto-shi	243293	足利市	Ashikaga-shi	149452	difficult	182	B
八戸市	Hachinohe-shi	231257	日立市	Hitachi-shi	185054	difficult	184	A
八戸市	Hachinohe-shi	231257	高岡市	Takaoka-shi	172125	difficult	185	B
八戸市	Hachinohe-shi	231257	大垣市	Ogaki-shi	159879	difficult	187	A
八戸市	Hachinohe-shi	231257	今治市	Imabari-shi	158114	difficult	188	B
山口市	Yamaguchi-shi	197422	日立市	Hitachi-shi	185054	difficult	190	A
山口市	Yamaguchi-shi	197422	高岡市	Takaoka-shi	172125	difficult	191	B
山口市	Yamaguchi-shi	197422	大垣市	Ogaki-shi	159879	difficult	193	A
山口市	Yamaguchi-shi	197422	今治市	Imabari-shi	158114	difficult	194	B
日立市	Hitachi-shi	185054	高岡市	Takaoka-shi	172125	difficult	196	A
日立市	Hitachi-shi	185054	都城市	Miyakonojo-shi	165029	difficult	197	B
日立市	Hitachi-shi	185054	今治市	Imabari-shi	158114	difficult	199	A
日立市	Hitachi-shi	185054	足利市	Ashikaga-shi	149452	difficult	200	B
高岡市	Takaoka-shi	172125	大垣市	Ogaki-shi	159879	difficult	202	A
高岡市	Takaoka-shi	172125	今治市	Imabari-shi	158114	difficult	203	B
都城市	Miyakonojo-shi	165029	大垣市	Ogaki-shi	159879	difficult	205	A
都城市	Miyakonojo-shi	165029	今治市	Imabari-shi	158114	difficult	206	B
大垣市	Ogaki-shi	159879	今治市	Imabari-shi	158114	difficult	208	A
大垣市	Ogaki-shi	159879	足利市	Ashikaga-shi	149452	difficult	209	B

Supplementary information 2

the procedure for picking up questions in a relationships comparison task

As described in the main text, we picked up 50 cities and 21 countries used in Study 2b in our previous study[2] based on rates of correct judgments in the following procedure:

1) Among 100 questions in the original study[2], we accepted questions whose rates of correct judgments were lower .90 (in order to avoid ceiling effects). As a result, we picked up 50 questions and there were 50 city names and 21 country names (therefore 71 objects in total) in these 50 questions.
2) We sorted these 50 questions in the order of rates of correct judgments reported in the original study,
3) We split them into two question sets. The odd-ranked 25 questions (i.e., 1^{st}, 3^{rd}, …, 49^{th}) were called "relationships comparison set A" (25 questions) while even-ranked 25 questions (i.e., 2^{nd}, 4^{th}, …, 50^{th}) were called "relationships comparison set B" (also 25 questions).

question list (relationships comparison task; 50 questions)

qidx	city	city_En	altCorrect	altCorrect_En	altFalse	altFalse_En	difficultyLevel	meanCorrectRate	assign	num
63	ゴンダール	Gondar	エチオピア	Ethiopia	コンゴ民主共和国	Democratic Republic of the Congo	difficult	**0.27451**	A	1
42	ターイフ	Ta'if	サウジアラビア	Saudi Arabia	ウズベキスタン	Uzbekistan	difficult	**0.35294**	B	2
29	セビリア	Seville	スペイン	Spain	ウクライナ	Ukraine	difficult	**0.37255**	A	3
30	サラゴサ	Zaragoza	スペイン	Spain	スーダン	Sudan	difficult	**0.37255**	B	4
43	バルキシメト	Barquisimeto	ベネズエラ	Venezuela	ウズベキスタン	Uzbekistan	difficult	**0.39216**	A	5
69	ムブジマイ	Mbuji-Mayi	コンゴ民主共和国	Democratic Republic of the Congo	ミャンマー	Myanmar	difficult	**0.41176**	B	6
93	カラカス	Caracas	ベネズエラ	Venezuela	イエメン	Yemen	difficult	**0.41176**	A	7
88	バスラ	Baṣrah	イラク	Iraq	ウズベキスタン	Uzbekistan	difficult	**0.45098**	B	8
44	グアヤナ	Guayana	ベネズエラ	Venezuela	モザンビーク	Mozambique	difficult	**0.47059**	A	9
46	アンディジャン	Andijan	ウズベキスタン	Uzbekistan	イエメン	Yemen	difficult	**0.47059**	B	10
82	ハルキウ	Kharkiv	ウクライナ	Ukraine	モロッコ	Morocco	difficult	**0.47059**	A	11
37	ヒッラ	Hillah	イラク	Iraq	モロッコ	Morocco	difficult	**0.4902**	B	12
38	アルビル	Erbil	イラク	Iraq	サウジアラビア	Saudi Arabia	difficult	**0.4902**	A	13

92	ジッダ	Jiddah	サウジアラビア	Saudi Arabia	イエメン	Yemen	difficult	0.49021	B	14
68	キャラジ	Karaj	イラン	Iran	ミャンマー	Myanmar	difficult	0.50981	A	15
28	テグ	Daegu	韓国	Korea	ウクライナ	Ukraine	difficult	0.52941	B	16
47	ナンプラ	Nampula	モザンビーク	Mozambique	イエメン	Yemen	difficult	0.52941	A	17
89	ラバト	Rabat	モロッコ	Morocco	ウズベキスタン	Uzbekistan	difficult	0.52941	B	18
31	オデッサ	Odessa	ウクライナ	Ukraine	スーダン	Sudan	difficult	0.54902	A	19
36	マキンダイ	Makindye	ウガンダ	Uganda	モロッコ	Morocco	difficult	0.54902	B	20
83	ハルツーム	Khartoum	スーダン	Sudan	モロッコ	Morocco	difficult	0.54902	A	21
32	ドニエプル	Dnieper	ウクライナ	Ukraine	ウガンダ	Uganda	difficult	0.56863	B	22
57	イバダン	Ibadan	ナイジェリア	Nigeria	エチオピア	Ethiopia	difficult	0.56863	A	23
86	ナンサナ	Nansana	ウガンダ	Uganda	ベネズエラ	Venezuela	difficult	0.56863	B	24
33	アルハルツームバフリ	al-Khartûm Bahrî	スーダン	Sudan	ウガンダ	Uganda	difficult	0.58824	A	25
58	カノ	Kano	ナイジェリア	Nigeria	エジプト	Egypt	difficult	0.58824	B	26
14	アダマ	Adaamaa	エチオピア	Ethiopia	イラン	Iran	difficult	0.60784	A	27
35	キラ	Kira	ウガンダ	Uganda	イラク	Iraq	difficult	0.60784	B	28
75	マンダレー	Mandalay	ミャンマー	Myanmar	ウクライナ	Ukraine	difficult	0.60784	A	29
90	カサブランカ	Casablanca	モロッコ	Morocco	モザンビーク	Mozambique	difficult	0.60784	B	30
56	サルヴァドール	Salvador	ブラジル	Brazil	エチオピア	Ethiopia	difficult	0.62745	A	31

100	アデン	Aden	イエメン	Yemen	ナイジェリア	Nigeria	difficult	0.62745	B	32
45	サマルカンド	Samarkand	ウズベキスタン	Uzbekistan	モザンビーク	Mozambique	difficult	0.64706	A	33
72	リヴァプール	Liverpool	イギリス	British	スペイン	Spain	easy	0.64706	B	34
76	モーラミャイン	Mawlamyaing	ミャンマー	Myanmar	スーダン	Sudan	difficult	0.68627	A	35
91	リヤド	Riyadh	サウジアラビア	Saudi Arabia	モザンビーク	Mozambique	difficult	0.68627	B	36
34	ニャラ	Nyala	スーダン	Sudan	イラク	Iraq	difficult	0.70588	A	37
84	オムドゥルマン	Omdurman	スーダン	Sudan	サウジアラビア	Saudi Arabia	difficult	0.70588	B	38
39	フェズ	Fez	モロッコ	Morocco	サウジアラビア	Saudi Arabia	difficult	0.72549	A	39
81	キエフ	Kiev	ウクライナ	Ukraine	イラク	Iraq	easy	0.72549	B	40
85	カンパラ	Kampala	ウガンダ	Uganda	サウジアラビア	Saudi Arabia	difficult	0.7451	A	41
22	バーミンガム	Birmingham	イギリス	British	ミャンマー	Myanmar	easy	0.80392	B	42
13	アジスアベバ	Addis Ababa	エチオピア	Ethiopia	エジプト	Egypt	difficult	0.82353	A	43
17	テヘラン	Tehran	イラン	Iran	コンゴ民主共和国	Democratic Republic of the Congo	easy	0.82353	B	44
64	メックエル	Mäqälle	エチオピア	Ethiopia	イギリス	British	difficult	0.82353	A	45
99	サヌア	Sana'a	イエメン	Yemen	ブラジル	Brazil	difficult	0.84314	B	46
5	ブラジリア	Brasilia	ブラジル	Brazil	ナイジェリア	Nigeria	easy	0.86275	A	47
49	タイズ	Ta'izz	イエメン	Yemen	中国	China	difficult	0.86275	B	48

