# **Supplementary Material**

#### Prediction of Assistance Dog Training Outcomes Using Machine Learning and Deep Learning Models

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## Supplementary Table S1. List of original C-BARQ items.

#### **SECTION 1: Trainability**

When off leash, dog returns immediately when called (TRA1) Dog obeys a "sit" command immediately (TRA2) Dog obeys a "stay" command immediately (TRA3) Dog seems to attend to or listen closely to everything owner/handler says or does (TRA4) Dog is slow to respond to correction or reprimands (TRA5) Dog is slow to learn new tricks or tasks (TRA6) Dog is easily distracted by interesting sights, sounds, or smells (TRA7) Dog will fetch or attempt to fetch sticks, balls, and other objects (TRA8)

SECTION 2: Aggression. Dog displays aggression (growling, barking, biting, etc.):

When verbally corrected or reprimanded (scolded, shouted at, etc.) by you or a household member (AGG9)

When approached directly by an unfamiliar adult while being walked/exercised on a leash (AGG10)

When approached directly by an unfamiliar child while being walked/exercised on a leash (AGG11) Toward unfamiliar persons approaching the dog while s/he is in your car (at the gas station for example) (AGG12)

When toys, bones or other objects are taken away by a household member (AGG13) When bathed or groomed by a household member (AGG14)

When an unfamiliar person approaches you or another member of your family at home (AGG15) When unfamiliar persons approach you or another member of your family away from your home (AGG16)

When approached directly by a household member while s/he (the dog) is eating (AGG17) When mailmen or other delivery workers approach your home (AGG18)

When his/her food is taken away by a household member (AGG19)

When strangers walk past your home while your dog is outside or in the yard (AGG20)

When an unfamiliar person tries to touch or pet the dog (AGG21)

When joggers, cyclists, rollerbladers or skateboarders pass your home while

your dog is outside or in the yard (AGG22)

When approached directly by an unfamiliar male dog while being walked/exercised on a leash (AGG23)

When approached directly by an unfamiliar female dog while being walked/exercised on a leash (AGG24)

When stared at directly by a member of the household (AGG25)

Toward unfamiliar dogs visiting your home (AGG26)

Toward cats, squirrels or other small animals entering your yard (AGG27)

Toward unfamiliar persons visiting your home (AGG28)

When barked, growled, or lunged at by another (unfamiliar) dog (AGG29) When stepped over by a member of the household (AGG30) When you or a household member retrieves food or objects stolen by the dog (AGG31) Towards another (familiar) dog in your household (leave blank if no other dogs) (AGG32) When approached at a favorite resting/sleeping place by another (familiar) household dog (leave blank if no other dogs) (AGG33) When approached while eating by another (familiar) household dog (leave blank if no other dogs)

(AGG34) When approached while playing with/chewing a favorite toy, bone, object, etc., by another (familiar) household dog (leave blank if no other dogs) (AGG35).

#### SECTION 3: Fear. Dog displays anxiety or fear:

When approached directly by an unfamiliar adult while away from your home (FEAR36) When approached directly by an unfamiliar child while away from your home (FEAR37) In response to sudden or loud noises (e.g. vacuum cleaner, car backfire, road drills, objects being dropped, etc.) (FEAR38) When unfamiliar persons visit your home (FEAR39) When an unfamiliar person tries to touch or pet the dog (FEAR40) In heavy traffic (FEAR41) In response to strange or unfamiliar objects on or near the sidewalk (e.g. plastic trash bags, leaves, litter, flags flapping, etc. (FEAR42) When examined/treated by a veterinarian (FEAR43) During thunderstorms, firework displays, or similar events (FEAR44) When approached directly by an unfamiliar dog of the same or larger size (FEAR45) When approached directly by an unfamiliar dog of a smaller size (FEAR46) When first exposed to unfamiliar situations (e.g. first car trip, first time in elevator, first visit to veterinarian, etc.) (FEAR47) In response to wind or wind-blown objects (FEAR48) When having nails clipped by a household member (FEAR49) When groomed or bathed by a household member (FEAR50) When having his/her feet toweled by a member of the household (FEAR51) When unfamiliar dogs visit your home. (FEAR52) When barked, growled, or lunged at by an unfamiliar dog. (FEAR53)

