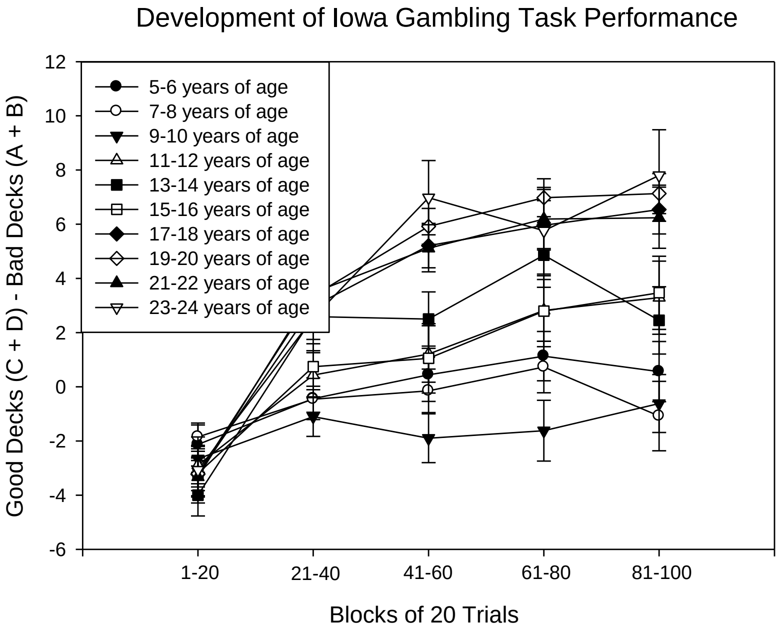
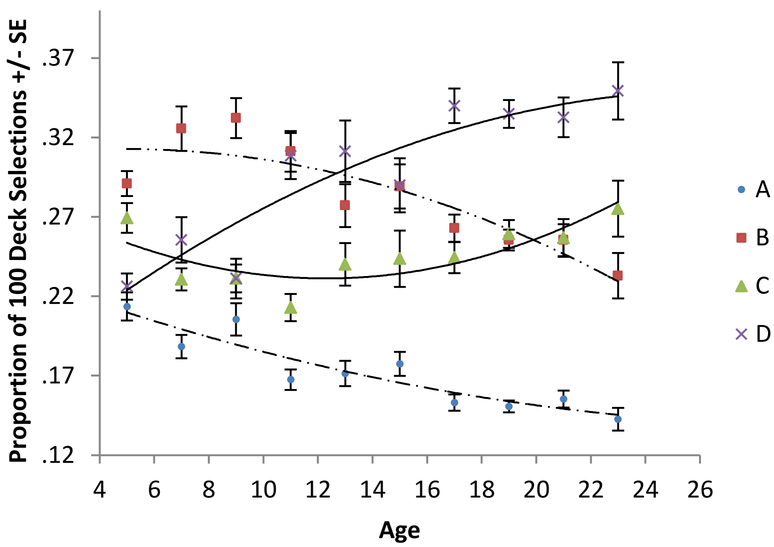
Age Group Division

Linear regression does not easily allow for simultaneous analysis of the effects of net outcome and loss frequency at different ages. An ANOVA better accommodates for these effects, yet does not allow for analysis of continuous age. Prior to analysis of deck preference, age groups were formed to examine abrupt changes in IGT performance during development. Because cognitive trends in children and adolescents may change sharply from year to year, individuals aged 5-24 were separated into two-year interval groups (e.g., 5-6, 7-8…23-24). The summed IGT score over 100 trials for each of these age groups was examined in a univariate ANOVA with $\alpha = .001$, and post hoc comparisons adjusted with the Bonferroni correction. Comparisons suggested three age groups: 5-10 (child group); 11-16 (adolescent group); and 17-24 (adult group). Only children and adults were statistically different, and adolescents did not clearly belong to either of these groups. Furthermore, the addition of 25-29 year olds did not statistically affect the adult group, and cognitive ability in the 25-29 years olds was not statistically different from that in the 17-24 year olds. This process was repeated for 30-89 year olds, and two additional age groups were formed from 30-59 (middle-aged adults) and from 60-89 (older adults). This allowed the large college student group to be analyzed separately from the middle-aged group containing fewer cases. Data for IGT performance and individual deck selections are summarized in supplemental figures 1 and 2 below.