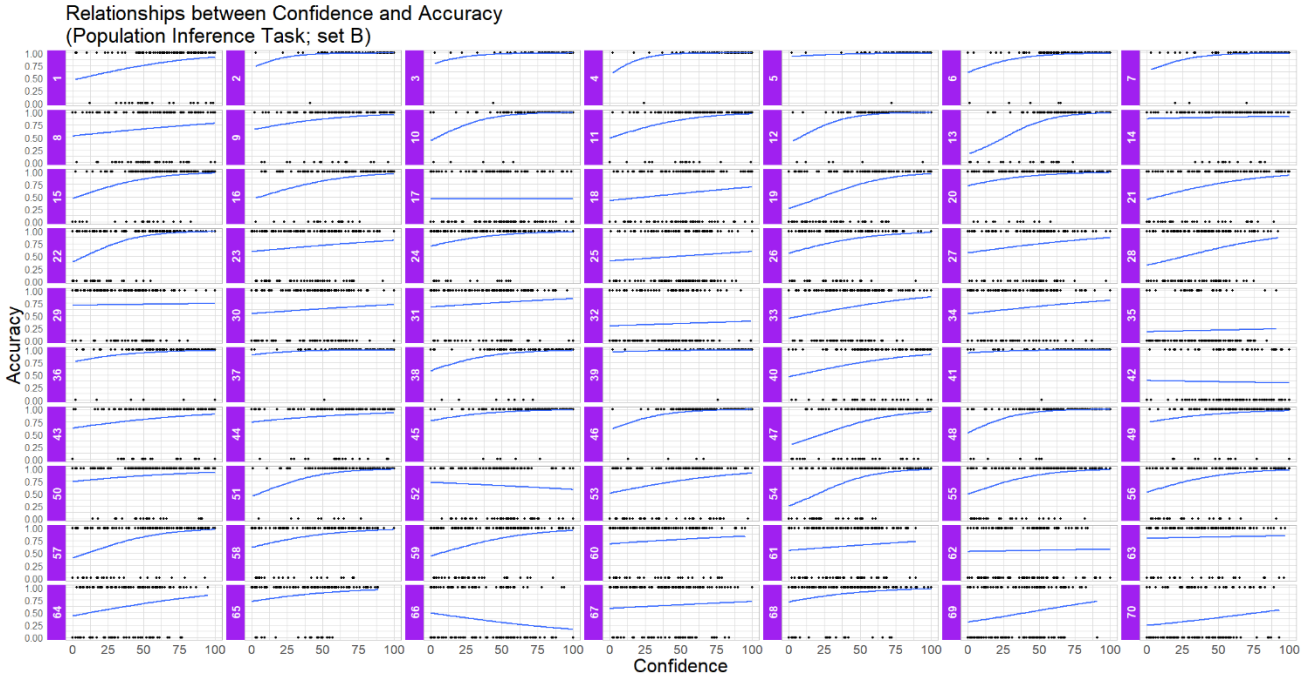
16	アレクサンドリア	Alexandria	エジプト	Egypt	コンゴ民主共和国	Democratic Republic of the Congo	easy	0.88235	A	49
40	タンジール	Tangier	モロッコ	Morocco	ベネズエラ	Venezuela	difficult	0.88235	B	50

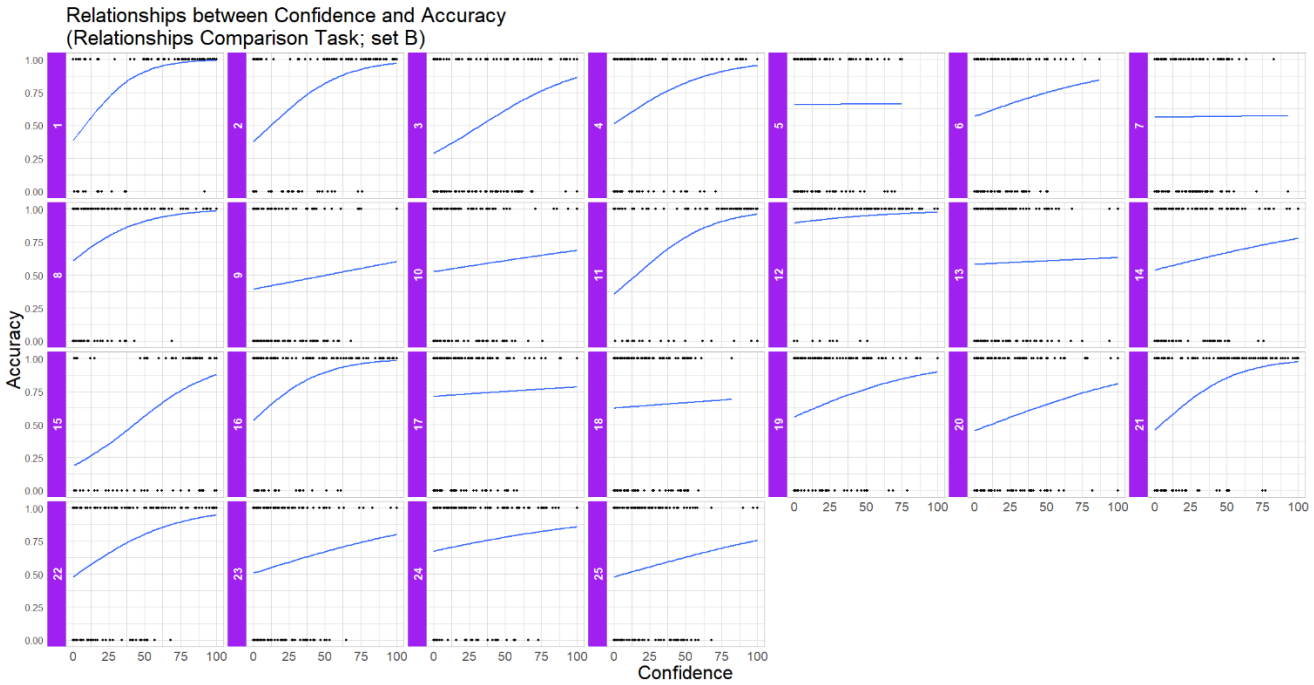
Supplementary information 3

Main results of computer simulations in set B

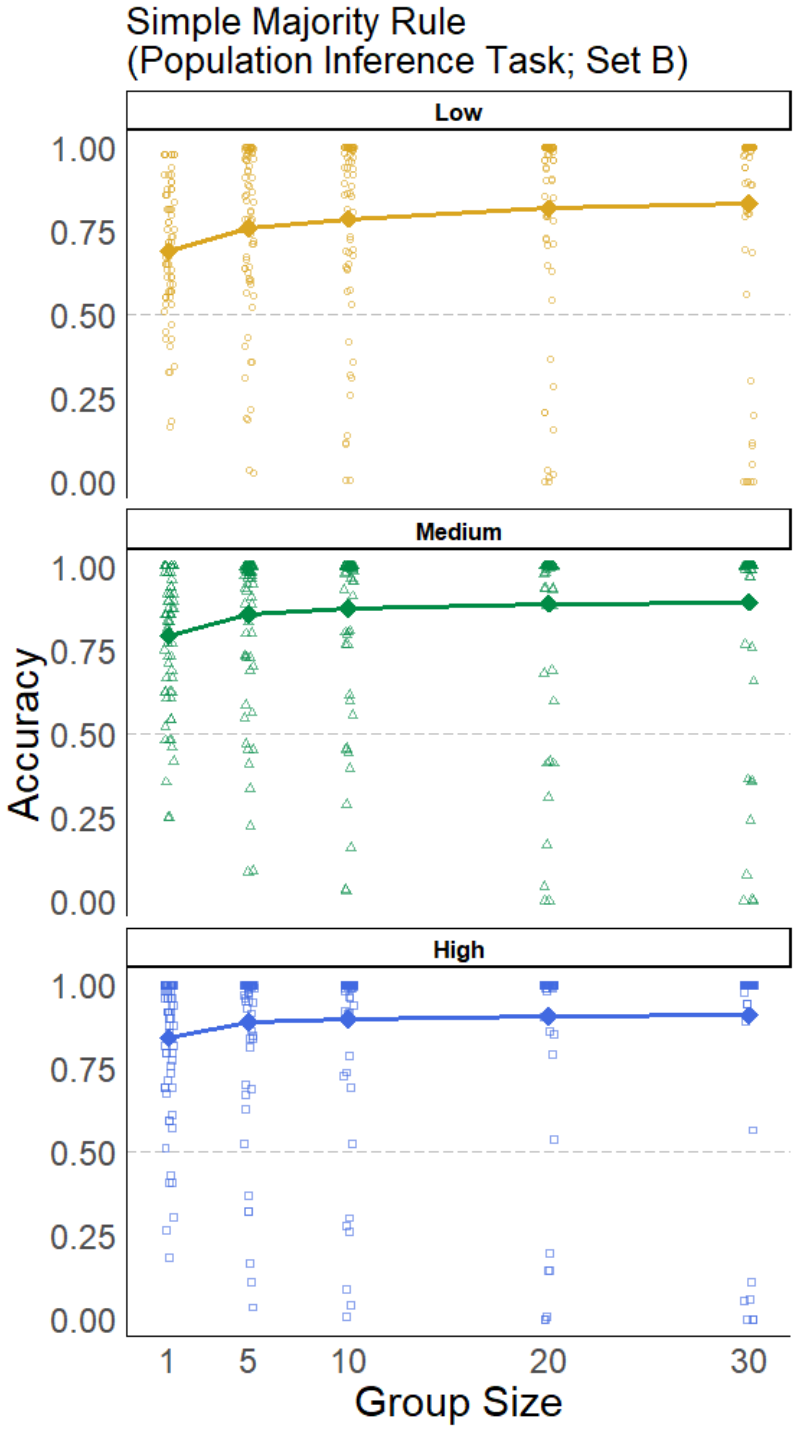
general tendencies of relationships between confidence and accuracy