## SECTION 4: Separation-related behavior:

Shaking, shivering or trembling (SEP54) Excessive salivation (SEP55) Restlessness, agitation, pacing (SEP56) Whining (SEP57) Barking (SEP58) Howling (SEP59) Chewing/scratching at doors, floor, windows, curtains (SEP60) Loss of appetite (SEP61)

#### **SECTION 5: Excitability. Dog is excitable:**

When you or other members of the household come home after a brief absence (EXC62) When playing with you or other members of your household (EXC63) When doorbell rings. (EXC64)

Just before being taken for a walk (EXC65) Just before being taken on a car trip (EXC66) When visitors arrive at your home (EXC67)

#### SECTION 6: Attachment /attention-seeking:

Dog displays a strong attachment for one member of the household (ATT68) Dog tends to follow household member about the house, from room to room (ATT69) Dog tends to sit close to, or in contact with, household member when s/he is sitting down (ATT70) Dog tends to nudge, nuzzle or paw household member for attention when s/he is sitting down (ATT71)

Dog becomes agitated (whines, jumps up, tries to intervene) when household member shows affection for another person (ATT72)

Dog becomes agitated (whines, jumps up, tries to intervene) when household member shows affection for another dog or animal (ATT73)

#### **SECTION 7: Miscellaneous behavior:**

Dog chases or would chase cats given the opportunity (MIS74) Dog chases or would chase birds given the opportunity (MIS75) Dog chases or would chase squirrels, rabbits and other small animals given the opportunity (MIS76) Dog escapes or would escape from home or yard given the chance (MIS77) Dog rolls in animal droppings or other 'smelly' substances (MIS78) Dog eats own or other animals' droppings or feces. (MIS79) Dog chews inappropriate objects (MIS80) Dog 'mounts' objects, furniture, or people (MIS81) Dog begs persistently for food when people are eating (MIS82) Dog steals food (MIS83) Dog is nervous or frightened on stairs (MIS84) Dog pulls excessively hard when on the leash (MIS85) Dog urinates against objects/ furnishings in your home (MIS86) Dog urinates when approached, petted, handled or picked up (MIS87) Dog urinates when left alone at night, or during the daytime (MIS88) Dog defecates when left alone at night, or during the daytime (MIS89) Dog is hyperactive, restless, has trouble settling down (MIS90) Dog is playful, puppyish, boisterous (MIS91) Dog is active, energetic, always on the go (MIS92) Dog stares intently at nothing visible (MIS93) Dog snaps at (invisible) flies (MIS94) Dog chases own tail/hind end (MIS95) Dog chases/follows shadows, light spots, etc. (MIS96) Dog barks persistently when alarmed or excited (MIS97) Dog licks him/herself excessively (MIS98) Dog licks people or objects excessively (MIS99) Dog displays other bizarre, strange, or repetitive behavior(s) (MIS100)

## 2 SUPPLEMENTARY TABLE S2. EXPERIMENT 1: OPTIMUM VALUES FOR EACH MODEL'S PARAMETERS AFTER

#### 3 HYPER PARAMETER TUNING

	Parameters	Value for Canine Companions	Value for Seeing Eye dataset	
Classifier		dataset		
Support Vector	С	1.8336	6.7252	
Machine	kernel	rbf	rbf	
	gamma	0.0491	0.0411	
	shrinking	True	True	
	tol	0.001	0.001	
	cache_size	200	200	
	random_state	42	42	
Random Forest	'n_estimators'	130	154	
	'max_depth'	19	19	
	'min_samples_split'	7	5	
	'min_samples_leaf'	3	3	
	'bootstrap'	True	True	
Decision Tree	С	0.1	0.1	
	solver	'sag'	'sag'	
	penalty	'12'	'12'	
	max_depth	17	16	
	min_samples_leaf	1	2	
	min_samples_split	2	3	
XGBoost	'n_estimators'	423	430	
	'max_depth'	9	8	
	'learning_rate'	0.1205	0.0933	
	'subsample'	0.5808	0.8243	
	'colsample_bytree'	0.9477	0.7184	
Multi-Layer	Hidden Layer Size	Layer 1: 128 neurons	Layer 1: 128 neurons	
Perceptron Neural		Layer 2: 64 neurons	Layer 2: 64 neurons	
Network		Layer 3: 32 neurons	Layer 3: 32 neurons	
	Activation Function in Hidden Layers	'relu'	'relu'	