Supplemental Figures 1 and 2. Age group division from 5 to 24 for IGT performance and deck selections over 100 trials.

Strategy and Cluster Analysis

Cluster analysis may be utilized when attempting to identify unique strategic groups. Strategic information was combined with preference information in a cluster analysis. Two-step cluster membership was saved and cluster centroids were examined. Cluster centroids are shown in Supplemental Table 1. The first cluster contained 12.4% of cases (197), the second 15.2% (240), the third 25.8% (408), the fourth 13.7% (217), and the fifth 32.9% (521). The first cluster was characterized by a consistent advantageous decision strategy in which a deck C was preferred. The second cluster involved low win-shift and high loss-stay with deck D preference. The next two clusters both involved a preference for a low frequency deck (B or D) coupled with medium win-shift decision making. The final cluster involved high win-shift, with a small preference for deck B. The number of cases in each strategy cluster division by age group is shown in Supplemental Table 2. Children and adolescents were primarily grouped into the impulsive cluster (74% of children), but gradually with age this strategy disappeared and was replaced with the first through third strategies (all advantageous). Middle aged individuals (30-59) were among the most successful, with most cases distributed to advantageous clusters 1-3 (73% of middle-aged adults). Finally, older individuals saw a fall in strategies 1 and 2, and a rise in strategy 4. Overall, older adults were more likely to engage in a loss frequency-based strategy than middle-aged and young adults. Most importantly, young adults engaged in impulsive decision behavior much more often than middle-aged and older adults. This may help explain why performance has been reported as highly variable in normal young adult populations, and implies that caution should be taken when attempting to interpret task performance in normal adult populations (Lin, Song, Chen, Lee, & Chiu, 2013; Steingroever et al., 2012).

Nevertheless, procedural limitations of the current analysis prevent any unequivocal conclusions about age-related decision processes. The clustering procedure itself is noisy, and outliers were not examined. Therefore, some individuals may have been incorrectly classified, or additional strategy groupings may exist. Additionally, cluster analysis is primarily an exploratory tool. Cluster groupings should be replicated in separate studies before assuming that they represent true strategies. Finally, clustering does not indicate if processes are related to cognition or emotion. Nonetheless, cluster groupings may inform both theory driven procedures such as cognitive modeling, and data driven procedures that relate cognition to net outcome or loss frequency preferences. Specifically, reinforcement-learning (RL) models may describe how multiple processes contribute to learning for each strategy cluster.

PVL Analysis

Supplemental Figure 3 describes PVL parameters stuck on the boundaries as explained in the manuscript. Those individuals with a parameter stuck on the boundaries were removed in the final manuscript, but were not removed for analysis reported in the supplemental materials. Supplemental Figure 4 shows PVL model performance for age and cluster groupings. The decay-reinforcement model was least effective in characterizing learning in the impulsive cluster 5, as would be expected if decisions were truly random (see Supplemental Figure 5 for full plots on all models). The percentage of matching predictions was the same for both decay rule models. Advantageous clusters 1 and 2 had the highest matching percentage (M_1 = 67%, SD_1 = 15%; M_2 = 72%, SD_2 = 12%), followed by loss frequency clusters 3 and 4 (M_3 = 49%, SD_3 = 11%; M_4 = 55%, SD_4 = 13%. Predictions for impulsive cluster 5 were at chance levels of 25%, M_5 = 27%, SD_5 = 10%. Model outcomes by cluster divisions strongly suggested covariance between selection switching and model performance. IGT learning in cluster 5 and for ages 5-16 were poorly predicted by cognitive models, and accordingly, these groups were excluded from further analysis (new *n* = 931). Descriptive statistics on all model parameters for the remaining cluster groups are shown in Supplemental Table 3, while Supplemental Table 4 shows correlations for each strategy group. For clusters 1-4, poor memory for prior feedback always resulted in fewer net outcome selections, yet consistent selections resulted in varying effects such as increased or decreased preference for net outcome.