Upper panel: population inference task (70 questions)
Lower panel: relationships comparison task (25 questions)

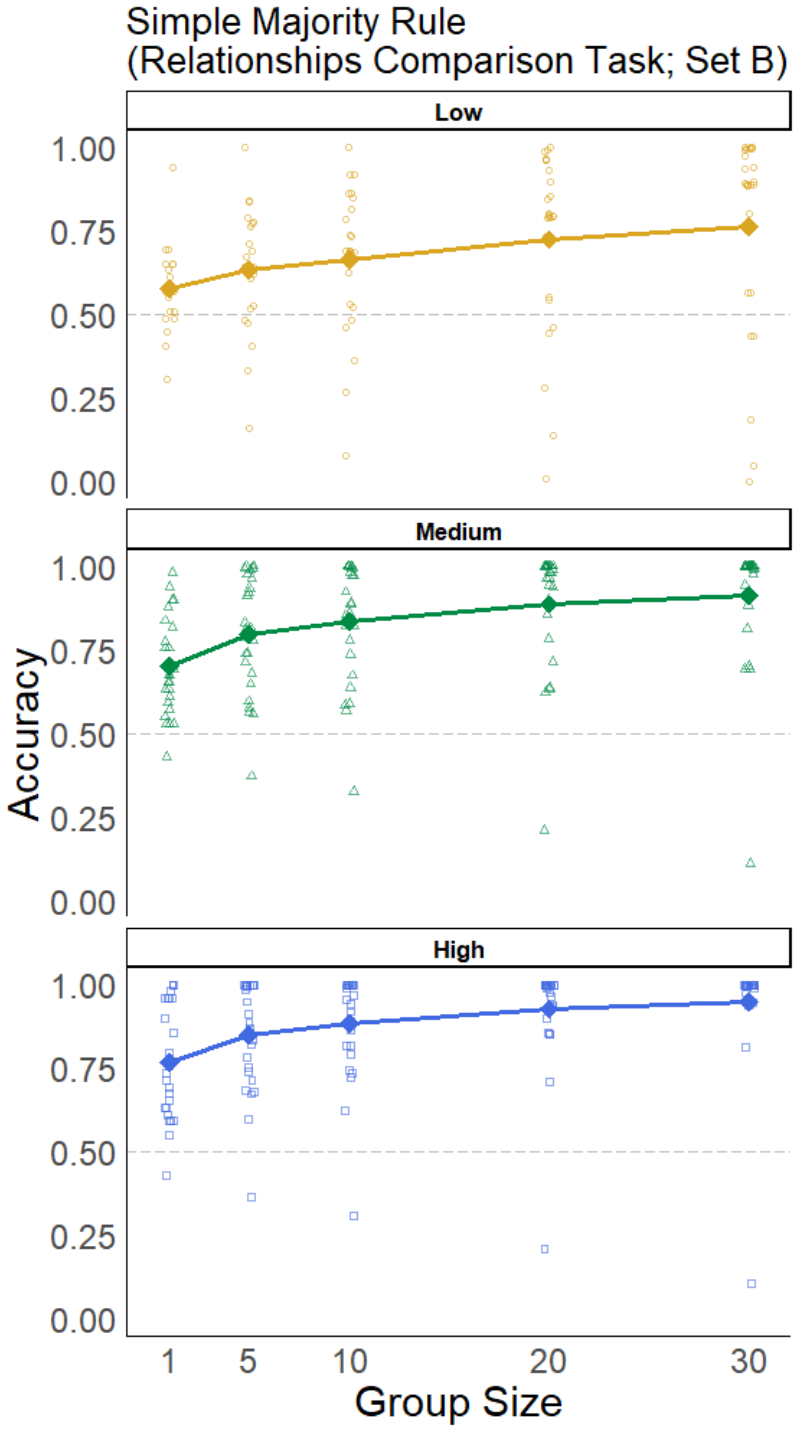



Relationships between Confidence and Accuracy
(Relationships Comparison Task; set B)
Accuracy
Confidence
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
0.00
0.25
0.50
0.75
1.00
0
25
50
75
100

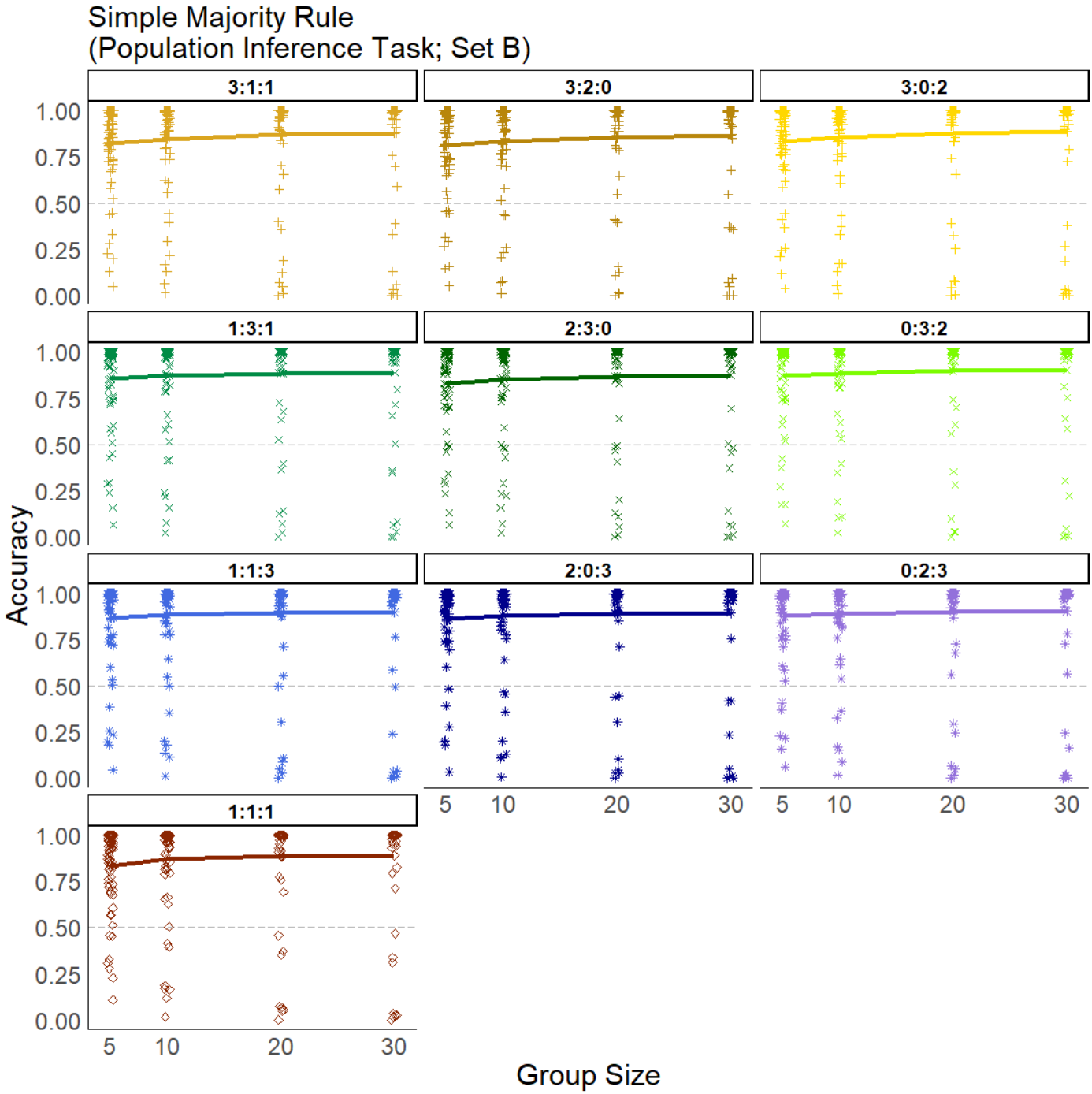
similar confidence group; population inference task