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	Activation Function in			
	Output Layer	'sigmoid'	'sigmoid'	
	solver			
	Learning Rate	'adam'	'adam'	
	Max Iterations	0.001	0.001	
	Batch Size	100	100	
		64	64	
Convolutional	Convolutional Layer	Conv1D Layer 1:	Conv1D Layer 1:	
Neural Network	Parameters	Filters: 64	Filters: 64	
(CNN)		Kernel size: 3	Kernel size: 3	
		Activation: 'relu'	Activation: 'relu'	
		MaxPooling1D Layer 1:	MaxPooling1D Layer 1:	
		Pool size: 2	Pool size: 2	
		Dropout Layer 1:	Dropout Layer 1:	
		Dropout rate: 0.3	Dropout rate: 0.3	
		Conv1D Layer 2:	Conv1D Layer 2:	
		Filters: 32	Filters: 32	
		Kernel size: 3	Kernel size: 3	
		Activation: 'relu'	Activation: 'relu'	
		MaxPooling1D Layer 2:	MaxPooling1D Layer 2:	
		Pool size: 2	Pool size: 2	
		Dropout Layer 2:	Dropout Layer 2:	
		Dropout rate: 0.3	Dropout rate: 0.3	
	Flatten Layer	Flattens the 2D data from the	Flattens the 2D data from the	
		Conv1D and MaxPooling layers	Conv1D and MaxPooling layers	
		into a 1D array to pass into	into a 1D array to pass into	
		dense layers.	dense layers.	
	Dense Layer Parameters	Dense Layer 1:	Dense Layer 1:	
		Neurons: 64	Neurons: 64	
		Activation: 'relu'	Activation: 'relu'	
		Dropout Layer 3:	Dropout Layer 3:	
		Dropout rate: 0.3	Dropout rate: 0.3	
		Dense Layer 2:	Dense Layer 2:	
		Neurons: 32	Neurons: 32	
		Activation: 'relu'	Activation: 'relu'	

Output Layer	Activation: 'softmax'	Activation: 'sigmoid'
Compilation Parameters	Optimizer: 'adam' Metrics: 'accuracy'	Optimizer: 'adam' Metrics: 'accuracy'
Training Parameters	Batch size: 64 Epochs: 100	Batch size: 64 Epochs: 100

# **SUPPLEMENTARY TABLE S3.** EXPERIMENT 2: OPTIMIZED VALUES FOR EACH MODEL'S PARAMETERS AFTER

## 8 Hyper Parameter Tuning

Classifier	Parameters	Value for Canine Companions	Value for Seeing Eye dataset
Classifier		dataset	
Support Vector	С	7.8969	1.9340
Machine	kernel	rbf	rbf
	gamma	0.0696	0.0404
	shrinking	True	True
	tol	0.001	0.001
	cache_size	200	200
	random_state	42	42
Random Forest	'n_estimators'	130	154
	'max_depth'	19	19
	'min_samples_split'	7	5
	'min_samples_leaf'	3	3
	'bootstrap'	True	True
Decision Tree	С	0.1	0.1
	solver	'sag'	'sag'
	penalty	'12'	'12'
	max_depth	17	16
	min_samples_leaf	1	2
	min_samples_split	2	3
XGBoost	'n_estimators'	423	428
	'max_depth'	9	7
	'learning_rate'	0.1205	0.1315
	'subsample'	0.5808	0.5650

	'colsample_bytree'	0.9477	0.5464
Multi-Layer	Hidden Layer Size	Layer 1: 128 neurons	Layer 1: 128 neurons
Perceptron Neural		Layer 2: 64 neurons	Layer 2: 64 neurons
Network		Layer 3: 32 neurons	Layer 3: 32 neurons
	Activation Function in		
	Hidden Layers	'relu'	'relu'
	Activation Function in		
	Output Layer	'sigmoid'	'sigmoid'
	solver		
	Learning Rate	'adam'	'adam'
	Max Iterations	0.001	0.001
	Batch Size	100	100
		64	64
Convolutional	Convolutional Layer	Conv1D Layer 1:	Conv1D Layer 1:
Neural Network	Parameters	Filters: 64	Filters: 64
(CNN)		Kernel size: 3	Kernel size: 3
		Activation: 'relu'	Activation: 'relu'
		MaxPooling1D Layer 1:	MaxPooling1D Layer 1:
		Pool size: 2	Pool size: 2
		Dropout Layer 1:	Dropout Layer 1:
		Dropout rate: 0.3	Dropout rate: 0.3
		Conv1D Layer 2:	Conv1D Layer 2:
		Filters: 32	Filters: 32
		Kernel size: 3	Kernel size: 3
		Activation: 'relu'	Activation: 'relu'
		MaxPooling1D Layer 2:	MaxPooling1D Layer 2:
		Pool size: 2	Pool size: 2
		Dropout Layer 2:	Dropout Layer 2:
		Dropout rate: 0.3	Dropout rate: 0.3
	Flatten Layer	Flattens the 2D data from the	Flattens the 2D data from the
		Conv1D and MaxPooling layers	Conv1D and MaxPooling layers