Supplemental Table 1
Centroid Values for Strategy Clusters

Variable	Cluster				
	1	2	3	4	5
B1	8.23	8.08	6.41	8.71	6.14
B2	4.15	3.01	5.80	7.00	5.92
B3	2.27	1.90	4.26	9.24	5.81
B4	1.18	2.29	3.66	10.59	5.88
B5	.91	2.72	3.40	10.76	6.16
C1	4.23	3.04	4.05	3.37	4.56
C2	6.98	3.10	4.09	3.64	4.64
C3	10.76	2.05	4.01	2.75	4.93
C4	13.79	2.35	4.55	2.60	5.13
C5	13.50	5.77	4.99	2.52	5.16
D1	3.73	5.08	5.47	3.67	4.55
D2	6.25	11.85	6.66	5.60	5.16
D3	5.09	14.53	8.86	5.00	5.29
D4	3.58	13.73	9.44	4.20	5.26
D5	4.50	9.41	9.64	4.30	5.29
LSTA	.25	.27	.15	.19	.09
WSHB	.44	.33	.62	.34	.83
WSHC	.29	.35	.64	.62	.88
WSHD	.42	.14	.43	.52	.85

Notes: LST = Loss-Stay; WSH = Win-Shift; letters A-D indicate deck, while numbers 1-5 indicates first through fifth block of 20 trials; higher centroid values indicate more deck selections or greater usage of strategy (highest value for deck selections = 20; highest value for strategies = 1)

Supplemental Table 2

Group Sizes by Age for Strategy Clusters

Age Group	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
5-10	3 (1.7%)	3 (1.7%)	15 (8.6%)	24 (13.8%)	129 (74.1%)
11-16	9 (5.3%)	16 (9.4%)	41 (24.0%)	20 (11.7%)	85 (49.7%)
17-29	113 (17.0%)	95 (14.3%)	178 (26.8%)	69 (10.4%)	209 (31.5%)
30-59	47 (16.7%)	70 (24.9%)	90 (32.0%)	33 (11.7%)	41 (14.6%)
60-89	25 (8.5%)	56 (19.1%)	84 (28.7%)	71 (24.2%)	57 (19.5%)

Notes: Number of cases per age group with percentage of the age group shown.

Supplemental Table 3

Means and Standard Deviations for Decay-Independent Parameters by Cluster

Cluster	α	λ	*A*	c
1	.34 (.35)	1.11 (1.40)	.72 (.26)	0.87 (.86)
2	.34 (.31)	0.85 (1.21)	.58 (.32)	1.11 (.91)
3	.35 (.32)	1.99 (1.83)	.69 (.34)	0.47 (.33)
4	.39 (.34)	1.18 (1.61)	.51 (.34)	.69 (.40)
All	.35 (.33)	1.39 (1.64)	.63 (.33)	.74 (.69)