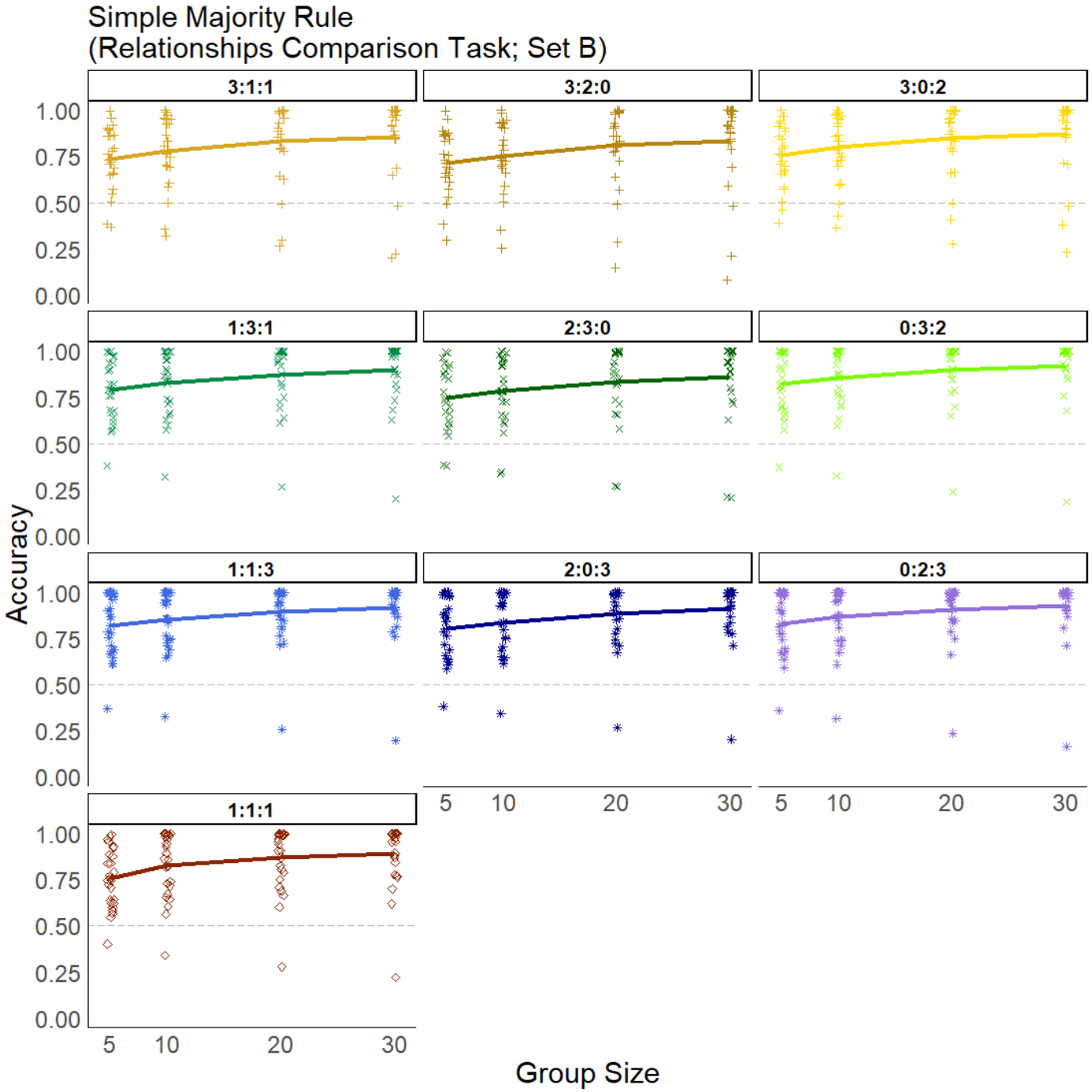
similar confidence group; relationships comparison task



diverse confidence group; population inference task



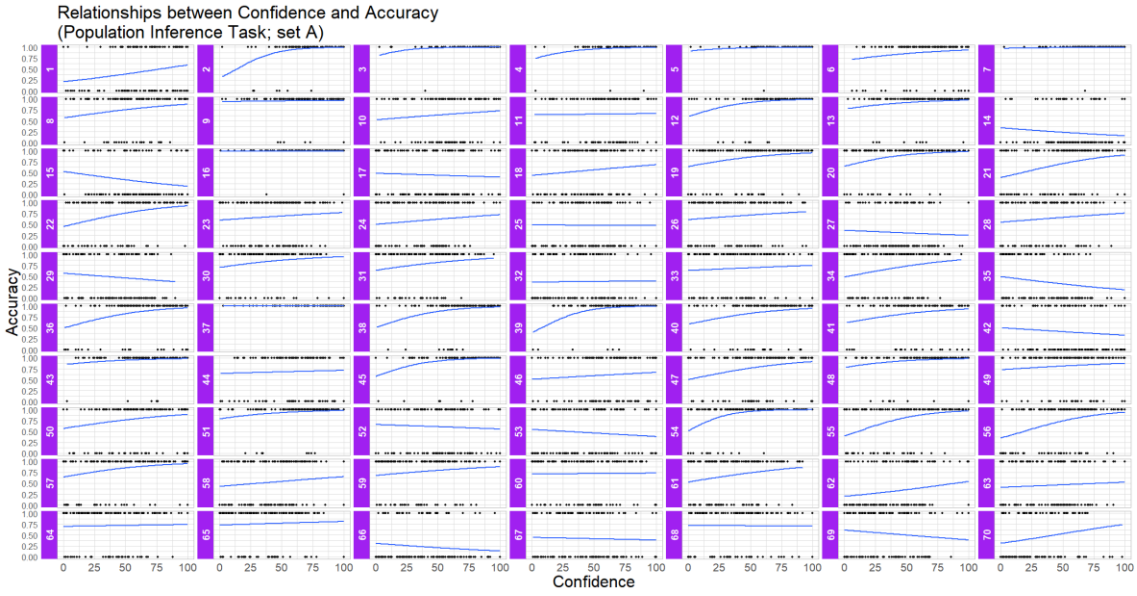
diverse confidence group; relationships comparison task

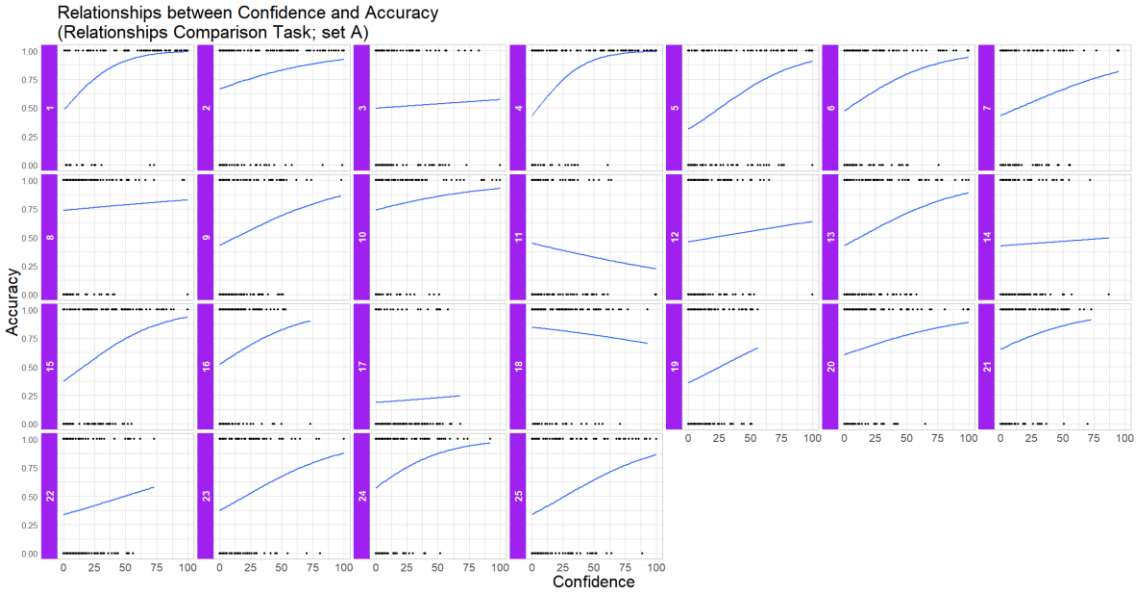


Supplementary information 4

General tendencies of relationships between subjective confidence and accuracy for each question in set A

Upper panel: population inference task (70 questions)
Lower panel: relationships comparison task (25 questions)





Supplementary information 5

Parameter estimations of generalized linear mixed models by using Markov Chain Monte Carlo method in set A

Although confidence and accuracy do not always have causal relationships, subjective confidence will be related to their judgmental accuracy. To quantitively examine effects of confidence on judgmental accuracy, we constructed a generalized linear mixed model (GLMM) and estimated the model's parameters using Markov Chain Monte Carlo (MCMC). In the following analyses, all statistical analyses were conducted using R software version 4.0.5. We used this GLMM and estimated the parameters in it using R package lme4, lmerTest[3,4], and brms[5,6].