	into a 1D array to pass into	into a 1D array to pass into
	dense layers.	dense layers.
Dense Layer Parameters		
	Dense Layer 1:	Dense Layer 1:
	Neurons: 64	Neurons: 64
	Activation: 'relu'	Activation: 'relu'
	Dropout Layer 3:	Dropout Layer 3:
	Dropout rate: 0.3	Dropout rate: 0.3
	Dense Layer 2:	Dense Layer 2:
	Neurons: 32	Neurons: 32
	Activation: 'relu'	Activation: 'relu'
Output Layer		
	Activation: 'softmax'	Activation: 'sigmoid'
Compilation Parameters		
	Optimizer: 'adam'	Optimizer: 'adam'
	Metrics: 'accuracy'	Metrics: 'accuracy'
Training Parameters		
	Batch size: 64	Batch size: 64
	Epochs: 100	Epochs: 100

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# **SUPPLEENTARY TABLE S4.** LIST OF CONSIDERED HYPERPARAMETER VALUES IN RANDOMIZEDSEARCHCV FOR

12 EACH MODEL AND PARAMETER IN BOTH EXPERIMENT 1 AND EXPERIMENT 2.

Classifier	Parameter	Distribution / Values Considered
Support Vector Machine (SVM)	С	uniform(0.1, 10)
	Kernel	['linear', 'poly', 'rbf', 'sigmoid']
	Gamma	uniform(0.01, 0.1)
	Shrinking	[True, False]
	Tol	[0.0001, 0.001, 0.01]
	Cache Size	[100, 200, 500]
	Random State	[42, None]
Random Forest	n_estimators	randint(50, 300)
	max_depth	randint(5, 20)

Classifier	Parameter	Distribution / Values Considered	
	min_samples_split	randint(2, 10)	
	min_samples_leaf	randint(1, 5)	
	Bootstrap	[True, False]	
Decision Tree	С	[0.01, 0.1, 1]	
	Solver	['sag', 'lbfgs', 'adam']	
	Penalty	['l1', 'l2', 'none']	
	Max Depth	randint(5, 20)	
	Min Samples Leaf	randint(1, 5)	
	Min Samples Split	randint(2, 10)	
XGBoost	n_estimators	randint(100, 500)	
	max_depth	randint(3, 10)	
	learning_rate	uniform(0.01, 0.15)	
	subsample	uniform(0.5, 0.9)	
	colsample_bytree	uniform(0.5, 0.9)	
Multi-Layer Perceptron (MLP)	Hidden Layer Sizes	[(64,), (128, 64), (128, 64, 32), (256, 128, 64)]	
	Activation Function (Hidden)	['relu', 'tanh', 'sigmoid']	
	Activation Function (Output)	['softmax', 'sigmoid']	
	Solver	['adam', 'sgd', 'lbfgs']	
	Learning Rate	loguniform(0.0001, 0.01)	
	Max Iterations	[100, 200, 500]	
	Batch Size	[32, 64, 128]	
Convolutional Neural Network (CNN)	Conv1D Filters (Layer 1)	[32, 64, 128]	
	Kernel Size	[3, 5, 7]	
	Activation (Conv Layers)	['relu', 'tanh']	
	Pool Size (MaxPooling)	[2, 3]	
	Dropout Rate	uniform(0.2, 0.5)	

Classifier	Parameter	Distribution / Values Considered
	Flatten Layer	['yes'] (Flattening applied to convert features to a 1D array)
	Dense Layer 1 (Neurons)	[32, 64, 128]
	Dense Layer 2 (Neurons)	[32, 64, 128]
	Activation (Output Layer)	['softmax', 'sigmoid']
	Optimizer	['adam', 'sgd', 'rmsprop']
	Metrics	['accuracy']
	Batch Size	[32, 64, 128]
	Epochs	[50, 100, 200]