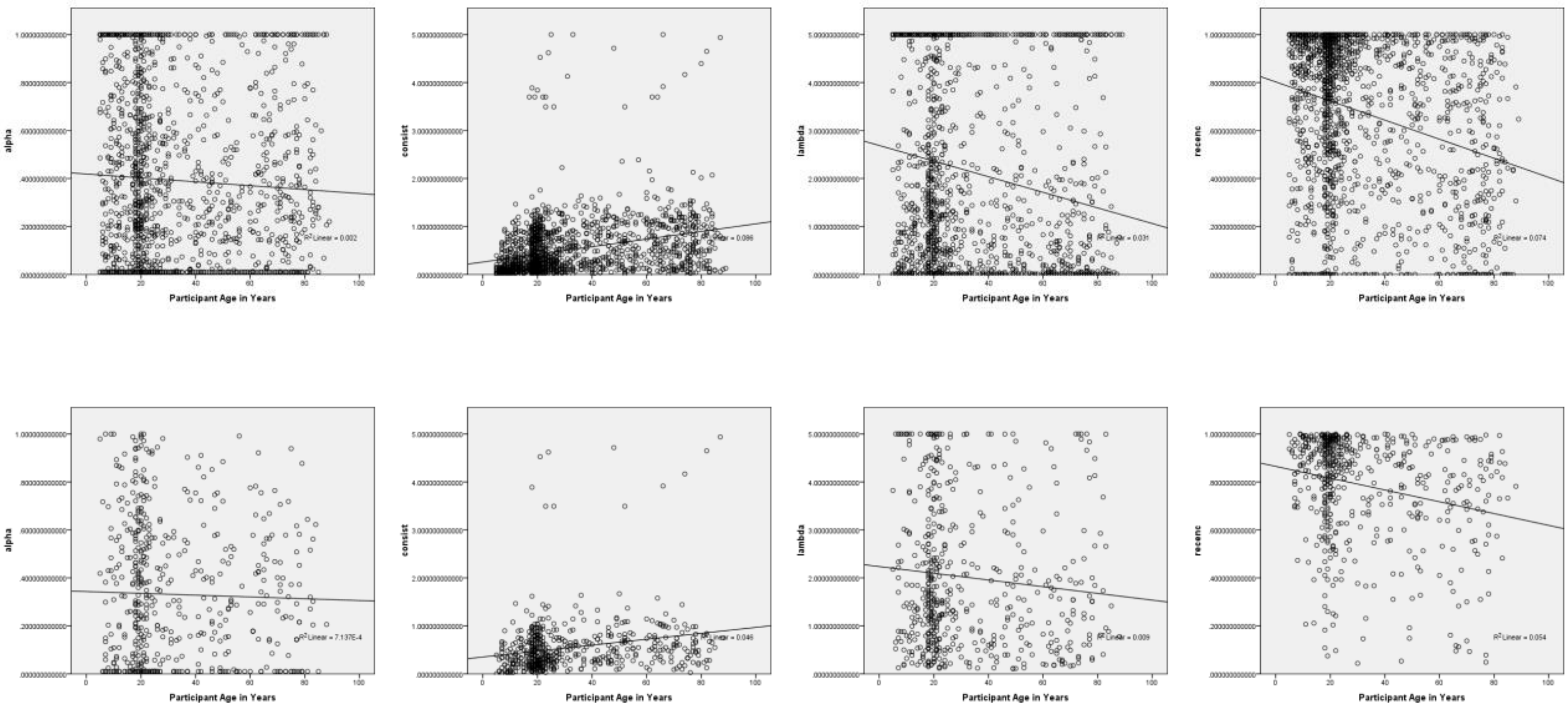
Notes: α = attention weight ($0.01 < \alpha < .9999$); λ = loss-aversion ($0.01 < \lambda < 5$); *A* = recency ($0 < A < 1$); c = consistency ($0 < c < 5$)

Supplemental Table 4

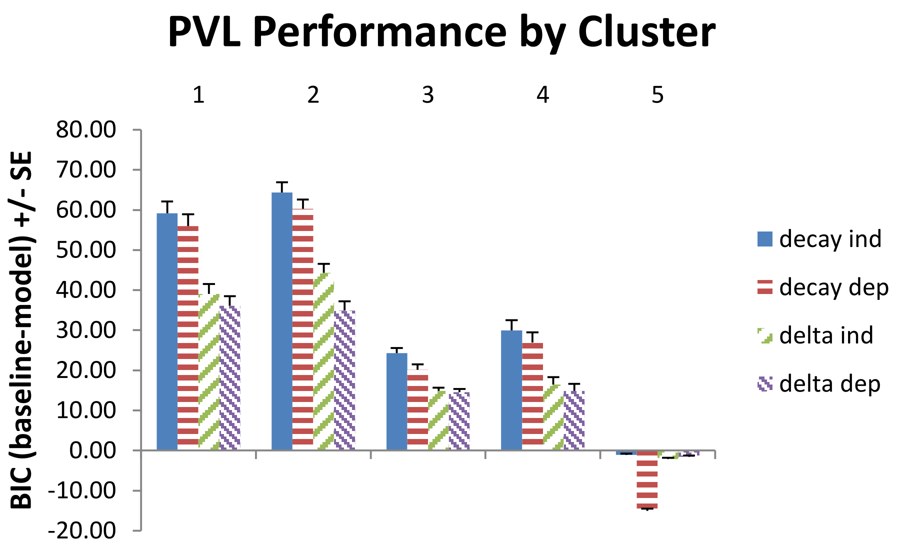
Correlations for Modeling Parameters by Cluster (Ages 17-89)