It was assumed that difficulty of questions and knowledge of participants would also affect the accuracy. So, we modeled GLMM as follows: A dependent variable was a dummy for correct (1) or false (0), a fixed effect was confidence that each participant rated for each question (0-100), and random effects (random intercepts and random slopes) were questions and participants. That is,

$$p(correct) \sim \beta_0 + \beta_1 * confidence + (confidence \mid questions) + (confidence \mid participants) \quad \#1$$

At first, in order to confirm whether individuals' confidence about their judgments really affected their accuracy, we confirmed whether the AIC of the above model 1 (with a fixed effect) became smaller than that of the below model 2 (without a fixed effect):

$$p(correct) \sim (confidence \mid questions) + (confidence \mid participants) \quad \#(2)$$

We found that, as predicted, the model that was introduced confidence as a fixed effect showed a significantly smaller AIC than the model that was not, both in a population inference task and a relationships comparison task (**Supplementary Table 1**; in a population inference task, model 1's AIC 10290, model 2's AIC 10413; in a relationships comparison task, model 1's AIC 4502.7, model 2's AIC 4662.0).

Supplementary Table 1　Model comparison in terms of goodness of fits for each task.

(A) Population inference task

	Nparameters	AIC	BIC	logLik	deviance	Chisq	Df	Pr(>Chisq)
w/o fixed effect	3	10413	19435	-5203.4	10407			
w/ fixed effect	4	10290	10319	-5141.1	10282	124.72	1	< .001

(B) Relationships comparison task

	Nparameters	AIC	BIC	logLik	deviance	Chisq	Df	Pr(>Chisq)
w/o fixed effect	3	4662.0	4680.7	-2328.0	4546.0			
w/ fixed effect	4	4502.7	4527.6	-2247.4	4494.7	161.3	1	< .001

Next, we investigate to what extent higher confidence was likely to lead to accurate judgements. We confirmed whether the coefficient of the fixed effect, β_1, became a positive value in model 1. We estimated model 1's parameters using Markov Chain Monte Carlo (MCMC) through 5,000 samplings (first 1,000 times as burn-in) repeated 3 chains. We could not assume any specific tendencies for these variables before the analyses, so we set non-informative priors.

We found that, as also predicted, the coefficients of the fixed effect were positive both in a population inference task and in a relationships comparison task. In Supplementary Table 2, only results about fixed effects were summarized (population inference task: β_1 = 0.01, 95%CI = [0.01, 0.02]; relationships comparison task: β_1 = 0.02, 95%CI = [0.02, 0.03]). We also show all descriptive data for parameters, and trace plots, density distributions plots, and values and 95% credible intervals of estimated parameters in MCMC. Taken together, these two results indicate that individuals' confidence about their judgments would tend to positively affect the accuracy of their judgments.

Supplementary Table 2 Results of parameter estimations by MCMC (3 chains, 5,000 samples, and 1,000 burn-in) in model 1. (A) population inference task. (B) relationships comparison task.

(A) Population inference task

	Estimates	Lower 95% CI	Upper 95% CI
Fixed effects			
Intercept (β_0)	0.22	0.03	0.43
Confidence (β_1)	0.02	0.01	0.02

(B) Relationships comparison task

	Estimates	Lower 95% CI	Upper 95% CI
Fixed effects			
Intercept (β_0)	-0.09	-0.38	0.20
Confidence (β_1)	0.02	0.02	0.03

population inference task MCMC

Family: bernoulli
  Links: mu = logit
Formula: correct ~ confidence + (1 + confidence | subIdx) + (1 + confidence | qidx)
   Data: analyzedApop (Number of observations: 10500)
Samples: 3 chains, each with iter = 5000; warmup = 1000; thin = 1;
         total post-warmup samples = 12000

Group-Level Effects:
~qidx (Number of levels: 70)

	Estimate	Est.Error	l-95% CI	u-95% CI	Rhat	Bulk_ESS	Tail_ESS
sd(Intercept)	0.57	0.09	0.40	0.77	1.00	8526	10156
sd(confidence)	0.02	0.00	0.01	0.02	1.00	5185	7180
cor(Intercept,confidence)	0.65	0.16	0.32	0.92	1.00	2901	2948

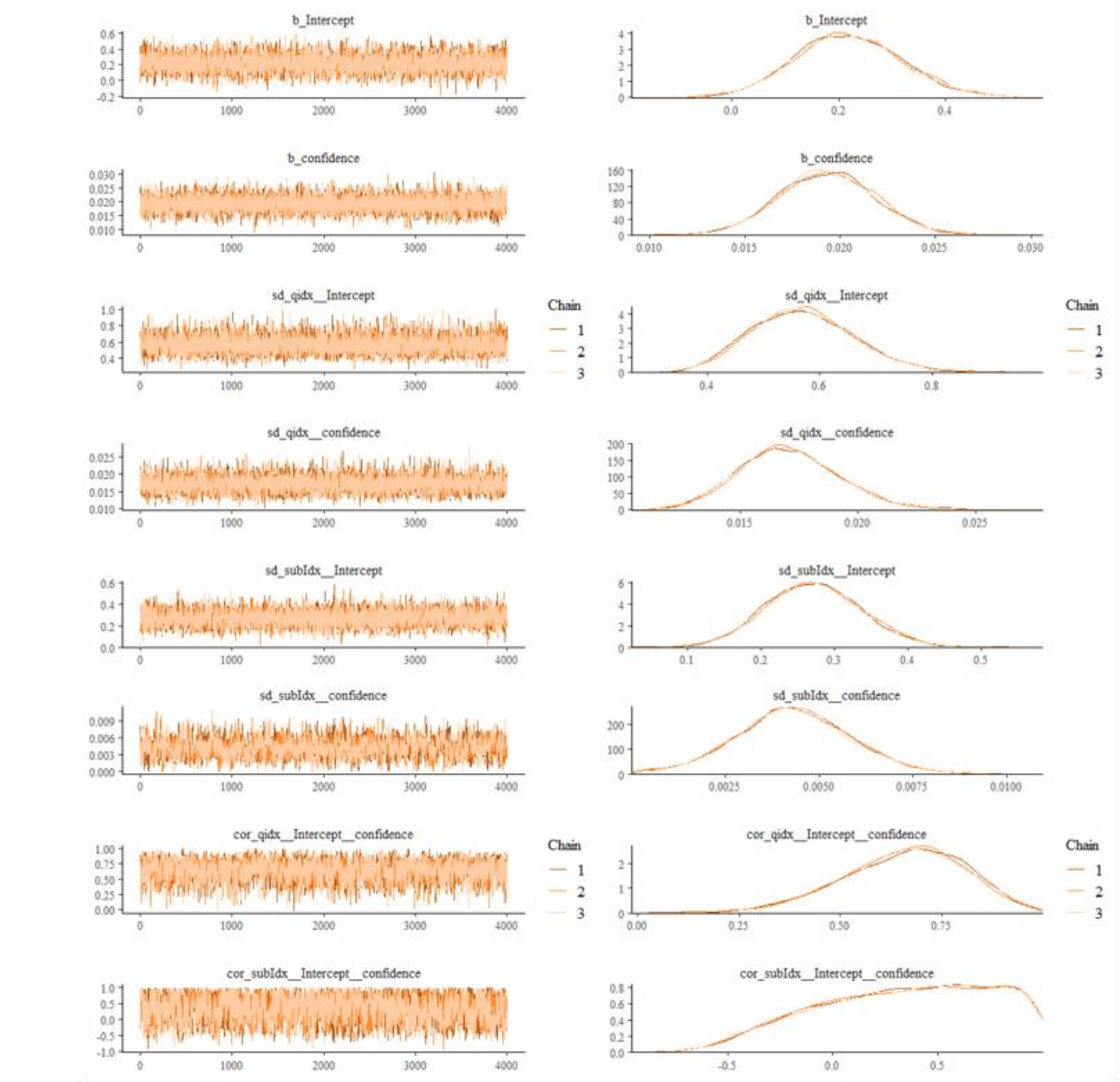
~subIdx (Number of levels: 150)

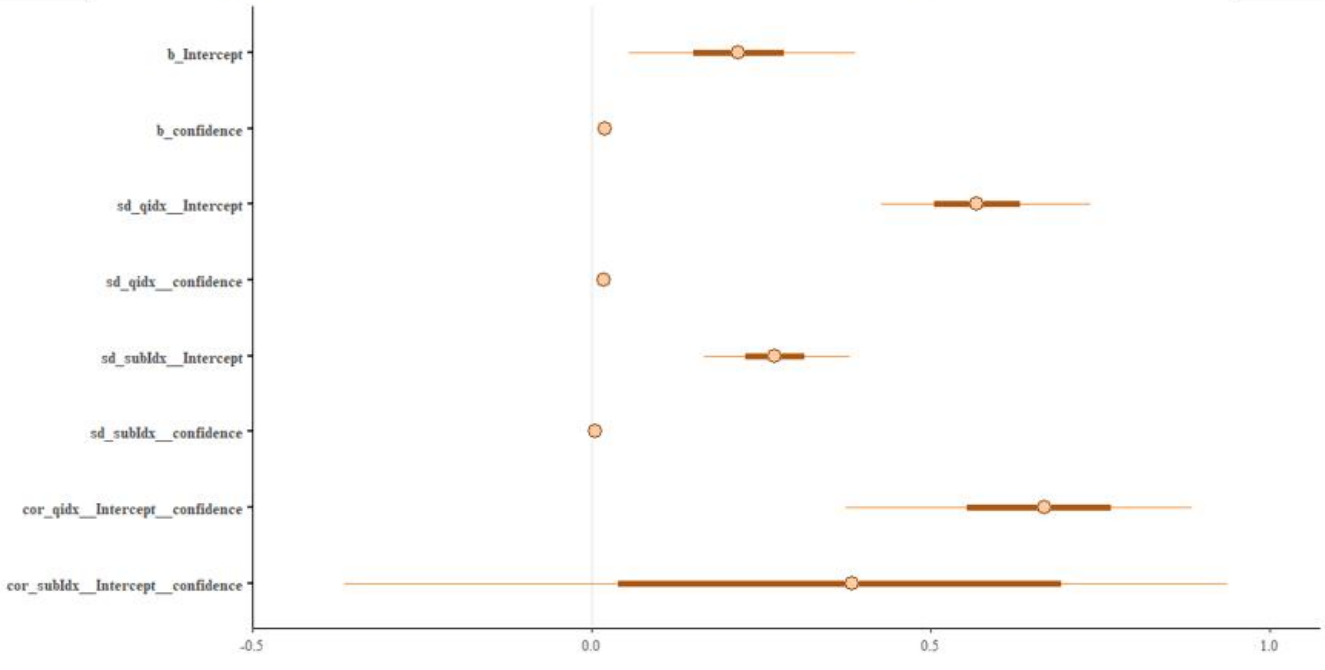
	Estimate	Est.Error	l-95% CI	u-95% CI	Rhat	Bulk_ESS	Tail_ESS
sd(Intercept)	0.27	0.07	0.14	0.40	1.00	6478	7612
sd(confidence)	0.00	0.00	0.00	0.01	1.00	1184	2602
cor(Intercept,confidence)	0.35	0.41	-0.46	0.97	1.00	1471	3977

Population-Level Effects:

	Estimate	Est.Error	l-95% CI	u-95% CI	Rhat	Bulk_ESS	Tail_ESS
Intercept	0.22	0.10	0.03	0.43	1.00	8109	9640
confidence	0.02	0.00	0.01	0.02	1.00	9827	9286

Samples were drawn using sampling(NUTS). For each parameter, Bulk_ESS
and Tail_ESS are effective sample size measures, and Rhat is the potential
scale reduction factor on split chains (at convergence, Rhat = 1).


b_Intercept
b_confidence
sd_qidx__Intercept
sd_qidx__confidence
sd_subIdx__Intercept
sd_subIdx__confidence
cor_qidx__Intercept__confidence
cor_subIdx__Intercept__confidence
Chain
1
2
3


b_Intercept
b_confidence
sd_qidx__Intercept
sd_qidx__confidence
sd_subIdx__Intercept
sd_subIdx__confidence
cor_qidx__Intercept__confidence
cor_subIdx__Intercept__confidence

relationships comparison task MCMC

Family: bernoulli
  Links: mu = logit
Formula: correct ~ confidence + (1 + confidence | subIdx) + (1 + confidence | qidx)
   Data: analyzedA (Number of observations: 3725)
Samples: 3 chains, each with iter = 5000; warmup = 1000; thin = 1;
         total post-warmup samples = 12000
Group-Level Effects:
~qidx (Number of levels: 25)

	Estimate	Est.Error	l-95% CI	u-95% CI	Rhat	Bulk_ESS	Tail_ESS
sd(Intercept)	0.68	0.12	0.48	0.96	1.00	5160	7575
sd(confidence)	0.01	0.00	0.01	0.02	1.00	4999	5527
cor(Intercept,confidence)	0.02	0.28	-0.50	0.59	1.00	6673	6043

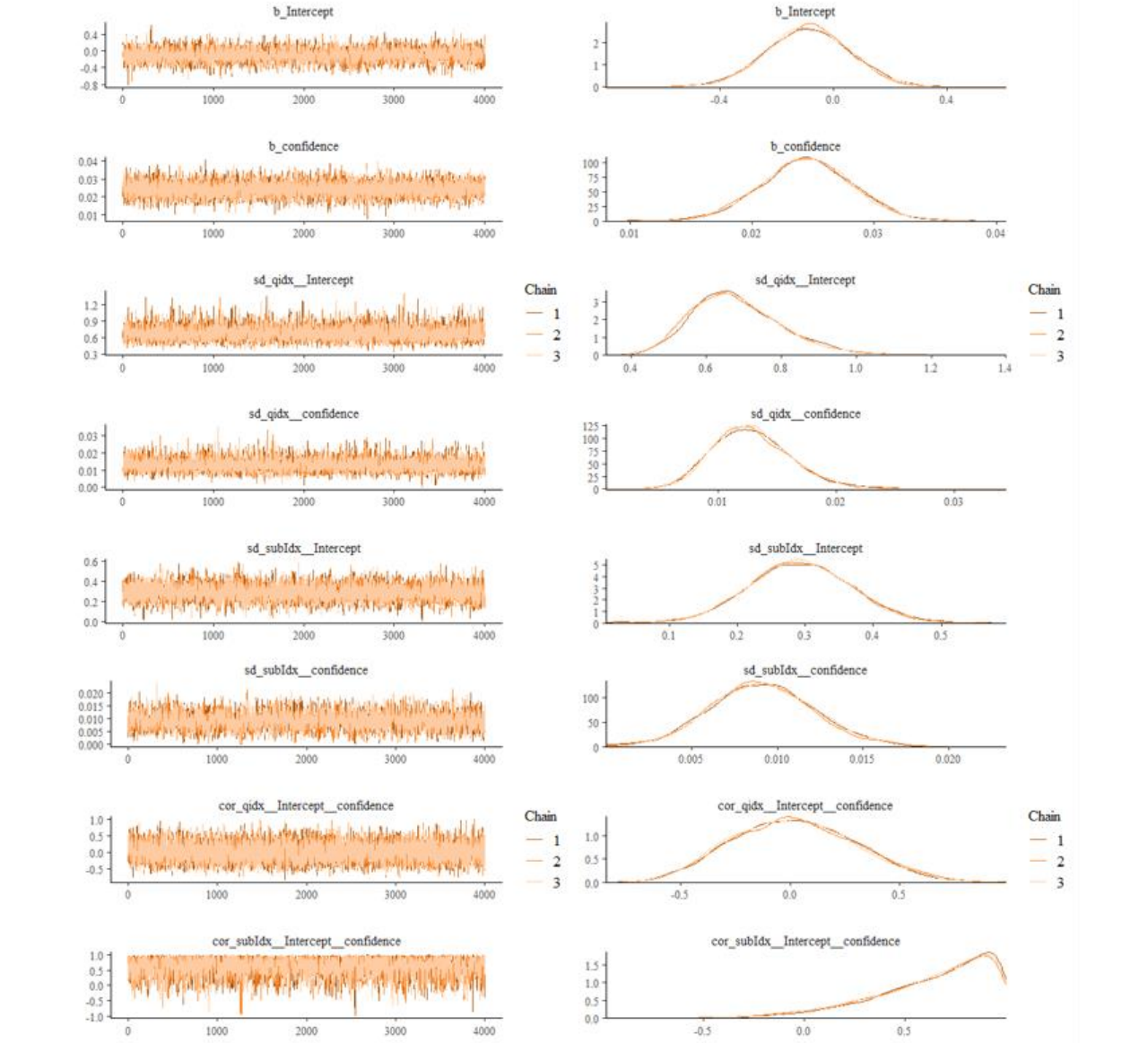
~subIdx (Number of levels: 149)