Cluster	*Parameter*	*Age*	*C+D*	*B+D*	*N*
1	*A*	-.24**	.26**	-.16*	185
	α	-.05	.27**	-.06	
	c	.29**	.26**	-.29**	
	λ	-.12	.37**	.03	
2	*A*	-.19*	.21*	.23**	221
	α	.16*	.11	.08	
	c	.15*	.09	.11	
	λ	-.16*	.19*	.13	
3	*A*	-.36**	.40**	.22**	352
	α	-.07	.21**	-.29**	
	c	.36**	-.23**	.00	
	λ	-.13*	.17*	.13*	
4	*A*	-.27**	-.09	.23**	173
	α	.12	-.33**	-.27**	
	c	.26**	.03	.07	
	λ	-.12	.38*	.16*	

Notes: *$p < .05$; **$p < .001$; C+D and B+D correlations controlled for age; α = attention weight ($0.01 < \alpha < .9999$); λ = loss-aversion ($0.01 < \lambda < 5$); A = recency ($0 < A < 1$); c = consistency ($0 < c < 5$)

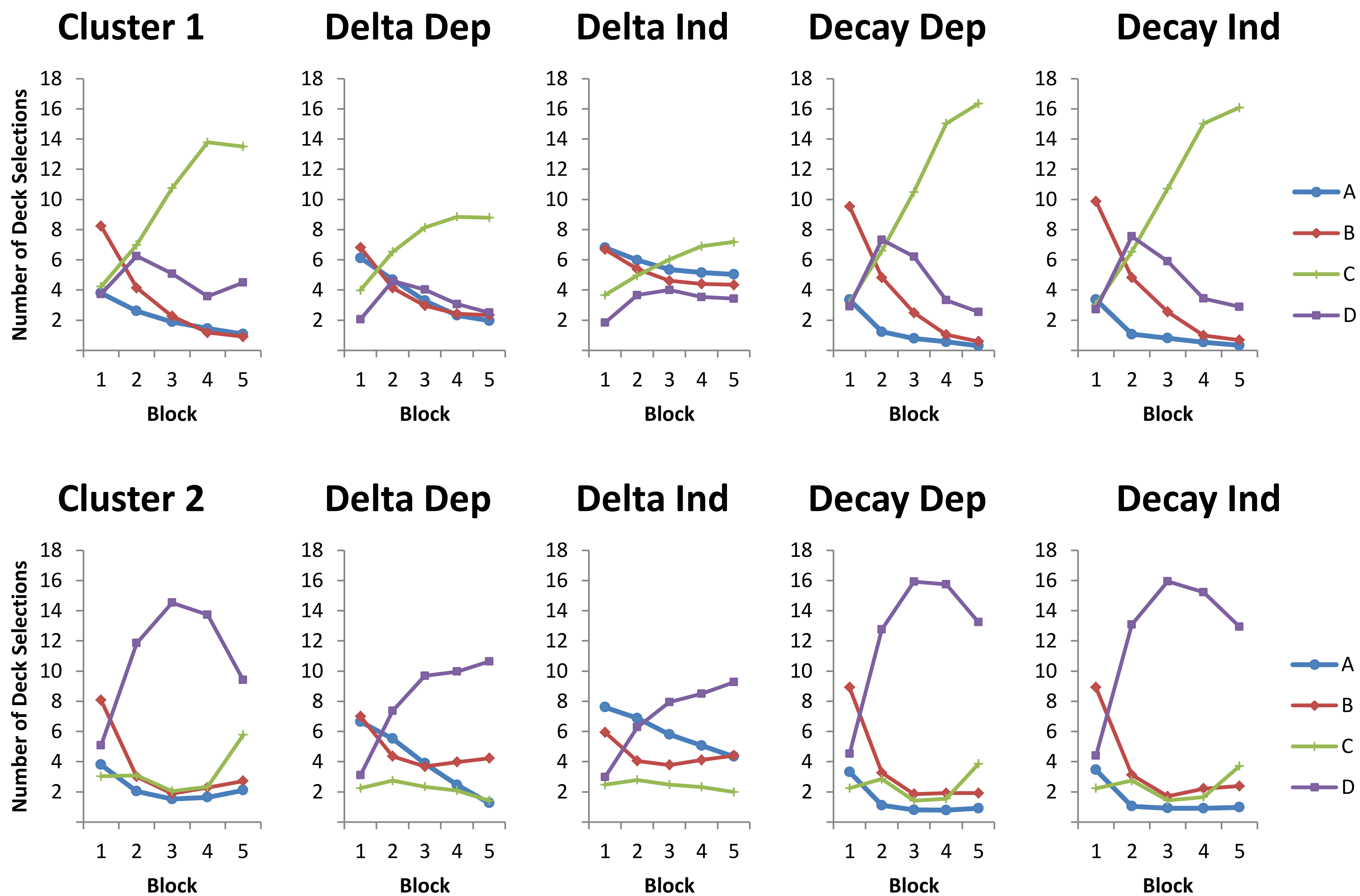


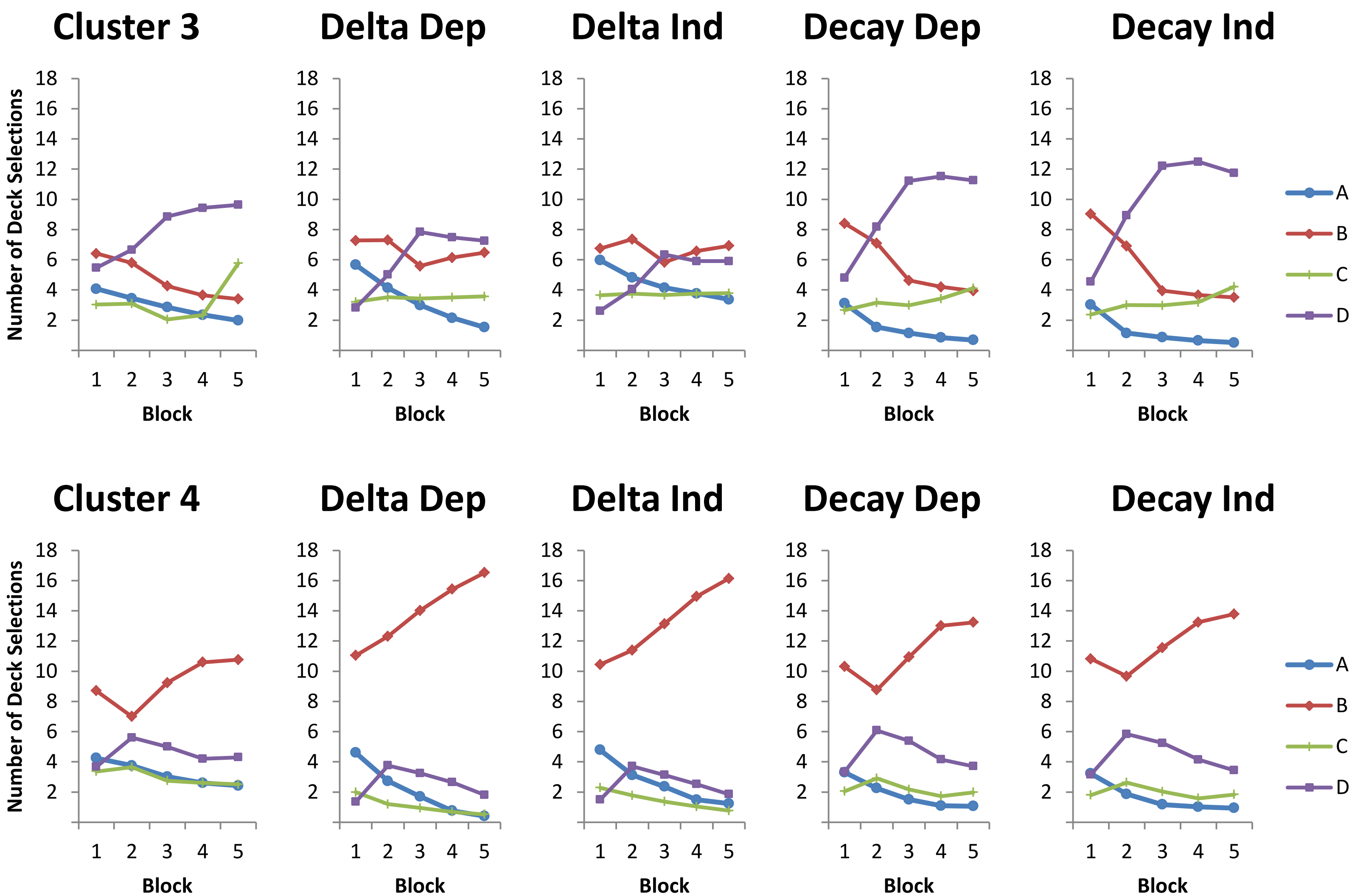
Supplemental Figure 3. PVL parameters stuck on the boundaries. The top four scatterplots show cases stuck on the boundaries, and the bottom four plots show cases after truncation.