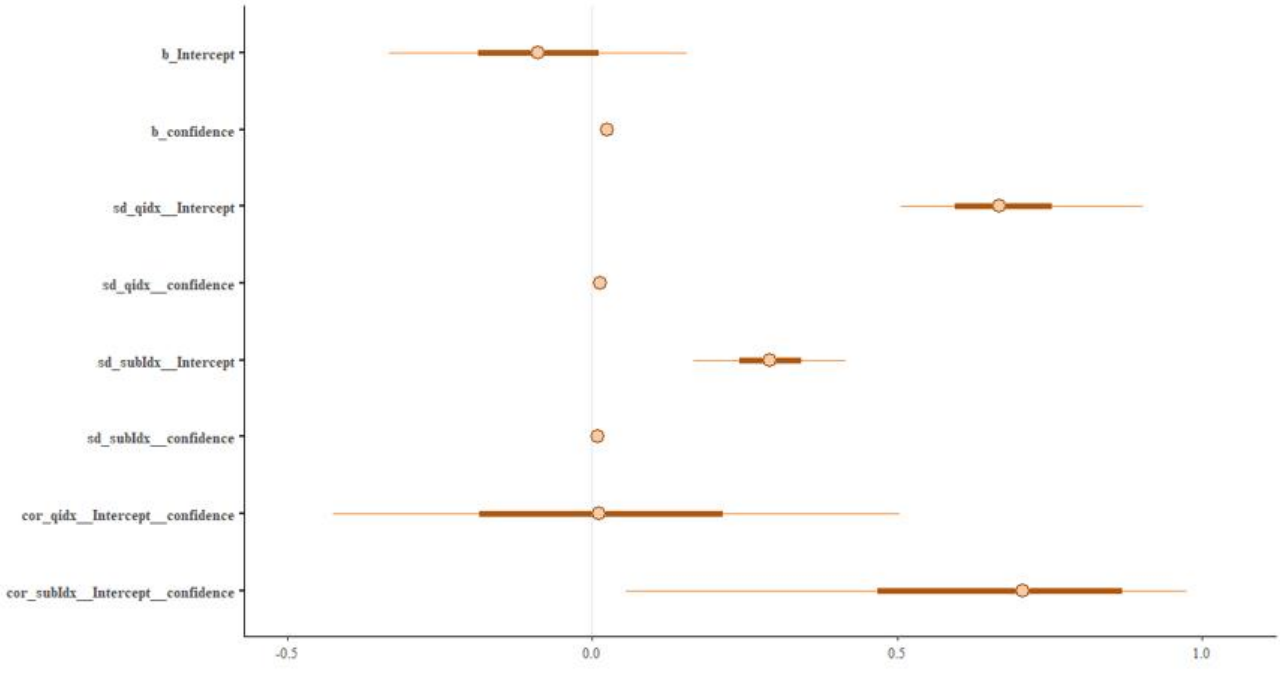
	Estimate	Est.Error	l-95% CI	u-95% CI	Rhat	Bulk_ESS	Tail_ESS
sd(Intercept)	0.29	0.08	0.14	0.44	1.00	4080	5993
sd(confidence)	0.01	0.00	0.00	0.02	1.00	2300	3570
cor(Intercept,confidence)	0.64	0.29	-0.07	0.99	1.00	2637	4358

Population-Level Effects:

	Estimate	Est.Error	l-95% CI	u-95% CI	Rhat	Bulk_ESS	Tail_ESS
Intercept	-0.09	0.15	-0.38	0.20	1.00	4191	6646
confidence	0.02	0.00	0.02	0.03	1.00	10818	9954

Samples were drawn using sampling(NUTS). For each parameter, Bulk_ESS
and Tail_ESS are effective sample size measures, and Rhat is the potential
scale reduction factor on split chains (at convergence, Rhat = 1).


b_Intercept
b_confidence
sd_qidx__Intercept
sd_qidx__confidence
sd_subIdx__Intercept
sd_subIdx__confidence
cor_qidx__Intercept__confidence
cor_subIdx__Intercept__confidence
Chain
1
2
3

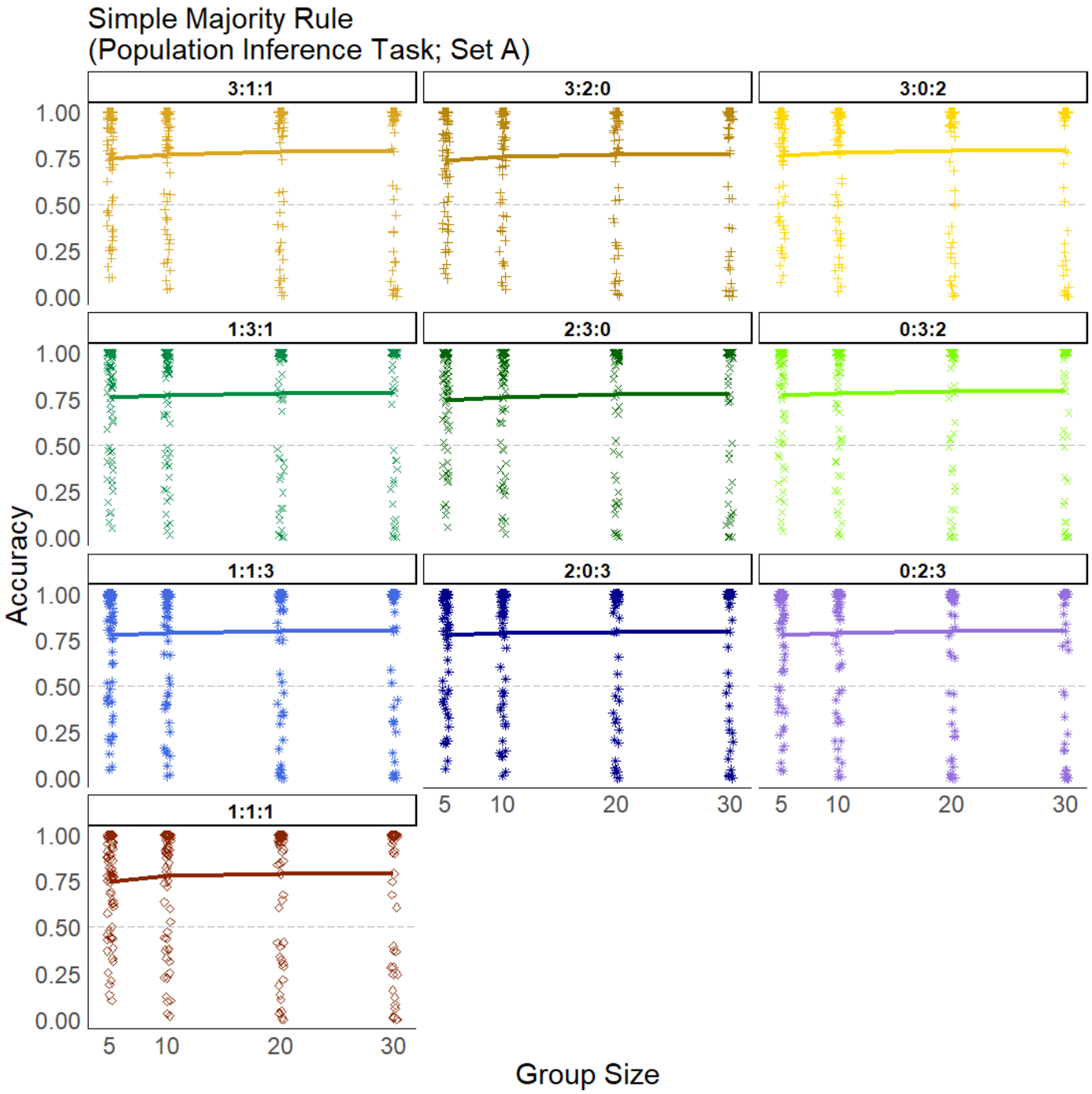

b_Intercept
b_confidence
sd_qidx__Intercept
sd_qidx__confidence
sd_subIdx__Intercept
sd_subIdx__confidence
cor_qidx__Intercept__confidence
cor_subIdx__Intercept__confidence

Supplementary information 6

Results of simulations of various confidence group in all group sizes in set A

Note: Since group sizes 5, 10, and 20 were not multiples of 3, we set the numbers of individuals in each confidence level as approximate one third of group sizes: (denoted "low + medium + high," respectively) "2 + 1 + 2" in group size 5; "3 + 4 + 3" in group size 10; and "7 + 6 + 7" in group size 20.

population inference task

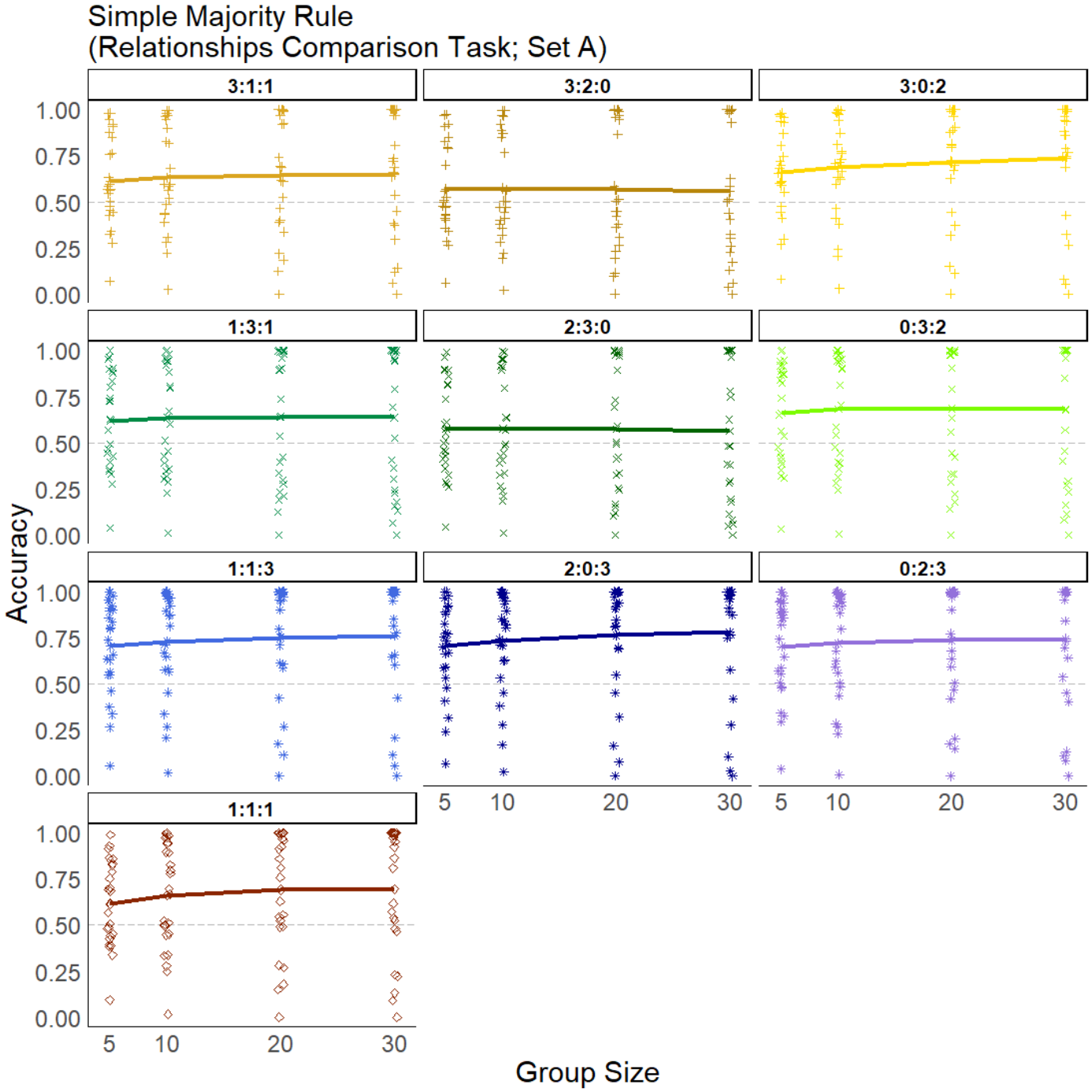


note: statistical test in a population inference task, group size 30 (pairwise t-test; Bonferroni adjusted)

```
#             0:2:3 0:3:2 1:1:1 1:1:3 1:3:1 2:0:3 2:3:0 3:0:2 3:1:1
#   0:3:2 1.00  -     -     -     -     -     -     -     -
#   1:1:1 1.00  1.00  -     -     -     -     -     -     -
#   1:1:3 1.00  1.00  1.00  -     -     -     -     -     -
#   1:3:1 1.00  1.00  1.00  1.00  -     -     -     -     -
#   2:0:3 1.00  1.00  1.00  1.00  1.00  -     -     -     -
#   2:3:0 1.00  1.00  1.00  1.00  1.00  1.00  -     -     -
#   3:0:2 1.00  1.00  1.00  1.00  1.00  1.00  1.00  -     -
#   3:1:1 1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  -
#   3:2:0 1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00

# P value adjustment method: bonferroni
#           0:2:3 0:3:2 1:1:1 1:1:3 1:3:1 2:0:3 2:3:0 3:0:2 3:1:1
# 0:3:2 FALSE    NA    NA    NA    NA    NA    NA    NA    NA
# 1:1:1 FALSE FALSE    NA    NA    NA    NA    NA    NA    NA
# 1:1:3 FALSE FALSE FALSE    NA    NA    NA    NA    NA    NA
# 1:3:1 FALSE FALSE FALSE FALSE    NA    NA    NA    NA    NA
# 2:0:3 FALSE FALSE FALSE FALSE FALSE    NA    NA    NA    NA
# 2:3:0 FALSE FALSE FALSE FALSE FALSE FALSE    NA    NA    NA
# 3:0:2 FALSE FALSE FALSE FALSE FALSE FALSE FALSE    NA    NA
# 3:1:1 FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE    NA
# 3:2:0 FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
```

relationships comparison task



note: statistical test in a relationships comparison task, group size 20 (pairwise t-test; Bonferroni adjusted)

```
#             0:2:3 0:3:2 1:1:1 1:1:3 1:3:1 2:0:3 2:3:0 3:0:2 3:1:1
#   0:3:2 0.366 -     -     -     -     -     -     -     -
#   1:1:1 0.721 1.000 -     -     -     -     -     -     -
#   1:1:3 1.000 0.527 0.117 -     -     -     -     -     -
#   1:3:1 0.163 0.288 0.393 0.153 -     -     -     -     -
#   2:0:3 1.000 0.861 0.159 1.000 0.224 -     -     -     -
#   2:3:0 0.037 0.077 0.022 0.028 0.084 0.035 -     -     -
#   3:0:2 1.000 1.000 1.000 1.000 1.000 0.089 0.086 -     -
#   3:1:1 0.347 1.000 0.740 0.044 1.000 0.017 0.374 0.024 -
#   3:2:0 0.041 0.289 0.026 0.018 0.972 0.015 1.000 0.021 0.023
#
# P value adjustment method: bonferroni
#       0:2:3 0:3:2 1:1:1 1:1:3 1:3:1 2:0:3 2:3:0 3:0:2 3:1:1
# 0:3:2 FALSE    NA    NA    NA    NA    NA       NA    NA    NA
# 1:1:1 FALSE FALSE    NA    NA    NA    NA       NA    NA    NA
# 1:1:3 FALSE FALSE FALSE    NA    NA    NA       NA    NA    NA
# 1:3:1 FALSE FALSE FALSE FALSE    NA    NA       NA    NA    NA
# 2:0:3 FALSE FALSE FALSE FALSE FALSE    NA       NA    NA    NA
# 2:3:0  TRUE FALSE  TRUE  TRUE FALSE  TRUE       NA    NA    NA
# 3:0:2 FALSE FALSE FALSE FALSE FALSE FALSE    FALSE       NA    NA
# 3:1:1 FALSE FALSE FALSE  TRUE FALSE  TRUE    FALSE  TRUE       NA
# 3:2:0  TRUE FALSE  TRUE  TRUE FALSE  TRUE    FALSE  TRUE  TRUE
```

References

1. Honda, H., Matsuka, T. & Ueda, K. Memory-Based Simple Heuristics as Attribute Substitution: Competitive Tests of Binary Choice Inference Models. *Cogn. Sci.* **41**, 1093–1118 (2017).
2. Shirasuna, M., Honda, H., Matsuka, T. & Ueda, K. Familiarity-Matching: An Ecologically Rational Heuristic for the Relationships-Comparison Task. *Cogn. Sci.* **44**, e12806 (2020).
3. Bates, D., Mächler, M., Bolker, B. M. & Walker, S. C. Fitting linear mixed-effects models using lme4. *J. Stat. Softw.* **67**, (2015).
4. Kuznetsova, A., Brockhoff, P. B. & Christensen, R. H. B. lmerTest Package: Tests in Linear Mixed Effects Models . *J. Stat. Softw.* **82**, (2017).
5. Bürkner, P. C. brms: An R package for Bayesian multilevel models using Stan. *J. Stat. Softw.* **80**, (2017).
6. Bürkner, P. C. Advanced Bayesian multilevel modeling with the R package brms. *R J.* **10**, 395–411 (2018).

All data, code, and materials used in our experiments are available at https://osf.io/ehzu6/?view_only=fb08ab0fc87c45eabb201316bd2c0881.