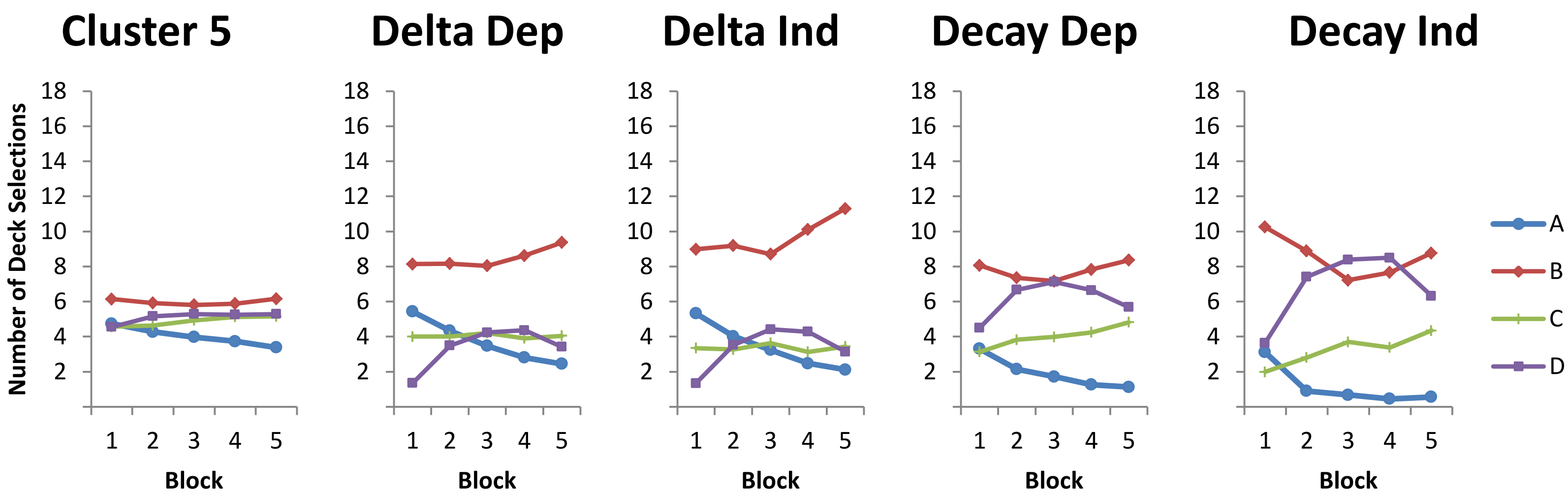


Supplemental Figure 4. Model evaluation using Bayesian Information Criteria by age group. Decay = decay reinforcement rule; Delta = delta learning rule; Dependent = trial-dependent choice rule; Independent = trial-independent choice rule

Supplemental Figure 5 PVL Model Performance by Block and Deck. Cluster1-5 are observed data. Other columns are one-step-ahead predictions.




Cluster 3
Delta Dep
Delta Ind
Decay Dep
Decay Ind
Cluster 4
Delta Dep
Delta Ind
Decay Dep
Decay Ind
Number of Deck Selections
Block
A
B
C
D


Cluster 5
Delta Dep
Delta Ind
Decay Dep
Decay Ind
Number of Deck Selections
18
16
14
12
10
8
6
4
2
1 2 3 4 5
Block
A
B
C
D